Modern Economic Growth Theories and the "Miracle" of the East Asian Tigers

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Abstract

This paper gives an overview of the modern economic growth theories and how the neoclassical growth models relate to the four "Asian Tigers" during the period of 1960 – 2000. A review of the literature of growth account exercises relating to the East Asian miracle reveals little consensus amongst economists to the sources of this long episode of high economic growth. In spite of low total factor productivity estimates in comparison with the developed world, it still remains much higher than other newly industrializing countries. Regression analysis of growth rates on capital intensity and educational attainment reveal a significant positive correlation for both factors over the forty year period, indicating that both physical and human capital accumulation can account for the experienced growth levels in the Asian Tigers.

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1. Introduction

The experience of the four East Asian Tiger economies is often cited as a textbook example of miracles of economic progress. From the early 1960's up to the onset of the Asian Financial Crisis in 1997, economic growth in Hong Kong, Singapore, South Korea and Taiwan has nearly averaged an impressive 8 percent per year. The high sustained rates of growth for almost four decades have allowed these countries to rapidly catch up with their industrialized, Western economic counterparts. The city-states of Singapore and Hong Kong in particular have managed to become important global centers of finance and trade, while simultaneously enjoying very high standards of living. East Asia as a whole succeeded in developing their initially poor and backward economies at a much faster pace than the rest of the developed world, which seems to suggest that these HPAEs (High Performing Asian Economies) follow the economic theories of global convergence of growth rates better than other regions.

The experiences of the four Asian Tigers and the other East Asian Newly Industrializing Economies have become an increasingly interesting case study for economists trying to explain the sources behind these phenomenal rates of growth. Although capital stocks have increased dramatically across the region, it remains a subject of academic debate to which extent total factor productivity increases have occurred. As technological progress and productivity growth are the key to long-run sustainable growth, it should be worth investigating whether this indeed has happened in this particular case. An increased understanding on the origins of this supposed miracle can serve as an important lesson for other developing nations that wish to emulate their success. However, economists investigating the issue seem to be divided in two main camps: first of all, the 'accumulationists', or 'fundamentalists', who support the view that the neoclassical process of capital accumulation alone caused East Asian growth, such as Krugman (1994). On the other hand, opposing the idea of a solely neoclassical explanation for Asia's growth experience are the 'assimilationists', which includes studies from Kawai (1994), who claim that total factor productivity did play a significant role in the success of the Tigers, and stress the importance of institutions and favorable government policies, citing a greater variety and interplay of factors as causes of Asia's growth.

Despite the evidence showing considerable growth of output in East Asia, the question remains whether this growth was caused as a result of improvements in worker

productivity. If instead this growth was caused by mere increase of factor inputs, it would imply that productivity growth would not follow, and should be considered anything but "miraculous". This paper will try to provide an insight on how East Asia's experience can be explained in terms of the neoclassical theory of economic growth, and whether productivity increases are evident from the data. It will provide an answer on the research question: Was capital accumulation or increases in total factor productivity the driving force behind the high rates of economic growth of the four East Asian Tigers? This paper covers the following sections: first an overview of the current ideas and models in economic growth theory, an investigation of economic convergence in the East Asian NICs as proposed by the neoclassical growth model, a review of the literature relating to growth accounting and finally a cross-country regression of the period of 1960 up to 2000.

If it appears that capital accumulation alone is indeed the cause of growth experienced in the past decades, it would mean that developing countries should sacrifice current consumption in favor of saving. These savings should be then used to develop more productive, capital-intensive industries. On the other hand however, as capital experiences diminishing returns over time, it should be expected that future productivity growth in the region will become more difficult to achieve.

2. Theoretical Framework of Economic Growth

The past fifty years has seen a considerate amount of literature explaining the phenomenon and sustainability of economic growth. Over time, economists have sought to identify the sources of growth and tried to provide for a model which accounts for the large income differences across countries. The mention of sources and sustainability of productivity growth appears as early in the literature of the classical economists such as Adam Smith and David Ricardo, while the 20th century saw the rise of theories describing the interaction of the various economic macroeconomic forces. Contemporary theories on economic growth are dominated by the neoclassical, or exogenous growth model as developed by Solow (1956), and more recently, endogenous growth theories. Finally, there is a separate branch of growth economics which emphasizes the role that institutions play in achieving economic growth. A greater understanding of this concept can help provide for a model of development for poor countries who wish to emulate the success story as has happened in East Asia.

2.1 The Solow-Swan Neoclassical Growth Model

The earliest framework on economic growth was independently pioneered by Harrod (1939) and Domar (1946), and was then called the dynamic theory of growth. The original model consisted only of capital and savings and stated that economic growth solely originates through capital accumulation, which is the result of increased savings in the country. Capital here refers to all physical capital including land, natural resources and minerals. The Harrod-Domar model would serve as the foundation for the neoclassical growth theory which is known today. In 1956, MIT professor Robert Solow published his famous paper: 'A Contribution to the Theory of Economic Growth', in which he formulated an economic model to describe and predict the future growth path of the US economy. The model was basically an extension of the Harrod-Domar model which added labor, along capital as factor inputs and similar models were also proposed by Swan (1956) and Meade (1961). This model became more commonly known as the exogenous growth model, or Solow-Swan model.

The Solow-Swan model relies on the following assumptions:

1. Countries produce a single, homogenous good of output.
2. Output is measured as units of a country's gross domestic product (GDP).

3. No government or international trade.
4. All factors of production are fully employed.
5. Technology stock is considered exogenous.
6. Capital inputs are subject to diminishing returns.

Solow further extended his theory by introducing the influence of technological progress on the production process in his 1957 paper: 'Technological Chance and the Aggregate Production Function'. The model introduces total factor productivity growth, represented by parameter *A*, which is sometimes also referred to as the available technology stock. The basic Solow model's production function exhibits constant returns to scale and is assumed to be capital-augmenting or Solow-neutral technology, as seen in the following Cobb-Douglas production function[1]:

(2.1) $$Y = f(K, AL) = AK^{\alpha}L^{(1-\alpha)}$$

Where *Y* equals the level of output in a given period, *A* an index for the level of total factor productivity, *K* the available level of physical capital, *L* the available labor supply and finally α, which is a parameter that represents the capital elasticity w.r.t. output. Because we are primarily concerned with productivity growth per worker, it is required to restate the above production function in per worker terms:

(2.2) $$y = Ak^{\alpha}$$

The level of α in the production function is the value of the relative capital share and denotes the production possibilities within a country. The precise value of this parameter remains a topic of academic debate, it is often taken from national account reports or in some cases (e.g. Kim and Lau 1994; Drysdale and Huang, 1997) a regression model is used to derive the level of α. Maddison (1987) calculated the value of α being 0.3 for advanced economies, while Kim and Lau (1995) and Harrison (1996) propose a value of 0.4 for newly industrialized countries. In practice however, it is often assumed that the capital share equals 1/3.

One of the important implications of the Solow model is the process of capital

[1] Other models suggest a "labor-augmenting" or "Harrod neutral" influence of technology as described in the production function: Y=F(K,AL) or "Hicks-neutral" technology Y=AF(K,L).

accumulation, which results in an increase of capital available per worker over time through savings and investments. Within the model, it is assumed that that the growth rate of savings, depreciation and labor stock are constant over time. Capital accumulation is the main force in driving output growth and is represented in the model by the superimposed dot above *k* in the capital accumulation function:

$$\dot{k} = sy - (n + g + \delta)k \tag{2.3}$$

Where $\dot{k}$ equals the amount of new capital available per worker, *s* equals the savings rate ($0 < s < 1$), *n* shows the population growth ($\dot{L}/L$) and δ is the amount of capital depreciation ($\delta > 1$).

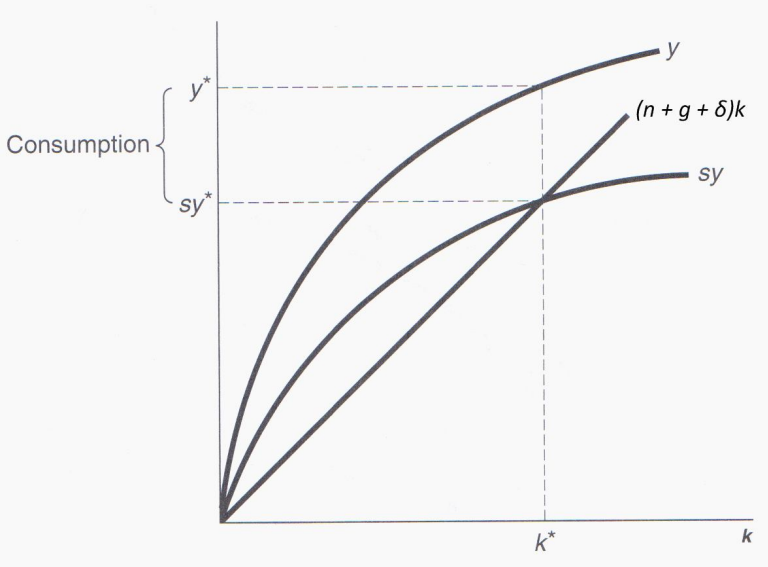


Figure 1: The Solow Diagram and the production function, source: Jones (2002)

Figure 1 shows the dynamics of the Solow model and how capital is accumulated over time. Output per worker is represented by line $y = k^{\alpha}$, which is equal to income per worker. Total investment per capita equals savings per capita and is represented by the *sy*-line, which equals $sy = sk^{\alpha}$. The line $(n+g+\delta)k$ represents the amount of investments requirement to keep the capital-labor ratio constant. When savings exceed the sum of population growth, technology growth and capital depreciation, capital per worker *k* increases, which is the case of capital deepening. Similarly, if savings are less than the sum of the three variables, capital per worker decreases and capital widening takes place.

The economy will eventually settle in a position where the capital-labor ratio remains constant, due to the assumption of diminishing returns on capital. This is referred to as the

steady state of an economy, where: $(n + g + \delta)k = sy$, i.e. $\dot{k} = 0$. In the case when capital, output, consumption and population are growing at constant rates, the economy is assumed to be along a balanced growth path. The model of transitional dynamics explains the path of an economy towards its steady state.

2.2 Transition Dynamics in the Neoclassical Model

The level of economic growth in the exogenous growth model is explained through the process of transitional dynamics, as shown in figure 2. Capital accumulation will allow productivity to increase up to the point where the economy reaches its steady state. Figure 2 shows what happens if the rate of investment in capital, as result of more savings, increases. In the new situation, savings exceed the natural decrease in per worker capital as a result of depreciation, population and technological growth. A higher investment rate therefore leads to more capital available per worker, which causes the economy to move towards the right into a higher steady state level of growth. An economy beyond its steady-state however, will experience stagnation, or even a slowdown in future growth rates.

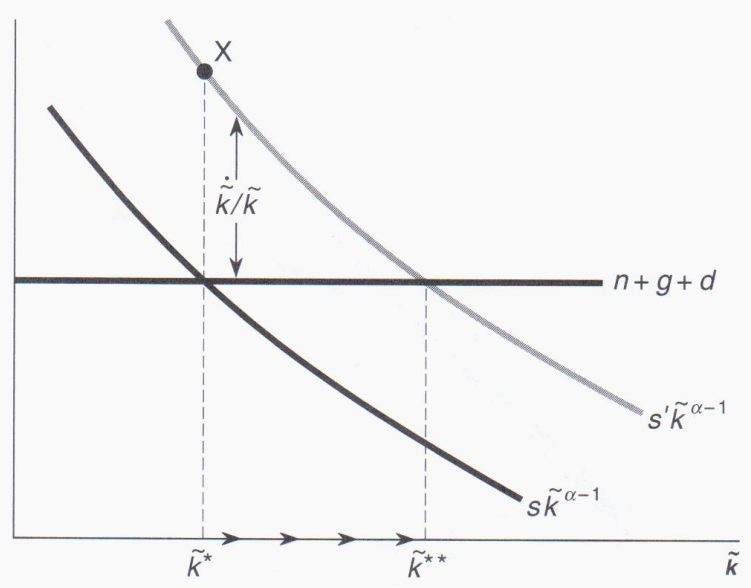


Figure 2: An increase in the investment rate: Transition Dynamics, source: Jones (2002)

The neoclassical growth model predicts that poor countries, characterized as having low initial capital stocks, tend to have high growth rates as they start off well below their steady states, in which their situation allows for a high accumulation of new capital goods. Rich countries, however, are settling in, or are beyond their steady state, in which their relatively abundant capital stocks will experience diminishing returns to capital and thus have

lower per capita growth rates. If taken for the world as a whole, the model of transitional dynamics will eventually predict a convergence of growth rates between poor and rich countries, as the former catch up towards higher levels of productivity and income.

2.3 Alternative Models of Economic Growth

In response to Solow's work, several extensions were proposed by various researchers in the subsequent decades to further improve the neoclassical growth theory. Their main objective was to provide for an overall more detailed model and further increase the statistical fit of the mode. Most notable amongst these extensions was the application of the Ramsey growth model (1928) and his concept of an 'optimal savings rate', which introduced endogenous savings by assuming that savings are variable over time.

Another important addition to the neoclassical model was laid out by Mankiw, Romer and Weil (1992), who recognized the importance of human capital and education in contributing to economic growth. Mankiw et al. incorporate the labor-augmenting parameter *H*, which can be interpreted as a measure on the skill level of the labor supply. They propose the following Cobb-Douglas production function:

(2.4) $$Y = f(K, AH) = K^{\alpha}(HL)^{1-\alpha}$$

(2.5) $$H = e^{\psi u}L$$

In this model, *H* denotes the measure of the effectiveness of labor, or human capital, ψ is the measure of the effectiveness of the learning process, while *u* equals the fraction of an individual's time learning skills, or schooling. This idea seemed consistent with literature in labor economies which state that each additional year of schooling has a positive effect on future earnings.

An important criticism of the neoclassical growth theory is that exogenous models provide insufficient insight on the sources of economic growth, because it does not account for how technological progress originates and how it interacts in the model. In 1980 a "new" growth theory was developed by Romer (1986, 1990) and Lucas (1988), which is known as endogenous growth theory. Endogenous growth describes how technological change originates by introducing a model in which research and development is the result of economic incentives and expected profits. It also recognized the importance of ideas and innovation. It states that sustained growth is only possible with a growing population, which

would provide for a larger stock of researchers, and subsequently for more ideas and research, driving further technological progress.

2.4 Institutional Approach to Economic Growth

An alternative, institutional approach for explaining long-term sustained economic growth has been proposed in the form of social infrastructure. The quality of a state's legal, political and educational institutions can vary greatly depending on its history and geography, and can prove to be a significant cause of a country's development (or lack thereof). It can be argued that a stable rule of law and a healthy investing climate in which property rights are strongly enforced can contribute greatly to economic performance. The institutional approach recognizes the following four fundamental determinants of economic growth:

1. Institutions ('man-made factors', e.g. enforcement of property rights, equality of opportunity and effectiveness of markets).
2. Geography ('role of nature', e.g. natural endowments, climate and disease burden).
3. Culture (e.g. religion, 'social capital', norms, preferences and values of population).
4. Luck (multiple equilibriums, 'right place at the right time').

Glaeser, La Porta, Lopez-de-Silanes and Schleifer (2004) studied whether political institutions can cause economic growth and if human capital and growth leads to institutional improvements. In the study, institutional quality is measured through government effectiveness and the degree of executive constraints. The authors conclude that institutions are not a source of growth in itself, but rather the accumulation of human capital. They also show that developing nations often experience high growth during dictatorial regimes that are effective in promoting beneficial economic policies. Subsequently, as poor countries develop, institutional improvements will take place over time.

A historical explanation on the presence of institutions that favor economic progress was offered by Acemoglu, Johnson and Robinson (2000), who studied the effects on the decision of Europeans to settle in particular regions, and its long-term effects on a country's future development. Acemoglu et.al argues that initial (potential) settler mortality of European colonists is a good instrument for institutions. Their idea is that colonies which were ideally suit for settlement would model their institutions to those of the mother country, and that these managed to persist till present day. This would give way to a sophisticated institutional framework, which they argue is the root cause for current day economic

performance. The study further shows that countries where Europeans established settler colonies were much better off than those which were merely used as 'exploitative' colonies, and cited the lack of effective legal and political institutions as being the primary cause of their weak economic performance.

2.5 Conclusion

An important policy consequence of the Solow growth model is that government programs geared for economic growth can only result in a temporary increase in growth rates, as the economy moves towards its new steady state. Although policies can have level effects as per capita output levels increase or decrease, the Solow model predicts that changes in policy do not have any long-run growth effects.

The Solow model also offers a possible explanation on why certain countries are wealthy while others are less prosperous. First of all, rich countries have lower population growth rates and a higher per capita propensity to save, which allows them to invest more. More investments allow rich countries to accumulate a higher rate of capital per worker, resulting in higher labor productivity and consequently income. Second, the neoclassical theories tell that technological progress is the only source of long-run economic growth. Technological change drives sustained growth as it offsets inevitable diminishing returns on capital. Endogenous growth models are required to explain why such technological progress takes place, because the exogenous models fail to tell us where technological progress originates. On the other hand, the institutional approach tells us that governments should focus more on strengthening economic and educational institutions.

3. Total Factor Productivity, Growth Accounting and Technology Transfer

The production function from the neoclassical model identifies factor accumulation and total factor productivity as the two components driving economic growth. Cross-sectional studies by Hall and Jones (1999) and Parent and Prescott (2000) show that differences in total factor productivity across countries are to a large extent responsible for differences in per capita output levels. Klenow and Rodriguez-Clare (1997) further argue that TFP growth rates have a significant effect in explaining the per capita growth rates of income across countries. Economists have sought to identify and measure the different sources that compromise overall output growth by using the methods of growth accounting and econometric estimation. These two techniques can give a more detailed understanding of economic growth, which can be used to measure the overall impact and significance of total or multi-factor productivity growth.

3.1 Growth Accounting

Solow (1957) introduced the concept of growth accounting to decompose the impact of the various factors compromising growth. It assumed that the level of TFP, or technology stock is determined exogenously, assumed as being "manna from heaven". Also referred to as the Solow residual, the level of total factor productivity therefore represents the amount of growth that does not result from capital accumulation or increased labor inputs. Table 1 gives an overview of the output growth across developed and developing regions, decomposed in capital, labor and technical progress. The overall pattern indicates that rate of total factor productivity tends to be the greatest source of growth in the industrialized economies, whilst growth in the developing world is mostly the result of increases in factor inputs, in particular capital.

Table 1

Contributions of Capital, Labor and Technical Progress to Output Growth (%)

Region	Capital	Labor	Technical Progress
Developing countries, 1960-87	65	23	14
Africa	73	28	0
East Asia	57	16	28
Europe, Middle East, and North Africa	58	14	28
Latin America	67	30	0
South Asia	67	20	14

Selected developed countries, 1960-85:			
France	27	-5	78
West Germany	23	-10	87
Japan	36	5	59
United Kingdom	27	-5	78
United States	23	27	50

Source: Lim (1994), data by World Bank, World Development Report (1991)

3.2 Interpretations of TFP Growth

The amount of total factor productivity growth can be easily calculated using Solow's theory, but its precise meaning remains quite ambiguous. Lipsey and Carlaw (2001) list the several different definitions of TFP which are commonly used in economic literature:

1. TFP is the measure of technological change (e.g. by Krugman, Young and Barro).
2. TFP is the measure of externalities and scale effects of economic growth (e.g. Jorgenson and Griliches).
3. TFP is simply a residual, i.e. it does not measure anything useful.

The estimations to the sources of TFP vary widely due to these various interpretations. Growth accounting exercises therefore raise the question on how meaningful such decompositions actually are. Abramovitz (1956) noted that TFP is rather a "measure of our ignorance"[2], while Nadiri (1970) argues that when factor inputs and their interaction are properly measured and specified, residual growth should always be zero. Collins and Bosworth (1996) argue that new capital goods in themselves are composed of technological advances, and that TFP might actually promote capital accumulation because it raises returns to capital. Capital accumulation in itself might therefore be a "transmission of growth"[3].

The Solow residual is an important concept as any notion of an 'East Asian miracle' should be reflected in high values of TFP growth. Within the neoclassical model, TFP is described as $\dot{A}/A$ in the following growth accounting equation, which estimates the growth rate of aggregate output:

$$\frac{\dot{Y}}{Y} = \alpha\frac{\dot{K}}{K} + (1-\alpha)\frac{\dot{L}}{L} + \frac{\dot{A}}{A} \tag{3.1}$$

[2] Abramovitz (1956, p. 11)
[3] Grossman and Helpmann (1994, p.26)

In this equation $\frac{\dot{Y}}{Y}$ denotes the growth rate of output, $\alpha \frac{\dot{K}}{K}$ the contribution of the growth rate of capital stock, $(1-\alpha)\frac{\dot{L}}{L}$ the contribution of the growth rate of the labor supply, and finally $\frac{\dot{A}}{A}$ equals the residual or total factor productivity growth rate. Using this equation, we can derive the per capita output growth equation:

(3.2) $$\frac{\dot{y}}{y} = \alpha \frac{\dot{k}}{k} + \frac{\dot{A}}{A}$$

The basic growth accounting equation shows that per capita productivity growth can be decomposed in contributions of growth in both physical capital $\dot{k}/k$ and multifactor, or TFP growth: $\dot{A}/A$. It remains unclear which factors exactly causes TFP growth, because multi or total-factor productivity is by definition a residual value. The degree of technology transfer, educational attainment, effectiveness of governance, economic policies, political stability, entrepreneurship and openness to trade are all factors which are all mentioned to be of some impact to this level.

3.3 Technology Transfer

If technological progress is indeed an important determinant of TFP growth, it is important to understand how developing countries acquire new technologies. The theoretical framework relating to the process of technology transfer describes how technology leaders (countries with high innovation due to large investments in research & development) interact with the rest of the world, which are referred to as technology followers as they benefit from international knowledge spillovers. The level to which this spillover takes place in a follower-country depends on factors such as: the distance from the frontier, human capital stocks and openness to international trade and foreign direct investments (Coe, Helpman and Hoffmaister 1997; Hejazi and Safarian 1999). The mention of a closing 'idea gap' was also proposed by Romer (1993), as cited by Pack (1992): "the source of growth in a few Asian economies was their ability to extract relevant technological knowledge from industrial economies and utilize it productively within the domestic economy"[4].

[4] Romer (1993, p. 547); Pack (1992, p. 299)

3.4 Conclusion

Growth accounting tries to decompose output growth to measure how much each factor contributes to output growth. Empirical studies show that productivity growth remains the most important source of economic growth for the industrialized world, while growth in the developing world is mainly the result of increases in factor inputs. Growth accounting exercises measure that in contrast with Latin America and Africa, East Asia's output growth has been a result of technological progress. This progress, measured as Total Factor Productivity growth measures residual growth not resulting from factor inputs, therefore its precise meaning is not clearly agreed upon. The ambiguity surrounding this concept makes it difficult to assess whether it is valid to tell whether the Tigers' achievements have been extraordinary or not.

Table 2 gives an example of a basic growth accounting for the four East Asian Tigers, as calculated by Young (1995). His results show that between 1966 and 1990, while growth rates of output have been very high in all of the four countries, productivity growth has contributed only a limited amount. The apparent low estimates of TFP in the Tigers made Young to further strengthen his and Krugman's opinions that capital accumulation alone accounted for all growth. However, deviations in methodology and statistical data have made other researchers to reach very different results and conclusions on the subject.

Table 2

Growth Accounting Exercise by Young (1995)

	Assumed cost share of capital α	Growth rate of output $\dot{Y}/Y$	Contribution of Capital $\dot{K}/K$	Contribution of Labor $\dot{L}/L$	Contribution of TFP $\dot{A}/A$
Hong Kong	0.30	7.3	0.41	0.28	0.32
Singapore	0.49	8.7	0.65	0.33	0.02
South Korea	0.30	10.3	0.40	0.44	0.17
Taiwan	0.26	9.4	0.34	0.39	0.28

4. Empirical Evidence of Convergence in East Asia

This section examines how the neoclassical growth theory performs in practice and tries to assess whether the theoretical implications of the neoclassical framework are evident from empirical data. Although Solow's model performed quite well in his original paper for advanced economies such as the United States during the first half of the 20th century, it might prove to behave very differently for developing countries, which are characterized by high population growth and low initial capital stocks. The role of technology and how it interacts with factor inputs might also differ significantly between the advanced and developing economies.

4.1 The Economic Experience of the East Asian Tigers

There can be little doubt that in the past four decades tremendous political and social changes have swept across East Asia as a result of rapid economic progress. During the period after World War 2, this region was characterized by high rates of illiteracy, poverty and regional conflicts. It was generally thought to be one of the least likely areas to experience high economic growth and escape poverty. However, contrary to Africa and Latin America, their newly acquired wealth has allowed several of these Asian countries to transform their societies from poor, third-world nations to the equivalence of those of advanced, industrialized economies within the span of a single generation. Although international trade theory acknowledges the mutual benefits of improved wealth for all sides, the media and public opinion in the industrialized world often seem to perceive these economic developments as some sort of a threat to the current economic order.

Another previous Asian example was Japan's own rise to economic dominance with its amazing pace of economic recovery during the period after World War 2. The popular notion was that its economy would soon outpace that of the USA. While Japan indeed managed to become one of the highest per capita income countries in the world, it did not seriously challenge living standards in the USA or the rest of the industrialized world. These episodes of great growth reminisces that of other growth episodes such as China today. Unlike miraculous instances of growth such as happened in Stalin's Soviet Union, literature seems to suggest that the case of Japan was indeed a result of great increases in productivity and technology. Krugman (1994) suggests that Japan has currently already largely converged with advanced economies, which can be interpreted from its sluggish performance in recent

decades.

The impressive growth that was taking place in Asia made the World Bank (1993) coin the term HPAEs (High-Performing Asian Economies) to describe the countries of Hong Kong, Singapore, Taiwan, Malaysia, Indonesia, Thailand and Japan, in which real GDP growth averaged 6.8%. Several studies (World Bank, 1993; Page, 1994 and Stiglitz, 1996) cite openness to trade, a well-educated workforce and favorable government policy as main factors contributing to growth in the HPAEs. A small group of countries have stood out in particular amongst the HPAEs: Singapore, Hong Kong, South Korea and Taiwan. These four so-called "East Asian Tigers" have consistently been the most successful performers and achieved the amazing feat of sustaining high growth for such an extended period of time.

4.2 Economic and Demographic Indicators

Table 3 gives an overview of the basic demographic and economic figures across the major regions, with emphasis on East Asia and China during 1960 and 1990. The industrialized world shows a pattern of low GDP growth, population and labor participation, while the developing world is generally characterized by relative high rates of population and GDP growth. The economies of both China and the East Asian NICs (Newly Industrialized Countries) have fared on average much better than other developing areas in the world, such as South Asia, Latin America and the Middle East.

Table 3

Basic Indicators of Economic Growth, by Region and Country

Region	Population 1990[a]	Per capita income[b]		Annual growth rates 1960-94		
		1960	1990	GDP	Population	Labor force
China	1,134	0.6	1.3	6.8	1.8	2.3
East Asia	380	0.9	3.6	6.8	2.2	2.5
Indonesia	178	0.6	2.0	5.7	2.1	2.2
South Korea	**43**	**0.9**	**6.7**	**8.5**	**1.7**	**2.6**
Malaysia	18	1.4	5.1	7.0	2.6	3.0
Philippines	61	1.1	1.8	3.8	2.7	2.5
Singapore	**3**	**1.6**	**11.7**	**8.3**	**1.7**	**2.7**
Thailand	56	0.9	3.6	7.7	2.4	2.5
Taiwan	**20**	**1.3**	**8.1**	**8.7**	**2.1**	**2.7**
South Asia	1,130	0.8	1.1	4.2	2.3	1.9
Africa	432	0.6	0.7	2.9	2.8	2.6
Middle East	175	1.9	3.0	4.5	2.9	2.9

Latin America	421	2.4	4.1	4.2	2.4	2.7
Industrialized Countries	853	6.4	14.9	3.5	0.9	1.1

Source: Collins and Bosworth (1996), data from Penn's World Tables and World Bank

a. In millions

b. In thousands of 1985 dollars

Table 4 shows the annual growth rates of real GDP, capital stock and labor for the four tiger economies, Japan and four G-5 (Group-of-Five) countries, taken from Kim and Lau (1994). Average real GDP growth has remained a staggering 8 percent for all four countries for almost forty years. For all four countries there was a consistent growth in the utilization of capital and capital stock, while labor hours increased to a smaller extent. The tiger economies and Japan show significantly higher rates of growth in all these areas than the G-5 countries. The latter experienced only a marginal increase in labor hours, or even a decrease. The sustained annual increases of these factors of production can provide an insight on why GDP growth has remained so high for nearly four decades, since higher levels of inputs naturally translate into higher rates of output growth. The question is to which extent a convergence of technology took place as well.

Table 4

Average Annual Rates of Growth of Real GDP, Capital, and Labor (Percentage)

Country	Period	GDP	Capital Stock	Utilized capital	Employment	Labor hours
Hong Kong	**1966-1990**	**7.8**	**9.0**	**8.7**	**2.9**	**2.6**
Singapore	**1964-1990**	**8.9**	**10.4**	**11.0**	**4.4**	**4.4**
South Korea	**1960-1990**	**8.6**	**12.4**	**12.4**	**3.1**	**3.5**
Taiwan	**1953-1990**	**8.7**	**12.1**	**12.1**	**2.8**	**2.5**
France	1957-1990	3.7	4.4	4.6	0.4	-0.1
West Germany	1960-1990	3.2	4.4	4.5	0.1	-0.4
Japan	1957-1990	6.7	10.1	10.4	1.2	0.7
UK	1957-1990	2.5	3.2	3.2	0.4	0.2
United States	1948-1990	3.1	2.9	3.2	1.8	1.6

Source: Kim and Lau (1994)

Table 5 gives an overview of the proportion of educational attainment of the working population in the East Asian countries, divided into primary and secondary education. Educational attainment of the working population is an important indicator of a country's

human capital stock and policymakers in East Asia have put a great emphasis in strengthening their education institutions. The overall pattern during the period of 1966 – 1990 clearly shows that educational attainment has increased in all reference countries, which could indicate that it was at least partly responsible to GDP growth. The proportion of working people without any formal education has been greatly decreased, with completely disappearing in the case of Singapore.

Table 5

Educational Attainment of the Working Population (percentage)

	Hong Kong		Singapore		South Korea		Taiwan	
	1966	1991	1966	1990	1966	1990	1966	1990
None	19.2	5.6	55.1	-	31.1	6.4	17.0	4.5
Primary	53.6	22.9	28.2	33.7	42.4	18.5	57.2	28.0
Secondary+	27.2	71.4	15.8	66.3	26.5	75.0	25.8	67.6

Source: Young (1995)

4.3 Evidence of Convergence between Developing and the Developed World

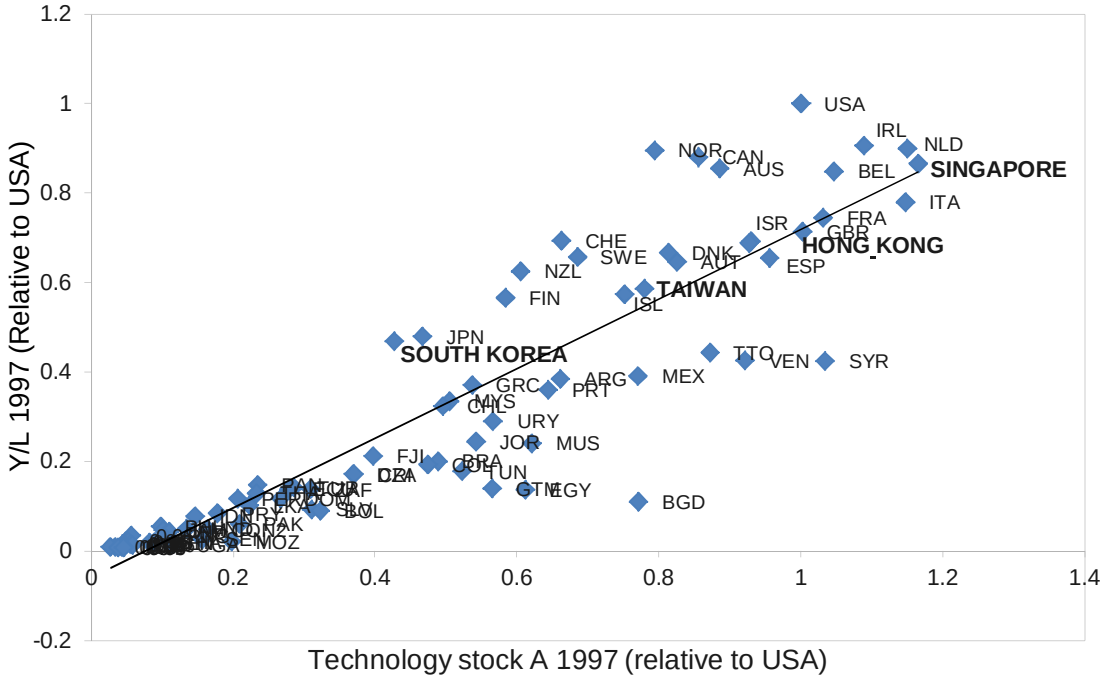
The second chapter explained how transitional dynamics can predict the future growth path of an economy. From these dynamics originated the convergence hypothesis, which predicts that income gaps between countries will eventually disappear as “backward” countries will experience on average higher rates of growth than “advanced” countries. International trade and globalization have allowed ideas and technology to be easily diffused and shared between the developed and developing world, giving the latter a better chance to catch up. The phenomenon that countries’ growth rates across countries will eventually converge was introduced by Gerschenkron (1952) and Abramovitz (1986). It is worth asking the question on how well the neoclassical model explains the growth paths of the East Asian economies, and whether poor countries indeed have such a thing as an ‘advantage of backwardness’. Using an 82 country dataset from Jones (2002), three cross-country estimations are made of relative per capita income levels. Several different approaches are used to test the theoretical implications of the convergence hypothesis.

Figure 1 plots the relationship between per capita outputs against their “technology stock” *A*. In both cases the variables are taken as relative values to those of the USA, i.e. USA=1.0. Furthermore, the values of *A* are derived using the following formula:

(4.1) $$A = \left(\frac{y}{k}\right)^{\alpha/(1-\alpha)} \cdot \frac{y}{h}$$

The graph shows a strong linear correlation between the two variables. Rich countries have high levels of *A*, as high-income countries tend to have abundant stocks of both physical and human capital, while at the same using these inputs more productively than low-income countries. The strong positive correlation between technology and productivity seems to hold very well in the current data set. The four tiger economies seem to follow the overall pattern this of quite well, which might suggest that technology is indeed a strong predictor for income levels.

Figure 1: GDP per Capita 1997 (Relative to USA)

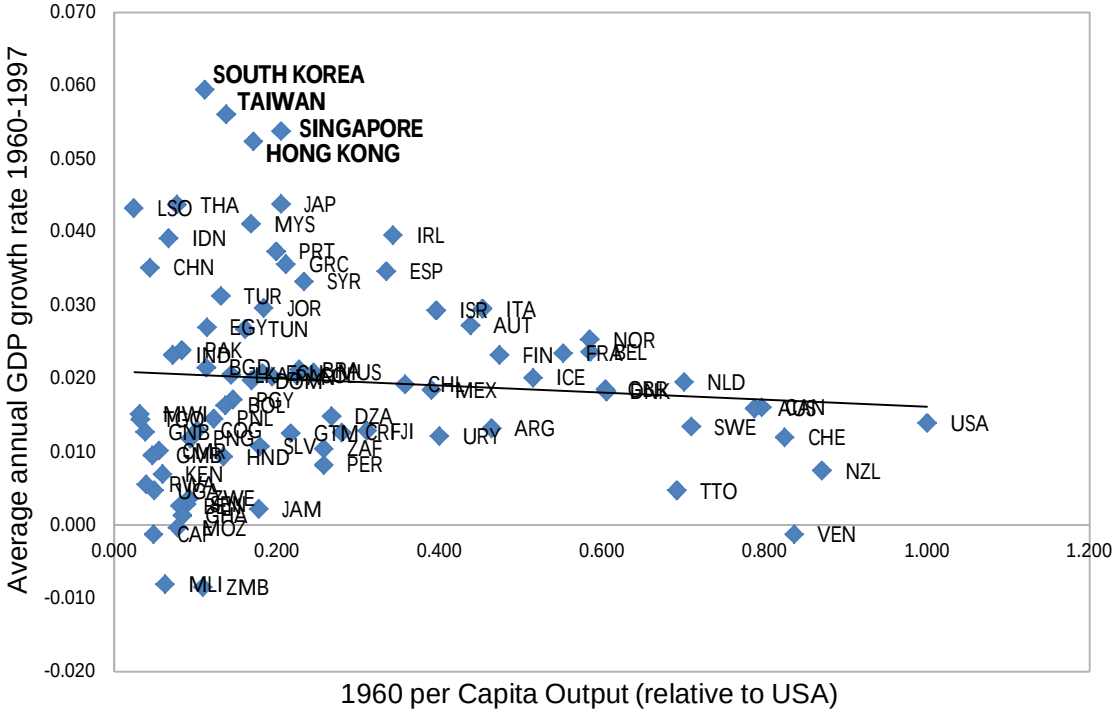


Source: Jones (2002), Table C.2

Figure 2 plots the average annual GDP growth rates between 1960 and 1997 against per capita output relative to USA in 1960 for 82 countries. Any evidence of convergence between the world's economies should imply that countries which were relatively poor in 1960 should have averaged higher growth rates in the subsequent decades than those that were initially relatively rich. The total dataset exhibits only a slight negative relationship between relative output in 1960 and average growth, which seems to disprove the convergence hypothesis for the world as a whole. The African countries in particular do not seem to follow the predicted pattern, including 'growth disasters' such as Mali and Zambia,

which appear to have averaged a negative growth rate during the 37-year period. However, most developing and industrialized economies do seem to follow the predicted trend: a relative per capita output close to USA in 1960 is correlated with a lower average annual growth. For the Tiger economies the hypothesis also does seem to hold very well, as all of four of them had a per capita income less than 20% of the USA back in 1960, but have since experienced an average annual growth between 5 and 6% up to 1997. Their values are considered significant positive outliers, having the highest growth of any country in the dataset.

Figure 2: Average Annual GDP Growth 1960-97



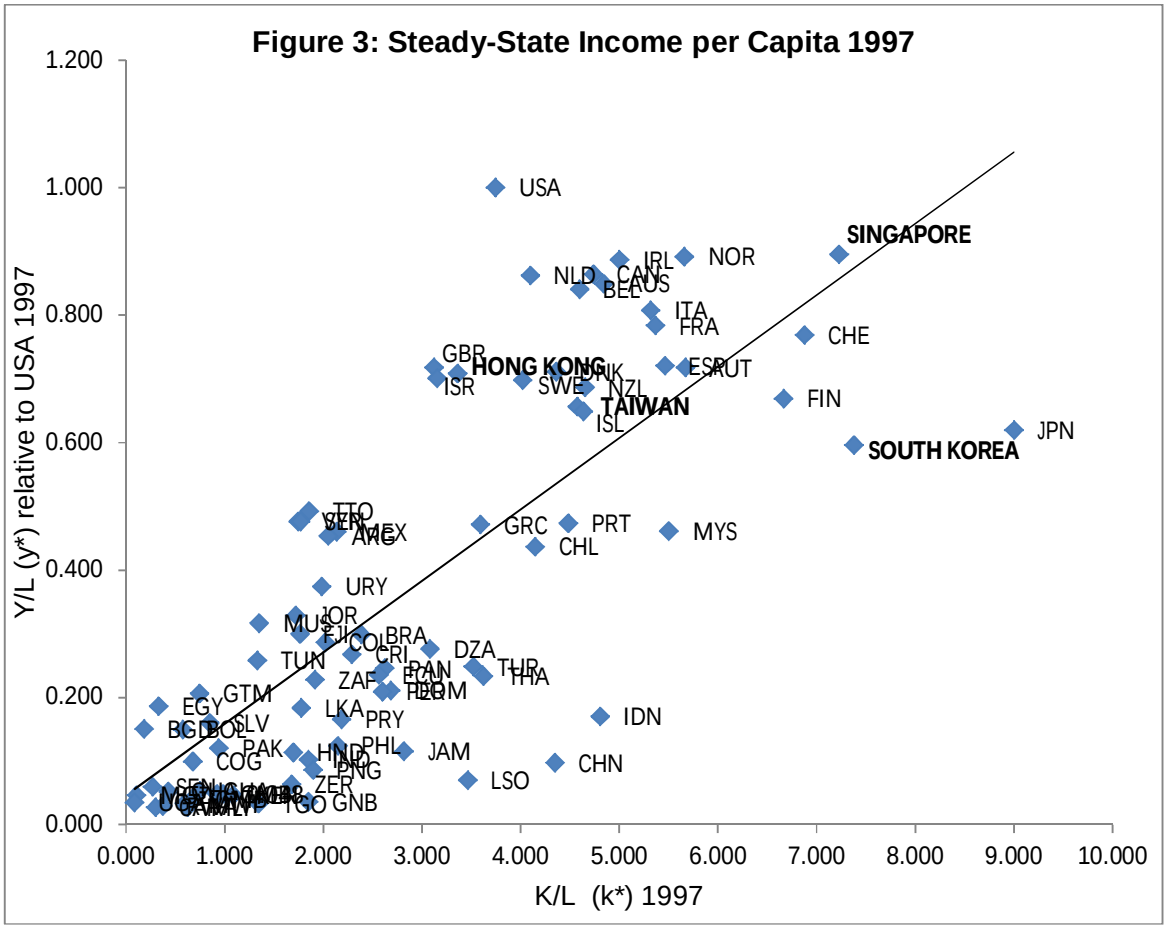
Source: Jones (2002), Table C.2

Figure 3 plots the amount of capital available per worker (or capital-labor ratio) at the steady state against relative income in 1997, similar as done by Young (1992). The steady-state level of k^* is derived using the formula:

$$k^* = \left(\frac{s}{n+\delta+g}\right)^{1/(1-\alpha)} \quad (4.2)$$

At first glance the graph indicates a clear positive relationship between the amount of capital per worker and income. The 82 county dataset seems to support the notion of a Harrod-neutral Solow function of $y = k^{\alpha}$, i.e. technology is labor-augmenting rather than capital

augmenting.



Source: Jones (2002), Table C.

4.4 Conclusion

Hong Kong, Korea, Singapore and Taiwan all started out in 1960 as relatively backward and developing economies. In the period up to 2000 these four countries have seen considerable increases their capital stocks and labor hours, as well as improvements in education. These factors likely contributed to the high pace of economic growth experienced in the region, which allowed the Tigers to rapidly converge towards income levels of those in advanced economies. When testing the real world implications of Solow's growth model using data by Jones (2002), it seems that the Asian Tigers fit the predicted patterns quite well. Both capital and technology stocks appear to be good predictors for measured income. The four countries also seemed to have fared better than others in exploiting their 'advantage of backwardness', having started out from low per capita output in 1960 (relative to USA), to the fastest growing economies in the world for the subsequent forty years.

5. Literature relating to TFP Growth in the East Asian NICs

5.1 The Debate of Capital Accumulation versus Assimilation

The following section will give an overview of the most well-known empirical studies relating to East Asia's supposed economic miracle. Economists investigating the sources of TFP growth in the Tiger economies remain fundamentally divided on whether significant productivity increase have occurred. The two groups consist on the one hand of studies supporting the neoclassical explanation of factor accumulation, with most notable studies including Young (1992, 1993, 1995), Kim and Lau (1994), Krugman (1994) and Collins and Bosworth (1996). These studies conclude that increases in factor inputs of labor and capital alone are responsible for the high rates of economic growth experienced in the Asian NICSs. Often referred to as fundamentalists, or 'accumulationists', they believe that these economies 'move along their production functions' according to a predicted growth path, as can be predicted by exogenous and endogenous growth models.

Opposing the neoclassical argument are studies supporting the process of assimilation, which tries to offer an alternative approach for explaining the sources of economic growth in East Asia. The theory of assimilation states that many more factors besides capital investments were responsible for high rates of growth. Although factor inputs have risen steadily across the years, unusually high rates of growth were achieved due to productivity gains, making it indeed a 'miraculous' achievement. The adoption of new technologies, improvements in human capital through investments in education, stimulation of entrepreneurship and innovation, more efficient organization are all important policies that helped the Tigers in becoming so successful. This concept tells us that the East Asian NICs, moving from little or no technological stocks at all, progressively learned to master their new production processes during the 1970s and 1980s. Proponents of this idea include Kawai (1994), King and Levine (1994), Sarel (1997), Drysdale and Huange (1997), Dowling and Summers (1998), as well as two publications by the World Bank (1993a, 1993b). Supporters of this theory are often referred to as 'assimilationists' or revisionists, as they reject the notion that neoclassical growth theory alone is a sufficient explanation. The revisionist studies conclude that after controlling for factor inputs, TFP growth remains an important determinant of experienced growth rates, especially in comparison to other developing regions. The striking success in which the Asian NICs have managed to adopt new technologies from the industrialized countries certainly contributed to this.

5.2 Factor Accumulation as Source of East Asian Growth: The Neoclassicists

5.2.1 Paul Krugman

In 1994, Paul Krugman published a controversial article in *Foreign Affairs* called "The Myth of Asia" in which he laid out the misconceptions on economic growth in the particular case of the East Asian tiger economies. In the article he shattered any notion of an Asian 'miracle' and argued that neoclassical growth theory is entirely sufficient to account for the sustained high rates of growth for over thirty years. Krugman challenges the notion that economic growth there was a result of increases in productivity and efficiency, and draws a parallel between the experiences of Singapore's leadership under Lee Kuan Yew and the 'cautionary fable' of Stalin's Soviet Union during the 1950s. A more careful investigation behind these growth stories reveals that such staggering growth rates are often entirely caused by input-driven growth. According to Krugman, the mere steady process of capital accumulation through increased savings, rather than technological progress, accounts for most of the increases in growth levels in East Asia. Consequently, Krugman warns in his paper that economic growth based on capital accumulation is unsustainable for the long run: "Mere increases in inputs, without an increase in efficiency with which those inputs are used – investing more in machinery and infrastructure – must run into diminishing returns; input-driven growth is inevitably limited."[5]

5.2.2 Alwyn Young

London School of Economics professor Alwyn Young published a series a papers dealing with the apparent miracle in East Asia (1992, 1993, 1995), in which he also denies the existence of significant growth in productivity in the four Tiger economies. Young (1992) investigated the extent of total factor productivity in the city-states of Hong Kong and Singapore. Both countries share a British colonial history, with Hong Kong having the advantage to have started out with a relatively high educated workforce since the 1960s. Young estimates that during 1970 and 1990, although TFP contributed a substantial amount to output growth in Hong Kong (30 – 50%), it was overall slightly negative in Singapore (-8%). In the latter case it appeared that productivity growth is hugely susceptible to business cycle fluctuations, as well as being reliant on capital formation for output growth. A cross-estimate of capital stocks reveals that Singapore has been experiencing one of the lowest returns to physical capital in the world since the mid 80s. Diminishing returns to capital

[5] Krugman (1994)

clearly have been reached in the case of Singapore, threatening the extent to which input-driven growth can still persist in the future. Young cites high rates of endogenous depreciation of capital as a partial explanation for the low rates of TFP recorded in Singapore. Young agrees with Krugman that future growth of the Tigers, especially in the case of Singapore, remains uncertain: "… it is clear that Singapore will only able to sustain further growth by reorienting its policies from factor accumulation toward the considerably more subtle issue of technological change."[6]

In a follow-up paper, Young (1994) puts the productivity gains in all East Asian NICs in an international perspective using OECD and Summer and Heston (1990) datasets. Although annual per capita output growth of the four Tigers appear to be amongst the highest in the world during 1960 – 1985 (showing more than a four-fold growth in living standards), these are almost entirely attributable to a rise in the aggregate participation rates. A further measure of TFP shows that, with the exception of Hong Kong, productivity growth in the remaining three Tigers is not much different than that of the rest of the world. Young finds that the crucial characteristic of the Asian NICs is that they have rapidly industrialized as a result of an expansion of investment and employment in the manufacturing sector, not due to rapid increases in productivity. He therefore concludes: "In general, rapid factor accumulation, of both capital and labour, explains the lion's share of the East Asian growth miracle, both in the aggregate economy and in the manufacturing sector. Consequently, it would be a mistake to conclude that the East Asian NICs are a prime example of the potential dynamic gains from outward oriented policies."[7]

In a third paper dealing with the subject of East Asian economic growth, Young (1995) revisits the historical patterns of TFP growth and factor accumulation of the four Tigers. He reaffirms his previous conclusions that productivity growth in East Asia has not been particularly high compared to other NICs by post-war standards: once one allows their rapid growth of inputs, "the productivity performance of the "tigers" falls "from the heights of Olympus to the plains of Thessaly."[8], and: "Neoclassical 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

[6] Young (1992, p.50)
[7] Young (1993, p. 15)
[8] Young (1995, p. 645)

economies"[9]

5.2.3 Jong-Il Kim and Lawrence J. Lau

Kim and Lau (1994) studied a dataset consisting of four East Asian NICs and five OECD countries. They conclude that the most important source of growth in the Asian countries has been capital accumulation, as opposed to the industrialized OECD countries, whose growth rates have been mainly due to technological progress. Their methodology consists of their so-called 'meta-production function', which estimates the relationship of aggregate inputs and output with the inclusion of technological progress. Kim and Lau measure that between 48 and 73 percent of economic growth of the tiger economies has been due to capital accumulation, they state that "the hypothesis that there has been no technical progress during the post-war period cannot be rejected for the four East Asian newly industrialized countries."[10] They also see little evidence supporting the hypothesis of convergence in technology, as their data shows that the productive efficiency gap between the US and the group of East Asian NICs as whole has in fact widened. Kim and Lau fear that the East Asian NICs might find difficulties catching up with the industrialized nations, because that despite their high capital accumulation, productivity continues lags behind. Although this seems counterintuitive to the presence of a high educated workforce in East Asia, it seems that innovation and research and development are areas in which there should be a much high devotion of resources. In a second paper, Kim and Lau (1996) widen the scope of study to all NICs in the Asia Pacific region, in which they again conclude that increases domestic savings have been driving output growth of the Asian NICs for the past decades.

5.2.4 Susan M. Collins and Barry P. Bosworth

Collins and Bosworth (1996) examined a group of 88 industrialized and developing economies, which focuses on seven HPAEs. They reach strikingly similar conclusions to Young in the sense that East Asian TFP growth has been strikingly low indeed, although still being higher than other developing regions in the world: "it appears that the East Asian economies do well because they are willing to make sacrifices necessary to accumulate capital at very high rates"[11]. Further results show that productivity gains remain low across the whole developed world, suggesting that widespread transfer of more efficient production processes, management expertise and technology from industrialized countries has not taken

[9] Young (1995, p. 675)
[10] Kim and Lau (1994, p. 246)
[11] Collins and Bosworth (1996, p. 173)

place on a large scale. Collins and Bosworth observe that TFP growth was modest because technology transfer remained limited in countries during early stages of development, in which physical and human capital accumulation took precedence. It is not until the country reaches a specific threshold that these investments pay off in the form of long-term productivity increases. The reason that capital accumulation could take place for such an extended time is due to high rates of domestic savings, especially in Singapore with its state-mandated savings programs. Finally, the authors disagree with Krugman's notion that the days of high growth in East Asia are numbered. A consistent and steady rate in investments, improvements in education and the apparent recent gains in TFP pose a promising outlook for the region. Further convergence of the Asian NICs with income levels of the OECD countries is certainly a realistic prospect.

5.3 Opposing a Neoclassical Explanation for the East Asian Tigers: The Revisionists

5.3.1 Hiroki Kawai

Kawai (1994) investigated a dataset of seven HPAEs (excluding Japan), including China and the Philippines, as well as a group of seven Latin-American countries over the period of 1970 until 1990. In the paper the author tries to find a link between productivity growth and the extent of trade liberalization policies by governments. The study concludes that the growth experiences of East Asian and Latin-American countries are remarkably different from each other in terms of TFP growth. The Asian NICs show a much higher level of multi-factor productivity growth than their Latin American counterparts. Kawai further notes that besides capital accumulation, TFP growth remains an important factor in explaining growth in developing countries. Another important aspect is trade liberalization, in which East Asia and Latin America remarkably differ, as the former mainly stressed an export-driven agenda since the 1980s, while the latter mostly focused on inward-oriented policies. Kawai does note however, that effective trade policy largely depends on a country's unique characteristics and its current stage of development. Although trade liberalization and the promotion of export-oriented industries worked out well for the HPAEs during the 1970s and 1980s, it would be better for countries in an early stage of economic development to adopt policies which to some extent protect infant industries.

5.3.2 Peter Drysdale and Yiping Huange

Drysdale and Huange (1997) also pose a contrary view to the findings of the 'fundamentalists' proponents, concluding that the higher than average growth of East Asian

tiger economies, with the exception of Singapore, are in attributed to technological progress. In other words, estimates of TFP growth of the Tigers are a distinctly different story from the experiences former Soviet economy in the 1950s and 1960s. They conclude by using more reliable data on investment rates by Summer and Heston (1991), that Krugman was wrong to assume that factor inputs alone accounts for growth in East Asia. Drysdale and Huange compute that around a third of all economic growth in Hong Kong, Taiwan and South Korea during 1950 – 1990 was caused as result of productivity increases. Singapore's findings however, confirm earlier results which suggest factor accumulation was the sole determinant of growth, as in the case of Singapore TFP growth was still only 0.8 percent. The authors further note that improvements in productivity and technology are crucial elements in explaining their rapid economic transformation for the East Asian NICs as a whole.

5.3.3 Michael Sarel

Sarel (1996) agrees on the notion that the four Tigers have accumulated labor and capital at a much faster rate than other regions in the world. This accumulation of factor inputs accounts for a large portion of experienced growth rates, but according to Sarel productivity increases remain an important source of output growth as well. TFP growth in the four Tigers, although in a lesser extent in the case of Singapore, is more or less at par with advanced economies such as Japan or the United States. Sarel's findings differ much from Young (1995), because Young used a specific time period of 1970 – 85 and a relatively high value of α (0.45). According to Sarel, both of these assumptions lead to a significant underestimation of actual productivity growth, and might be the cause of Young's pessimistic view of TFP growth in the four Tigers. The results between Sarel's baseline estimation of overall productivity increases in the four countries and those of Young are quite striking: a TFP growth of 0.0308 compared to 0.0100. Sarel remains inconclusive what exactly was the root cause of the growth successes in Asia, but cites the initial conditions in the four countries as important indicators. Although it is ambiguous to which exact government policies are favorable for growth and which not, he stresses that government should aim at 'getting the basics right'.

5.3.4 Robert J. Barro and Chang-Tai Hsieh

During the aftermath of the Asian financial crisis of 1997 – 98, the popular opinion on the Tigers' achievements started to falter and questioned the ability of the countries to sustain growth rates in the future. Robert J. Barro (1998) however writes that "the East Asian Tigers have plenty to roar about", and defends the view that technological progress did play a

significant part in output growth of the region. In contrast with Young, Barro does believe that the long-run high growth rates of the Tigers can only be explained by improvements in technology. He argues that even though they invented little for themselves, it would have been fairly easy for them to copy or imitate superior production processes from the industrialized world. Barro cites Hsieh's study (1998) to challenge Young's findings. In contrast with Young, Hsieh finds out that Singapore had national accounts dramatically overstated its capital stocks, which caused Young to erroneously conclude that productivity has been spectacularly low over the past decades. Hsieh tries to solve the problem of bad national income accounts by computing price-based estimates of TFP growth. He uses a dual measure of the Solow residual by taking the share-weighted growth in factor prices, which in the case of Singapore results in a discrepancy between market trends and as stated in national reports. While Hong Kong and Korea seem to have measures on market returns on capital consistent with their accounts, Taiwan also appears to have higher dual estimates than previously estimated.

5.4 Conclusion

Krugman and Young were amongst the first to conclude that East Asian growth was entirely factor driven. The proposition that productivity increases were almost non-existent offered a completely new perspective on the developments that took place in the region. It also posed the question on how sustainable this trend will be for the future. In the subsequent years however, with new available data and methodology, other researchers concluded that the Tigers indeed experienced significant increases in productivity.

Previous sections have highlighted the ambiguous nature of the concept of TFP growth, which makes it difficult to accurately measure and interpret the results made by growth accounting studies regarding the East Asian NICs. The differences in methods of measuring residual growth rates and inconsistencies in national account data have led researchers to reach very different conclusions. Table 6 gives an overview of TFP growth estimates of the previously mentioned studies, as well as estimates from other notable papers, which show the discrepancy between the different measurements.

Table 6

A Comparative Overview of Total Factor Productivity Growth Estimates (percent per annum)

	Hong Kong	Singapore	South Korea	Taiwan
World Bank (1993a)	3.6 (60 – 90)	1.2 (60 – 90)	3.1 (60 – 90)	3.7 (60 – 90)
World Bank (1993b)	2.4 (60 – 90)	-3.0 (60 – 90)	0.2 (60 – 90)	-
Kawai (1994)	-	1.1 (70 – 90)	1.7 (70 – 90)	4.5 (70 – 90)
Kim and Lau (1994)	2.4 (66 – 90)	1.9 (64 – 90)	1.2 (60 – 90)	1.2 (53 – 90)
Nehru and Dhareshwar (1994)[a]	-	0.6 (60 – 90)	2.2 (60 – 90)	-
Young (1994)	2.5 (70 – 85)	0.1 (70 – 85)	1.4 (70 – 85)	1.5 (70 – 85)
Drysdale and Huang (1995)	3.1 (60 – 90)	0.8 (60 – 90)	2.1 (53 – 90)	2.9 (50 – 90)
Young (1995)	2.3 (66 – 90)	0.2 (66 – 90)	1.7 (66 – 90)	2.6 (66 – 90)[b]
Collins and Bosworth (1996)	-	1.5 (60 – 94)	1.5 (60 – 94)	2.0 (60 – 94)
Sarel (1996)	3.8 (75 – 90)	2.0 (75 – 90)	3.0 (75 – 90)	3.5 (75 – 90)
Hsieh (1999)	2.7 (66 – 91)	2.0 (68 – 90)	1.6 (66 – 90)	3.7 (66 – 90)

a. model with human capital, first difference model
b. excluding agriculture

6. Regression Analysis

6.1 Methodology

The per worker growth accounting equation (3.2) from the Solow model reveals that output is primarily the result of capital and labor inputs, with any residual growth indicating improvements in total factor productivity. Endogenous growth studies cite human capital as one of the main forces driving long-run improvements in productivity levels. In the context of the Asian Tigers, these variables relating to factor inputs should reveal an impact on per capita growth levels over the forty year period of 1960 - 2000. The extent of TFP growth should provide an answer to which degree a neoclassical explanation is applicable, and how miraculous or unique the developments of the four Tigers in fact are. In the following section a simplified regression analysis will be performed in order to determine which factors had a significant impact in explaining the sustained increases in income across East Asia. The following regression equation is used:

(6.1) $\text{LnRealGDP} = \beta_0 + \beta_1 * \text{Capital Intensity} + \beta_2 * \text{Higher Education Completion}$

Output growth per worker is measured by taking the logarithmic values of real GDP levels at 2005 US Dollars. The explanatory variables that compromise the sources of output growth are capital intensity for capital accumulation and higher education completion rates for total factor productivity. Capital intensity denotes a country's total level of investments as a percentage of real GDP (at constant 2005 USD). Higher education completion rates are an indicator of the educational attainment and skill of the workforce. A higher proportion of workers that has completed college or university level are an important factor in raising the productivity and human capital of the overall population.

Real GDP and investment data are taken from Summers and Heston's *Penn World Tables* (2009). Educational attainment data is provided by Barro-Lee's (2000) study on worldwide educational performance, which provides attainment and completion rates from 1960 to 2000 over five year intervals. The gaps between these intervals were estimated using linear interpolation.

6.2 Regression results

Table 7

Regression results Hong Kong

Period	Capital intensity	Educational Attainment	Adjusted R^2
1960 – 1970	0.010 (0.002)*	1.239 (0.066)*	0.979
1970 – 1980	0.027 (0.014)	0.014 (0.150)*	0.958
1980 – 1990	-0.012 (0.005)**	0.237 (0.025)*	0.962
1990 – 2000	0.003 (0.004)	0.058 (0.014)*	0.802
1960 – 2000	-0.033 (0.011)*	0.302 (0.025)*	0.805

dependent variable: rgdpch; std. error between parentheses

* significant at 1% level

** significant at 5% level

Table 8

Regression results Korea

Period	Capital intensity	Educational Attainment	Adjusted R^2
1960 – 1970	0.006 (0.005)	0.269 (0.071)*	0.934
1970 – 1980	0.005 (0.004)	0.169 (0.022)*	0.992
1980 – 1990	0.029 (0.005)*	0.143 (0.015)*	0.990
1990 – 2000	0.014 (0.001)*	0.053 (0.002)*	0.991
1960 – 2000	0.029 (0.002)*	0.081 (0.006)*	0.984

dependent variable: rgdpch; std. error between parentheses

* significant at 1% level

** significant at 5% level

Table 9

Regression results Singapore

Period	Capital intensity	Educational Attainment	Adjusted R^2
1960 – 1970	0.000 (0.006)	0.281 (0.020)*	0.960
1970 – 1980	0.004 (0.005)	0.756 (0.060)*	0.967
1980 – 1990	0.000 (0.006)	0.371 (0.106)*	0.767
1990 – 2000	0.012 (0.005)**	0.132 (0.011)*	0.941
1960 – 2000	0.016 (0.006)**	0.369 (0.018)*	0.915

dependent variable: rgdpch; std. error between parentheses

* significant at 1% level

** significant at 5% level

Table 10

Regression results Taiwan

Period	Capital intensity	Educational Attainment	Adjusted R^2
1960 – 1970	0.081 (0.034)	-0.095 (0.588)	0.826
1970 – 1980	0.027 (0.012)	0.298 (0.053)*	0.875
1980 – 1990	0.020 (0.004)*	0.500 (0.022)*	0.985
1990 – 2000	0.007 (0.005)	0.153 (0.008)*	0.992
1960 – 2000	0.043 (0.007)*	0.278 (0.016)*	0.960

dependent variable: rgdpch; std. error between parentheses

* significant at 1% level

** significant at 5% level

6.3 Conclusion

The regression results for the four Tigers over the period 1960 – 2000 show that both capital intensity and educational attainment are good predictors for observed growth rates. With the exception of Singapore, the two factors reveal a high significant ($\alpha = 0.01$), positive influence on output growth, suggesting that the Tigers' economic successes are attributable to the continuous improvements and investments in the accumulation of human, as well as physical capital. If we break up the period of 1960-2000 into four decades, the regressions reveal a different picture: educational attainment still appears to be significant in each ten-year interval, but investments only prove to be significant in less than half of the observed periods.

The results reveal that the proportion of college graduates in the Asian countries appears to be strongly correlated with real GDP growth over the years, challenging Krugman and Young's claims that capital accumulation alone was responsible for the Tigers' growth. Excluding Hong Kong, the first two decades following 1960 show hardly any significant correlations between output and capital inputs. According to these regressions, a neoclassical explanation would be clearly insufficient; instead it favors the assimilationist view that, amongst other factors, education proves to be the key factor in development. Assuming human capital alone drives total factor productivity growth, the previous estimates strongly support the notion that the Tigers have achieved miraculous improvements in economic growth. While this simplified assumption does not take into account the role of government and technology transfers, it does question the validity of the fundamentalist hypothesis in this particular set of countries.

7. Conclusions

The countries of Hong Kong, South Korea, Singapore and Taiwan clearly have been amongst the fastest growing economies in the world for the past fifty years, which has led to a swift income convergence with the industrialized world. Their successful emergence to the world stage has sparked considerable interest of growth economists. Solow's neoclassical growth theory proves to be remarkably robust in explaining the growth paths of not only the US, but also of most emerging economies in the world. Exogenous, endogenous and institutional approaches to economic growth theory each have been proposed to explain the origins of long-term sustained growth in Asia.

East Asia's story of rapid economic progress has been a clear example of how developing countries can successfully reap the benefits of globalization. The four Asian Tigers have shown that initially backward and poor countries can achieve tremendous increases in living standards in a short period of time. The neoclassical model correctly predicts that high rates of savings, investments in new capital and increases in labor hours and participation have helped the Asian NICs in achieving this growth. However, this explanation alone understates their economic achievements, as the regression results indicate that the steady improvements in education have allowed this trend to continue for such a prolonged time. When taking in account the evolution and transformation of the four economies over forty years, perhaps a more twofold explanation is required: "technological progress provides the engine of long-run growth, accumulation will play an independent role during a (perhaps prolonged) transitional phase."[12]

Empirical literature investigating the sources behind the Tigers' development has been fundamentally divided due to inconsistencies in national statistics and methodology. Productivity growth estimates from a great variety of researchers have shown wide disparities, which makes it difficult to determine how reliable such calculations are. Growth accounting exercises as envisioned by Solow seems simple to comprehend, but it appears that reaching conclusive results on the experiences of the Tigers proves to be difficult. While interpretation of growth accounting remain largely ambiguous, in comparison, East Asia seemed to have fared much better than Latin America and Africa, which might be puzzling considering the three regions started out from similar, if not worse, initial conditions.

[12] Grossman and Helpman (1994, p. 26)

To account for the discrepancy found between the different regions across the world, future studies should not ignore the institutional variables which unquestionably played an important role. More studies like Kawai (1994) centering on the effect of trade liberalization and which economic policies exactly are most effective in promoting productivity growth are thus imperative for impoverished countries. Besides government policy, social infrastructure and institutions played an important part in the East Asian NICs. It might prove interesting to which political freedom, corruption and domestic conflicts influenced domestic developments in the Asian NICs.

Krugman's warning of future diminishing returns to capital becomes ever more crucial after nearly fifty years. If he were to prove right in asserting that East Asian growth is merely input-driven, it implies that further economic growth is unsustainable for the East Asian economies. The Asian Financial Crisis of 1997-98 has had a big impact on most Southeast Asian countries, but most of the region eventually has managed to return to its former growth pace. It seems that technological change and human capital have allowed the Tigers to offset this diminishing capital returns by improving productivity.

In conclusion, it seems that the Tigers might not have experienced a miracle in the technical sense, as TFP growth is still not at par with the industrialized world. However, their progress can indeed be considered miraculous from a developing country's perspective. When considering other developing countries, which started from initially worse conditions since mid-20th century, the overall lack of high growth and convergence from other NICs becomes apparent. The important policy lesson developing countries can draw from the success story of the East Asian Tigers, is that governments need to pursue policies that stress the promotion and formation of both human and physical capital. However, getting the political and institutional "basics right" proves to be difficult in practice for most countries seeking economic progress.

8. Appendix 1

1. Deriving the per capita Solow production function:

Transformation from aggregate to per capita notation, lowercase variables describe *per capita*, uppercase *aggregate* values. Considering the following identities: $y \equiv Y/L$ and $k \equiv K/L$, output per worker is computed as:

(A.1) $$y = \frac{AK^{\alpha}L^{1-\alpha}}{L} = \left(\frac{AK}{L}\right)^{\alpha} = Ak^{\alpha}$$

2. The growth accounting equation

Consider the following production function:

(A.2) $$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha}$$

Take logs and then derivatives w.r.t. time:

$$\log Y = \log A + \alpha \log K + (1-\alpha) \log L$$

$$\frac{d \log Y}{dt} = \frac{d \log A}{dt} + \alpha \frac{d \log K}{dt} + (1-\alpha) \frac{d \log L}{dt}$$

(A.3) $$\frac{\dot{Y}}{Y} = \frac{\dot{A}}{A} + \alpha \frac{\dot{K}}{K} + (1-\alpha)\frac{\dot{L}}{L}$$

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