Take-Offs, Landing and Economic Growth[1]

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Abstract

Economic growth in the East Asian economies has been remarkable over the later part of the last century, starting with Japan just after the Second World War, followed by the Asian Tigers in the 60s, the tiger cubs after that and most recently China and India. The 6-10% sustained economic growth rates of these economies during their boom period has reduced the disparity between the West and these countries (in terms of standard of living) and the source of such growth has hence been a matter of great interest since. The questions that we will be addressing in this paper are: can technological stickiness explain the relatively constant rate of growth that the Asian catch-up economies experienced in the decades following their take-off and before their landing? How and exactly when did the take-off occur? Why did the take-offs occur when they did? What are the essential features of the political economy of take-offs? We empirically define take-offs and landings, and provide an overlapping generations model to answer these questions.

Keywords: Take-off, Landing, East Asian Tigers, technology trap.

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1 Introduction

The growth take-off in Europe during the Industrial Revolution caused massive income divergence between the present developed and undeveloped nations. Per capita incomes of the West European countries rose from only 30% above those of China and India at the beginning of the Industrial revolution to about 900% that of China and the other poor nations by 1870 (Madison 1983, Bairoch 1993). Economic growth in the East Asian economies however took-off only in the later part of the 20th century, starting with Japan just after the Second World War, followed by the Asian Tigers in the 60s, the 'tiger cubs' after that and most recently China and India. The 6-10% sustained economic growth rate during their boom period reduced the disparity between the West and the East Asian tigers (in terms of standard of living) and placed the newly industrialized countries of yesterday among the advanced economies of today.

The economic reforms of the 1980s have transformed China from a predominantly agrarian economy to an urban-based manufacturing growth hub. China is now the second largest economy of the world, having overtaken Germany in 1982 and Japan in 1992 in purchasing power parity terms (Madison and Wu, 2008) and is expected to soon overtake United States as the largest economy of the world. Interestingly enough, India has also experienced a high and stable output growth per year over the last two decades surpassed only by China and some of the East Asian countries.

The impressive performance of the Asian Economies has been the basis for a large and varied literature, most of them focussing only on the reasons for such growth. This is important as the sources of economic take-offs are much less well understood than the long term elements of growth. Take-offs remain rare in recent times limited to the few Asian success stories while several countries still await their own take-off miracle (Easterly, 2005). The questions that we address in this paper are: how best to define take-off and landing empirically? How and exactly when did the take-off occur? Why did the take-offs occur when they did? What are the essential features of the political economy of take-offs? Can technological stickiness explain the relatively constant rate of growth that the Asian catch-up economies experienced in the decades following their take-off and before their landing? We empirically define take-offs and landings as the presence or not of sustained economic growth higher than that of the United States for a specified number of years, and provide an overlapping generations model to answer the rest of the questions.

The model formalizes the political economy idea that take-offs and landings are determined by forces that are internal to the economic system and is the result of a 'spontaneous and discontinuous change' (Schumpeter, 1911) that displaces the equilibrium state previously existing. New innovations are continuously made possible in the research and development sector with the available state of technology and the resources devoted to this sector. An irreversible technology upgrade that can put the economy on a higher technology frontier is available but can be attained only at a higher political, social and psychological cost that provide severe impediments to technology adoption. It is this change to the production method in the form of a 'creative destruction' (Schumpeter, 1942) that provides a big push sufficient enough to escape the poverty trap in the sense of zero growth and to take-off into self-sustained growth.

Our Neoclassical-Schumpeterian hybrid growth model with overlapping generations and sticky technology is able to explain not only the high growth rates experienced by the Asian miracles for decades but also the political economy underlying take-offs and landing. The growth patterns along with the take-offs and landings of the model economy closely approximates that of the real world. The predictions of the model are also rather optimistic as it re-enforces the importance of a low level equilibrium trap (Nelson, 1956) and a critical minimum effort (Leibenstein, 1957) necessary to put a stagnant economy on a higher growth trajectory.

The remainder of the paper is organized as follows. Section 2 generates an empirical rule of thumb to determine when each of the Asian miracles took off and landed (if they have already landed). In the third section of the paper we make an attempt to model take-offs as “radical changes in the methods of production” in an overlapping generation setup with finitely lived individuals and neoclassical capital accumulation so that it presents the dynamic behaviour with those properties. In the last section of the paper, we present the propositions and results of the paper and run simple regressions to test the propositions derived in the theoretical section of the model.

2 Take-offs[4] and Economic Growth

In the1950s Western Europe, the US and the 'European satellites' (Australia, New Zealand and Canada) produced more than 50% of the world economy, and it accounted for close to 75% if we include the regions of Eastern Europe and the former USSR into our definition of ‘the West’. China on the other hand accounted for less than 5% of world GDP then, which by 2004 had increased to 12% of the World economy and is expected to dominate the world economy soon (Frijters et al, 2008). To better understand the unprecedented growth of China, India and the other Asian economies in the later part of the last century we begin by empirically defining take-offs and landing using a rule of thumb in this section and then use it to determine exactly when did these countries take-off and land (if they have already landed). Thus while take-off is important, the determinants of take-offs are far from clear and warrant attention.

[4] “Economic Takeoff” is a term coined by Rostow (1960).

2.1 Defining Take-offs and Landing

A country is said to have taken off in terms of economic growth if it has effectively applied radical changes to its available resources and has set ahead on a path of sustained economic growth extending for decades (Rostow, 1960).

Earlier papers in the literature on the identification of take-offs that used empirical rules have defined ‘takeoff’ as going from about zero growth (between -0.5 and 0.5 percents) to “permanent” sustained positive per capita growth (above 1.5 percent) Easterly (2005). Out of the experience of the 127 countries examined take-offs were found in only 9 of them (that too using both the baseline definition and the robustness checks). Both definitions used were not consistent and could not be used to identify all the take-offs at a time. In another paper Aizenman and Spiegel (2007) defined take-offs as periods when real per capita GDP growth exceeded 3% over a minimum of 5 years within 10 years of the stagnation period. It found that “Of the 241 stagnation episodes in our full sample of 146 countries, 1950-2000, 54 % are followed within 10 years by takeoffs”. This paper identified too many countries with an average duration of takeoffs exceeding 9 years and hence we consider it a very general definition that fails to capture the real essence of take-offs and the possibility of sustained economic growth for decades. Thus we believe that permanent take-offs from poverty traps are indeed rare (Easterly, 2005; Aizenman and Spiegel, 2007) and are limited mostly to the Asian economies. The papers that have attempted to identify take-offs and landing empirically so far have chosen arbitrary values as an empirical rule of thumb and so resulted in inconsistency (Easterly, 2005) or over-determination of take-offs that are often not sustainable (Aizenman and Spiegel, 2007).

We obtained different results from the empirical investigations of takeoffs presented in the literature so far mostly because of the different definitions considered to determine take-offs in growing economies. The definition that we adopt to identify the take-offs in this paper is more stringent and close to Aizenman and Spiegel (2007). Instead of choosing this rule a priori we experimented with alternative rules and chose the one that lacked the earlier deficiencies but could be easily used to identify take-offs and landing.

Take-off in this paper is defined as a higher growth rate than the United States[5] consecutively for five years at a stretch. The first year of this five year window is taken to be the take-off period. Intensive study has proved that any country which has survived maintaining higher than United States growth rate for five years has set ahead on a period of long sustained ('permanent') economic growth until they land a few decades in the future.

We define the landing phase of a country in a similar light as a year in a 5 year window period during which the country has experienced less than United States growth for at least 3 years in a row. The first year of slower growth than the United States in that window period marks the landing for that particular country[6].

2.2 Identifying Take-off and Landing Stage

Having defined take-offs and landing in the last subsection, we use these definitions to identify the year the country in question took-off and landed. Take-offs and landing of each and every country that has taken off post 1900s has been determined using the per capita

[5] We have used United States as a benchmark in this model to locate the take-off of countries post 1900s. United States has been used as the benchmark in this paper for a number of reasons. Firstly, it has grown at a constant rate of exactly 2% on average between 1871 and 2008. Secondly, data for United States is available for every year without a break (measured in International dollars) and lastly, it has itself not experienced take-off during this period.

[6] Except two countries, Indonesia and Malaysia, took off prematurely in 1968 but failed to sustain high growth rates and hence landed. But both of them have taken off again and this time they are expected not to land prematurely and our definition was able to capture both of them.

GDP measured in 1990 Geary Khamis International dollars from the Statistics on World Population, GDP and Per Capita GDP, 1-2008 AD. Table 1 reports the results followed by a brief discussion of an example from each of the groups of Asian Miracle economies.

[Table 1]

Table 2 represents the average growth rates for all the countries which have taken off for three periods of interest: pre-take-off period, the period between take-off and landing and post landing (if any). If the countries have not landed yet we show the average growth rate for the period till the year 2008. For three countries: Malaysia, Indonesia and Myanmar which experienced one failed take-off each before taking off again, we only specify the details of the first take-off.

[Table 2]

2.3 Advanced Economies

Most of the advanced economies of the West took off in the past, well before 1900s with Japan being the only one among them to take-off as late as the 1950s and being the lead goose in the 'flying geese paradigm' (Akamatsu, 1962) of South East Asia. We discuss the experience of Japan over here under the growth experience of the advanced economies, as its recent experience is quite interesting.

[Figure 1]

[Figure 2]

Japan has experienced average growth rate of about 1.88% every year between 1871-1944 (excluding 1945[7]) and 2.02% every year when we only consider the growth experience

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[7] 1945 is excluded from our discussion as it is considered to be an outlier year for Japan which experienced tremendous blow to its economy in 1945 due to the two atomic bombing incidents against the cities of

between 1900-1944 (excluding 1945). Japan took off in the year 1946, soon after the bombing incident and landed in the year 1973. During this period Japan grew at an average rate of 7.97%, which is an almost fourfold increase in per capita GDP growth rate at 1990 international GK international $. Japan's per capita GDP at PPP grew from $1,444 in 1946 to $11,434, thereafter growing at about 2.01% per year between 1974-2008, which is the same as the growth rate of United States.

2.4 East Asian Tigers

Even though some of the East Asian Tigers who had extremely high growth rates in the 1960s are counted as advanced or developed countries today by many institutions like IMF, World Bank and OECD. We have grouped them separately under a different subsection for ease of understanding. The East Asian Tigers or the Asian Miracle countries include countries like Hong Kong, Taiwan, South Korea, and Singapore which have transformed themselves from technologically backward and relatively poor nations to relatively modern, affluent societies in the last 35 years, thereby experiencing more than a fourfold increase in per capita GDP. Their growth performance has far exceeded the experiences of virtually all comparable economies in the West. We use Hong Kong as an example over here for all practical purposes.

[Figure 3]

[Figure 4]

Hiroshima and Nagasaki by the United States during the final stages of the World War II. The US dropped the nuclear weapon “Little Boy” on the city of Hiroshima on August 6, 1945 followed by the “Fat Man” over Nagasaki on August 9, 1945.

Hong Kong grew at an average rate of 2.11% per year between 1914-1959 until it took off in 1960 thereafter growing at 5.74% per year between 1960-1994. Finally, it landed in 1995 after which it has grown at an average rate of 3.13% but it has never been a steady growth again.

2.5 China and India

At last we turn our attention to China and India which has been at the centre of a number of discussions in the last two decades. The Chinese economic miracle has been a classic example for its decades of extraordinary high steady growth similar to that experienced by the East Asian tigers between 1960 and 1980. According to our definition, both China and India has already taken off: in 1977 and 1988 respectively but has not yet landed. Per capita GDP of China increased from $894 in 1977 measured in 1990 Geary Khamis International dollars to $6725 in 2008, an eight fold increase. Compared to China, India's Per capita GDP increased from $1216 in 1988 to $2975 in 2008 at 1990 dollars.

[Figure 5]

[Figure 6]

The per capita GDP growth rate of China experienced about a tenfold increase from a staggering average of 0.68% per annum in the pre-reform period (1901-1976) to a post-reform average of 6.73% per annum (1977-2008). India however took off only during 1988 growing from an average growth rate of 0.81% per year between 1901-1987 thereafter growing at 4.76% per year between 1988-2008.

[Figure 7]

[Figure 8]

They have been experiencing a period of long sustained economic growth extending well over two decades now without any sign of tapering off over the years. The growth rate since take-off has been not only extra-ordinarily high (“positive”) but also stable, and the economy seems to be able to withstand unexpected shocks.

[Table 3]

We provide a regression estimate to show that growth rate in the Asian Economies post-take-off and pre-landing has been more stable, thereby sustaining ‘positive’ growth rate over the years.

A striking feature about the incidence of take-offs is that they are rare and geographically concentrated (Easterly, 2005), in Asia amongst countries which are now recognized to have had a range of government strategies in place, from extreme laissez-faire to extensive beneficial interventions (World Bank, 1993a; Stiglitz, 1996). Like Japan, the Asian Economy governments played a major role in maintaining law and order, expanded schooling, targeted investments in the R& D sector and to bring about structural changes in the economy like economic reforms for China, trade liberalization for India, etc that were largely successful. The governments were pro-growth, subsidizing exports, promoting green revolution, investments in education or schooling, encouraging FDI, etc.

3 The Theoretical Model

Once we have empirically defined and identified take-offs we model take-offs as "radical changes in the methods of production" in this section.

An AK type production function that lacks diminishing returns could have been used to explain the stable growth experience post take-off but that will imply positive long run per capita growth without any possibilities of a landing. This is a substantial failing of the model as it fails to explain the 'landing' that was found to be an empirical regularity among countries that have taken off.

In a neoclassical model on the other hand there are declining growth rates along the transition due to the existence of diminishing returns to capital and it would have been impossible to maintain per capita growth just by accumulating capital. There may however be constant returns to capital when capital is broadly defined to include both physical, human and knowledge capital similar to Lucas (1988). The model that we set up in this section is able to explain the annual growth rate of 6-10% that the Asian economies have maintained for decades. The growth patterns along with the take-offs and landings of the model economy closely approximates that of the real world in terms of its sustained positive growth for decades which could not be explained by any other model to the best of our knowledge

3.1 The Basic Assumptions of the Model

We start our analysis with a very simplified version of the neoclassical growth model, with the same basic general equilibrium structure as the Solow (1956) and Mankiw et. al (1992). Each household (or family) is identical in this model economy, has the same preference parameters, and owns the inputs and assets (including the firms) which transforms the inputs such as physical capital and human capital into output using the available technology. All output produced by the firms is either consumed, saved by the individuals or taxed by the government (to fund public expenditure). The economy transforms the available inputs into output using a Cobb Douglas type production function of the form

$$Y(t) = K(t)^{\alpha} KN(t)^{1-\alpha} \quad ; 0 < \alpha < 1 \qquad \text{(Equation 1)}$$

The notation used is standard where Y denotes the level of output or gross domestic product of the economy, composed of not only physical capital (K) with decreasing returns but also a composite human capital component called 'knowledge capital' (KN), a result of labour augmenting technological progress undertaken in the Research and Development Sector of the government.

The production function is adjusted so that it exhibits "no scale effects" by dividing both sides of equation (1.1) by L, the total population in the economy so as the state the production function and the entire model in per capita terms. We will use lower-case letters henceforth to denote the per capital variables in this paper.

$$y(t) = k(t)^{\alpha} kn(t)^{1-\alpha} \qquad \text{(Equation 2)}$$

where k is the capital per worker and kn is the per capita knowledge base. All the characteristics of a neoclassical production function is satisfied (including the Inada conditions), it is increasing, concave, and twice continuously differentiable.

A constant fraction of the output, s, 0<s<1which is exogenously set is saved and invested (Basu and Weil, 1998, Solow, 1956). Therefore, each unit of output is homogeneous, equally productive irrespective of the time of their production and can either be consumed or invested (either in physical capital or in innovation), such that one unit of output devoted to investment yields exactly one unit of capital. While new addition is made to the existing sock of capital, old capital depreciates at an exogenous fixed rate of δ .

The evolution of capital overtime is exactly the same as in the neoclassical model and is given by

$$\dot{K}(t) = sY(t) - \delta K(t) \; ; 0 < s, \delta < 1 \qquad \text{(Equation 3)}$$

which in per capita terms is denoted by

$$\dot{k}(t) = sy(t) - (n+\delta)k(t) \qquad \text{(Equation 4)}$$

This is the fundamental capital equation of the Solow Swan model where the term $(n+\delta)$ is the effective depreciation rate for the capital-labour ratio.

In addition we have an overlapping generation model in continuous time where agents live for a finite interval of time which presents life cycle behaviour as developed by (Cass and Yaari, 1967; Blanchard, 1985; Samuelson, 1958, Diamond, 1965). Time is continuous and indexed by $t \in [0, \infty)$. Individuals are identical in every respect except for their time of birth. A new cohort $B(t)$ is born at each instant of time $t > 0$ who live for a finite period of time, $l > 0$, devote a unit of labour when employed in the labour force (there is no labour-leisure choice) and ultimately die out. Each individual lives through four phases (also 'generations' henceforth), where each generation is T periods long with the oldest generation dying and exiting the model when they turn 4T.

The size of an individual cohort at any point in time is denoted by $B(t)$ and is assumed to grow at an exogenous rate of n.

$$B(t+\tau) = B(t)e^{n\tau} \qquad \text{(Equation 5)}$$

Only a part of the population that had finished or completed the level of education $\theta \in [0, T]$ chosen by the government at time t will enter the labour force at $(t+\theta)$ and is called the 0^{th}

generation of the economy. It is interesting to note over here that we have constructed the variables in such a way that we can see the effect of the government's choice of education on the outcomes in the economy, i.e. a decision made today will affect the outcomes only when the agents in question enter the labour force after graduating. So, we may notice a lag in between the decision making procedure (regarding the state of technology) and the changes experienced by the outcomes.

Let ζ be the age at which a child born in this model enter school or in other words the school going age of the individual which could also be chosen by the government. ζ is assumed to be 0 in this model for simplicity. Information education before joining school is not considered to be formal education over here.

As four generations coexist at any point of time in this model, the total population of individuals in this model economy include the mass of pre-existing individuals, the new born kids but minus the people who die and move out.

$$L(t+\theta) = \int_{\tau=0}^{4T} B(t+\theta-\tau)d\tau \qquad \text{(Equation 6)}$$

The total population also grows at the rate of n, which is the same as the cohort growth rate because of the net influences of fertility and mortality (migration is not included over here).

$$L(t+\tau) = L(t)e^{n\tau} \qquad \text{(Equation 7)}$$

Even though four generations coexist at any point in time, the labour force will include only a part of the newest generation and generations 1 and 2. Generation 3, the oldest generation in this four generation model, including individuals who have turned 3T are retired and therefore not included in the labour force. Similarly, a part of generation 0 (part of the youngest group of individuals) who is still at school cannot be included in the labour force unless they have completed the compulsory level of education imposed by the government.

Labour force participation at any point in time is then denoted by

$$LF(t+\theta) = \int_{\tau=0}^{3T} B(t+\theta-\tau)d\tau \qquad \text{(Equation 8)}$$

3.2 Structuring the "radical change"

Growth is believed to have been faster among latecomers[8], especially the East Asian Economies as they had access to the advanced technology of the developed economies (Collins and Bosworth, 1996), which they imitated or borrowed from the early starters (Gerschenkron, 1962) and argued to have led to take-offs into sustained growth.

Technology in this model can be broadly defined as structural changes or institutional changes, stability in law and order, reforms, trade liberalization: openness to trade, imports of capital goods, direct foreign investment, etc that can improve the productivity of every dollar spent in the R&D sector. Every country has access to both a traditional technology historically available to every country as well as a modern technology that is more in line with those used in the R&D sector of the advanced economies.

$$\mu \, \varepsilon \, [\underline{\mu} \, , \, \overline{\mu}] \quad \text{where } \mu > 0, \text{ and } \underline{\mu} \neq 0$$

$$\mu = \begin{cases} \underline{\mu} & \text{the traditional technology} \\ \overline{\mu} & \text{the modern technology} \end{cases}$$

[8] Due to catching up a process also referred to as "leapfrogging"

This irreversible change to the production method in the form of a 'creative destruction' (Schumpeter, 1942) if undertaken provides a big push sufficient enough to escape the poverty trap and to take-off into self-sustained growth.

$$C[\dot{\mu}(t)] = \begin{cases} C\left[\overline{\mu} - \underline{\mu}\right] & \text{if } \dot{\mu}(t) > 0 \\ 0 & \text{if } \dot{\mu}(t) = 0 \end{cases}$$

However, to adopt the new technology the country has to incur this one-time initial set up cost which can be expected to be quite large to make the incidence of 'take-offs' and therefore 'landing' so 'rare' in the literature and in this theoretical model. This set up cost can include psychological, political as well as financial costs. The country can however continue to use the primitive technology without paying any extra cost, unless they are prepared to make the shift towards that new advanced technology.

Other papers which have modelled barriers to growth and traps are Parente and Prescott (2005), Basu and Weil (1998) and Benhabib and Spiegel (2005). Murphy, Shleifer, and Vishny (1989) and Banerjee and Newmann (1994) have also set out a model of poverty trap while Azariadis and Stachurski (2004) provide a survey of a number of theoretical models on poverty traps.

3.3 The Role of the Government

Throughout the 1960s development economists have often defined underdevelopment as a state which arose when the economy failed to achieve the necessary coordination or push needed to land on that higher balanced growth path. This provided a theoretical justification for the role of government and several developing countries opted for a more centrally planned mode of development (Leibenstein, 1957; Nelson, 1956; Rosenstein-Rodan, 1961). Even in East Asia, the governments have often been cited to play a major role, by initiating and significant pro-growth policy changes that led to persistent growth (Collins and Bosworth, 1996).

Even though economists today are in favour of a free market or the “invisible hand” as a better economic system, we emphasize an important role of the government sector to plan strategies in the region as targeted intervention required for the efficient functioning of the economy (more in a complementary role than as a substitute for the market economy).

The government in our model affect the human capital stock of the economy by investing in the technology to be used in the R&D sector, and choosing the level of (formal) schooling to be imparted to the youngest population of the economy by the education system of the country, also called the “compulsory level of education”. An economy does not only have to focus on the accumulation of resources but also need to use the accumulated knowledge to increase the productivity of the economy as a whole. The importance of technology adoption was renewed by Schumpeter (1961), Nelson and Phelps (1966), that connected technology lags to the growth performance of the developing nations, Benhabib and Spiegel (1994), Parente and Prescott (1994) and Segerstrom (1999) who linked human capital formation, and technology adoption to economic growth.

There are many channels to assimilate the knowledge accumulated through the research efforts in the R&D sector. It could be through formal education gained while attending school, on the job training, through experience, etc. In a developing nation new innovations or inventions is mostly absorbed through formal education while at school due to the lack of substantial investments made to update their skills (with current information) once they graduate and enter the labour force.

Endogenous technical progress through purposeful activities carried out in the research and development carried out in universities or government research institutes may also allow escaping from diminishing returns.Take-off and sustained ‘positive’ economic growth in this model is driven by technological change in the research and development sector and so subsidies to R&D and other government policies can influence economic growth (Romer, 1990; Grossman and Helpman, 1991; and Aghion and Howitt, 1992). The research and development sector in this model has an AK type production function similar to the one used by Jones (1995) and Aghion and Howitt (2007).

$$i(t) = \mu(t) rd(t) \qquad \text{(Equation 9)}$$

Thus the intermediate good that is produced in the R&D sector using the available technology, new innovations or inventions (new patents, trademarks and blueprints) are proportional to the resources devoted to the sector, which is a constant fraction η of the total income of the economy and is exogenously set in this model.

$$rd(t) = \eta y(t) \qquad \text{(Equation 10)}$$

Equation (9) after substitution in equation (10) can then be rewritten as

$$i(t) = \eta \mu(t) y(t) \qquad \text{(Equation 11)}$$

It is important to note over here that new innovations in this model take place not only as a by-product of an increase in the R&D expenditure but also due to adoption of a better technology that leads to a productivity increase in the R&D sector. Thus the R&D sector described in the model incorporates not only a “R&D effect” but also a “Mu-effect”, both of which ultimately lead to higher inventions or innovations. However, as R&D is exogenously given in this model and constrained by η, the fraction of output that is actually spent on R&D, the only interesting effect in this model can arise through the “Mu-effect”.

3.4 Dynamics of Human Capital

Human capital of a typical worker in the economy is a result of the assimilation of the skills available in the economy absorbed through formal education chosen by the government and provided by the education system. The quality or skill adjusted human capital of an individual is then denoted by the product of the cohort specific discoveries made in the R&D sector and the absorption capacity of the cohort which learns and absorbs the new technology.

$$h(t) = a(t)i(t) \qquad \text{(Equation 12)}$$

There is thus a general difference between the two parts of the human capital (index of labour quality), the part which is affected by the productivity in the R&D sector and is the "accumulation" part of the model as well as a human specific part which is affected by the skills and skill formation through schooling (benefits of education are embodied in workers) and is the "assimilation" part of the human capital formation equation.

Education affects the skills of the individual which in turn increases the absorption capacity and the "assimilation" part of the model and can be represented by a strictly increasing function of the length of schooling achieved

$$a(t) = \psi(\theta(t)) = \phi\theta(t); \quad \phi > 0 \qquad \text{(Equation 13)}$$

Where ϕ captures the conversion of education to human capital or labour adjusted for education or skills. The total human capital (skill-adjusted measure of the labour input) of a specific cohort born at a point in time will then be a product of the number of individuals belonging to that cohort and the human capital of a typical worker, h.

$$H(t) = h(t)B(t) \qquad \text{(Equation 14)}$$

The human capital of each of the generations can then be denoted by a set of three different stocks of human capital spanning all the human capital by the generation they belonged to in the labour force.

The human capital of the newest generation will then be including only that part of the labour force that had finished the level of education θ chosen by the government at period t and so they enter the labour force only at $(t+\theta)$ and includes all the individuals of the 0th generation born before t.

$$G_0(t+\theta)=\int_{\tau=\theta}^{T} h(t+\theta-\tau)B(t+\theta-\tau)d\tau \qquad \text{(Equation 15)}$$

The human capital of the first generation will then be

$$G_1(t+\theta)=\int_{\tau=T}^{2T} h(t+\theta-\tau)B(t+\theta-\tau)d\tau \qquad \text{(Equation 16)}$$

The oldest working population (a part of the labour force) will then be individuals of the second generation and is different from generation 3, the oldest living generation by definition.

$$G_2(t+\theta)=\int_{\tau=2T}^{3T} h(t+\theta-\tau)B(t+\theta-\tau)d\tau \qquad \text{(Equation 17)}$$

An organization, such as the firms combine the human capital of all the three generations of individuals employed in the workforce to produce an economy wide knowledge capital which is then used to produce the final output using the aggregate production function.

$$KN(t+\theta)=G_0(t+\theta)^{\beta}G_1(t+\theta)^{\gamma}G_2(t+\theta)^{\chi} \qquad \text{(Equation 18)}$$

With the additional assumption that $\beta=\gamma=\chi \quad and \quad 0<\beta<1$

Then knowledge capital of the economy at a time in the future can be rewritten as a complex function of the choices made at time t about the level of technology, μ *and* θ, the level of education.

$$KN(t+\theta) = \prod_{x=0}^{2} G_x(t+\theta)^{\beta} = \varphi(\mu, \theta) \qquad \text{(Equation 19)}$$

It is important to note over here that knowledge capital in this model is produced by disaggregating human capital by generations as generations differ in skills owing mainly to their access to different levels of technology. A number of other papers have also used disaggregated inputs, like the use disaggregated capital in Romer (1990), by input quality in Jorgenson and Griliches (1967) , Jorgenson et.al (1987) and adjusted for education levels in Aggrey et al.(2010).

3.5 Sticky Technology and Take-offs

New knowledge is continuously being created by the government through the infusion of funds in the R&D sector but obsolete technology is extremely sticky (often due to the rigid institutions or high cost of changes), taking a few generations to die out in the developing nations. There is this inter-generational knowledge effect in the developing nations, which lacks in the developed nations where new technology quickly replaces outdated technology (through on the job-training to update skills). In other words the learning of skills and knowledge only through formal education makes complete replacement of old technology by advanced technology impossible and the creative destruction is slow and gradual rather than rapid and instantaneous as in developed nations.

4. The Political Economy of Take-off

The government in this model thus maximizes the net present discounted value of all future per capita income of the population. There is a trade-off that the government faces while choosing the level of education, θ. A higher level of θ will imply a higher direct effect on the absorption capability of the society forever in the future but an indirect effect is also involved, a higher level of education will also mean that students will be compelled to attend school longer, affecting their contribution to the labour force adversely, thereby resulting in foregone or lost income during the extra time they will be attending school. So, there is a trade-off involved between higher benefits tomorrow versus losses today.

The government chooses the level of education and the state of the technology to be adopted in the R&D sector so as to maximize the net (expected) present discounted value (NPDV) of all future income, which is the objective function of the government.

$$\underset{\theta \quad \mu}{Max} \;\; \omega(t) = v(t) - F\{\theta(t)\} - C\left[\dot{\mu}(t)\right] \qquad \text{(Equation 20)}$$

$$v(t) = \int_{\tau=0}^{\infty} e^{-\rho\tau} E\left[y(t+\tau)\right]\partial\tau = \int_{\tau=0}^{\theta} e^{-\rho\tau} y(t+\tau)\partial\tau + \int_{\tau=\theta}^{\infty} e^{-\rho\tau} E\left[y(t+\tau)\right]\partial\tau \qquad \text{(Equation 21)}$$

The present discounted value of future income $v(t)$ can be rewritten as two separate parts using the "Additivity property" of the integration for any choice of education $\theta \in [0, T]$, where T is a finite number, $T < \infty$. The per capita income is discounted using the discount factor $e^{-\rho\tau}$ where ρ is the rate of time preference or the discount rate; $0 < \rho < 1$.

$C(.)$ is the set cost associated with the adoption of the superior technology and $F\{\theta\}$ is the cost of providing education to those kids of generation 0 that are not a part of the labour force depends on the level of education, it includes infrastructure cost, cost of hiring teachers in the international market, expenses to be undertaken by the government to provide incentives and regulations to oversee that the compulsory level of education is actually properly enforced. Incentives provided by the government to attend school and complete compulsory education account for a higher percentage of the cost of education in the developing nations (like mid day meals, educate your daughters schemes, etc) compared to the developed nations where compulsory schooling is enforced through law.

The decision makers in this model is assumed to be characterized by myopic behaviour defined as "short-sighted expectations". Thus the formation of expectations about the future is based entirely on the current observed market and economic situations which assumes that the present circumstances will also continue in the future. Thus the expectation at t when education level θ is chosen for all future incomes post $t+\theta$ is the same as the output resulting from the current investment decisions. So,

$$E\left[y(t+\tau)\right] = y(t+\theta); \forall\, \tau > \theta \qquad \text{(Equation 22)}$$

After substituting (22) in equation (20) and maximizing the objective function of the government (using Leibniz Integration rule) for the optimal level of education we get

$$\int_{\tau=\theta}^{\infty} e^{-\rho\tau} \frac{\partial}{\partial\theta}\left\{y(t+\theta)\right\}\partial\tau = F'(\theta) + e^{-\rho\theta} y(t+\theta) \qquad \text{(Equation 23)}$$

The first term is the present discounted value of the increase in future income from a marginal increase in schooling, the second term denotes the (direct cost) marginal cost of an increase in compulsory level of education while the third term is the (indirect cost) forgone income (or the opportunity cost of education) from a marginal increase in schooling. Thus the equilibrium level of education is determined by the first order condition of the maximization problem.

The equilibrium level of education in this model is specific to a particular choice of the level of technology i.e. $\theta^* = \theta(\mu)$ and μ are θ will be complements in this model. The social planner or the government also decides whether to install the new advanced technology or to continue with the traditional one using forward calculation given that they know the optimal education for every choice of technology. The social planner will pay for this new technology (incur the setup cost) if and only if the increase in per capita output from this new advanced technology is sufficient to offset the setup cost.

$$NPDV = \begin{cases} v(t)\left[\overline{\mu}, \theta^*(\overline{\mu})\right] - f[\theta^*(\overline{\mu})] - C\left[\overline{\mu} - \underline{\mu}\right] & \text{if the advanced technology is used} \\ v(\mathrm{t})\left[\underline{\mu}, \theta^*(\underline{\mu})\right] - f[\theta^*(\underline{\mu})] & \text{if primitive technology is used} \end{cases}$$

So, the decision to install [9] is optimal if and only if

$$\underset{\theta}{Max}\ \omega(t)\big|_{\mu=\overline{\mu}} \geq \underset{\theta}{Max}\ \omega(t)\big|_{\mu=\underline{\mu}} \qquad \text{(Equation 24)}$$

Proposition 1: A country take offs into sustained ‘positive’ stable growth if and only if it crosses a certain threshold level.

Proof of Proposition 1: A country will take-off into self sustaining growth if and only if

$$\underset{\theta}{Max}\ \omega(t)\big|_{\mu=\overline{\mu}} \geq \underset{\theta}{Max}\ \omega(t)\big|_{\mu=\underline{\mu}} \qquad \text{(Equation 24)}$$

It will be optimal for a country which is still using the traditional or primitive technology to install the new or advanced technology if the NPDV from the advanced technology is higher than the NPDV when the use of the conventional technology is continued.

[9] where there is no cost if there is no installation at all. This cost C can include both psychological as well as financial cost associated with this new installation of μ. Technology shift cost is a onetime fixed cost and there are only two alternative modes of production (R&D technology) available to the countries.

As the per capita income is a function of the past per capita incomes and their associated growth rates we can always rewrite[10] $y(t+\tau)$ as a product of $y(t)$ and a complex function of the growth rates of all past periods (Ψ).

$$y(t+\tau) = y(t)\prod_{z=1}^{\tau}\left[1+g(t+z)\right]^{\partial z} = y(t)\Psi \qquad \text{(Equation 25)}$$

Thus we can write the take-off condition in (24) after substitution as

$$\int_{\tau=0}^{\infty} e^{-\rho\tau} E\left\{y(t+\tau)\right\}\partial\tau\Big|_{\mu=\bar{\mu}} - \int_{\tau=0}^{\infty} e^{-\rho\tau} E\left\{y(t+\tau)\right\}\partial\tau\Big|_{\mu=\underline{\mu}} \geq f\left\{\theta^*(\bar{\mu}) - \theta^*(\underline{\mu})\right\} + C\left[\bar{\mu} - \underline{\mu}\right] \text{(Eq. 26)}$$

We can rewrite equation (26) by substituting in equation (25) as

$$y(t)\int_{\tau=0}^{\infty} e^{-\rho\tau} E\left\{\Psi\big|_{\mu=\bar{\mu}} - \Psi\big|_{\mu=\underline{\mu}}\right\}\partial\tau = y(t)\int_{\tau=0}^{\infty} e^{-\rho\tau}\chi\partial\tau \qquad \text{(Equation 27)}$$

Rearranging this we get that the social planner will install the new technology iff

$$y(t) \geq y^*$$

Where the threshold level is $y^* = \dfrac{f\left\{\theta(\bar{\mu}) - \theta(\underline{\mu})\right\} + C\left[\bar{\mu} - \underline{\mu}\right]}{\int_{\tau=0}^{\infty} e^{-\rho\tau}\chi\partial\tau}$ (Equation 28)

This condition ensures that the social planner will incur the set up cost and move to a higher technology frontier only when the per capita output has reached a certain threshold level.

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[10] $\prod_a^b f(x)^{dx} = \lim_{\Delta x \to 0}\prod f(x)^{\Delta x} = \exp(\ln\int_a^b f(x)dx)$ This is called the "geometric integral" and is the multiplicative operator. This definition of the product integral is the continuous equivalent of the discrete product operator $\prod_{i=a}^{b}(with\ \ i,\, a,\, b \in \square)$ and the multiplicative equivalent to the classical Reiman integral $\int_a^b dx\ (with\ \ x \in [a,\, b])$.

Then an economy may be stuck in "low level equilibrium" even when the "better technology" is definitely available for adoption.

The cost associated with the so called radical change constraints the adoption of the new technology, even though the countries are willing to undergo the change and this cost can be treated as an impediment to success and in fact a reflection of the "poverty trap" operating in the developing nations. This is very similar to (Basu and Weil, 1998) where the follower was only able to use the technology of the leading country if it had sufficiently high level of development and Azariadis and Drazen (1990) which discussed threshold level in terms of a similar "technological jump".

Thus we define take-off as

$$\Phi_{it} = \begin{cases} 1 \text{ iff } & y_{it} \geq y_t^* \\ 0 \text{ iff } & y_{it} < y_t^* \end{cases}$$

Countries that start off with higher levels of per capita income at ceteris paribus will always take-off earlier.

[Figure 9]

However, when possibilities of such multiple equilibria exist in the developing nations where one of the equilibrium is the failure to escape from the "poverty trap" and the other equilibrium is a good one it puts emphasis on the role of government policy in attaining the better outcome.

4.1 Balanced Budget Condition

Research & Development expenditure incurred by the economy and the costs associated with education and the cost of installing the new technology (if actually installed) endogenously determines the total tax revenue of the government that is required to maintain the balanced budget condition of the government and is collected by levying a constant tax rate of λ per unit of output.

The balanced budget condition of the government is

$$\lambda y(t) = \eta y(t) + F\{\theta(t)\} + C\left[\dot{\mu}(t)\right] \qquad \text{(Equation 29)}$$

Once sy is invested into the accumulation of capital per worker and the government recovers the costs incurred by levying a tax rate λ,the rest of the per capita output is consumed and individual level of consumption ξ can be denoted as

$$\xi(t) = (1 - s - \lambda)y(t) \qquad \text{(Equation 30)}$$

The results from the calibrated model closely approximate the (per capita GDP) growth pattern of the Asian miracle economies and is presented in figure 10. The values of the parameters assumed in this paper are as follows: $T = 20$, $l = 80$, $\beta = \frac{1}{3}$, $\alpha = 0.35$, $\delta = 0.05$, $s = 0.3$, $\eta = 0.01$, $\rho = 0.0001$ and $\frac{\overline{\mu}}{\underline{\mu}} = 6$.

[Figure 10]

5 Propositions and Results

The above mentioned growth theory gives rise to a number of propositions and results which will be discussed in much detail over here.

Corollary 1: Countries which are more patient have relatively lower rate of time preference or discount rate will always take-off earlier and choose higher levels of education in equilibrium.

Proof of Corollary 1:

Poor countries are caught up in a technology trap which has its roots ingrained in a poverty trap, which can only be escaped when the country crosses a certain threshold level through gradual increase, or a "Big Push" in the form of increased aid, or investment. So, it is this technology trap that is the barrier to sustained economic growth in poor economies.

As we know from the take-off condition, a country will take-off if and only if $y(t) \geq y^*$ where the threshold level of per capita income is a function of the costs and a present discounted value of the growth prospects from a better technology given in equation (28).

$$y^* = \frac{f\left\{\theta(\overline{\mu}) - \theta(\underline{\mu})\right\} + C\left[\overline{\mu} - \underline{\mu}\right]}{\int_{\tau=0}^{\infty} e^{-\rho\tau} \chi \partial\tau} \qquad \text{(Equation 28)}$$

A decline in the rate of time preference or discount rate, $\rho \to 0$ will mean that countries are relatively more patient and value future more, thereby leading to an increase in the discounting and $\int_{\tau=0}^{\infty} e^{-\rho\tau} \partial\tau = \frac{1}{\rho} \to \infty$. Thereby, leading to a decline in the critical threshold level y* and the country will take off earlier as patience will make them value the future more.

Now, we analyse the effect of a fall in ρ on the optimal choice of education in the economy. We know that the optimal level of education from the first order condition of the government's maximization problem is

$$\int_{\tau=\theta}^{\infty} e^{-\rho\tau} \frac{\partial}{\partial\theta}\left\{y(t+\theta)\right\} \partial\tau = F'(\theta) + e^{-\rho\theta} y(t+\theta) \qquad \text{(Equation 23)}$$

The LHS of the equation (23) can be rewritten in the form of a present discounted value of the marginal increase in schooling.

$$\int_{\tau=\theta}^{\infty} e^{-\rho\tau} \frac{\partial}{\partial\theta} \left\{ y(t+\theta) \right\} \partial\tau = \int_{\tau=\theta}^{\infty} e^{-\rho\tau} MR_{\theta} = MR_{\theta} \frac{e^{-\rho\theta}}{\rho} \qquad \text{(Equation 31)}$$

Thus we will be able to rewrite Equation (23) as

$$MR_{\theta} \frac{e^{-\rho\theta}}{\rho} = F'(\theta) + e^{-\rho\theta} y(t+\theta)$$

A decline in the discount rate will lead to an increase in the marginal benefit at every level of education and lead to higher levels of education in equilibrium (along with an increase in the incentives to take-off.

Corollary 2: Countries with ethnic similarity and less political tensions will take-off earlier.

Proof of Corollary 2:

The threshold level of per capita income is a function of the costs and a present discounted value of the growth prospects from a better technology.

$$y^* = \frac{f\left\{ \theta(\overline{\mu}) - \theta(\underline{\mu}) \right\} + C\left[\overline{\mu} - \underline{\mu} \right]}{\int_{\tau=0}^{\infty} e^{-\rho\tau} \chi \partial\tau} \qquad \text{(Equation 28)}$$

The incidence of a take-off thus depends on the costs associated with the adoption of the new technology, which may include costs due to structural changes or economic reforms.

$$\Phi_{it} = \Phi\left\{ y_{it} \;, C(.) \right\}$$

Rephrasing the take-off condition in other words, a country will not take-off if the costs required to take-off is extremely high, i.e. if there are ethnic dissimilarity and political tensions.

$$\Phi'(C) < 0$$

Corollary 3: Countries which lack enforcement of minimum age laws or child labour laws choose lower levels of education in equilibrium.

Proof of Corollary 3:

Given that optimal level of education is determined from the first order condition of the government's maximization problem with respect to the level of education is given by

$$\int_{\tau=\theta}^{\infty} e^{-\rho\tau} \frac{\partial}{\partial\theta}\{y(t+\theta)\}\partial\tau = F'(\theta) + e^{-\rho\theta} y(t+\theta) \qquad \text{(Equation 23)}$$

When minimum age laws are not properly enforced (very common in many developing nations), the forgone income to the society constitute an important part of the cost of higher level of compulsory education and countries choose comparatively lower levels of education in equilibrium (as it is optimal).

In this corollary if we define cost of education as $F\{\theta\} = c\theta$ where c is the marginal cost (from direct costs) of choosing a higher level of education then the optimally condition for the level of education can be shown as in the figure.

[Figure 10]

The total marginal cost for every level of education is the vertical summation of both marginal costs (direct and indirect costs) - marginal cost of education c and forgone lost income and is denoted by MC while the left hand side of the optimality condition is the MB. $\theta*$ is the equilibrium level of education under the absence of minimum age laws while $\theta**$ is the equilibrium with minimum age laws. Equilibrium choice of education is always higher in economies with minimum age laws.

6. Estimation Results

This section of the paper attempts to apply simple regression tests to the model like Aizenman, J and Spiegel, M (2007) but we were limited by the scarcity of data on Take-offs. Moreover we had focused on only Asian Economies in this paper as the growth experience of different regions have been quite diverse.

We run simple regressions using a set of independent variables on two different dependent variables, which is of particular interest in this model. The variables that we use on the LHS of the regression equation are incidence of take-offs and year of take-off. In this section we want to see which countries actually took off? And out of all the countries that actually took-off which countries took-off earlier?

For the purpose of our analysis we used data on 24 Asian economies from the Madison tables and used the rule of thumb that we discussed in this paper to determine the date of take-offs (if any). 75% of the Asian economies studied actually experienced take-offs mostly in the later part of the 20th century starting with Japan.

The set of independent variables that we considered in this paper included per capita GDP at PPP as of 1950 from the Madison tables, polity score from the Polity IV data set which coded the authority characteristics of the states in the world. The "Polity Score" captures this regime authority spectrum on a 21-point scale ranging from -10 (hereditary monarchy) to +10 (consolidated democracy). Another variable that we include in the regressions is Ethnic Similarity which captures how similar the population is in terms of ethnicity. The larger the value of “Ethnic or religious Similarity” more similar is the country in terms of its composition and so can be used an indicator of political or religious stability. The last variable is the date of independence from historical data of the country.

[Table 4]

[Table 5]

The regression estimates obtained from the paper are quite consistent with the propositions and results presented in this paper. We find that while late independence of the country from colonial rule delayed take-off for a country, both ethnic similarity and polity score had a positive effect on the take-off status of a country. So, political stability or better political atmosphere increases the chances of a take-off. Polity score was found to have the largest significant positive effect of 0.279 in the baseline line. Similarly, countries with higher per capita GDP at PPP as of 1950 were found to take-off earlier and delayed independence from colonial rule delayed the year of take-off (if any). While polity score and ethnic similarity played an important in explaining the incidence of take-offs, it did not play much of a role in the regressions with year of take-off.

8. Conclusion

After relatively stable stagnant growth rates for many years lasting from the Stone Age till the Industrial Revolution, a number of countries have started taking off into periods of sustained ‘positive’ economic growth. Mechanisms that could trigger such a growth take-off may include structural change and technological adoption and hence is a matter that warrants attention as take-offs are relatively rare but there are a number of countries that are waiting for a economic miracle.

This paper develops a simple theory of technology adoption, human capital accumulation and economic take-offs and landing to explain the experience of the East Asian Economies who have managed to take-off and maintain stable rate of growth of the economy for many years. It shows that technology adoption has a threshold effect that affects the timing of the economic take-offs. Then an economy may be stuck with“low technology” equilibrium even when the “better technology” was available.

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Figure 1: Take-off and Landing of the Japanese economy.

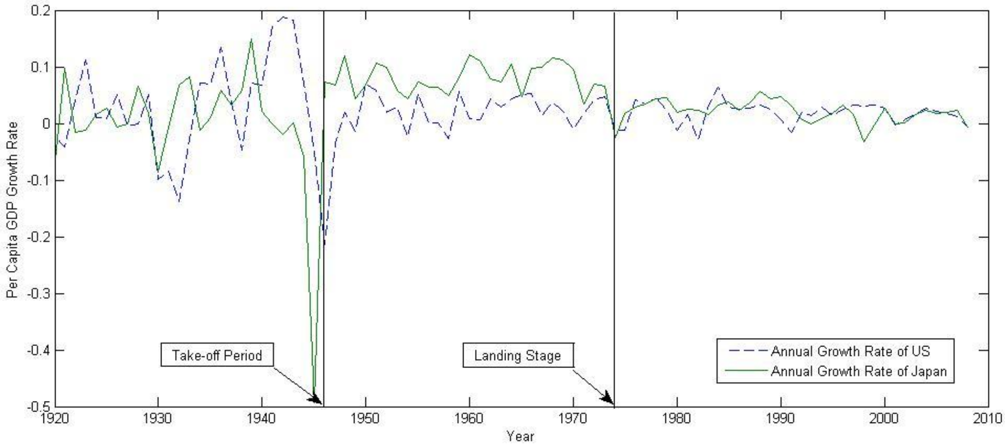

Figure 2: Per Capita GDP Growth Rate of the Japanese Economy

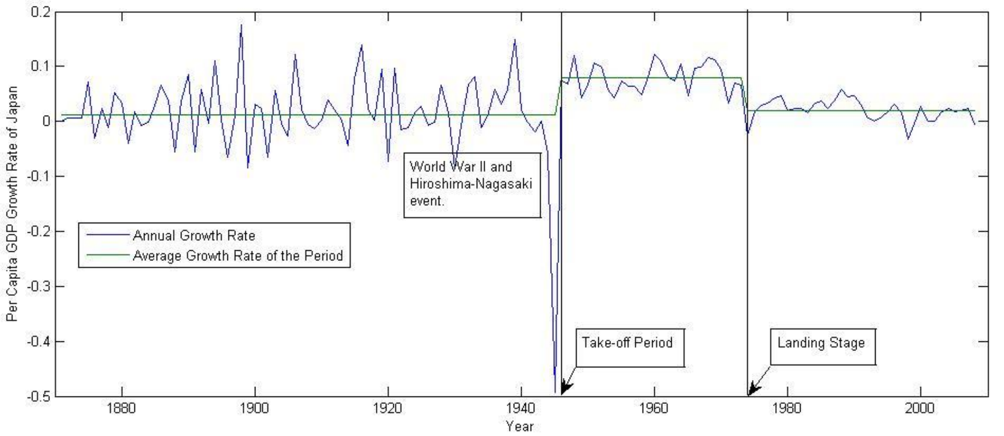

Figure 3: Take-off and Landing for the economy of Hong Kong.

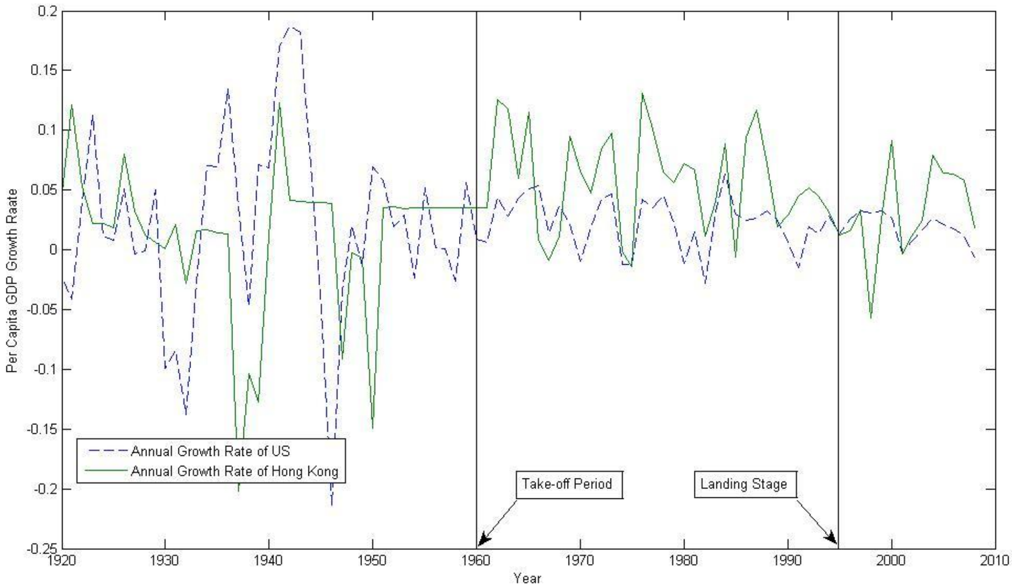

Figure 4: Per Capita GDP Growth Rate for the economy of Hong Kong.

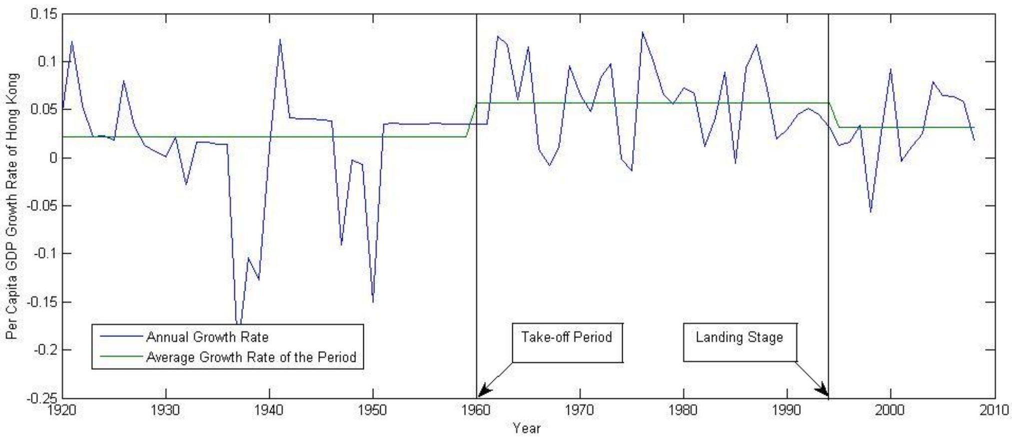

Figure 5: Take-off and Landing of the Chinese Economy.

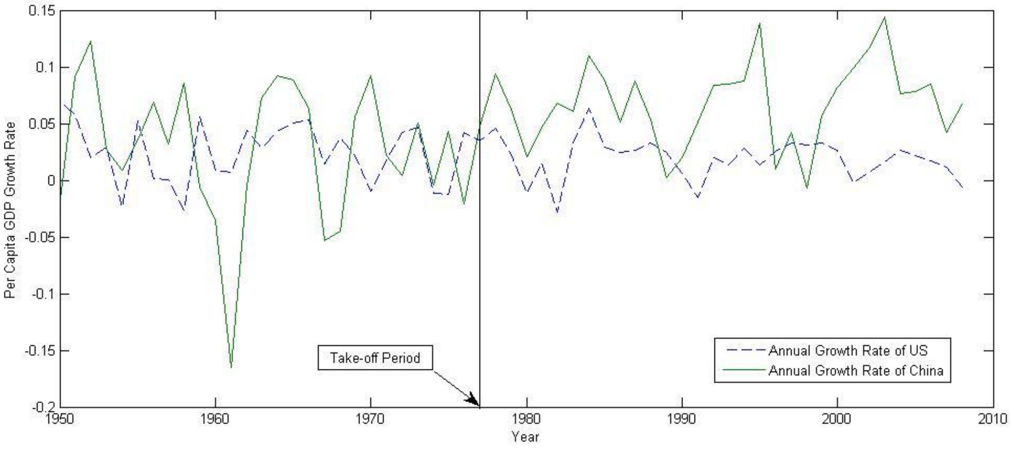

Figure 6: Per Capita GDP Growth Rate of the Chinese Economy.

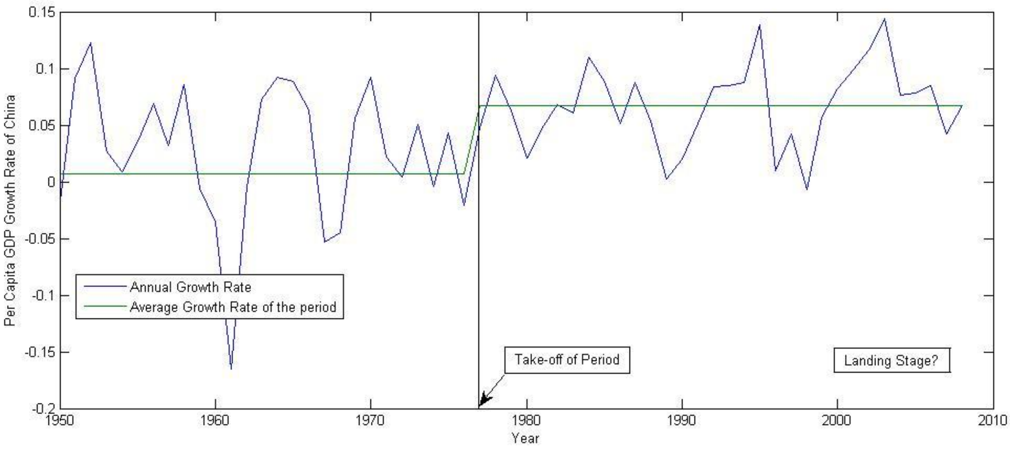

Figure 7: Take-off and Landing of the Indian Economy.

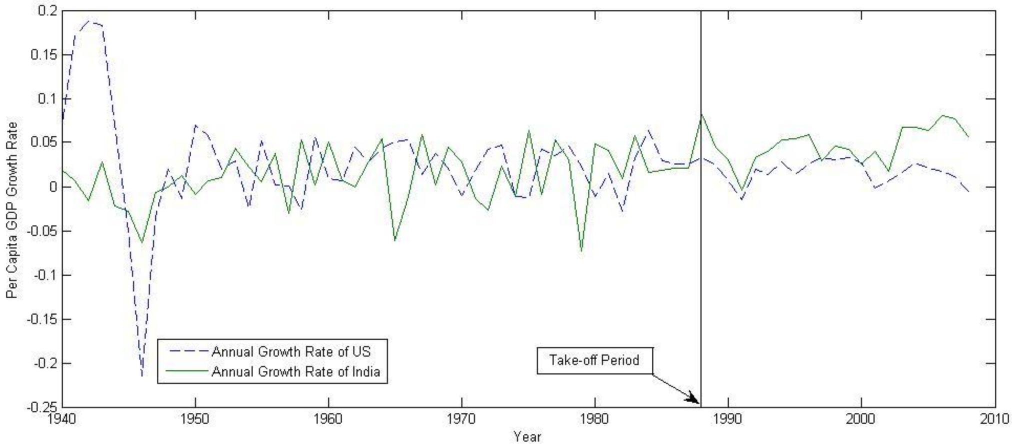

Figure 8: Per Capita GDP Growth Rate of the Indian Economy.

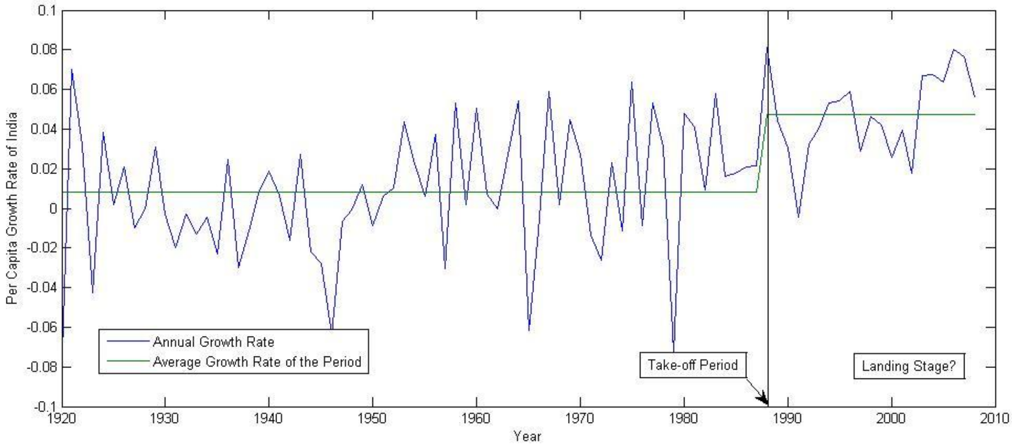

Figure 9: Who take-offs earlier?

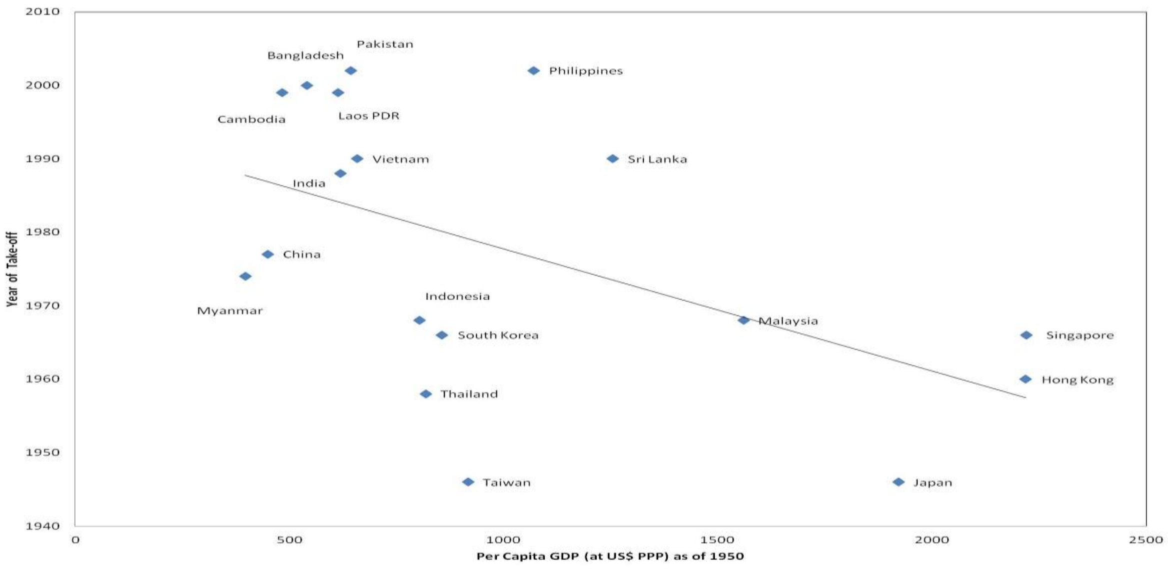

Figure 11: Optimum level of education and “minimum age laws

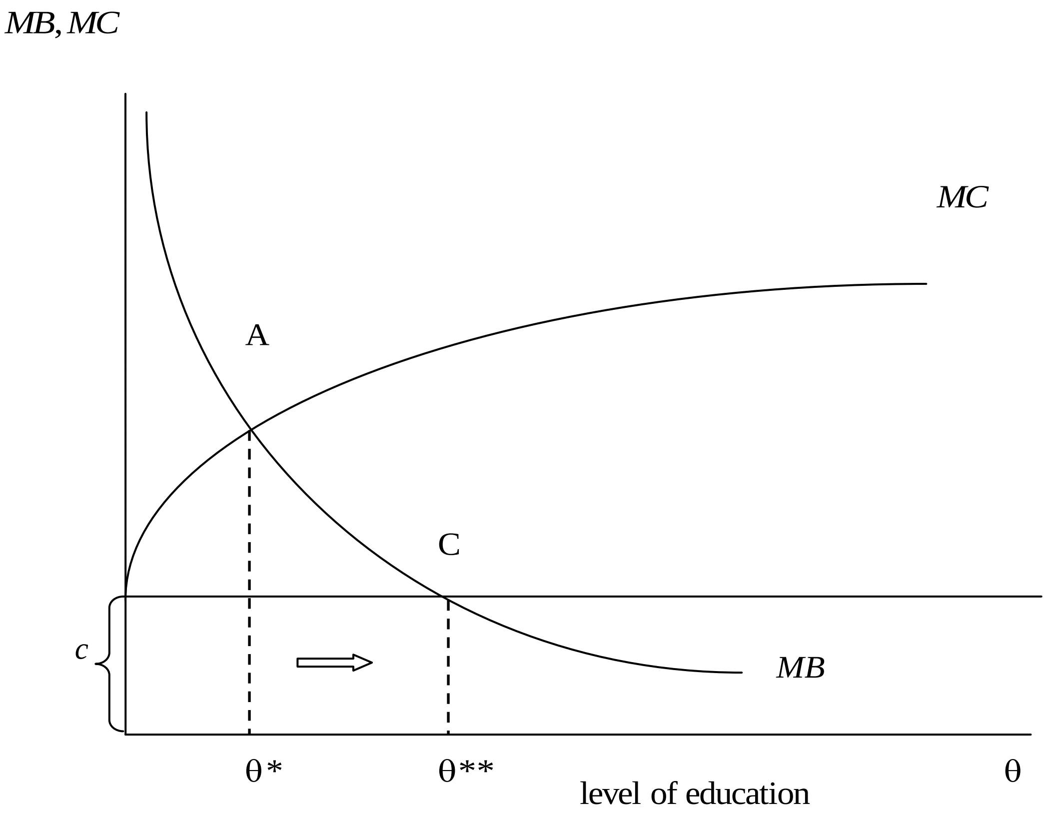

Table 1: Asian Economies and their Take-offs and Landing dates

Country of Interest	Year of Take-off	Year of Landing
Japan	1946	1974
Taiwan	1946	-
Thailand	1958	-
Hong Kong	1960	1995
Singapore	1966	1998
South Korea	1966	-
Malaysia*	1968, 1987	1984
Indonesia*	1968, 1986	1982
Myanmar*	1974, 1992	1983
China	1977	-
India	1988	-
Vietnam	1990	-
Sri Lanka	1990	-
Cambodia	1999	-
Lao PDR	1999	-
Bangladesh	2000	-
Pakistan	2002	-
Philippines	2002	-

Source: Historical Statistics of the World Economy.
Based on the author's calculations from Maddison tables.
* Failed first take-off and then took-off again.

Table 3: Stability of post take-off and pre-landing Per Capita GDP Growth Rate

	Per Capita GDP Growth Rate			
Independent variables	Japan	Hong Kong	China	India
Year	0.00031	-0.0005	0.00146**	0.00209*
	(0.000626)	(0.000633)	(0.000613)	(0.00115)
Constant	0.0755***	0.0659***	0.0163	0.0464***
	(0.00942)	(0.0147)	(0.0129)	(0.0149)
Observations	28	35	32	21
R-squared	0.01	0.015	0.217	0.101

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

$$\text{Per capita GDP growth rate} = \beta_0 + \beta_1 (Year - Year_0)$$

$Year_0$ is the year of take-off

Table 4: Probit Regression for Take-off Status

Variables of Interest	Take-off Status as of 2008			
Year of Independence		-0.00219*	-0.000921	-0.000346
		(0.00121)	(0.00140)	(0.00148)
Ethnic Similarity		0.0292***		
		(0.0108)		
Polity Score		0.279***	0.196***	
		(0.0910)	(0.0691)	
Per capita GDP in 1950	0.170			
	(0.498)			
Constant	0.511	3.517	2.875	1.334
	(0.557)	(2.180)	(2.616)	(2.826)
Observations	24	24	24	24

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Per Capita GDP is measured in thousand dollars

Table 2: Average Per Capita GDP Growth Rates of the Asian Economies during Take-offs and Landing

Country of Interest	Pre-take-off Period	Pre-take-off Growth	Take-off-landing Period	Take-off-landing Growth	Post-landing Period	Post-landing Growth
Japan*	1900-1944	2.02%	1946-1973	7.97%	1974-2008	2.01%
Taiwan	1902-1945	-0.09%	1946-2008	6.36%	-	-
Thailand	1951-1957	1.63%	1958-2008	4.60%	-	-
Hong Kong	1914-1959	2.11%	1960-1994	5.74%	1995-2008	3.13%
Singapore	1914-1965	1.51%	1966-1997	6.64%	1998-2008	2.95%
South Korea	1912-1965	1.74%	1966-2008	6.33%	-	-
Malaysia**	1948-1967	2.95%	1968-1983	5.20%	-	-
Indonesia**	1950-1967	1.13%	1968-1981	5.58%	-	-
Myanmar**	1951-1973	-0.33%	1974-1982	2.87%	-	-
China	1901-1976	0.68%	1977-2008	6.73%	-	-
India	1901-1987	0.81%	1988-2008	4.76%	-	-
Vietnam	1951-1989	1.19%	1990-2008	5.93%	-	-
Sri Lanka	1901-1989	0.73%	1990-2008	4.06%	-	-
Cambodia	1951-1998	1.80%	1999-2008	6.46%	-	-
Lao	1951-1998	1.25%	1999-2008	4.16%	-	-
Bangladesh	1951-1999	0.86%	2000-2008	4.22%	-	-
Pakistan	1951-2001	2.07%	2002-2008	3.19%	-	-
Philippines	1903-2001	2.47%	2002-2008	3.10%	-	-

Source: Historical Statistics of the World Economy on Per Capita GDP, 1-2008 A.D from Angus Maddison.

United States, the benchmark country of this model grew at an average rate of exactly 2% between the years 1871 and 2008.

**Malaysia, Indonesia and Myanmar had one failed take-off and then took-off again later after a few years (here only the first take-off is mentioned).

*1945 is excluded from our discussion as it is considered to be an outlier year for Japan because of the World War II Hiroshima-Nagasaki bombings.

The second take-off – Landing growth is 1987-2008 is 4.34% for Malaysia; 1986-2008 is 3.68% for Indonesia; 1992-2008 is 6.74% for Myanmar.

Table 5: Ordinary Least Square Regression for Take-offs

Variables of Interest	Year of Take-off			
Per capita GDP as of 1950	-16.61*** (4.598)	-16.38*** (4.463)	-15.36*** (4.699)	-23.02** (8.471)
Year of Independence		0.0386*** (0.00700)	0.0365*** (0.00664)	0.0305*** (0.00851)
Ethnic Similarity			-0.237 (0.180)	
Polity Score				1.137 (0.918)
Constant	1,994*** (6.691)	1,921*** (10.82)	1,941*** (16.64)	1,940*** (17.92)
Observations	18	18	18	18
R-squared	0.267	0.383	0.456	0.471

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Per Capita GDP is measured in thousand dollars

Figure 10: Calibrated Results from the Baseline Model.