Krugman and Young Revisited: A Survey of the Sources of Productivity Growth in a World with Less Constraints

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Young (1994) and Kim and Lau (1994), among others, argue that the "Asian Miracle" of relatively high growth was largely due to increases in factor inputs. Productivity growth would eventually slow because of diminishing returns to factors. Thus total factor productivity growth was not the reason for the Asian Miracle. Krugman (1994) summarized this research, comparing the growth experience of Singapore, among the other Asian Tigers, to that of the Soviet Union and argued that there was reason to expect a similar outcome, namely a collapse of the political institutions due to economic stagnation. Interestingly, Krugman consistently refers to efficiency growth and technical progress as equivalent terms. In this paper and survey we discuss alternative explanations for economic growth in Asia as well as elsewhere in the world in the post WWII years. The alternative explanation is explicit in Krugman's treatise. It is economic growth due to a world with less constraints.

Keywords: Total factor productivity growth, East Asia, Efficiency change

JEL Classification: C5, C8, O2, O3, O5, O11

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[**Seoul Journal of Economics** 2009, Vol. 22, No. 1]

I. Introduction

East Asian countries have achieved relatively high rates of growth in the decades since the 1960's, interrupted only by the financial crisis and contagion that dominated the last few years of the 1990's and the present world recession, a recent and unfolding event that we do not address in this survey. Young (1994) and Kim and Lau (1994), among others, argued that the "Asian Miracle" of relatively high growth was largely due to increases in factor inputs. According to Young (1994), the most important source of factor accumulation was the increase in input. The decline in the post-war birth rates and increase in the female labor participation ratio led to an increase in the aggregate labor participation rate. Along with labor input, capital input grew along with human capital accumulation. However, because of diminishing returns to factors, productivity growth would eventually slow. That is, total factor productivity growth was not the reason for the Asian Miracle. Krugman (1994) summarized this research, comparing the growth experience of Singapore, as an example, to that of the Soviet Union. He pointed out that there was reason to expect a similar outcome, namely a collapse of the political institutions due to economic stagnation. Krugman also noted that the rapid growth in output could be explained by rapid growth in inputs: expansion of employment, increases in education level, and above all massive investment in physical capital. Asian growth, like that of the Soviet Union in its high-growth era, appeared to be driven by extraordinary growth in inputs like labor and capital rather than gains in efficiency. Interestingly, Krugman uses efficiency growth and technical progress interchangeably.

In this survey we discuss alternative explanations for economic growth in Asia as well as elsewhere in the world in the post WWII years. The alternative explanation is explicit in Krugman's treatise. It is that economic growth was due to a world with less constraints, or efficiency growth using the term in the productive efficiency literature.

In Section 2 we discuss in more detail the explanations of sources of economic growth. In Section 3 we provide alternative explanations to Krugman, Kim, and Lau and Young's explanation, specifically the effects of lessening constraints on productivity growth. Section 4 outlines how total factor productivity growth can be decomposed into technical change and efficiency change components utilizing the Malmquist productivity index. In Section 5 we focus on the neoclassical growth literature and

how the new innovations in that literature have much in common with the efficiency literature that ascribes efficiency change as the main source of productivity growth. Section 6 focuses somewhat asymmetrically on the crucially important information and communication technology sector which is thought to play such a dominate role in recent economic growth. Section 7 points to the measurement problems inherent in any systematic attempt to empirically sort out the sources of productivity growth by focusing on two complementary studies of regulatory changes, one at the macro level and one at the industry level. Section 8 provides a brief discussion of how such measurement problems may be overcome using statistical techniques of factor modeling. Section 9 concludes.

II. Traditional Explanations for Sources of Economic Growth

The achievements of Kim and Lau, Young, and Krugman motivated many researchers to uncover the sources of the strong economic growth in Asia. According to Kim and Lee (2006), debates among researchers on the primary sources of economic growth and development are centered on two basic explanations that are rooted in the decomposition of economic growth sources: factor-accumulation and productivity-growth components. According to Kim and Lau (1994), Young (1992, 1995) and Krugman (1994), rapid economic growth in East Asia was largely explained by the mobilization of resources. They claimed that the increase in input factors was the main source of productivity growth rather than a change in technology. Although the methods and data utilized in their studies are somewhat different, their main findings were quite congruent leading Liang (2006) to coin their joint findings as the Krugman, Kim, Lau, and Young (KKLY) hypothesis. Kim and Lau (1994) use pooled time series on aggregate meta-production functions using a sample of four East Asian countries and five developed countries. They attributed the economic growth to three factors: growth in capital, growth in labor and technical progress. They concluded that by far the most important factor in East Asian development was capital accumulation, while technical progress was found to be the most important source of economic growth in developed countries. However, they point out that East Asian countries experienced a significant decline in productive efficiency relative to the U.S. Thus, an

increase in capital input alone was not sufficient for the East Asian countries to maintain current rates of economic growth. It would be necessary for them to devote greater proportions of their resources to research and development (R&D) in order to attain positive rate of productive efficiency. Young (1994) used a cross sectional regression on OECD data, and measured the productivity growth in the aggregate economy and in manufacturing sectors in particular. His conclusion was that gains from factor accumulation of both capital and labor were the primary factors in the growth of most of the East Asian economies.

III. Alternative Explanations for Sources of Economic Growth

An alternative explanation to the KKLY hypothesis comes from Liang (2006). According to Liang (2006), factors that explain Asian economic growth include governmental industrial policies and liberalization policies. His conclusion is that the KKLY input-driven growth hypothesis for the newly industrialized Asian economies has no empirical basis. This point has been raised before. According to Liang (1995), Young (1994) considers the thirty year period without considering the different characteristics of subperiods and ignoring the heterogenous characteristics of inputs by sector. According to Liang (2006), the quality changes in inputs caused by changes in industrial structure or the "input reallocation effect" should be taken into account in calculating the total factor productivity for the economy as a whole. Following Gollop and Jorgenson (1980), Jorgenson *et al.* (1987), and Young (1994), Liang (2006) measured sector-level productivity by using the translog production function, incorporating the quality changes in inputs caused by changes in industrial structure over six subperiods from 1961 to 1999. Liang (2006) concluded that the effect of industrial structural changes was important in measuring TFP growth correctly. The factors that explained the effect of industrial structural change during 1970-1999 included changes in government industrial and liberalization policies. Liang's findings thus point to the importance of industrial policies in the development of East Asian countries, which is somewhat at odds with the KKLY interpretation of the main sources of economic growth. In contrast to the KKLY hypothesis, which explains the rapid growth of East Asian Countries as input driven rather than due to improvements in TFP, Liang (2006) concludes that improvements

in TFP play a significant role in their rapid growth.

The sources of East Asia's growth using an alternative to the standard neoclassical model is provided by Kim and Lee (2006). Here the role of catch-up due to an increase in productive efficiency is made explicit by utilizing stochastic frontier production methods (Aigner *et al.* 1977). Applying the panel stochastic production frontier with time-varying and country specific efficiency change components using the methods of Cornwell *et al.* (1990) with data on 49 countries over the period 1965 to 1990, they decompose total factor productivity growth into technical innovation change and technical efficiency change. They show that although the main driver of productivity growth is technical innovation change, the change in technical efficiency has a significant positive effect on productivity growth. Their study provide support for the positive effects of efficiency changes on TFP and the importance of the adoption of frontier technologies of developed countries by developing countries. In this model every country has its own temporal pattern of technical inefficiency specified by a quadratic function of time. Alternative models for time-varying patterns of efficiency have been proposed by Kumbhakar (1990), Battese and Coelli (1992), and Lee and Schmidt (1993). Kim and Lee (2006) generalized the Lee and Schmidt (1993) model by considering different patterns for different groups, thus eliminating the unrealistic restriction that the temporal pattern be the same for all firms. Kim and Lee (2006) report that technical efficiency gains for East Asian countries are much more rapid than that of other countries.

The regression-based approaches to estimating sources of time varying and country specific total factor productivity growth utilize panel data methods in specifying time varying technical inefficiency captured by the (possibly time-varying) intercept of fixed effects. On the other hand, technical inefficiency can also be identified through error components in a random effects model with technical inefficiency explicitly specified as one-sided frontier errors. With a parametric distribution the model can be estimated by maximum likelihood using, for example, a truncated normal distribution with time varying means as the one-sided error process for technical efficiency. Such a random effects model estimated by maximum likelihood was proposed by Battese and Coelli (1992), whose model allows for a transparent adjustment for an unbalanced panel since a different function of time can be specified for each country. Cuesta (2000) generalized Battese and Coelli (1992) by allowing each country to have its own time path of technical

inefficiency. According to Kim *et al.* (2008), Cuesta's model is desirable because it can utilize the information that technical efficiency is one-sided, while the model has an advantage of not imposing a common pattern of inefficiency change to all sample firms. However, the model has to assume independence between inputs and technical efficiency, or it suffers from the incidental parameters problem of mle since the number of parameters would otherwise increase with the sample size. Kim *et al.* (2008) model is a counterpart of Kim and Lee (2006), and provides a solution to Cuesta's (2000) large sample size problem by grouping the firms. Kim *et al.* (2008) apply their model to estimate frontier production functions for a 57 country sample grouped over four time periods: 1970-75, 1975-80, 1980-85 and 1985-90. Their results indicate country groups have different time varying technical efficiencies. Between the early 1970's and late 1980's the East Asia region has one of the fastest growth rates in technical efficiency.

Proper specification of the catch-up process within a neoclassical growth model context has also been found to require a similar heterogeneous treatment of the catch-up, or technical efficiency growth, process. Hultberg *et al.* (1999, 2004) modify the standard neoclassical convergence model to allow for such heterogeneity in the efficiency catchup rates. In Hultberg *et al.* (2004) they analyze the relationship between growth in labor productivity of manufacturing sectors and transfers of technology from a leading economy to sixteen OECD countries. In the standard catch up literature, the greater the gap in per capita income between low and high growth countries the faster the convergence occurs. However, this literature assumes identical technologies across countries. In addition to the existence of an external technology gap the ability to adopt new technology is an important source of growth. Hultberg *et al.* (2004) also find that proper control for unobserved production heterogeneities is important in identifying the catching up effect.

A. Sources of Economic Growth - Constraints to Progress

Hultberg *et al.*'s (1999) study is instructive in that it proposes that the determinants of efficiency levels can be proxied by a set of variables related to economic, political, and social institutions of a country. Their indicator variables are bureaucratic efficiency, which consists of three variables: judiciary system, red tape and bureaucracy, and corruption; political stability, which contains six indicators: political

change-institutional, political stability, social change, probability of takeover by opposition group, stability of labor, relationship with neighboring countries, and terrorism; economic openness, which consists of two measures of openness, the Sachs and Warner and Summers and Heston index. The Sachs-Warner index measures the fraction of years during the period 1950 to 1994 that an economy has been considered open. A country is open if five criteria are satisfied: (1) nontariff barriers cover less than 40 percent of trade, (2) average tariff rates are less than 40 percent, (3) any black market premium was less than 20 percent during the 1970s and 1980s, (4) the country is not socialistic, and (5) the government does not monopolize major exports (Sachs and Warner 1995). The Summers and Heston index is the fraction of imports and exports summed to GDP. Education explains in part the potential constraints to efficient use of complementary resource inputs in the production process through embodied human capital. It is well known that education increases economic growth. There are at least two ways that education may effect productivity: adoption and diffusion of new technology, and more efficient use of inputs. Freedom is another constraint to the growth process and is related to political and civil rights. After extracting their measures of efficiency from the modified growth model estimates, Hultberg *et al.* examine a second stage regression of efficiency on these aforementioned institutional variable proxies. Although the significance of individual variables is not widespread since there is often little country specific variation these factors have an important combined effect in explaining the extent to which efficiency impacts the growth convergence experience of developing Asian countries. About 60% of the variation in efficiency could be attributed to the combined effects of the institutional constraint proxies.

IV. Decomposition of Economic Growth - Innovation and Efficiency Change Identified by Index Numbers

Identifying the sources of TFP growth while imposing minimal parametric structure has obvious appeal on grounds of robustness. Sharpness of inferences may, however, be comprised vis-a-vis parametric structural econometric models. There has been a long standing tradition in utilizing index number procedures and structural econometric estimation to quantify TFP growth and its determinants. The essential

differences between the approaches is discussed in Good *et al.* (1997). Parsing productivity growth into a portion representing technological change and a portion representing efficiency change has been a long-standing research issue and it is crucial in developing a proper understanding of the dynamics and sources of productivity growth. As we have discussed, Kim and Lee (2006) provide one answer to this question by decomposing total factor growth of 49 countries into technological change and technical efficiency change components by using a stochastic frontier production model. Utilizing the stochastic frontier structure of Lee and Schmidt (1993), in which technical efficiency is time-varying with an arbitrary temporal pattern of technical efficiency, they identified and estimated the temporal pattern of productivity changes in certain regions and compared their regional characteristics. The results of their study show that technical efficiency had a significant positive effect on productivity growth and they concluded that East Asian countries had high growth rates and led the world in total factor productivity growth because technical efficiency gain is much more faster than that of other countries. Han *et al.* (2003) compared the sources of growth in East Asia with the rest of the world by decomposing the total factor productivity growth into technical efficiency changes and technological progress, relaxing the assumption of the standard neoclassical model of full technical efficiency and allowing the possibility that the economy may be inside the best practice frontier. Their methodology allows them to distinguish between changes in technical efficiency and technical progress in cross country analysis. Utilizing a varying coefficient production frontier approach, they isolate catch up to the frontier from shifts in the frontier, borrowing much from Kalirajan *et al.* (1996). Their research suggests that TFP growth can be achieved largely by following best practice techniques. Thus the most important determinant of economic growth is not the level of input use but rather the method of application of inputs. They are able not only to rank TFP but also the technical efficiency of over 45 countries. Of course these and other studies discussed in earlier sections are just a few examples of work at the time KKLY hypothesis was put forward. For example, in the Rochester Conference Series on Public Policy (1994), in their "Reply to Alwyn Young," Pack and Page pointed out a number of very important problems with the KKLY hypothesis. In particular they noted that "... Studies of best-practice production frontiers within and across countries demonstrate that many firms, particularly in developing countries, utilize much more

labor and capital per unit of output than the most efficient ones. This strand of research simply does not support the assumption of all countries operating on an identical production function along which accumulation is the sole source of growth ...."

One approach to decompose TFP into its sources is based on the economic theory of index numbers, instead of relying on empirical reduced form associations or more formal structural models. The Färe *et al.* (1994) decomposition is based on the Malmquist index. Although the method pursued in Färe *et al.* has many theoretical aspects to it which are quite appealing, its implementation and statistical properties illustrate the difficulties in identifying the statistically significant sources of productivity growth while at the same time being sensitive to overly parametric assumptions. We briefly explain this index number method and then discuss its use in explaining the statistically significant sources of Asian productivity growth based on the work of Jeon and Sickles (2004).

The approach assumes that there are two best practice frontiers based on period t and $t+1$ data. Observed input and output data from period $t+1$ are above the period t best practice frontier and the period t data are below the period $t+1$ best practice frontier. This is consistent with positive productivity growth.

For a particular country the output-based Malmquist productivity change index can be written as

$$M_0^{t,t+1} = \frac{D_0^{t+1}(x^{t+1}, y^{t+1}, b^{t+1})}{D_0^{t}(x^{t}, y^{t}, b^{t})} \cdot \left(\frac{D_0^{t}(x^{t+1}, y^{t+1}, b^{t+1})}{D_0^{t+1}(x^{t+1}, y^{t+1}, b^{t+1})} \cdot \frac{D_0^{t}(x^{t}, y^{t}, b^{t})}{D_0^{t+1}(x^{t}, y^{t}, b^{t})} \right)^{1/2}$$

where the first term measures the change in relative efficiency between t and $t+1$ (ECH), and the second term captures the shift in technology between the two periods (TCH). The decomposition of the Malmquist total factor productivity index into a portion due to technological and efficiency change is based on a simple algebraic manipulation of the Malmquist output oriented TFP index. Jeon and Sickles (2004) calculate productivity growth and its component for 11 Asian countries for 1980-1995 with such an index. Utilizing bootstrapping techniques introduced by Simar and Wilson (2000), Jeon and Sickles found that there was no statistical significance to the productivity decompositions at standard nominal significance levels.

Førsund and Hjalmarsson (2008) point out what they consider to be

the main problem with the Malmquist index and its decomposition. The Malmquist index blurs the distinction between the ex ante micro function relevant for investments and the short-run production possibilities for the industry as a unit. When estimating technological change and technical efficiency change with the Malmquist index it is assumed that any producing firm may potentially produce at the frontier. According to Førsund and Hjalmarsson (2008), this would be the case only when there are no vintage effects, an assumption that could hold in industries where capital has a minor role, unlike paper, pulp, cement, *etc*. where the Malmquist index has been used to study productivity growth. In the case of disembodied technical change, wherein the shift in the production function over time is not incorporated into a specific best practice production function, the technical change in principle can only be relevant for existing units and thus the index cannot discriminate between efficiency change and disembodied technical change.

Grosskopf and Self (2006) utilize the Färe *et al.* methodology to calculate the Malmquist index and its decomposition into technical and efficiency change components for Asian countries. They also provide estimates based on a neoclassical production approach with embodied technical change. In summarizing their findings Grosskopf and Self note that country differences are crucial in developing the proper structural interpretations for what are essentially reduced form correlations between factor accumulation and TFP growth on the one hand and economic growth in the region on the other. They also point out that "... Growth is complicated; for a set of countries with apparently similar growth patterns, similar geographical location and relatively similar socioeconomic and cultural environments, we find complex and dissimilar explanations for their recent growth ..."

V. Modifications of the Neoclassical Model: The New Growth Theory

The theme of this survey is that a major source of post WWII East Asian economic growth has been efficiency change. Efficiency change constitutes a loosening of constraints imposed by institutions, historical inertia, the incentive system, and political traditions on the behavior of individuals and firms that prevent them from unconstrained economic choices. As pointed out by Abramovitz (1986), Dowrick and Nguyen (1989), and Nelson and Wright (1992), among many others, sources of

productivity differences in post WWII industrialized countries can be explained by neoclassical growth models that incorporate knowledge spillovers, technological diffusion, and convergence to a best practice production process (Smolny 2000), that is the new growth theory. One set of papers that provides an efficiency interpretation of this growth process is Hultberg *et al.* (1999, 2004), and Ahn *et al.* (2000). These papers explicitly introduce inefficiency into the growth process. Of course the standard neoclassical model without explicit treatment of efficiency has been used by many authors in examining growth and convergence.

A. The Neoclassical Production Function and Economic Growth

Kevin Stiroh (2001) provides a coherent treatment that frames the problem of measuring sources of TFP growth in the context of the neoclassical production $Y=f(K, L, T)$ where variables are indexed by a time subscript. The production function is typically assumed to have constant returns to scale, positive and diminishing returns with respect to each input, and marginal products of each input that approach zero (infinity) as each input goes to infinity (zero). As noted by Stiroh (and many others) "... The striking implication of the neoclassical model is that, in the long run, per capita output and productivity growth are driven entirely by growth in exogenous technical progress and they are independent of other structural parameters like the savings rate. If the savings rate and investment share increase, for example, the long-run level of productivity rises but the long-run growth rate eventually reflects only technical progress. In this sense, the neoclassical growth model is not really a model of long-run growth at all since productivity growth is due to exogenous and entirely unexplained technical progress ...."

Gauging the relative importance of capital deepening and technology has also been an important part of the debate in evaluating the performance of the Asian Tigers. The KKLY studies and many subsequent ones are based on this traditional neoclassical model.

B. Endogenous Growth Models

Endogenous growth models were developed to weaken the strong neoclassical assumption that long-run productivity growth could only be explained by an exogenously driven change in technology. The classic model put forth by Romer (1986), which began the "new growth theory," allowed for non-diminishing returns to capital due to external

effects. For example, research and development by a firm could spill over and affect the stock of knowledge available to all firms. In the simple Romer model firms face constant returns to scale to all private inputs. The level of technology A can vary depending on the stock of some privately provided input R (such as knowledge) and the production function is formulated as $Y=A(R)f(K, L, R)$. In the "new" growth theory, an observation subscript is meant to represents firm-specific variables and a time subscript is explicitly dropped. Frontier production is shifted by a technology that may be endogenously determined.

What is the source of the spillover? Arrow (1962) emphasized "learning-by-doing" while Romer (1986) modeled A as a function of the stock of research and development. Lucas (1988) modeled A as a function of stock of human capital. Coe and Helpman (1995) bring in trade spillovers by showing that the rate of return on R&D is not limited to performing countries but to their trade partners. By using a sample of 21 OECD countries they estimate the average long-run rate of return of R&D investment and their trade partners. Coe *et al.* (1997) analyzed a set of less developed countries during the period 1971-1990 to see to what extent these countries might also benefit from R&D activities. They find that international trade plays an important role in transmitting technology and that developing countries can increase their productivity by importing a larger variety of intermediate products and capital equipment. Assuming openness in trade Diao *et al.* (2005) analyzed international spillovers and productivity growth in Thailand. Their focus was on endogenous productivity growth in the transition towards long-run balanced growth. They noted that Thailand had economic growth above world averages in its transformation from a "rice economy" to an industrialized one with labor-intensive exports. They also analyzed productivity growth through learning by doing, technology adoption and foreign technology spillover, addressing the issue of a country's ability to adopt a new technology which requires advanced skills. To better understand the role of openness, they examined the impacts of both a protectionist alternative and shock liberalization and concluded that reduced openness had a negative impact on the overall growth rate due to reduced learning from the foreign spillover. However, if the explanation for the spillover that endogenously determines technology change is the loosening of constraints on the utilization of that technology, then this is just a another way of saying that TFP growth is primarily determined by the efficiency with which the existing technology (inclusive of innovations) is utilized.

Production spillovers have important implications for economic growth and for its management. If any type of investment whose gains are not internalized by private agents impacts long-run growth then there is no unique long-run growth path and thus no so-called "golden rule." Another implication is that from the point of view of public policy, spillovers provide a clear role for government intervention. Government intervention may take many forms if investment is too low from society's perspective. Investment tax credits or research and development grants are two traditional forms of government intervention. However, government intervention may also take the form of relaxing constraints on businesses *via* deregulatory reforms, reduced "red tape," private sector market reforms, or any other aspect of the institutional and political mechanism established in a country and its markets that increase *A*. The later set of external effects can be summed up as "governmental actions that reduce constraints," or "efficiency enhancing investments." If one examines the "new" growth model more closely it must be recognized that it is indistinguishable empirically from the stochastic frontier model wherein *A* is an efficiency term.

VI. The Importance of Information and Communication Technologies in Economic Growth

In the endogenous growth model, research and development, knowledge accumulation, and human capital frame the effectiveness of the labor input. A particular dimension of the overlay of embodied technical quality change provided by such factors are information and communications technologies (ICT) consisting of hardware, software, and telecommunications equipment. The work of Stiroh (2002a) on the impact of ICT in the growth process has shown that ICT is its driving force. Van Ark *et al.* (2002) and Stiroh's (2002a) contribution to the ICT growth literature is found in their ability to model its contribution to aggregate inputs at the industry level, thus allowing one to analyze productivity growth over time and across industries by exploring their links with ICT capital. Ramlan (2008), in a study of the contribution of ICT to Malaysian economic development, points out that ICT may have a positive effect on economic growth if appropriate policies are in place, suggesting that market forces in association with governments' adoption of sound economic policies are keys to a successful development program. On the other hand, Ramlan also reports that ICT may be

found empirically to have a negative effect on growth due to data mismeasurement and/or definitional confusion of what constitutes ICT related investments. Moreover, failure to include other conditioning variables may lead to misspecification in the relative contributions of ICT capital accumulation to economic growth and its determinants.

Empirical findings on the size and significance of ICT's impact on economic growth studies is mixed, some studies find statistically significant associations and others do not. Van Ark *et al.* (2002) examine differences in labor productivity performances across ICT-producing industries, intensive ICT-using industries and less intensive users, in 16 OECD countries and 52 industries over the period 1999-2000. They conclude that in the ICT-producing sector computers and communication equipment showed strong productivity growth and acceleration in virtually all countries, but differences are much bigger across countries for ICT-producing services, such as telecom services. Similar to Van Ark *et al.*'s finding, Stiroh (2002b) finds a positive impact of ICT over the period 1987-2000 for a sample of 49 countries and analyzes the link between ICT and U.S. productivity growth. This work is instructive in that it aims to examine the productivity performance in the late 1990's of individual industries that either produce ICT, use ICT, or are relatively isolated from the ICT revolution. One of Stiroh's insights is that by examining variation in productivity growth over time and across industries and by exploring the link with ICT capital accumulation one can better understand the role of ICT in the U.S. productivity revival. He estimates mean productivity acceleration for 61 industries from 1987-95 to 1995-99 to be 1.09% and the median to be 0.67%. Nearly two-thirds of these industries show a productivity acceleration. He excludes ICT producing industries in his analysis and continues to find a significant acceleration in productivity for the remaining industries. This research strengthens the empirical connection between ICT accumulation and productivity growth in U.S. industries, and possibly by extension, to other countries that have invested heavily in ICT, such as the countries comprising East Asia.

Ahmed (2004) provides another ICT study focusing primarily on Malaysia, Indonesia, Philippine, Singapore, Thailand, Japan, China and South Korea over the period of 1965-2004. To calculate the growth rates of productivity indicators he uses the translog index approach developed by Jorgenson *et al.* (1987). This approach requires explicit specification of the production function. However, as with the Malmquist index it must be extended to allow for statistical inferential procedures

to be used to assess the confidence of its point estimates. The study is instructive in the sense that it introduces the effect of governments' policies in improving productivity growth and the results are consistent with Young (1992) and Kim and Lau (1994) in that productivity growth of the newly industrialized Asian countries' appears to be input driven. The study also finds that the impact of ICT is positive but small on productivity growth. Lee and Khatri (2003) employ an extension of the standard growth accounting framework using estimated stocks of ICT capital growth in seven Asian countries over the period 1992-1999 and conclude that ICT's contribution to economic growth is mainly through capital deepening.

Although these studies point to a possible link between ICT and TFP growth, the "productivity paradox" still exists. ICT still is not empirically secure as a determinant of productivity growth. For example, Daveri (2003) defines the "productivity paradox" of information technology as "the lack of correlation between investments in information technology and productivity growth gains" and concludes that information technologies have so far delivered little aggregate productivity gains outside the U.S. Quah (2003) is more specific regarding the time frame and defines the paradox as "the puzzle that, from the 1970s onward, massive investment in ICT did not appear to improve substantially many economies' measured productivity." According to Ramlan (2008) one possibility is that ICT may displace existing capital without much productivity gain. Another possibility is the impact of ICT on the spillover effect, which Tanuwidjaja (2006) examines in a study of the relationship between domestic and foreign ICT research and development. Using a model of ICT research and development spillovers, Tanuwidjaja concludes that in the non-G5 countries (Australia, Canada, Finland, Ireland, and Italy), in his sample of 10 OECD countries, the diffusion of ICT is slower due to the inability of the non-G5 countries to appropriate the spillover's effect in a reasonable time frame.

VII. Problems with the Measurement of Sources of Productivity Growth

How then do we provide a vehicle for addressing the sources of spillovers, or efficiency changes, or loosening of constraints that drive the world economy? It may not be possible from purely econometric models, no matter how sophisticated. There are a variety of reasons.

Hopefully they can be illustrated in the next three subsections. The first is based on experience gleaned by Sickles as the Senior Research Coordinator for the Development Economic Policy Reform Analysis Project (DEPRA), USAID/Egyptian Ministry of Economy, Contract No. 263-0233-C-00-96-00001-00. A portion of this research was the basis for the Getachew and Sickles (2007) study which analyzed the impact of regulatory and institutional distortions on the Egyptian private manufacturing sector from the mid 1980's to the mid 1990's, focusing particularly on the impact of economic reforms undertaken since 1991. The second is based on work of Sickles and Streitwieser (1992, 1998) addressing the impact of the Natural Gas Policy Act of 1978 on the U.S. interstate natural gas transmission industry. The third focuses on the lack of proper data collection protocols pointed out in Ramlan's (2008) exhaustive study of ICT investments and Malaysian economic development.

A. The Development Economic Policy Reform Analysis Project - How Can We Identify Specific Constraints at the Macro Level?

The aim of the structural adjustment program was to transition from the planned economy left by the Soviets to a private sector market economy. Initial efforts focused on macroeconomic stabilization which involved a reduction of the fiscal deficit through (1) cuts in public investment and subsidization programs (2) tax reforms, particularly through the introduction of a general sales tax (3) improvements in collection, and (4) monetary policy tightening to fight inflation. The structural adjustment program also involved extensive price liberalization and adjustments of relative prices. Each sector of the Egyptian economy was affected by the reforms. Trade and financial sector reforms removed all export quotas, except for tanned hide. Tariffs on almost all imported capital goods were lifted as were nominal interest rate ceilings, administrative credit allocation, foreign exchange controls and prohibitions against international capital mobility. Labor law reforms gave employers the right to hire and lay off workers in accordance with economic conditions. How do we develop a model that identifies such a plethora of structural changes in the Egyptian economy? One approach was undertaken by Getachew and Sickles (2007) who utilized a virtual cost system to identify the allocative distortions that existed before the reforms were undertaken and those that existed after the reforms had worked their way through the

Egyptian private sector after the deregulatory reforms. Getachew and Sickles found substantial welfare benefits accruing to the Egyptian economy due to these reforms in total. Unfortunately, the specific determinants of the benefits of market reforms could not be ascertained since the specific constraints could not be modeled and thus incorporated into an estimable structural model.

B. U.S. Interstate Natural Gas Policy Act of 1978 - How Can We Identify Specific Constraints at the Micro Level?

Assessing the impact of burdens of doing business on efficiency, both within the pre-and post-reform contexts is informative in that it reveals the extent of impediments resulting from such burdens. However, modeling each specific constraint formally is problematic since the constraints are difficult to quantify and measures. This point is brought home by the second example from Sickles and Streitwieser (1992, 1998), which analyzed the impact of the U.S. Interstate Natural Gas Policy Act of 1978 on the performance of the U.S. Interstate Natural Gas Pipeline Industry. The regulatory history of natural gas transmission industry is long and complicated. As the following chart of the regulations and their impact on the various firms involved in the deregulatory initiatives shows, formal modeling of the constraints in an estimable structural econometric model is doomed. Sickles and Streitwieser utilize instead a quasi-fixed factor dynamic model of short-run and long-run costs to extract reduced form parameters that allow the combined impacts of these constraints to be empirically calculated. Sickles and Streiwieser were able to use counterfactual simulations to assess the impact of the 1978 reforms on consumers and producers and found the 1978 Act to have had a net positive benefit.

C. Assessing the Contribution of Information Communication Technologies in Economic Growth - An Example of Data Limitations

The most common challenge in quantifying and empirically assessing the impact of spillovers in the growth processes of developing countries is data, or lack thereof. Developing countries tend not to have publicly available disaggregated data. Attempting to establish a link between, for example, the important innovations and changes in processes brought on by information communication technology innovation and spillovers requires a substantial amount of information itself. Thus a number of

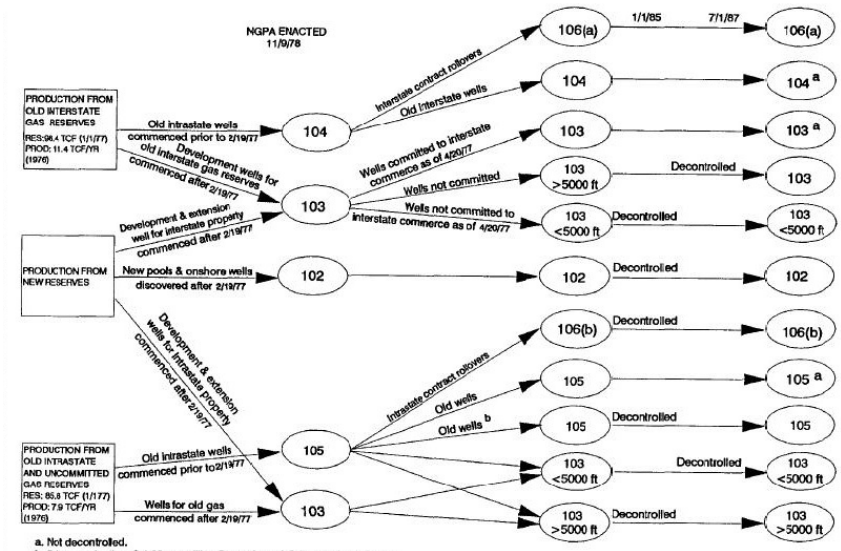

FIGURE 1

MAXIMUM CEILING PRICE CATEGORIES: NGPA TITLE I FOR ONSHORE LOWER - 48 NATURAL GAS ABOVE 15,000 FEET.

studies fail to empirically establish such a link between ICT investments and productivity, leading to familiar conclusions of a "productivity paradox." Siegel and Griliches (1994) note that official statistics often do not capture the changes in output, quality, and cost savings associated with ICT and hence its impact is often understated. The Ramlan (2008) study points out that solutions to the measurement problems inherent with ICT are more problematic than in manufacturing because many service transactions are idiosyncratic and therefore not subject to relatively straightforward statistical aggregation. Data measurement problems also occur since a large proportion of the benefits of ICT will not appear in productivity statistics because they take the form of improved product quality, variety, timeliness and customization, which may be interpreted as changes in inputs (Pohjola 2001). This latter measurement issue may provide a false justification for the support of the KKLY hypothesis and its rather stark conclusions about the end game for countries that rely on input driven

growth.

VIII. What Do We Do Next? - An Illustrative Example

How do we proceed from here? One course of action is to conduct a structured survey of business leaders, political leaders, World Bank, International Monetary Fund, and Non-governmental Organizations to identify what are the most important of an array of factors contributing to economic growth. The conclusions of such a survey would highlight the contribution of efficiency change, in the form of loosening of binding constraints, to economic growth and its relative contribution vis-à-vis technical progress.

Until such information is available, however, there remain alternatives. Below we outline one such alternative that provides a glimpse of what the contribution of relaxation of constraints has had in the growth experience of a set of Asian economies. We provide a brief analysis of the determinants of productivity growth in Asia using proxies for the survey methods which may ultimately provide a more discriminating method for parsing the contributions of innovation and efficiency. What we propose is illustrative in that it does not purport to be an exhaustive empirical study. However, it is instructive as to how such an analysis could proceed and the potential for insightful findings with significant policy implications to be gleaned from such an undertaking.

As Hultberg *et al.* (1999) and others have shown, a significant portion of efficiency change can be explained by institutional variables such as bureaucratic efficiency, political and civil rights, openness of the economy to foreign investment and trade, and other political, institutional, economic constraints to the growth and development process. The World Productivity Database (UNIDO) provides information on measures of the level and growth of TFP based on twelve different empirical methods across 112 countries over the period 1960-2000. We utilize a number of measures of TFP and then use the World Development Indicators (WDI) as proxies to decompose the sources of variation in TFP growth due to constraints on the growth process. Because many of the proxies we use have minimal variation over time we utilize principal components to summarize the canonical information contained in the joint variation of the constraint proxies. Using scree plots we then find the number of principal components (common factors) whose explanatory power is significant and use them to decompose variation

in TFP change due to changes in the constraint proxies. There are thirteen different methods used to measure TFP and its growth. The methods include data envelopment analysis, stochastic frontier approaches, long memory data envelopment analysis, panel regression, pooled regression, fixed effects panel, stochastic frontier random effects and various specifications of the static and dynamic growth accounting model with Hicks and Harrod neutral technical change.

The World Bank provides more than eight hundred indicators of economic development and growth for more than one hundred and fifty countries. In this short illustration we focus on China, Hong Kong, Indonesia, Korea, Malaysia, Philippines, Singapore and Thailand. The indicator variables are obtained from the World Bank except for the Freedom index. The Freedom index ranges from 1 to 10 where 10 indicates free and includes political and individual freedom within the country. Openness is another indicator that is a proxy for lessening trade barriers. It is calculated as the percentage share of imports and exports over the GDP. Higher technology exports reflect knowledge accumulation across countries and as concluded in Hultberg *et al.* (2004), a smaller technology gap with the leader country contributes significantly to labor productivity. Life expectancy at birth is another proxy for a constraint on the development process and is measured by the average number of years newborns can be expected to live based on current health conditions. It reflects the environmental conditions in a country, the health of its people, the quality of care, and their living conditions. Official development assistance and aid is an indicator that captures the flow of aid to promote the economic development To characterize the trends of the data the scree plots identify the first three principal components as the most important and we use them in analyzing the contribution of these efficiency factors to TFP growth in Asia. The growth of TFP calculated by UNIDO using the thirteen different measures was averaged for each country. The change in TFP was then regressed on the principal components obtained from changes in the indicators. The results suggest that for the sampled countries excepting China the median variation in TFP explained by the efficiency proxies is on the order of 35-40%. China's TFP growth is not explained by the efficiency proxies.

IX. Conclusions

This paper has briefly surveyed the literature on productivity growth in East Asia. We started with a discussion of "Asian Miracle" according to KKLY who pointed out that East Asian countries achieved relatively high growth rates due to increases in factor inputs. An alternative to their explanation comes from Liang (2006), among others, that factors explaining East Asian economic growth include governmental industrial policies, liberalization policies. Following Hultberg *et al.* (1999), we extend Liang's (2006) explanation to suggest that policies which lead to a world with less constraints are an often ignored and possibly main source of productivity growth due to increased productive efficiency. Various approaches to decomposing total factor productivity into sources that are due to efficiency change and due to technological change are discussed. One popular index number approach based on the Malmquist decomposition was introduced by Färe *et al.* (1994). Of course, regression based approaches using either traditional neoclassical growth models, growth models in which endogenous growth is allowed, or growth models in which inefficiency is explicitly introduced via a frontier technology offer potentially richer empirical specifications and a more structural determination of the sources of productivity growth. However, all approaches suffer due to poor empirical proxies for the measures of loosening constraints to business activity. On possibility to circumvent the paucity of reliable empirical measures of the determinants of productivity growth would be to conduct a structured survey of business leaders, political leaders World Bank, International Monetary Fund, and Non-governmental Organizations to identify what are the most important of an array of factors contributing to economic growth. The results of such a survey would provide us the contribution of efficiency change, in the form of loosening of binding constraints, to economic growth and its relative contribution vis-à-vis technical progress. Absent such information we proposed to use indicator variables as proxies for the survey methods. The World Bank provides more than eight hundred indicators of economic development and growth for more than hundred and fifty countries. By applying principal component analysis to explain the variation in the change in and growth of TFP we were able to analyze the contribution of these efficiency factors to TFP growth in Asia. Future analyses may turn to the use of survey data and measure the effects of policy changes on productivity growth

through the points of view of leaders, producers, and policy makers.

(Received 23 November 2008; Revised 15 February 2009)

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