ABSTRACT

Measurement of Total Factor Productivity Growth in Countries
with High Rates of Structural Change

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In a neoclassical framework, high rates of economic growth can be sustained if the main source of this growth is improvements in technical efficiency, measured by Total Factor Productivity Growth (TFPG). This study argues that traditional aggregate growth accounting methods might not be a useful measure of technological gains when such gains are predominantly sector-specific. In rapidly industrializing countries, rates of structural change from changing of industries are high. This allows us to form the testable hypothesis: the observed change in the capital labor ratio in response to a change in the wage to capital cost ratio should be lower in economies with high rates of structural change than in economies with lower rates of structural change. We find robust empirical evidence supporting this hypothesis.

Measurement of Total Factor Productivity Growth in Countries
with High Rates of Structural Change

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A Thesis

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Submitted to the Graduate Faculty of
Baylor University in Partial Fulfillment of the
Requirements for the Degree
of
Master of Science

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CHAPTER ONE

Introduction

Rapid and sustained economic growth in developing countries has been a goal for world leaders and policymakers since the end of World War II. The economies of Taiwan, Korea, Singapore, and Hong Kong were able to move out of poverty and into ranks of the first world by sustaining growth rates of six percent per year for almost three decades since 1960. Over the same time period countries in Latin America, South Asia, and Sub-Saharan Africa have experienced slower or sometimes negative rates of growth. As a result of the rapid and steady rates of growth, the East Asian economies tend to have higher life expectancies, education levels access to clean water food, and shelter. During this time, they have increased their exports in quantity greatly and have provided a diverse portfolio of goods including automobiles and electronics. Their economies exhibit both low unemployment rates and low levels of inflation.

In a neoclassical framework, high rates of economic growth can be sustained if the main source of this growth is improvements in technical efficiency. Efficiency gains are typically measured by the so-called Solow residual or Total Factor Productivity Growth (TFPG). A number of influential studies, however, have attributed low rates of TFPG to this period of growth in these East Asian economies. Most of the growth had apparently been driven by high rates of growth of capital. This result is a paradox since such a long period of sustained growth is not consistent with merely growth of factor \inputs. Or if it is, then the necessity of growth in 'technology' for sustained economic growth is brought into question.

Our study explores the argument presented by Van and Wan (1999) that the Solow residual might not be a useful measure of technological gains when such gains are predominantly sector-specific. When the gains come in the form of learning in a specific industry allowing the economy to move to the world frontier one industry at a time, such gains might be perceived merely as a movement along the world technology frontier and capital deepening. In this localized technical gains mechanism, the observed elasticity of substitution between labor and capital should be lower than the elasticities implied by the aggregate production function used to calculate TFPG.

In these rapidly industrializing countries, the rates of structural change from changing of industries are high. This allows us to form the following hypothesis which we can test with data: the observed change in the capital labor ratio in response to a change in the wage to capital cost ratio should be lower in economies with high rates of structural change than in economies with lower rates of structural change.

The information from our research requires multiple data sources. We use data ranging from 1970 to the most currently available data. Data on capital (K) and Labor (L) are obtained from the Penn World Tables 6.2. Interest rates (*r*) were primarily obtained through the International Monetary Fund's International Financial Statistic databases. Different measures of interest rates are used to calculate the cost of capital for each country year. Wage data (*w*) were obtained through the International Labor Organization's website using the wages of non-agricultural workers. To measure structural change, export data from the United Nations - National Bureau of Economic Research Trade Data are used to calculate Change in Export Composition (CEC).

Background

The quest for strong economic growth continues to be the driving force of world leaders and politicians. Seemingly small effect of differences in growth rates can be better understood when looking at historical growth patterns worldwide. From 1870 to 1990, the United States experienced an average growth rate of about 1.75 percent per year. If we lower that growth rate by 1 percent, we mirror the growth rates of countries such as India (0.64 percent per year) and the Philippines (0.86 percent per year) from 1900 to 1987. With a growth rate of 0.75 percent per year, the real per capita GDP of the US would have grown from $2244 in 1870 to only $5519 in 1990 (Barro and Martin, 1999). However, given the actual growth rate of the US, the real per capital of the US in 1990 was more than triple that amount at $18,258. In terms of GDP per capita, the United States would have been ranked right around Mexico and Hungary.

In the previous example, the effects of compound growth were illustrated over 120 years. From 1960 to 1990, South Korea experienced an average growth rate of 6.7 percent per year. This resulted in a 7.4 fold real per capita GDP from $883 in 1960 to $6578 in 1990. Despite the economic slowdown in the late 1990s, South Korea was able to recover and had a real per capita GDP of $17,690 in 2006. It's real per capital GDP ranking increased from 83 out of 118 countries in 1960 to 49 out of 209 countries in 2006 (World Bank, 2007).

Initially, economic growth was believed to be achievable through increasing investments in physical capital. The idea was born in 1946 out of Evsey Domar's article on economic growth, "Capital Expansion, Rate of Growth, and Employment." Domar explained the relationship between short-term recessions and investment, and the model was subsequently used to explain long term growth. A few years earlier, Roy F. Harrod had described a similar theory, and it would be known as the Harrod-Domar Model. They both found a simple explanation for economic growth which stated that GDP growth is proportional to the share of investment spending in GDP. Using this model, economists believed there was a gap in investing due to a poor country's propensity to save when compared to richer countries. Low level of investment would prevent the creation of physical capital, thus resulting in slow growth. Foreign aid was thought to be the mechanism to close this gap; richer countries would supply machinery, roads, and buildings to poorer countries who might not be wealthy enough to do so themselves. Domar never intended that his model be used in economic growth exercises and later acknowledged the neoclassical growth theory created by Robert Solow was more appropriate for growth in the long term. Still today, the Harrod-Domar model continues to be used as justification for the foreign aid.

Past Research on East Asian Countries

Kim and Lau examined the sources of growth in East Asia using a meta-production function based on Solow's neoclassical model (Kim and Lau, 1995). They first identify Singapore, Hong Kong, Taiwan, and Korea as their countries of interest and describe them as newly industrialized economies (NIEs). They proceed by decomposing the growth of output across capital, labor, and Total Factor Productivity. Using data between 1950-1980, they observe no evidence of technical progress in the East Asian countries, but find significant technical progress contributing to the growth of the industrialized economies. Capital accumulation appears to be the most important source of growth in the NIEs (Table 1).

Table 1. Percent Contributions of Factor Inputs and Technology to Economic Growth

Economy	Capital Inputs	Labor Inputs	Technological Progress
Hong Kong	74	26	0
Singapore	68	32	0
South Korea	80	20	0
Taiwan	85	15	0
Non – Asian G5 Countries	36	6	59

Source: Kim & Lau, 1994

This is consistent with our hypothesis that there exists a structural difference in the way that technology is acquired, and is thus reflected in traditional growth accounting methods. Assumptions for the neoclassical model therefore are appropriate in developed countries, but do not hold true in for the East Asian countries.

Young's research suggests that the high rates of growth in East Asia could not be sustained (1994). Among these NIEs, he points out that from 1960 to 1985, they occupy the second to fifth fastest growing economies based on annual growth of output per capita out of 118 countries. A further analysis confirms the strong growth of the NIEs by observing the annual growth of output per worker. While their rankings are lower Young observes that the observed countries are still ranked in the top 14 compared to other 118 countries. Young then uses the neoclassical model to measure the growth in Total Factor Productivity (A) which in $Y= A \times K^{\alpha} \times L^{1-\alpha}$ is the measure for technological increases accounting for GDP growth (Y) with capital (K) and Labor (L). He observed that when ranking countries by annual growth of Total Factor Productivity, their rankings dropped considerably. Hong Kong was ranked sixth, Taiwan was ranked twenty first, South Korea was ranked twenty-fourth, and Singapore was ranked just below India at sixtythird of the 118 countries. He concludes that with the exception of Hong Kong, the East Asian NIEs grew rapidly primarily due to growth in investments and employment in manufactures, not an unusually rapid growth in manufacturing productivity. Young further demonstrates the growth capital and labor in an article published a year later using more detailed data sources. He finds that growth rates in both factors outgrow that of Total Factor Productivity (Young, 1995).

In the case of the NIEs, their source of technological growth has differed from those countries in the developed world. For example, the United States relies heavily on domestic research and development (R&D) for increasing efficiency. Inventions such as the automobile, personal computer, and the telephone were invented in the US. These innovations and many others come with high start up costs, but are the foundation for global competitiveness for the United States. The creation of industries, particularly highly technical industries generates expensive goods and services as well as relatively high paying jobs. In the NIEs, they avoid costly R&D by utilizing existing technologies in their production processes.

Take for instance the case of the assembly line which was initially developed by the Ford Motor Company. In developing countries, manufacturing industries use the assembly line as their principal form of operation. By acquiring technology in this follow-the-leader method, they use the R&D process performed by other companies. However, the borrowing an innovation also means that there are no benefits from the initial monopoly profits whenever a novel production method is discovered. The incomes in these industries provide a boost over traditional agricultural work. Economic growth in a developing country is achieved by switching from simple manufacturing industries to more complex manufacturing industries. It is common for a country to begin growth by opening textile manufacturing plants, luring farm workers seeking higher paying jobs. Opening new plants and adding labor continues to push economic growth until both factors are saturated and there are diminishing returns to scale. To increase profits, the textile industry would need to increase labor and capital efficiencies. When the operations are at the most efficient level, economic growth in the sector stops. The textile industry can no longer get more output given a fixed level of inputs. To continue growth, the country would have to shift to more expensive goods, which typically involve more complex production processes. An example would be when a country's export profile moves from the garment industry to the toy industry. Relative to the textile industry, income in the toy industry is higher due to a higher skill level requirement. Again at its infant stage, the toy industry grows by adding more machines and workers, and eventually streamlines its production process until its productive capabilities are maximized. This continues towards higher value products within industries such as biotechnology and electronics, where skill levels and salaries are quite high. Compared to other lower skilled industries, there is a great deal of research and development is still going on, providing opportunities for economic growth.

While product change and adding useful machinery and buildings achieves increases profits, long term growth is sustained by investments in R&D. In practice, technology transfer cannot be duplicated exactly. There is still a process of learning by doing where a new production process must go through a 'trial and error' phase.

Rather than technological gains from R&D, we suggest that NIEs have benefited from successive technical gains in capital intensive industries. These rapid structural changes would not be accounted for in the neoclassical model as these technological increases would be attributed to capital accumulation in the neoclassical model. Misspecification of the growth model was observed by Diamond, McFadden, and Rodriguez in 1978. At the time, most studies had used cross-sectional data to measure technical growth using the Cobb Douglas Production function. They suggest that given the time series of all observable market phenomena, it is possible that the same time series could have been generated by and altogether different production function. This alternative production function would have an arbitrary elasticity or bias at the observed points.

The newer industries in the East Asian countries did demonstrate a shift away from labor intensive industries to higher capital intensity. While this does contribute to the theory that the NIEs changes were due to capital accumulation, there is an alternative explanation which also fits well. We suggest that there are technological changes occurring as shifts to more capital intensive industries occur. Since the NIEs had policies geared towards advancing to more advanced industries, the efficiency gains are represented in a learning-by-doing manner, rather than technological gains through research and development.

Solow Model

Nobel laureate Robert Solow provided alternative theories of growth demonstrating that investment in machinery does not produce a source of growth in the long run. He published his theories in two major papers published in 1967 and 1957. Solow found that increases in physical capital could not sustain growth because of the law of diminishing marginal returns. In a poor country, introducing new machinery, roads, and dams will have a large effect on increasing productive capabilities. However, each additional piece of machinery achieves a smaller effect than the previous one introduced. There is an effective saturation where there may be no more capital needed. At this point, a steady state is reached where production is maintained at a certain production capacity and growth levels off.

Solow also realized that productivity was not only based on adding new machines. In addition to physical capital, he recognized that workers were key determinants of production. A person's ability to create goods was included in his economic growth model as labor productivity. Education is the primary means to develop "human capital," and thereby increase labor output. Similar to physical capital, human capital was also subject to the law of diminishing returns. Take for example a clothing manufacturing plant. Imagine there are ten sewing machines and five workers, and sewing machine can only accommodate one worker. The addition of another five workers will put all of the machinery to work. Adding another five workers in the plant will not increase the return from each sewing machine as all positions are filled.

Using a capital and labor model implies that both are needed increase to maintain growth. Solow observed that despite growing populations, labor was in fixed supply. When foreign aid donated large amounts of physical capital, there were not enough workers to keep up. Their results concluded the only way to experience sustained economic growth is through technological change. It is important to point out that economic growth defines 'technology' as the way inputs are transformed into output during the production process. In the field of economics, increases in technology are synonymous to in increases in efficiency. The development of the assembly line and other mass production techniques is an illustration of a technological improvement. His documented paper in 1957 estimated that approximated seven-eighths of GDP per capita growth in the US was due to improvements in technology.

In the production function described by Solow, the growth of output can be decomposed into two parts. The first source of growth comes from increases of measured inputs, capital and labor, shown by movement along a production function. Secondly, the growth of output can be measured by increases in Total Factor Productivity (TFP) or equivalently increases in productive efficiency.

To observe how technology translates into growth, we focus on Total Factor Productivity. In the model, TFP growth allows a country to produce the same output with fewer resources. Economists generally believe that TFP growth is the only means of sustaining increases in standards of living through higher incomes. Another way to look at the Total Factor Productivity is to think if as the weighted average of real wages and the real cost of capital. When TFP growth rises, either the real wages or real cost of capital will rise. Therefore, if we want real wages to rise without reducing the returns to capital, TFP growth must occur. This relationship can be used to explain the GDP differences in between the US and India. In 2006, the World Bank ranked the United States' GDP first at $13.2 trillion US dollars. India was ranked 12th out of 183 countries during same year with an output of $906 billion US dollars. Given the population of India, the model implies that the United States can more efficiently convert inputs to output (a higher A) or has a higher capital stock (K), or most likely, is a combination of both higher A and K.

Our theory is based on a country development pattern which flows through a standard demographic transition. In the first stage, a country is classified as pre-industrialized, and there are high mortality rates and the presence of extreme poverty. In the next stage, the country starts to increase basic infrastructure. Improvements in farming technologies, education, and basic health care contribute to increases in living standards. During the next phase, labor in agriculture declines as urbanization grows. There is an increase in manufacturing as a major source of economic growth resulting in increases in per capita income, typically focusing on the labor intensive industries, like textiles. In the United States, this was demonstrated by the Industrial Revolution during the late 18th and early 19th centuries. In this time, huge gains in productivity were seen due to improved transportation, the development of new machinery, and better labor management techniques. Within this transition stage also seems movement from labor intensive industries to capital intensive industries like steel production. At the most evolved stage, economic growth is driven by highly technical goods and services. For example, Korea's growth during the 1970s and 1980s was driven by POSCO, a steel company and automobile companies, such as Hyundai. During the 1990s automobile manufacturing continued to drive growth and was supported by consumer electronics companies like LG and Samsung.

Productivity growth in developed countries relies on new ideas and making new discoveries. In developing countries, growth and development focus on changing the structure of production to direct it towards higher levels of productivity. For the most part, this is achieved largely by adopting and adapting pre-existing technologies, entering external markets, in addition to rapid accumulation of physical and human capital.

Dynamic structural change involves more than just the growth of industry and modern services. It requires the ability to constantly enter into new productive activities. The capacity of a domestic economy to undergo rapid structural change influences its ability to gain from international trade and investment. Patterns of structural change since the 1960s indicate that such dynamic transformations are hallmarks of the fast-growing economies in East Asia. Countries characterized by low levels of structural change have experienced low levels of economic growth, particularly shown in Africa. In many slow growth countries, including those in Latin America, agriculture continues to be a main source of GDP. In the NIEs, agriculture production declined as industrial and service sectors expanded.

Since the 1960s, the newly industrialized countries experienced rapid changes in the composition of their exports. Most of these exports originated from manufactured products, indicating that there were rapid structural changes in the manufacturing sector. Van and Wan suggest that this pattern of development where efficiency gains were made were sector specific. Furthermore, they suggest that these technological advances were created deliberately in key industries at specific points in time. The process of focusing on particular industries was common place during the 1970s. In Korea, targeted infant industry promotion played a critical role in driving economic growth. Certain industries were granted protection in the domestic market through import controls. At the same time, the government favored these same industries as to make their exports competitive at world prices.

Localized Technical Gains

The idea of localized technological gains was initially described by Atkinson and Stiglitz (1969). Technical change in a one-sector model, or TFP growth, is represented by an upward shift in the production function. (See Figure 1). Atkinson and Stiglitz would interpret the aggregate production function in Figure 1 instead as an envelope of output in many different industries in an economy. Each industry is indexed by the capital-labor ration K/L, or the capital intensity of the industry. The usual TFP growth in this context implies TFP growth for each and every sector in the economy.

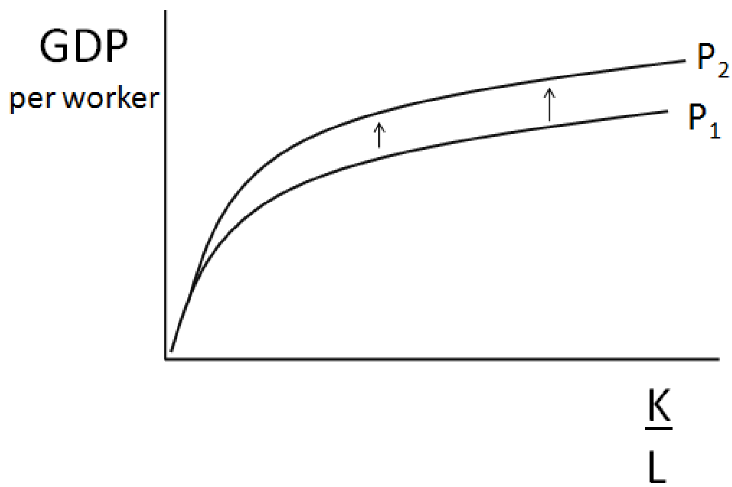

Figure 1. Global Technological Growth

When a technological advance is made in a specific industry, then the actual change is more accurately represented by an upward spike as shown in Figure 2. In this case, the technical progress is localized. Other industries do not increase in efficiency because the technological gains are contained within a single industry. Atkinson and Stiglitz suggest that in reality, there are some technological spillovers, but for an overall shift in the production function, the technology would have to improve the productive capabilities in all industries.

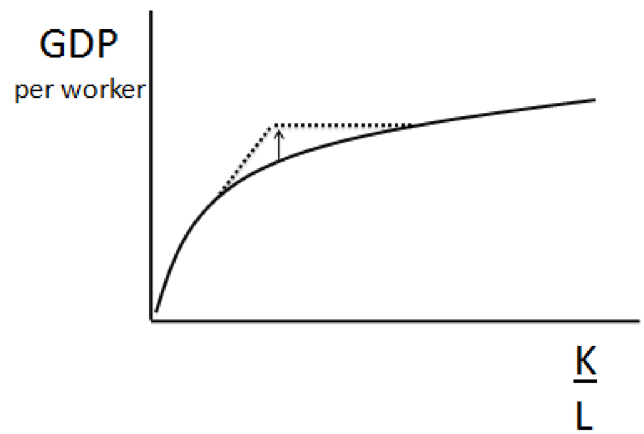

Figure 2. Typical Technological Growth in the Cobb-Douglas Production Function

The process of technological gain can also be represented by shifts of the unit value isoquants. In Figure 3, the isoquant AA' represents the maximum output of a product given a mix of the two factor inputs, capital (K) and labor (L). Production isoquants located closer to the origin indicate higher levels of efficiency as less inputs are required to product the same amount of output.

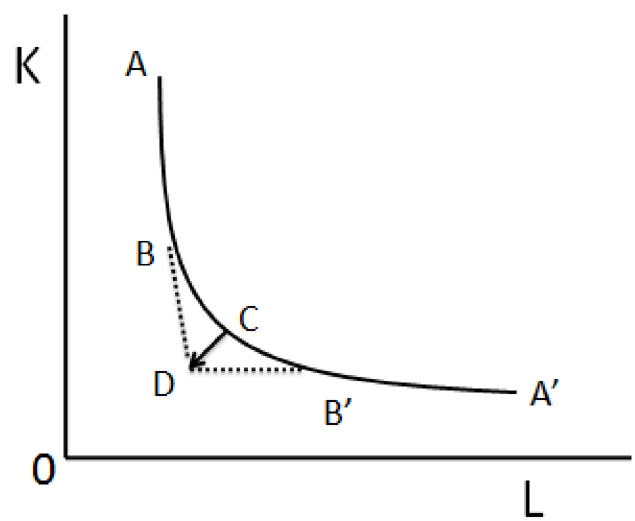

Figure 3. Technical Gains in One Industry

Technical gains localized to one industry may be a movement of point C to point D. The new envelope BDB' represents the gain from an improvement in technology. In a developing country, growth in technology represents a sequential set of movements by different industries moving towards the origin. In developed countries, a technological shift would be seen by movement of the whole isoquant inwards. Innovations like fax machines, e-mail, and the assembly line increase efficiencies in all production processes. In developing countries, movement occurs differently.

Take for example the set of production possibilities shown of a developing country shown at curve AA' in Figure 4. The goal is to reach efficiency levels similar to those in more advanced countries like in the United States, given by curve UU'.

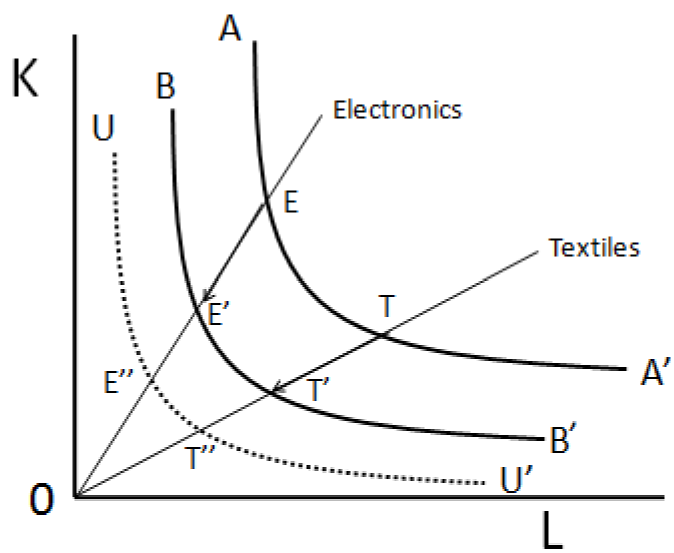

Figure 4. Technological Growth through Emulation

Deployment of technology might not allow for an exact level of production efficiency from where the technology was borrowed, and so the production possibilities curve might only yield results at BB'. In the model, we are shown how the Electronics industry starts at E and reaches efficiency point E' on the way to E". Textiles are shown to be more labor intensive that electronics industry, as it lies closer to the labor axis.

During the economic growth of a country, production typically moves from labor intensive activities to capital intensive activities. This was the case of the East Asian Countries, and so we see movement along the production possibilities frontier indicated by the movement from A' to E' in Figure 5. The unit value isoquant for the economy depicted in Figure 5 moves successively from the curves CC' to CA'B' to CT'A'B' to CS'T'A'B' to CE'S'T'A'B.   This shift in the unit value isoquant is due to technical gains that occur in one industry at a time in succession. But traditional growth accounting exercise would posit an aggregate production function with corresponding isoquant BB' and therefore the same evolution of production in this country (from A' to T' to S' to E') would be in misinterpreted as only capital gains.

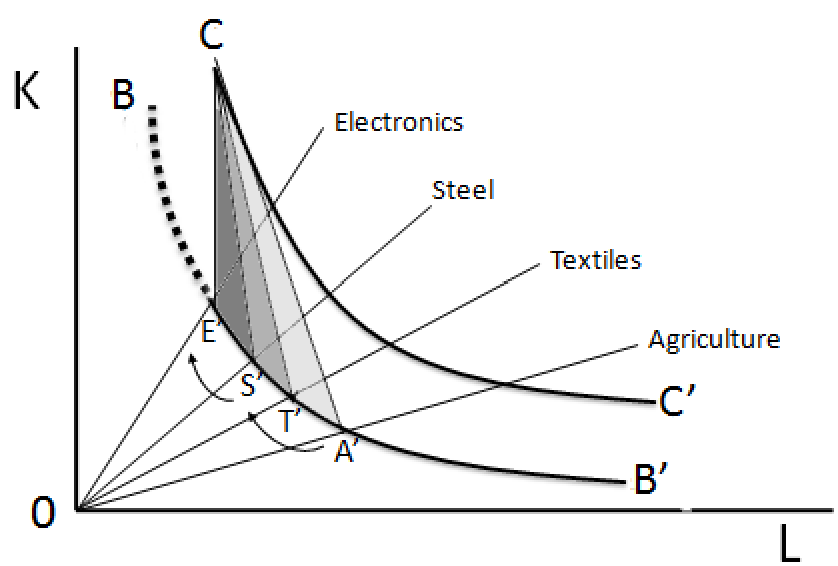

Figure 5. Staged Technological Growth

In this case, agriculture benefits from having a surplus of labor and is the primary source of a country's income at the beginning stages of development. Over time, the country switches to industries which require higher skill levels from its workers as well as more sophisticated technologies for production process to occur. This switch as well as investment to capital intensive industries coinciding with the decline of labor intensive industries represents technological gains.

The increases in complexity across the industries contain the technological growth for a developing country. Given technological growth observed through a staged transition, we can represent a similar type of growth represented through the production function in Figure 6. This interpretation of technological growth is illustrated by tracing out the path of industry specific growth over time, shown as P_2. Here we see that the staged addition of new industries does create a shift in the production curve. Structural change can be empirically calculated by looking at the changes within these industries.

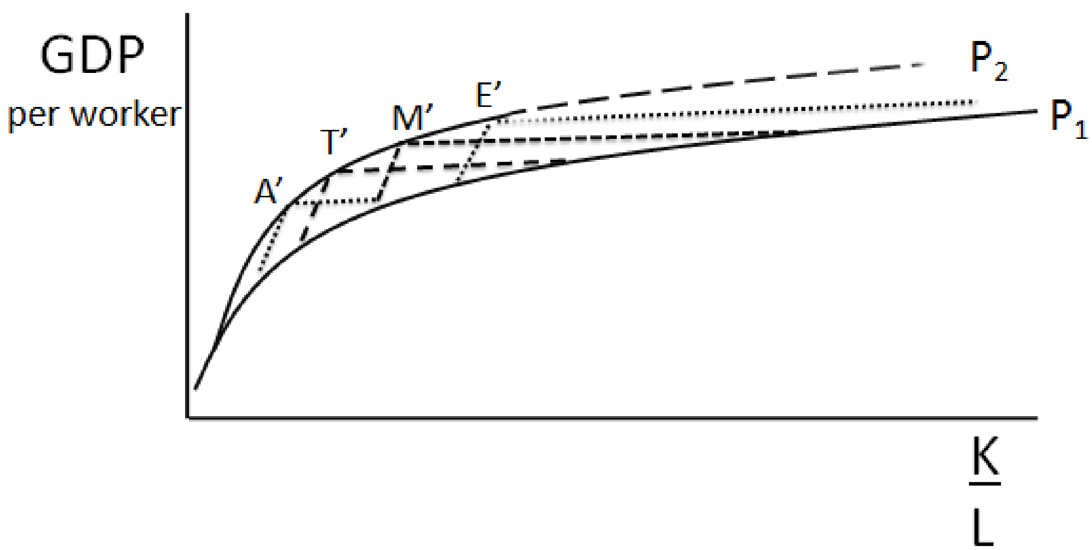

Figure 6. Staged Technological Growth in the Cobb-Douglas Production Function

Elasticity of Substitution

We begin with the Cobb-Douglas production function with capital (K), labor (L), and TFP (A) and α is a constant representing the labor share of productivity.

$$F(K,L,A) = Y = AK^{\alpha}L^{1-\alpha}$$

We define the marginal product of labor (MPL) and marginal product of labor (MPK) by taking the partial derivatives of labor and capital so that:

$$\frac{\partial Y}{\partial L} = (1-\alpha)AK^{\alpha}L^{-\alpha} = MPL = \text{wage rate}$$

$$\frac{\partial Y}{\partial K} = \alpha AK^{\alpha-1}L^{\alpha} = MPK = \text{rental rate}$$

The marginal rate of technical substitution (MRTS) is the ratio of the MPL to MPK.

$$\frac{MPL}{MPK} = MRTS$$

And therefore:

$$MRTS = \frac{1-\alpha}{\alpha}\frac{K}{L}$$

The elasticity of substitution is defined by the left-hand-side below, and we that

$$\frac{d\log(K/L)}{d\log MRTS} = \frac{d\log(K/L)}{d\log\left[\frac{1-\alpha}{\alpha}\frac{K}{L}\right]}$$

$$= \frac{d\log(K/L)}{\left[\underbrace{d\log\frac{1-\alpha}{\alpha}}_{=0} + d\log(K/L)\right]} = 1$$

If growth is driven by global technology gains and the aggregate production function is Cobb-Douglas, we expect the observed elasticity of substitution to be unity. However if technology gains are localized, then a smooth Cobb-Douglas production function is not appropriate. We expect the elasticity of substitution to be less than unity.

Furthermore, the faster the rate at which an industry gains technologically, the faster will be the rate of structural change. The unit value isoquant associated with the evolution of this economy will be characterized by smaller values for the empirical elasticity of substitution.

In this project we try to observe the misspecification of the current model by observing the effect of structural change of the production function. We calculate the elasticity of the substitution using factor prices and compare them to the elasticity of substitution implied by the neoclassical model. The elasticity of substitution between factor price ratios, capital and labor and the ratio of implied marginal products, cost of capital and wage rate, can be measured empirically given available macroeconomic data. By comparing these two ratios, we look for evidence of model misspecification.

We test three hypotheses. First, we test to see if there is a relationship between structural change and economic growth. Secondly, we see if the observed elasticity of substitution is less than one. This allows us to determine whether or not an aggregate Cobb-Douglas production function is inappropriate to model the economy. Second, we test the hypothesis that countries experiencing rapid structural change will have lower values for elasticity of substitution between capital and labor.

CHAPTER TWO

Methodology

Our first model observes the relationship between economic growth and the structural change. We would expect that countries undergoing high rates of structural change tend to have higher growth rates. We also expect that countries which are initially wealthy would experience slower rates of economic growth on average. This is because poor countries only require small amount of economic growth to experience a high rate of growth, when compared to richer countries. The concept of structural change is represented in a variable called the Change in Export Composition (CEC), which measures the absolute change in exports for a given country. We control for total exports, so that our change in export composition so that our CEC variable only reflects structural change, and not economic growth due to a large export industry. We would expect countries which have a greater dependence on exports to have high growth rates, due to export-led growth theory.

The model is specified as:

$$growth_i = \alpha + \beta cec_i + \gamma_1 \text{cgdpinit}_i + \gamma_2 \text{expshare}_i + \varepsilon_i$$

where $growth_i$ is the average growth rate in country i, cec_i is the average change in export composition in country i, cgdpinit_i is the log initial real gdp per capita in the year 1970, expshare_i is the average share of gdp contributed by exports in country i, and ε_{it} is the nonsystematic independent and identically distributed error. With the exception of the cgdpint_i, data for this model are taken from 1970 to 2000.

In our second model, we use a county-year fixed effects model to determine whether the empirical elasticity of substitution is less than one and thereby indication a model misspecification. We also expect to see a negative relationship between structural change, measured by cec and our wage-to-rental rate ratio. We include controls for real GDP per capita and the total exports.

The model is specified as:

$$KL_{it} = \alpha + \beta_1 wr_{it} + \gamma_1 cec_{it} + \gamma_2 wr\_cec_{it} + \gamma_3 \text{cgdp}_{it} + \gamma_4 \text{realexport}_{it} + \eta_i + \mu_t + \varepsilon_{it}$$

Where KL_{it} is the log Capital-to-Labor ratio in country i in year t, wr_{it} is the log wage-to-rental rate ratio in country i in year t with β_1 equal to the calculated empirical elasticity of substitution, cec_{it} is the country's log change in export composition in country i in year t, cgdp_{it} represents the country-time varying control for real GDP per capita, realexport_{it} represents the country-time varying control for total exports , η_i is the unmeasured determinant of log elasticity of substitution that is time invariant and is fixed within a country, μ_t is the time varying determinant of the log empirical elasticity of substitution that is fixed across countries, and ε_{it} is the nonsystematic independent and identically distributed error.

To further verify if the Cobb-Douglas production function is misspecified, we use a country fixed effects model observing the effects of structural change on the calculated empirical elasticity. The neoclassical production function based on capital, labor, and technology is defined as $Y = A \times K^{\alpha} \times L^{1-\alpha}$, where K is aggregate physical capital in use, L is aggregate human capital - i.e. labor output, and A captures Total Factor Productivity, the measure of how efficiently the aggregate stocks are used in the production of gross domestic product *Y*. The empirical elasticity of substitution is calculated as the dlog (*K/L*) / dlog (*w/r)*, where *K* is equal to capital.

The model is specified as:

$$ee_{it} = \alpha + \beta cec_{it} + \gamma \text{gdp}_{it} + \eta_i + \mu_t + \varepsilon_{it}$$

where ee_{it} is the calculated log empirical elasticity of substitution country *i* in year *t*, cec_{it} is the country's log change in export composition in country *i* in year *t*, gdp_{it} represents the country-time varying control *gdp*, η_i is the unmeasured determinant of log elasticity of substitution that is time invariant and is fixed within a country, μ_t is the time varying determinant of the log empirical elasticity of substitution that is fixed across countries, and ε_{it} is the nonsystematic independent and identically distributed error.

In this model we also run regressions for oil exporting non-OPEC and non-OPEC/non-Middle Eastern countries separately because oil exporting countries do not follow typical industrialization patterns. They do not have a staged technical progress as oil remains a constant source of GDP income. The *middle_east* classification by the World Bank is an additional specification beyond oil because there are oil exporting countries not included in OPEC. While Indonesia is a member of OPEC, it is excluded from the *oil* grouping as it has a diverse GDP income portfolio.

Country fixed effects are created through STATA to control for variations due to country-specific characteristics. Year fixed effects from 1970 – 2004 are used to control for unmeasured factors which influence the elasticity of substitution in all countries to the same degree. We control for African nations as they may derive income primarily through agricultural means. We control for real gross domestic product and real gross domestic product squared further control for differences in overall income levels.

Data

Calculation of Structural Change

The change in export composition is the aggregate value of all industry specific export changes in one year. It is defined as:

$$\text{CEC}_t = \sum_{i=1}^{n} \left| \, s_{it} - s_{it-1} \right|$$

where *s* is the amount of trade in real domestic currency for a particular industry *i* during year *t*.

The data used to calculate the Change in Export Composition was obtained from the United Nations – National Bureau of Economic Research (UN-NBER) at http://www.nber.org/data. Explanation of this dataset are provided by Feenstra, et al. (2005). The UN-NBER database contains bilateral trade data by commodity ranging from 1962 – 2000 for 130 countries. The raw data are packaged in 38 separate files containing global trade data for one year ranging from 25 to 50 MB. To overcome size limitations in STATA 9.2, import data was dropped before merging yearly data.

The original data set organizes each commodity by the 4-digit Standard International Trade Classification (SITC), revision 2, whereby each succeeding digit denotes a higher level of specificity. The UN-NBER data contains a 4-digit SITC code ending in A to demarcate an aggregate of all codes matching to the first 3 digits. For example, a code of 123A, would contain the aggregate of all the 4-digit SITC codes within that the 3-digit code, 123. There are also 4-digit SITC codes ending in X, indicating the extra trade of some 4-digit code within the three digit code, or within our example 123. This extra trade is the result of inaccuracies in reporting bilateral trade data between one country and another. Data was aggregated and analyzed at the 3 digit level as a higher level of specificity results in a large drop off historical values, particularly in high technology commodities, for example computer related hardware, which did not have recorded data in the earlier decades. In some rare cases, commodity trade data was only available at the 2-digit level of aggregation, indicated by the 4-digit SITC code ending in either AA or XX. In these cases, the data was not used as it did not provide a suitable level of specificity, and could result in a CEC based on two different commodities.

Data was adjusted using 1996 prices in the US using the data from the Penn World Tables 6.2. The absolute change in yearly exports was calculated per 3-digit SITC code. The Change in Export Composition variable was calculated by aggregating the yearly export changes. To normalize the data, the natural log of CEC was used in our calculations.

Calculation of the Capital Stock

Country level data concerning inflation, capital, and labor output was obtained from the Penn World Tables version 6.2 (PWT) provided by the Center for International Comparisons at the University of Pennsylvania. Capital stock (K) is calculated from the investment variable within Penn World Tables. The capital stock is calculated using a standard perpetual inventory approach with geometric deprecation. The capital stock is calculated by the formula below. Explanation of variables within the PWT 6.2 database is given in Summers and Heston (2002).

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

where K_t is capital stock at time *t,* K_{t-1} is the previous year's capital stock, I_t is the current year investment, δ is the depreciation rate for the asset. In this exercise a standard depreciation rate of 0.07 is used for all countries in all years. The initial stock calculation is assumes that the first five years of the investment series is representative of growth prior to the beginning of the series. The initial capital stock is therefore calculated by the formula:

$$K(0) = I(0) / (g + \delta)$$

where I(0) is the first year of the investment data series, g is the average growth of investment in assets in first five years of the investment series.

The investment data series and average growth of investment must be calculated from the Penn World Tables. Investment data are provided as a component of real GDP per capita, using price levels in the US with 1996 as the base year. Multiplying the real GDP per capita (*rgdp*) by the total population (*pop*) yields the real GDP. The amount of investment for a given year I_t can be calculated by multiplying total real GDP by the investment share of real GDP (*ki)* where *ki* is < 1.

The average growth rate g is then calculated using a five year average of the first five entries in the investment series.

Calculation of Labor Inputs

Calculation of the contribution of labor to economic growth is performed using data from the Penn World Tables. Labor input is calculated by multiplying the working population by the real GDP per worker. Labor input is based on using price levels in the US during 1996 as the base year.

Calculation of the Cost of Capital

Lending rates, deposit rates, Treasury bill rates, and money market rates were the nominal interest rates used to calculate the cost of capital (r). Interest rates were downloaded from the International Monetary Fund's (IMF) International Financial Statistics table. For Taiwan, interest rates were not available through the IMF International Financial Statistics website. Interest rates were downloaded manually from the Central Bank of Taiwan website (Central Bank of Taiwan, 2007). The aggregate capital rental price aims to be the average of the rental price of buildings, machinery, and other physical equipment. According to Christensen and Jorgenson, if firms have perfect foresight capital follows a geometric depreciation, the real rental price of investment good j, r_{j}, can be calculated as:

$$\frac{r_{\mathrm{j}}}{p^{\mathrm{y}}} = \frac{p_{\mathrm{j}}^{\mathrm{K}}}{p^{\mathrm{y}}} (i - \hat{p}_j^{\mathrm{K}} + \delta_j)$$

Where $\hat{p}_j^{\mathrm{K}}$ is the growth rate of the price of investment good j, i is the nominal interest rate, δ_{j} is the rate of depreciation at 0.07, and p^{y} is the GDP deflator (1969).

Calculation of Wage Rates

The International Labor Organization's LABORSTA database provides yearly statistics (time-series) on employment for over 200 countries from 1969 to 2005. The data are collected from country labor ministries or relevant statistical offices and covers core labor statistics including wages, occupation, labor cost, and days worked. For this project we obtain data concerning wages in manufacturing, readily available as table 5B. Depending on the country, the wage data are available as an average weekly wage, average monthly wage, or average yearly wage. The data are separated into three gender classes: 1) Men, 2) Women, and 3) Men and Women. We used data filtered by 'Men and Women,' as it was typically the available data among low-reporting countries. In Great Britain, Switzerland, Uruguay, Australia, and Malaysia, historical data are not provided for women and so the wage rate for 'Men' is substituted. Depending on the available data, the data may include sub-classifications depending on the industry type. The sub-classification column includes a 'Total' value containing the weighted average wage across all industry types. Data was filtered by the 'Total' value within the sub-classification column to obtain the most accurate data. In Germany, the wage rate is not adjusted accordingly when the switch to the Euro occurred in 2001. All data are provided for in nominal terms. We use the price level within the Penn World Tables to convert average yearly wage data to real terms based on the US in 1996. Data was verified by comparing real wage data to the Key Indicators of the Labour Market Data Set, additionally provided by the International Labour Organization, but only ranges from 1980 to 2006.

For Taiwan, wage data for the 1970s was not readily available through the International Labor Organization's Laborsta website. Average monthly earnings data, indexed to 1996 was provided by the Council for Economic Planning and Development within the Taiwanese government (CEPD, 2002).

Calculation of Elasticity of Substitution

Data identification across the databases required the creation of a custom concordance file. Each database used a unique alphanumeric coding system and included a full country name which was used to match databases. General macroeconomic indicators from The Penn World Table database used a 3-letter coding scheme labeled *countryisocode*. Wage data from the International Labour Organization's International Financial Statistics used a 2-letter coding scheme labeled *codecountry*. Trade data provided by the United Nations-National Bureau of Economic Research used a 6-digit coding scheme labeled *ecode.* Lending and money-market rate data from the International Monetary Fund's International Financial Statistics used a 3 digit coding scheme labeled *countrycode*.

After combining the data, we calculated empirical elasticities of substitution. Yearly capital-to-labor ratios and wage-to-rent ratios were calculated. Log values were used to calculate the final elasticity of substitution, show as :

$$\frac{\text{dlog}\,(K/L)}{\text{dlog}\,(w/r)} = \frac{\log\,(K/L)_t - \log\,(K/L)_{t-1}}{\log\,(w/r)_t - \log\,(w/r)_{t-1}}$$

CHAPTER THREE

Results

For our first hypothesis, we see that there is a positive and statistically significant relationship between structural change and real per capital GDP growth rates, robust across sample type (See Table 2). We see that an in our full sample, a 1 percent increase in CEC results in a 0.293 percent increase in the growth rate, statistically significant at the 1% level with $|t| = 2.72$. Removing the OPEC countries, we see that the relationship is maintained where a 1 percent increase in CEC results in a 0.321 increase in the mean growth rate. When removing the African countries, the relationship is maintained, although lowered to the 5% level where a 1 percent increase in the CEC results in a 0.273 increase in the average growth rate.

Table 2 : Relationship between Average Growth Rates and Structural Change

	Entire Sample	Non-OPEC Countries	Non-OPEC, Non-Middle East	Non-OPEC, Non-African countries
ln_cec	0.293***	0.321***	0.358***	0.273**
	(2.72)	(2.89)	(3.12)	(2.26)
cgdpinit	-0.414**	-0.393*	-0.495**	-0.881***
	(2.15)	(1.98)	(2.4)	(3.68)
expshare	0.517	0.964	1.201	1.856
	(0.39)	(0.71)	(0.88)	(1.25)
Observations	154	145	137	107

Absolute value of t statistics in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

As expected, we see that countries with higher initial real per capita GDP growth rates have a lower rate of economic growth, robust across sample type. In the analysis of our entire sample, we find evidence of a negative and statistically significant association where an increase in the between initial real per capita growth by 1 percent results in a 0.414 percent decrease in the growth rate with $|t| = 2.15$.

In our second sample, we do not include OPEC countries. Our theory is based on countries which undergo development based on economic through manufacturing based industries. We believe that oil producing countries do not fit this model and remove them in our second analysis. It is observed that there are oil producing countries not included in the OPEC agreement, and so we run a sample removing both OPEC and Middle Eastern Countries. We the relationship increase in point estimate and in significance after removing the OPEC and African countries where a 1 percent increase in the real per capital GDP growth rate results in a 0.881 percent decrease in the growth rate, statistically significant at the 1% level. Although not statistically significant, we find a positive relationship between the export share of GDP and growth, as expected.

For the second hypothesis, we use a country-year fixed effects model to determine if the true elasticity of substitution is less than one. If an aggregate Cobb-Douglas production function is inappropriate to model the economy, since the theoretical elasticity of substitution is unity, by definition. We run the test with under four different samples, similar to our previous tests. We also run the tests with and without our control variables, gdp and total exports. Furthermore, we increase robustness by testing our hypothesis by running our tests with three different measures of the wage-to-rental rate ratio, depending on the source of the nominal interest. Results regarding these tests are found in Tables A1-A3 located in Appendix A.

We ran a t-test to determine if the beta coefficient on wage-to-rental rate variable is equal to one, when the alternative hypothesis is that the value is equal to less than one. Among the three specifications where different nominal interest rates were used to calculate the rental rate, we found all of them to have a value of $p = 0$ (See Tables 5-7, bottom). We saw that in general, there was a positive and statistically significant effect of the wage-to-rental rate ratio on the capital-to-labor ratio. Among the different samples and controls for both the wage-to-rental rate ratio based on all three nominal interest rates, the point estimates for the beta coefficients ranged from 0.0562 to 0.176, typically significant at the 1% or 5% level.

In our first set of tests, we use the lending rate as our nominal interest rate in the calculation of the rental rate. We see that when using the entire sample, a 1 percent increase in the wage-to-rental rate ratio results in a 0.0788 increase in the capital-to-labor ratio, before adding controls. This is significant at the 1% level with $|t| = 3.13$. Statistical significance is maintained at the 1 percent level when removing OPEC and Middle Eastern Countries. When removing countries part of OPEC and African countries, we see that a 1 percent increase in the wage-to-rental rate ratio results in a 0.0715 increase in the capital-to-labor ratio, statistically significant at the 5% level with $|t| = 2.41$.

We observed the interaction term between CEC and the wage-to-rental rate ratio to be negative and statistically significant, robust across sample type and inclusion of control variables. When using the entire sample, we that beta coefficient for the interaction between CEC and the wage-to-rental rate ratio to be -0.0054, with $|t| =3.03$, statistically significant at the 1% level. Adding the gdp and export control variables did not change the level of statistical significance, and the point estimate changed little to -0.0046 with $|t| = 2.67$. After removing the oil producing countries, we still see a statistically significant relationship with $|t| = 2.87$, although when including the control variables we see significance at the 5% level with the control variables and $|t| = 2.57$. When removing the OPEC and African countries, we continue to see a negative statistically significant relationship, in the case at the 5% level with $|t| = 2.24$ and when including the control variables, we see statistical significance drop to the 10% level with $|t| = 1.91$.

The relationship between the capital-to-labor ratio and the wage-to-rental rate ratio continue similar trends and levels of significance when using the deposit rate and t-bill rates as the nominal interest rate when calculating the rental rate (See Tables A2 and A3 in Appendix A).

We observe our control variable, GDP to consistently have a statistically significant and negative relationship with the capital-to-labor ratio at the 1% level across all sample type and across all three wage-to-rental rate calculations. When using the wage-to-rental rate based on lending rates, we see that when using the entire sample, a 1 percent increase in real GDP per capita results in a 0.117 percent decrease in the capital-to-labor ratio with $|t| = 3.29$. When removing the OPEC and Middle Eastern countries we still see at negative and statistically significant relationship with $|t| = 3.47$. When removing OPEC and African countries, again we see statistical significance at the 1% level where a 1 percent increase in re GDP per capita results in a 0.166 percent decrease in the capital-to-labor ratio, with $|t| = 4.29$.

The export control variable appears to have a statistically significant and positive relationship with the capital-to-labor ratio at the 1% level robust across all sample type and across all three wage-to-rental rate calculations. When using the wage-to-rental rate based on lending rates, we see that when using the entire sample, a 1 percent increase in real GDP per capita results in a 0.153 percent decrease in the capital-to-labor ratio with $|t|$ = 8.25. When removing the OPEC and Middle Eastern countries we still see a very strong relationship with $|t|$ = 7.45. When removing OPEC and African countries, we still see statistical significance at the 1% level where a 1 percent increase in re GDP per capita results in a 0.155 percent decrease in the capital-to-labor ratio, with $|t|$ = 7.48.

Our third hypothesis suggests that countries with high levels of structural change, measured by CEC, are associated with low levels of elasticity of substitution. Our results display a statistically significant negative relationship between log CEC and log elasticity of substitution, robust across sample type and inclusion of control variables.

In the first model shown in Table 3, we use the lending rate as our nominal interest rate to measure the cost of capital (r). Among our variables used in this exercise, the cost of capital displayed the most variability, and so we use a second measure for nominal interest rates shown in Table 4 using money market rates. Using lending rates, we see that using the entire sample, there is a negative and significant relationship when using log GDP as a control variable. The relationship is weakly significant at 10% where $|t|$=1.69. We see that a 1 percent increase in CEC results in a 0.432 percent decrease in the elasticity of substitution.

Similar to our analysis of growth and structural change, we run samples removing oil producing countries and African Nations. Our regression without the OPEC countries yields significant results, even before adding control variables. We see that a 1 percent increase in CEC results in a 0.497 percent reduction in the elasticity of substitution. After adding in the control variable, we see that significance is maintained yielding a 0.564 decrease in the elasticity of substitution with a 1 percent increase in CEC.

We include a second specification removing oil producing countries by removing both OPEC and Middle Eastern Countries. We see that significance is maintained at the $p < 0.05$ level in both the non-controlled and controlled tests, $|t|=2.30$ and $|t|=2.44$, respectively. Without the control variable, we see that a 1 percent increase in CEC results in a 0.550 percent decrease in the elasticity of substitution. When including log gdp, we see that 1 percent increase in CEC results in an even greater decrease in the elasticity of substitution of 0.641 percent.

Our final sample removes both OPEC countries and African countries. Underdeveloped countries in Africa may have not experienced industrialization and may depend on agricultural activities for employment of most of their workers. There may be no growth, whether in the form of staged technological growth or through generalized technical growth. When dropping OPEC and African countries, we see that there is still a significant and negative relationship between structural change and our elasticity of substitution. The statistical relationship is weaker, reaching significance at the 10% level with $|t|=1.94$. Adding the control variable, we see the significance increase in strength at $|t|=2.16$ where a 1 percent increase in CEC result in a 0.683 percent decrease in our calculated elasticity of substitution.

Table 3. Effect of Structural Change on Empirical Elasticity of Substitution, Country Year Fixed Effects using Lending Rates to Calculate Cost of Capital

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Entire Sample	Entire Sample, controls	Non-OPEC Countries	Non-OPEC Countries, controls	Non-OPEC, Non-Middle East	Non-OPEC, Non-Middle East, controls	Non-OPEC, Non-African countries	Non-OPEC, Non-African countries, controls
ln_cec	-0.326	-0.432*	-0.497**	-0.564**	-0.550**	-0.641**	-0.559*	-0.683**
	(1.4)	(1.69)	(2.1)	(2.18)	(2.3)	(2.44)	(1.94)	(2.16)
ln_gdp		1.03		0.671		0.857		1.03
		(1.0)		(0.65)		(0.84)		(0.95)
Obs.	348	348	340	340	332	332	306	306

Absolute value of t statistics in parentheses, Country-Year Fixed Effects
* significant at 10%; ** significant at 5%; *** significant at 1%

We used an alternative measure of nominal interest rates, namely the money market rate to calculate our cost of capital, displayed in Table 4. Using money market rates, we see the sample decrease to 240 from 348 when using lending rates. This is because of a lower reporting to the IMF from participating countries. Our findings demonstrate a similarly negative and statistically significant relationship between the structural change measured by CEC and the elasticity of substitution, albeit with larger standard errors. When using the entire sample, the simple country-year fixed effects model does yield significance at the 10% level where $|t|=1.70$. We see that a 1 percent increase in CEC results in .456 decrease in the elasticity of substitution. This relationship is maintained when adding controls where a 1 percent increase in CEC results in a 0.474 percent decrease in the elasticity of substitution. Removing the oil producing countries did not affect the outcome as most like no OPEC or Middle Eastern countries provided data on money market rates. However, when removing the removing the African nations, the sample is reduced by 20 observations. We still see significance at the 10% level where a 1 percent increase results in a .553 decrease in the elasticity of substitution. When controlling for gdp, the model still demonstrates a statistically significant and negative relationship where a 1 percent increase in CEC results in a 0.556 percent decrease in the empirical elasticity of substitution.

Table 4. Effect of Structural Change on Empirical Elasticity of Substitution, Country Year Fixed Effects using Money Market Rates to Calculate Cost of Capital.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Entire Sample	Entire Sample, controls	Non-OPEC Countries	Non-OPEC Countries, controls	Non-OPEC, Non-Middle East	Non-OPEC, Non-Middle East, controls	Non-OPEC, Non-African countries	Non-OPEC, Non-African countries, controls
ln_cec	-0.456*	-0.474*	-0.456*	-0.474*	-0.456*	-0.474*	-0.553*	-0.556*
	(1.7)	(1.66)	(1.7)	(1.66)	(1.7)	(1.66)	(1.81)	(1.71)
ln_gdp		0.204		0.204		0.204		0.0322
		(0.19)		(0.19)		(0.19)		(0.03)
Obs.	240	240	240	240	240	240	220	220

Absolute value of t statistics in parentheses, Country-Year Fixed Effects

* significant at 10%; ** significant at 5%; *** significant at 1%

CHAPTER FOUR

Summary and Discussion

Growth in the East Asian countries has been said to have been due to its focus on outward oriented policies. Globalization advocates have used such success stories as these countries to demonstrate how incomes can rise when countries do not focus on domestic markets. Economists including Kim, Lau, and Young warn that East Asian countries should not be used as an example of the potential gains from outward oriented policies, but rather the gains from factor accumulation.

Policy research and empirical literature on economic growth has investigated the causes of differences in per-capita incomes across different countries. The fundamental question is the role of measured factors, such as physical and human capital, relative to that of unobservable Total Factor Productivity. The most used analysis involves the neoclassical production function which is a Cobb-Douglas form of Robert Solow's growth model. In the Solow model, where $Y = AK^{\alpha} L^{1-\alpha}$, cross-country variation in the levels of GDP per capita output (Y), can be decomposed into factors (K and L) and Total Factor Productivity (A).

Our first hypothesis showed that there is a relationship between our CEC variable and average growth rates from 1970-2000, even when controlled for GDP and exports. The positive and statistically significant results confirm that high levels of structural change are associated with high rates of economic growth.

Our second hypothesis tested the hypothesis that the empirical elasticity of substitution for countries is less than unity. We observed low values for the empirical values of the elasticity of substitution measured though the beta coefficient of the wage-to-rental rate ratio. These observations were since consistently across different measures of the wage-to-rental rate ratio, across different sample types, and with all controls included. Since the Cobb-Douglass production function assumes an elasticity of substitution of 1, this is evidence that the Cobb-Douglas production function may be inappropriate for modeling economic growth.

Additionally, our third hypothesis supposed that the observed change in the elasticity of substitution should be lower in economies of with high rates of structural change than in economies with lower rates of structural change. In countries that experience localized technical gains and high levels of structural change, we would not expect to see evidence of aggregate technical gains due to misspecification by the Cobb-Douglas production function. In our estimation, we found evidence that there is a negatively significant effect between structural change and the calculated elasticity of substitution, consistent with the story of localized technical gains that would otherwise be undetected during aggregate growth accounting exercise.

When countries focus on perfecting a single industry before moving into a more capital intensive and highly technical industry their growth may be shown as primarily capital accumulation. In countries undergoing rapid structural change exhibit localized technical gains, it may be more appropriate to focus on one industry at a time. Industry level growth exercises may be better a better predictor of whether or not economic growth can be sustained.

APPENDICES

APPENDIX A

Wide Format Table, Capital-to-Labor Ratio and Wage-to-Rental Rates

Table A-1: Relationship between the Capital-Labor Ratio and the Wage-Rental Rate Ratio using Lending Rates to Calculate the Cost of Capital

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Entire Sample	Entire Sample, controls	Non-OPEC Countries	Non-OPEC Countries, controls	Non-OPEC, Non-Middle East	Non-OPEC, Non-Middle East, controls	Non-OPEC, Non-African countries	Non-OPEC, Non-African countries, controls
lnwr_lend	0.0788***	0.0711***	0.0783***	0.0698***	0.0780***	0.0714***	0.0715**	0.0634**
	(3.13)	(2.89)	(3.07)	(2.82)	(3.06)	(2.86)	(2.41)	(2.20)
lncec	0.0116	-0.0383***	0.0133	-0.0373**	0.0062	-0.0375**	-0.0119	-0.0487***
	(0.97)	(2.66)	(1.09)	(2.55)	(0.50)	(2.54)	(0.89)	(3.09)
lnwr_lend_cec	-0.0054***	-0.0046***	-0.0053***	-0.0045***	-0.0051***	-0.0045**	-0.0046**	-0.0038*
	(3.03)	(2.67)	(2.97)	(2.59)	(2.87)	(2.57)	(2.24)	(1.91)
ln_cgdp		-0.208***		-0.227***		-0.212***		-0.293***
		(5.71)		(5.94)		(5.50)		(7.25)
ln_realexport		0.120***		0.123***		0.110***		0.110***
		(6.82)		(6.89)		(6.07)		(5.68)
Observations	942	942	922	922	901	901	824	824

p-value for H0: coefficient on lnwr_lend=1 = 0

Absolute value of t statistics in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Table A-2 : Relationship between the Capital-Labor Ratio and the Wage-Rental Rate Ratio using Deposit Rates to Calculate the Cost of Capital

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Entire Sample	Entire Sample, controls	Non-OPEC Countries	Non-OPEC Countries, controls	Non-OPEC, Non-Middle East	Non-OPEC, Non-Middle East, controls	Non-OPEC, Non-African countries	Non-OPEC, Non-African countries, controls
lnwr_dep	0.0749***	0.0612**	0.0752***	0.0614**	0.0745***	0.0616**	0.0744**	0.0562*
	(2.96)	(2.50)	(2.95)	(2.49)	(2.91)	(2.48)	(2.38)	(1.85)
lncec	0.0438***	-0.0330**	0.0455***	-0.0317**	0.0392***	-0.0310**	0.0223*	-0.0475***
	(3.74)	(2.22)	(3.82)	(2.10)	(3.27)	(2.03)	(1.68)	(2.86)
lnwr_dep_cec	-0.0050***	-0.0041**	-0.0050***	-0.0041**	-0.0048***	-0.0040**	-0.0047**	-0.0036*
	(2.82)	(2.40)	(2.81)	(2.38)	(2.72)	(2.33)	(2.23)	(1.72)
ln_cgdp		-0.117***		-0.125***		-0.110***		-0.166***
		(3.29)		(3.47)		(3.01)		(4.29)
ln_realexport		0.153***		0.155***		0.143***		0.155***
		(8.25)		(8.27)		(7.45)		(7.48)
Observations	991	991	974	974	953	953	868	868

p-value for H0: coefficient on lnwr_dep=1 = 0

Absolute value of t statistics in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Table A-3 : Relationship between the Capital-Labor Ratio and the Wage-Rental Rate Ratio using T-bill Rates to Calculate the Cost of Capital

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Entire Sample	Entire Sample, controls	Non-OPEC Countries	Non-OPEC Countries, controls	Non-OPEC, Non-Middle East	Non-OPEC, Non-Middle East, controls	Non-OPEC, Non-African countries	Non-OPEC, Non-African countries, controls
lnwr_tbill	0.176***	0.151***	0.176***	0.151***	0.176***	0.151***	0.146***	0.0720**
	(5.04)	(4.62)	(5.04)	(4.62)	(5.05)	(4.63)	(3.56)	(1.97)
lncec	-0.0203	-0.0829***	-0.0203	-0.0829***	-0.0207	-0.0838***	-0.0405**	-0.0858***
	(1.27)	(4.34)	(1.27)	(4.34)	(1.29)	(4.37)	(2.27)	(4.24)
lnwr_tbill_cec	-0.0119***	-0.0104***	-0.0119***	-0.0104***	-0.0120***	-0.0104***	-0.0098***	-0.0050**
	(4.95)	(4.59)	(4.95)	(4.59)	(4.96)	(4.60)	(3.50)	(2.01)
ln_cgdp		-0.384***		-0.384***		-0.384***		-0.602***
		(7.52)		(7.52)		(7.50)		(11.01)
ln_realexport		0.163***		0.163***		0.164***		0.165***
		(6.98)		(6.98)		(6.99)		(6.61)
Observations	591	591	590	590	587	587	525	525

p-value for H0: coefficient on lnwr_tbill=1

Absolute value of t statistics in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

APPENDIX B

Stata Code

```
* ************************************

* ************************************
* growth exercise by  Racsa/Van
* program written by Racsa/Van
* last revision by Patrick Racsa Feb 06 2008
* ************************************
clear
capture program drop _all
program growth
        clear
        set memory 512m
        set more off

  * ReadPwt
  * ReadIfs
  * ReadUnnber
  * ReadIlo

  * CalcCostCapital
  * CalcStructuralChange
  * CalcKL
  * CalcRealWage
  * CalcEe

   FullData
end // -------

* ************************************
* ************************************
* Read in Penn World Tables 6.2
* ************************************
* ************************************
program ReadPwt
    insheet using "../data/raw/pwt62.csv", clear
        keep countryisocode country year pop ci cgdp rgdpch rgdpwok p pi grgdpch
        destring pop - grgdpch, force replace ignore("na")
        sort countryisocode
        rename grgdpch growth_rate
        save "../data/pwt62.dta", replace

    insheet using "../data/raw/concordance.csv", clear
        sort countryisocode
        save "../data/concordance.dta", replace
        merge countryisocode using "../data/pwt62.dta"
            tab _merge
            keep if _merge == 3
```

```
			drop _merge
			sort countrycode year
			tsset countrycode year
			sort countryisocode year
		save "../data/pwt62.dta", replace
	insheet using "../data/raw/class.csv", names clear
		rename code countryisocode
			replace countryisocode="GER" if countryisocode=="DEU" //adjustments for 
different code IDs between databases
			replace countryisocode="MYA" if countryisocode=="MMR"
			replace countryisocode="SAM" if countryisocode=="WSM"
			replace countryisocode="ARB" if countryisocode=="ABW"
		encode income_group, gen (incgroup)
		encode region, gen (reg)
		gen incgroup1 =.
			replace incgroup1 = 1 if class2=="L"
			replace incgroup1 = 2 if class2=="LM"
			replace incgroup1 = 3 if class2=="UM"
			replace incgroup1 = 4 if class2=="H"

		keep countryisocode  reg incgroup
		sort countryisocode
		merge countryisocode using "../data/pwt62.dta", uniqmaster
			tab _merge
			drop if _merge==1
			drop _merge
		gen oil = 0
			foreach x in 612 614 248 443 429 694 453 456 299 449 {
				replace oil=1 if countrycode==`x'
			}
			tab nation if oil==1
		gen africa=0
			replace africa=1 if reg==6
			foreach x in 469 611 686 612 {
				replace africa=1 if countrycode==`x'
			}
			tab nation if africa==1
		gen soviet=0
			foreach x in 912 911 915 916 917 923 995 995 994 941 939 921 922 926 946 
913 {
				replace soviet=1 if countrycode==`x'
			}
			tab nation if soviet==1

		gen wafrica=0
```

```
        foreach x in 204 854 132 384 270 288 324 624 430 466 478 562 566 686 694
768 {
            replace wafrica=1 if countrycode==`x'
        }
    gen oilafr=0
        replace oilafr=1 if oil==1
        replace oilafr=1 if africa==1
    gen alloil=0
        replace alloil=1 if oil==1
        replace alloil=1 if reg==4


  label var pi "Price Level of Investment"
  label var p "Current Price Entries,Price Level of Gross Domestic Product, US =100,
GDP deflator"
  label var rgdpch "Constant Price Entries,Real GDP per capita (Constant price: Chain
series)"
  label var rgdpwok "Constant Price Entries,Real GDP chain per worker"
  label var cgdp "Constant Price Entries,Real GDP per capita"
  label var ci "Constant Price Entries, Investment share of RGDPL"
  label var nation "Country name"
  label var countrycode "Country ID for IMF IFS Data (3 digits)"
  label var countryisocode "Country ID for Penn World Tables (3 letters)"
  label var codecountry "Country ID for ILO Wage Data (2 letters)"

  sort countrycode year
  save "../data/pwt62.dta", replace
end

program ReadIfs
 insheet using "../data/raw/ifslend.csv",clear
    keep countrycode v9-v57
    reshape long v, i(countrycode) j(var)
    gen year = var + 1951
    destring v, force replace
    rename v ifslend
    drop var
    sort countrycode year
    save "../data/ifs.dta", replace
  foreach x in mm tbill dep {
  insheet using "../data/raw/ifs`x'.csv",clear
    keep countrycode v9-v57
    reshape long v, i(countrycode) j(var)
    gen year = var + 1951
    destring v, force replace
    rename v ifs`x'
```

```
        drop var
        sort countrycode year
        save "../data/ifs`x'.dta", replace
        use  "../data/ifs.dta",clear
        merge countrycode year using "../data/ifs`x'.dta"
          tab _merge
          drop _merge
        sort countrycode year

        save "../data/ifs.dta", replace
        }
    sort countrycode year
    save "../data/ifs.dta", replace

    insheet using "../data/raw/interest_add.csv", clear
        sort countrycode year
        save "../data/interest_add.csv", replace
        merge countrycode year using "../data/ifs.dta"
          tab _merge
          drop _merge
        sort countrycode year
        save "../data/ifs.dta", replace

    label var ifsdep "Average Yearly Deposit Rates, nominal"
    label var ifstbill "Average Yearly T-Bill Rates, nominal"
    label var ifsmm "Average Yearly Money Market Rates, nominal"
    label var ifslend "Average Yearly Lending Rates, nominal"
    save "../data/ifs.dta", replace
end

program ReadUnnber
    use "../data/wtf00.dta", clear
        keep if icode == "100000"
        drop if ecode == "100000"
        drop if strpos(sitc4,"XX")>0 // dropping data which is underspecified
        drop if strpos(sitc4,"AA")>0 // dropping data which is underspecified
        gen sitc3 = substr(sitc4,1,3)
        destring ecode, replace
        keep ecode year sitc3 value
        collapse (sum) value, by(ecode sitc3 year)
        sort ecode year sitc3
        save "../data/wtf.dta", replace

        forval years = 62/99 {
        use "../data/wtf`years'.dta"
            keep if icode == "100000"
```

```
            drop if ecode == "100000"
            drop if strpos(sitc4,"XX")>0
            drop if strpos(sitc4,"AA")>0
            gen sitc3 = substr(sitc4,1,3)
            destring ecode, replace
            keep ecode year sitc3 value
            collapse (sum) value, by(ecode sitc3 year)
            sort ecode year sitc3
            append using "../data/wtf.dta"
            save "../data/wtf.dta", replace
            clear
                  }

          *label var sitc4 "Four digit Standard International Trade Classification"
          *label var sitc3 "Three digit Standard International Trade Classification"
    *label var value "Country-sitc3 yearly export data "
end

program ReadIlo
    insheet using "../data/raw/ilo5b.csv", clear
        foreach x in GB CH UY AU MY {
            replace codesex="5A" if codecountry=="`x'" & subclassification == "Total" &
codesex=="5B"
        }
        replace codecountry="DE" if codecountry=="D2" & subclassification == "Total"
& codesex=="5A"
        keep if subclassification == "Total" // wage data for all industries
        keep if codesex == "5A" // men and women's wages
        collapse d1969 - d2005, by (codecountry typeofdata workercoverage classification)
        reshape long d , i(codecountry typeofdata workercoverage classification) j(year)
        drop if codecountry=="TW"
        save "../data/ilo.dta", replace
    insheet using "../data/raw/wage_add.csv", clear
    append using "../data/ilo.dta" // addition of wage data for missing countries
        sort codecountry year

    label var typeofdata "Earnings per hour/week/day"
    label var workercoverage "Worker wage type"
    label var classification "Data Revision Type"
    label var d "Nominal Wages"
    save "../data/ilo.dta", replace
end

program CalcCostCapital
    use "../data/ifs.dta"
        sort countrycode year
```

```
    merge countrycode year using "../data/pwt62.dta"
        tab _merge
        drop if _merge==1
        drop _merge
    sort  countrycode year
    tsset countrycode year
        by countrycode: gen pi_rate = ((pi-L1.pi)/L1.pi) // create growth rate of price of
investment good
        gen depreciation = 0.07
        foreach x in lend mm tbill dep { // calculate real rental price using Jorgenson
(1963)
            gen R_`x' = ((pi/p)*(ifs`x' - pi_rate + depreciation))
        }
    *    foreach x in lend mm tbill dep { // 5 year moving average of R0
    *        by countrycode : gen R_`x' = (F1.R0_`x' + F2.R0_`x' + R0_`x' + L2.R0_`x' +
L1.R0_`x') / 5
    *    }

     label var R_lend "Cost of capital based on lending rates"
     label var R_tbill "Cost of capital based on T-bill"
     label var R_mm "Cost of capital based on money market rates"
     label var R_dep "Cost of capital based on deposit rates"
   save "../data/working.dta", replace
end

program CalcStructuralChange
    use "../data/working.dta"
        sort ecode year
        save "../data/working.dta", replace
    use "../data/wtf.dta"
    sort ecode year sitc3
    merge ecode year using "../data/working.dta", uniqusing
        tab _merge
        drop if _merge==1
        drop _merge
    gen realexport = (p/100)*value  //  adjust nominal data to real values
    drop if realexport == .
    sort ecode sitc3 year
    by ecode sitc3: gen abstrade = abs(realexport[_n-1] - realexport)
    collapse (sum) cec = abstrade, by(ecode year)
    merge ecode year using "../data/working.dta"  // nonunique
        tab _merge
        *drop if _merge==1
        drop _merge
    label var cec "Changes in export Composition"
```

```
    save "../data/working.dta", replace
end

program CalcKL
    use "../data/working.dta", clear  // calculate initial capital stock using moving average
        gen I = cgdp*pop*(ci/100)
        sort countrycode year
        by countrycode: gen I_rate = ((I-L1.I)/L1.I)
        by countrycode: gen I_ave_rate = (F1.I_rate + F2.I_rate + I_rate + L2.I_rate +
L1.I_rate)/5
        gen inv_dep_rate = I_ave_rate + 0.07
        gen K0=I/inv_dep_rate

        by countrycode : gen K0sum  = sum(K0)  // keep only the first initial capital
calculation
        by countrycode : gen K =.
        by countrycode : replace K = K0 if K ==. & K0 == K0sum
        by countrycode : gen K_lag = K[_n-1]

        foreach year of num 1950/2008 { // calculate K = previous year K + investment
less depreciation
            by countrycode : replace K_lag = K[_n-1]
            by countrycode : replace K = K[_n-1] + I - (0.07*(K[_n-1])) if K == . & K_lag
!= .
        }

        gen work_force = ((rgdpch/rgdpwok)*pop) // calculate Labor
        gen L = work_force*rgdpwok

        order year cec oil soviet alloil oilafr wafrica africa growth_rate K L R_lend R_tbill
R_mm R_dep p codecountry nation
        * drop pop - work_force

    label var L "Labor output"
    label var K "Capital output"
    * label var I "Investment"
    * label var I_rate "Investment rate"
    * label var I_ave_rate "Investment rate, 5 year moving average"
    * label var K0 "Initial capital"
    * label var K0sum "First initial capital filter variable"
    * label var K_lag "Capital output, lagged by one year"
    * label var work_force "Total workforce population"
    * label var inv_dep_rate "Investment depreciation rate"
    save "../data/working.dta", replace
end
```

```
program CalcRealWage
    use "../data/working.dta"
        sort codecountry year
        merge codecountry year using "../data/ilo.dta", uniqmaster
            tab _merge
            drop _merge
        gen real_W = (p/100)*d  // adjusting wages using price level, p
        sort codecountry typeofdata workercoverage classification year
        by codecountry typeofdata workercoverage classification : gen W = ((real_W -
real_W[_n-1])/real_W[_n-1])
        collapse W, by (year - incgroup2) // mean real wages rates
        sort nation year
        drop if ecode == .
        drop if K == . & L == . & W == . &  R_lend == . &  R_tbill== . & R_mm== . &
R_dep== .

        label var W "Wage rate"
        *label var real_W "Adjusted yearly wage, constant"
    save "../data/working.dta", replace
end

program CalcEe
    use "../data/working.dta"
        gen KL=K/L
        gen lnKL = ln(K/L)
        gen lncec = ln(cec)
        egen R_mean = rowmean(R_lend R_mm R_tbill R_dep)
        drop if year < 1970
        foreach x in lend mm tbill dep mean{
            gen wr_`x'=W/R_`x'
            gen lnwr_`x' = ln(W/R_`x')
            sort countrycode year
            by countrycode: gen ee_`x' = (lnKL - L1.lnKL)/(lnwr_`x' - L1.lnwr_`x')
            gen lnee_`x' = ln(ee_`x')
        }
        gen usg=.
        replace usg=cgdp if ccode==840
        egen usgdp= median(usg), by(year)
            gen relgdp = cgdp/usgdp
            gen relgdpsq = relgdp*relgdp
        gen cgdpsq=cgdp*cgdp
        order relgdp relgdpsq cgdpsq
        drop K-codecountry ifs* KL W R_*  wr_* ccode-pop ci-rgdpch

    * label var KL "Capital to Labor Ratio"
    * label var wr_lend "Wage to Rental Rate, Lending Rate"
```

```
    * label var wr_mm "Wage to Rental Rate, Money Market Rate"
    * label var wr_tbill "Wage to Rental Rate, T Bill Rate"
    * label var wr_dep "Wage to Rental Rate, Deposit Rate"
    * label var ee_lend "Calculated Empirical Elasticity, Lending Rate"
    * label var ee_mm "Calculated Empirical Elasticity, Money Market Rate"
    * label var ee_tbill "Calculated Empirical Elasticity, T Bill Rate"
    * label var ee_dep "Calculated Empirical Elasticity, Deposit Rate"
    label var lnwr_lend "Log Wage to Rental Rate, Lending Rate"
    label var lnwr_mm "Log Wage to Rental Rate, Money Market Rate"
    label var lnwr_tbill "Log Wage to Rental Rate, T Bill Rate"
    label var lnwr_dep "Log Wage to Rental Rate, Deposit Rate"
    label var lnKL "log Capital to Labor Ratio"
    label var ecode "Country ID for UN NBER Trade Data (6 digits)"
    label var lnee_mean "Log Mean elasticity of substitution"
    save "../data/final_data.dta", replace
end

program FullData
    use "../data/final_data.dta", clear
        sort ecode year
        tsset ecode year
        tabulate year, gen(yeard)
            * list yeard*
        gen ln_cgdp=log(cgdp)

    ***High CEC is associated with Low EOS
    foreach rate in lend mm         {
          areg lnee_`rate' lncec yeard*, a(ecode)
                outreg lncec using "../results/ee_cec_`rate'.csv", replace comma nocons
nolabel coefastr  3aster nor2 bdec(4) title("Country Year FE `rate'") ctitle("Entire
Sample")
          areg lnee_`rate' lncec ln_cgdp yeard*, a(ecode)
                outreg lncec ln_cgdp using "../results/ee_cec_`rate'.csv", append comma
nocons nolabel coefastr  3aster nor2 bdec(4) title("Country Year FE `rate'") ctitle("Entire
Sample with controls")
        }
    foreach sampl in oil alloil oilafr {
    foreach rate in lend mm         {
          areg lnee_`rate' lncec yeard* if `sampl'==0, a(ecode)
                outreg lncec using "../results/ee_cec_`rate'.csv", append comma nocons
nolabel coefastr  3aster nor2 bdec(4) title("Country Year FE `rate'") ctitle("`sampl'")
          areg lnee_`rate' lncec ln_cgdp yeard* if `sampl'==0, a(ecode)
                outreg lncec ln_cgdp using "../results/ee_cec_`rate'.csv", append comma
nocons nolabel coefastr  3aster nor2 bdec(4) title("Country Year FE `rate'")
ctitle("`sampl' with cgdp cgdpsq")
        }
```

```
    }

***High CEC is associated with Low EOS
foreach rate in mm lend        {
        ttest ee_`rate' ==1 if ee_`rate'>0
}

end
end
```

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