UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

EXTERNAL DEBT AND GROWTH OF DEVELOPING COUNTRIES

A Dissertation

SUBMITTED TO THE GRADUATE FACULTY

In partial fulfillment of the requirements for the

degree of

Doctor of Philosophy

By

NURY EFFENDI

Norman, Oklahoma

2001

UMI Number: 9994070

UMI Microform 9994070

Bell & Howell Information and Learning Company
300 North Zeeb Road
P.O. Box 1346
Ann Arbor, MI 48106-1346

EXTERNAL DEBT AND GROWTH OF DEVELOPING COUNTRIES

A Dissertation APPROVED FOR THE

DEPARTMENT OF ECONOMICS

BY

A. J. Kondonassis

James F. Horrell

W. Robert Reed

Tade Okediji

This dissertation is dedicated to my wife Vita and my children

Vindi and Kanti

ACKNOWLEDGMENTS

I would like to express my sincere appreciation to Dr. A.J. Kondonassis, the chairman of Doctoral Advisory Committee, for his guidance, advice, and attention throughout the process of my dissertation. His wisdom, assistance, and motivation have made my study a challenging yet entertaining endeavor over the years.

I am also grateful to Dr. W. Robert Reed, who has given me an invaluable insight into the practice of econometrics, and to Dr. James F. Horrell, who has greatly enhanced my understanding of statistics. Equally appreciated are Dr. David Huettner and Dr. Tade Okediji, both of whom served on my dissertation committee. Their comments and suggestions have made this a better dissertation.

My involvement in the Carl Albert internship program at the Oklahoma Department of Human Services has proven to be a valuable experience for my life, my study, and the process of finishing the dissertation. Marilynn Knott has been a mentor as well as a sparring partner in strategic decision making processes and in the endless effort of pursuing a high standard in research. Frequent discussions with Kenneth Kickham, Robert Bentley, and Angela Harnden have made this dissertation more solid and well rounded. Their friendship, encouragement, and humor have helped me go over the hump and clear the path toward the finishing of the dissertation.

Very special appreciation goes to my wife, Vita, whose support and understanding throughout my study have been very comforting. My two children, Vindi and Kanti, also

deserve my best appreciation. Their presence and constant cheering have always been a source of motivational drive to finish the dissertation.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The idea of a 'financing gap' which is based on the Harrod-Domar theory has prompted developing countries to accumulate external debt since the 1960s. Unfortunately, debt repayment has to be financed by hard earned foreign exchange reserve. Therefore, a likely result of reliance on external debt would be to deplete domestic investment and slow economic growth.

This dissertation is an exploratory study of the effect of external debt on growth of (debtor) developing countries. The model developed for estimation is based on neoclassical growth theory. In particular, the Solow-Swan-Ramsey model for credit-constrained open economy is used. One of the important features of the model is its prediction of the occurrence of *absolute* and/or *conditional* convergence.

Driven by optimal control theory, the empirical model relates to two types of explanatory variables, i.e. the state variables and control variables. Using Barro-type regression, the state variables take the form of initial values of each variable during certain sub-periods. Control or environmental variables, on the other hand, are represented by the average values of the variables over relevant sub-periods.

Constrained by data availability, the time frame for this study is 1975-1984 which is then divided into three 5-year sub-periods. Data are extracted from the Penn-World Trade Table version 5.6, the Barro-Lee data set, and the World Debt Table from World Bank. The method of estimation is iterative seemingly unrelated regression (ISUR) which, for large

samples, yields parameter estimates that are numerically equivalent to those of the maximum likelihood (ML) estimator.

The estimated coefficient for the initial value of real per capita GDP is -0.0441 which is higher (in absolute value) than most other findings. This coefficient is also a measure of the speed of (conditional) convergence. The availability of limited capital resources from abroad speed up the process of (conditional) convergence.

External debt ratio has a negative and significant effect on the growth level. The estimated coefficient is -0.03296 with a p-value of 0.000. Debt repayment by debtor developing countries which requires the use of foreign exchange reserve slows down economic growth. This finding is more direct than the results of other studies which use foreign aid as the independent variable. The general finding in those studies is that foreign aid does not have significant effect on growth. The finding on this study, however, is consistent with the debt overhang hypothesis which states that there is an inverse indirect relationship between external debt and growth.

Debt overhang can be defined as a situation in which expected repayment on foreign debt falls short of the contractual value of debt. The debt overhang hypothesis states that the external debt burden provides a disincentive to domestic investment in developing countries and thus slows economic growth since any additional foreign exchange earnings would have to be turned over to foreign creditors. Using simultaneous equations and panel data from fourteen developing countries, assuming that the panel data has a one-way error component model, and using Baltagi's error component two-stage least square (EC2SLS), estimation shows modest support of debt overhang hypothesis. All key coefficients have the correct signs, but they are not significant.

The important finding that external debt tends to have an inverse relationship with growth suggests that relying on external debt to boost economic growth is not a good policy. Instead, developing countries may be better off by trying to reduce their external debt and supplement their lack of domestic saving with other forms of foreign capital such as foreign direct investment.

CHAPTER I

INTRODUCTION

Developing countries have been accumulating external debt since the 1960s. Many developing countries took advantage of the abundant availability of international loans resulting from the oil boom in the early 1970s. The lack of domestic savings and high current account deficit payments are the main reason why developing countries have been importing capital to augment domestic resources. The influence of the Financing Gap[1] model such as Harrod-Domar (1946) has also played a significant role in the proliferation of external debts. The practical reason, however, is that developing countries want to have the same standard of living as developed countries (or at least not very far behind). The common belief is that developing countries need to grow faster than developed countries in order to achieve some level of convergence and for that they need external resource injections. These external resources can take the form of foreign aids (grants and soft loans), external debts, foreign direct investment, or portfolio equity flows.

In the case of external debt, the natural question, therefore, is whether there is a positive correlation between external debt and growth in developing countries. In other words, the question is whether there is a positive impact of external debt on economic growth. The policy of acquiring external debt to induce economic growth will be more

---

[1]Financing gap is loosely defined as the idea of filling the gap of the difference between intended investment and domestic saving by importing capital from abroad.

justifiable if the correlation between the two is positive and significant. After all developing countries have been trying to catch up to developed countries in terms of their standard of living.

On the surface, using panel data of 53 debtor (developing) countries from 1970 to 1989[2], the correlation of external debt (measured as a ratio between external debt and Gross National Product) and per capita growth rate is as depicted in Figure 1.1.

From the figure it is apparent that the correlation is weak, in fact calculation shows that the simple correlation coefficient between the two variables is only -0.3393 and is not significant. Descriptive statistics show that the mean for the growth rate is 1.17% with a standard deviation of 3.62% while the mean for the external debt ratio is 46.94% with a standard deviation of 40.0%. This means that on average, during the specified time period, the 53 debtor countries have a positive growth rate but the dispersion is very high. The correlation coefficient does not differ by much if we use the ratio of external debt to export; the calculated simple correlation coefficient is -0.3674. The mean for the external debt-export ratio is 186.18% with a standard deviation of 142.49%.

There has not been a study that tries to investigate the direct impact of external debt on growth. Recently, however, several studies have addressed the impact of foreign aid on economic growth. Burnside and Dollar (1999), for instance, examine the relationships among foreign aid, economic policies, and growth of per capita Gross Domestic Product (GDP).

---

[2]The data is quinquennial, i.e. calculated from 5 year averages.

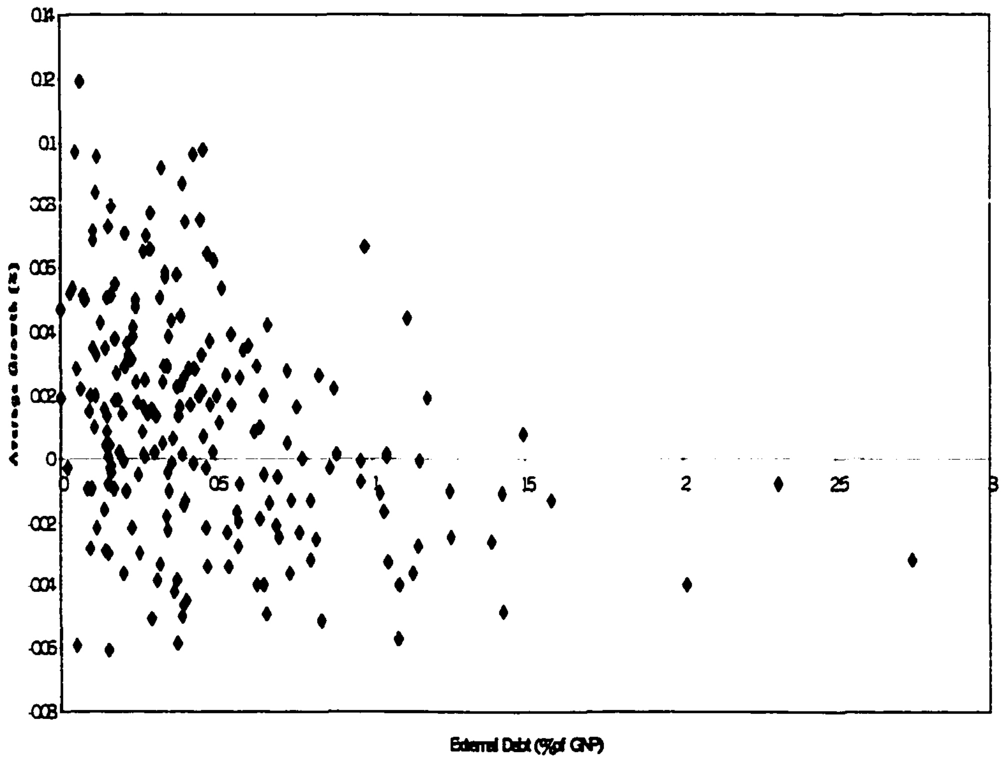

Figure 1.1. Correlation between External Debt and Growth

They find that, in panel growth regression for 56 developing countries and six four-year periods (1970-1993), the policies that have a large effect on growth are fiscal surplus, inflation, and trade openness. They also find that aid has a positive impact on growth in developing countries with good fiscal, monetary, and trade policies. Aid has no positive effect on growth, however, if poor policies are present.

Somewhat similar to the above research, the World Bank (1998) has released a report on policy research titled: "Assessing Aid, What Works, What Doesn't, and Why." The report summarizes the findings of World Bank research on aid effectiveness. Two factors are deemed important for foreign aid to be effective, i.e. that it requires the right timing and also the right mix of money and ideas.

The report contains estimations of the effect of foreign aid on growth similar to the work of Burnside and Dollar (1999).[3] The authors estimate 8 regression equations. Regression 1 explains growth as a function of initial conditions, the incentive regime, and an error term that captures external shocks. The measures of the incentive regime include the inflation rate, the budget surplus, a measure of trade openness, and a measure of institutional quality. The regression coefficients from regression 1 are then used to form an index of economic management in regressions 2-8. Each regression has a different set of independent variables. The general finding is that there is no direct relationship between foreign aid and growth.[4] However, if aid is interacted with the management index, the estimation shows that aid has a positive effect on growth in a good policy environment but there are diminishing marginal returns to aid.

The purpose of this dissertation is to analyze the effect, if there is one, of external debt on economic growth. The sample comprises of developing countries, since almost all debtors are developing countries.[5] Due to data availability, particularly external debt data

---

[3]In fact the policy research report was written by David Dollar and Lant Pritchett of the Development Research Groups, World Bank.

[4]Boone (1994) also finds that there is no relationship between aid and growth.

[5]Singapore was in the World Bank Debtor Reporting System (DRS) until 1980. South Korea is currently still in the list on DRS. Portugal, like Singapore, was in the DRS list until 1980.

from the World Bank and macroeconomic data from Penn World Trade (PWT) Table[6], the time frame of the analysis is constrained between 1970-1989. The theoretical framework is the Solow-Swan-Ramsey neoclassical growth model for the credit-constrained open economy. The method of estimation is the Barro-type regression[7] with quinquennial data. This choice of theoretical framework and estimation technique is considered to give a high degree of conformity between theory and empirical work. Using Barro-type regression as a vehicle, theory which is based on the Solow-Swan-Ramsey model is translated into empirical model by invoking optimal control theory which direct the types of independent variables used in the estimation.

After the introduction, this dissertation begins with a review of literature relevant to economic growth, external debt, and the interplay between the two with particular emphasis on empirical consideration. The theoretical framework guiding the empirical investigation is explained in Chapter III. Data, method of estimation, and empirical implementation of the augmented neoclassical growth model is discussed in Chapter IV. Chapter V is intended as a supplementary analysis of an indirect interplay between external debt and growth which takes the form in the debt overhang hypothesis. Chapter VI concludes with a summary and discussion of the findings.

---

[6]The Penn World Trade Table was originally developed by Summer and Heston. Version 5.0 was developed in 1991. The version used in this dissertation is PWT 5.6.

[7]Barro-type regression is basically a regression in which the dependent variable is an average measure and the independent variables are a mix of initial values and average variables of sub-periods. In the spirit of *optimal control theory*, the initial values are the state variables while the average variables are the control or environmental variables. See for example Barro (1997).

CHAPTER II

ECONOMIC GROWTH AND EXTERNAL DEBT: A REVIEW OF LITERATURE

Economic development can be broadly defined as a process of increasing the standard of living of the people in a particular area (Kondonassis, A.J., 1991). Traditionally, economic development can be most usefully defined as economic growth plus structural change. In other words, economic growth is a necessary condition for economic development. While economic development is mostly the concern of developing countries, economic growth has been the main macroeconomic target of developed countries as well.

In the literature, the study of economic growth emphasizes the use of rigorous mathematical models describing the quantitative relationships between economic variables, while economic development pays more attention to economic structures and institutions. Research on external debt, on the other hand, had not proliferated until the debt crisis that hit many developing countries in the early 1980s. This chapter is intended as a non-exhaustive survey of the literature on economic growth, external debt, and the interplay between the two. As was mentioned earlier, however, that since there has not been a study of the impact of external debt on growth, the review focuses on the interplay between foreign aids and growth. Even though foreign aids are not exactly the same as external debt it does have some similarities.

2.1. Economic Growth

The theoretical work on economic growth is as old as economics itself. Even though they did not study economic growth formally, classical economists such as Adam Smith (1776), David Ricardo (1817), and Thomas Maltus (1798) outlined the basic ingredients of economic growth. Included in this group are classical economists who appeared at much later time, such as Frank Ramsey (1928), Allyn Young (1928), Joseph Schumpeter (1934), Ray Harrod (1939), Evsey Domar (1946), and Frank Knight (1944). Ramsey, Harrod and Domar are considered pioneers who attempted to analyze economic growth with rigorous models. Solow (1956), Swan (1956), and Ramsey (1928) are the main contributors of neoclassical growth models. Romer (1986) and Lucas (1988), on the other hand, have initiated the last wave of economic growth theory which is formally known as the endogenous growth models.

2.1.1. The Harrod-Domar Model

The Harrod-Domar model uses a mathematical equation to show a direct relationship between savings and the rate of economic growth, and an indirect relationship between the capital/output ratio and the economic growth rate. The Harrod-Domar model, which attempts to integrate Keynesian analysis with elements of economic growth, assumes that economic growth is a direct result of capital accumulation in the form of savings. Development economists have used Harrod-Domar model to calculate a financing gap that needed to be filled if an economy was going to develop. They argue, like Domar, that the binding constraint on production is insufficient physical capital, since they believe that unskilled labor is in abundant supply. The model itself predicts that growth will be proportional to the investment rate; specifically, growth will be equal to the investment divided by the Incremental Capital Output Ratio (ICOR). If the target growth rate is set, the required investment to meet this target can be easily calculated by multiplying this target growth rate with the ICOR, which typically is assumed to be between 2 and 5. The financing gap is the gap between the available financing for investment (such as domestic investment) and the required investment. By filling this gap with imported capital (foreign aids or external debts) developing countries will get the required investment, which in turn will yield the target growth rate. The empirical evidence, however, does not support this theory. The massive external debt that has accumulated in the developing countries since 1960s was not accompanied by an increase in per capita income.

For a more formal exposition of the Harrod-Domar model, let saving (S) be some proportion, s, of national income (Y) such that $S = sY$. Investment (I) is defined as the change in capital stock, K, and can be represented by ΔK such that $I = \Delta K$. Total capital stock, K, is directly related to national income, Y, as represented by the capital-output ratio (COR), k, such that $K/Y = k$. This COR can also be written in its marginal value as $\Delta K/\Delta Y = k$, which is more popularly known as the incremental capital-output ratio (ICOR). Since in equilibrium saving, S, must equal total investment, I, it follows that $sY = k\,\Delta Y$ or, in a more familiar expression, $\Delta Y/Y = s/k$. This equation tells us that the rate of growth of outputs (national income) is determined jointly by the national saving ratio, s, and the national capital-output ratio, k. It also says that the growth rate of national income will be directly related to the saving ratio and inversely related to capital-output ratio (COR).

On theoretical grounds, the Harrod-Domar model suffers a shortcoming that the equilibrium is unstable since it requires the equalization of warranted and natural growth rates, and uses production functions with little substitutability among the inputs. The production function used in their model is of Leontief type fixed proportion of inputs[8]. These weaknesses have lead economists to abandon the Harrod-Domar growth model in favor of growth models that are less rigid and more empirically applicable. Despite its shortcoming, the Harrod-Domar model was popular from immediately after the Great Depression until early 1950s and has generated many papers in the field of economic growth.

2.1.2. Neoclassical Growth Models

The work of Solow (1956) and Swan (1956) which has been categorically defined as a neoclassical growth theory is an attempt to solve the Harrod-Domar dilemma. They use production functions that exhibit constant returns to scale, diminishing returns to each input, and positive substitutability among inputs. The production function is assumed to be a function of capital, labor, and technology. By assuming a constant saving rate the model predicts that growth in the long run is a function only of technical change and not of saving or investment. Saving will have an effect on the level of income but not on its growth rate.

---

[8]The Leontief production function, with two inputs, in general form is $Y = min(\alpha K, \beta L)$ where Y is national output, K is capital input, L is labor input, and α and β are constants.

This prediction implies that in the absence of continuous improvement in technology, per capita growth will eventually cease.

In a more formal exposition, the standard production function in neoclassical growth model is $Y = Ae^{\mu t} K^{\alpha} L^{1-\alpha}$, where Y is gross domestic product, K is the stock of human and physical capital, L is unskilled labor, A is a constant reflecting the base level of technology, and $e^{\mu t}$ represents the constant exogenous rate at which technology grows. In this formula α represents the elasticity of output with respect to capital (the percentage increase in gross domestic product resulting from a 1% increase in capital). Empirically, α is measured as the *share* of capital in a country's national income accounts. This formulation of the neoclassical growth model yields diminishing returns to capital and labor since α is assumed to be less than 1 and private capital is assumed to be paid its marginal product.

In that type of model, increases in saving, reflected in investment, will spark additional growth temporarily. However, as the ratio of capital to labor increases, the marginal product of capital will decline and the economy will then move back to a *steady state*, in which output, capital, and labor (after being corrected for quality) are all growing at the same rate. Growth in per capita income will continue and will equal μ, the annual rate of productivity improvement. The constant, μ, can be interpreted in several ways: as improvements in knowledge such as organization routines, rearrangement of the flow of material in a factory, better management of inventory, or other changes that do not require knowledge to be embodied in equipment. The central issue, however, is that the determinants of the size of μ, the rate of growth of per capita income, are left unexplained within the model.

Neoclassical growth theory suggests that two countries with the same technology will have the same steady state growth rate of per capita income. This implies that a country with lower capital/labor ratio will have a higher per capita growth rate than a country with a high capital labor ratio. This phenomena is called an *absolute convergence*. *Conditional convergence*, on the other hand, is a situation in which a country will have a higher growth rate if that particular country has a lower starting level of real per capita income relative to the long-run or steady-state position. This conditional convergence prediction that comes from the Solow-Swan (neoclassical) model has been exploited extensively as an empirical hypothesis with mixed results. For example, Barro and Sala-i-Martin (1992) observe convergence among the 48 states of the United States in terms of the growth rates of their per capita income and per capita gross state product, while Romer (1986) and Lucas (1988) cite the lack of convergence of the growth rates of different countries. Both Barro and Sala-i-Martin argue, however, that conditional convergence is more likely if regions or countries are more homogeneous as in the case of the 48 states in the United States.

Another important neoclassical growth theory, beside the Solow-Swan model, is the Ramsey model. The Ramsey model is a refinement of the Solow-Swan model. Chronologically, Ramsey's growth theory was developed before Solow-Swan's. In the literature, however, his model is usually put after Solow-Swan's. His work has been considered a masterpiece that several decades ahead of its time. One of the key features in his model is the assumption that households optimize their utility[9] over time. This assumption essentially makes the model dynamic. Using Ramsey's model as their starting

[9]This utility is also known as the intertemporal utility

point, Cass (1965) and Koopmans (1965) recast the saving rate that is exogenous under Solow-Swan model as endogenous. Even though this is considered a refinement of the neoclassical growth model, it does not eliminate the dependence of the long-run growth rate on exogenous technological progress. The works of Cass and Koopmans mark the end of the basic neoclassical growth era.

2.1.3. Endogenous Growth Models

There was a resurgence in the interest of the theory of economic growth in the mid-1980s. It was first started by the work of Romer (1986) and Lucas (1988). Unlike the Solow-Swan model in which the long-run growth rate is determined by an exogenous technological progress, Romer and Lucas suggest a model that endogenizes the growth rate of the economies. Models that have endogenous source of per capita economic growth, are called *endogenous-growth* models.

Endogenous growth models are similar to neoclassical models but they differ considerably in their underlying assumptions and the conclusions they suggest. Three factors are apparent. First, the neoclassical assumption of diminishing marginal returns to capital is discarded. Second, the models also envision increasing returns to scale in aggregate production, and, third, recognize the role of externalities in determining the rate of return on capital.

Many endogenous growth theories can be expressed by the simple equation $Y = AK$. Here, A can be interpreted as representing any factor that affects technology, while K

includes both human and physical capital. Notice in this case that there are no diminishing returns to capital, a feature that can be achieved by invoking some externality that offsets any propensity to diminishing returns. Investment (whether physical investment by a firm or human capital investment by an individual) leads to an increase in productivity that exceeds the private gain.

This model leaves open the possibility that an increase in the investment rate (either in physical or human capital) can lead to sustained growth if strong external economies are generated by investment itself so that α in the neoclassical model becomes unity. In this case, the growth equation $Y = Ae^{\mu t} K^{\alpha} L^{1-\alpha}$ reduces to the endogenous equation $Y = Ae^{\mu t} K$. The net result is sustained long-term growth resulting from increasing returns to scale. This model offers an alternative to the diminishing returns and absence of any sustained impact on growth that is characteristic of the basic neoclassical growth model. Another way of obtaining an equation like $Y = AK$ is to postulate that an increasing variety or quality of machinery or intermediate inputs offsets the propensity to diminishing returns. To summarize, in endogenous growth models diminishing returns do not occur or if it does it is offset by some other forces.

Endogenous growth theory can help explain anomalous international flows of capital that exacerbate wealth disparities between developed and developing countries. Developing countries potentially have high rate of return on investment (due to the law of diminishing returns); however, this is eroded by lower levels of complementary investments in human capital (education), infrastructure, or research and development. As a result, developing countries benefit less from the broader social gains associated with each of these alternative forms of capital expenditure. Endogenous growth models also suggest an active role for public policy in promoting economic development through direct and indirect investment in human capital formation and foreign private investment.

Two important shortcomings of the endogenous growth models are that the models do not predict convergence, either absolute or conditional, and the model has only limited empirical support.

2.2. External Debt

In an effort to accelerate their economic development, developing countries often rely on external resources of capital to supplement the lack of domestic capital. According to the World Bank[10], foreign capital transfer can be in the form of official grants (aids), official loans (bilateral and multilateral), private debt flows (commercial banks, bonds, others), foreign direct investment, and portfolio equity flows. External debts, official loans and private debts, are part of foreign capital transfer.

The issue of external debt has been at the center of the economic development policy debate for many years. External debt research proliferated in the mainstream of economic literature when debt crisis hit developing countries in the early 1980s. Since then the discussions on external debt and foreign aid have become an increasingly important subject for development economists.

---

[10]World Development Finance (World Debt Tables) 1996, World Bank.

2.2.1. The Early Stages

Developing countries have been influenced by the idea of a "financing gap," the difference between required investment and available (domestic) resources. One way to close the gap is by borrowing from abroad. The idea itself originated in April 1946 when Evsey Domar published an article on economic growth called "*Capital Expansion, Rate of Growth, and Employment*." Domar's approach to growth became popular for developing countries to adopt because it has a simple prediction: GDP growth will be proportional to the share of investment spending in GDP. As was explained earlier, by using the Incremental Capital Output Ratio (ICOR) and a target growth rate, development economists can calculate the required rate of investment. Even though Domar himself has acknowledged that his model made no sense as a growth model[11], his model has become the most widely applied growth model in economic history.

The idea of financing gap reappeared in the work of Rostow (1960) when he published "*The Stages of Economic Growth.*" In it, Rostow suggests that the transition from underdevelopment to development can be described in terms of a series of steps or stages through which all countries must proceed. The five stages he mentions in his article are *the traditional society, the pre-conditions for take-off into self-sustaining growth, the take-off, the drive to maturity*, and *the age of high mass consumption*. One of the principal ingredients of development necessary for any takeoff is the mobilization of domestic and foreign saving in order to generate sufficient investment to accelerate economic growth. According to

[11]Eleven years after publishing his article Domar endorsed Solow's growth model.

Rostow, the necessary condition for a *takeoff* is that investment increases from 5 to 10 percent of income. If a developing country does not have enough domestic resources it must fill the *gap* with foreign aid or external debt. These mechanism are in line with the idea of a financing gap.

Chenery and Strout (1966) augment the Harrod-Domar/Financing Gap model with a recognition of the need for national saving. The temporary gap between investment ability and saving ability is filled with foreign aids. Using the ICOR formulation, investment will induce growth. Self refinancing occurs if a particular country has a high enough marginal saving rate. Only then will a country be able to finance its investment out of its own saving.

2.2.2. The Debt Crisis

Early warnings about the danger of excessive indebtedness have been mentioned by Bhagwati (1966). He noted that Turkey had already developed debt servicing problems on its pass aid loans. P.T. Bauer (1972), one of the early opponents of foreign aid, ironically noted that "foreign aid is necessary to enable underdeveloped countries to service subsidized loans .... under earlier foreign aid agreements."

The debt crisis that hit many debtor countries in the early 1980s sparked the proliferation of the study of external debt. Topics such as debt solvency, debt forgiveness, and the identification of the causes of the crisis, have been surveyed intensively. Later, however, research interest has shifted to the interplay between external debt and investment, external debt and growth, foreign aids and growth, and foreign aids and poverty.

Articles by Cline (1984) and McFadden et. al. (1985) are two of the earlier studies that try to identify the causes of the debt crisis by estimating a probability model of rescheduling for a cross-section of debtor countries. Such studies, typically, try to explain the crisis by looking at the cross-country variation of a set of financial variables, such as the ratio of debt service to exports, the ratio of foreign exchange reserve to imports, and so forth. Berg and Sachs (1988) argue that those studies suffer from endogeneity problems since many of the supposedly causal variables (e.g. low foreign exchange reserves) are really symptoms of the crisis rather than fundamental causes. They instead use *foreign trade regime* in each country as an important determinant of which countries succumbed to the debt crisis, and which ones did not. Using a probability model they find that higher income inequality is a significant predictor of a higher probability of debt rescheduling in a cross-section of middle-income countries. Moreover, they also find that outward-orientation of the trade regime is a significant predictor of a reduced probability of debt rescheduling.

The debt crisis is argued to cause the investment decline and growth collapse in the 1980s, particularly in heavily indebted developing countries. Kaminsky and Pereira (1996) calculated the drop in growth rate for Latin American countries to be more than 4 percent (from around 6 percent in the 1970s to an average of 1.8 in the 1980s). Due to this drop in growth rate, they also call the 1980s the "lost decade" for these countries. In their studies, using simulation and econometric method, they find that if we account for the effects of social inequality on government policy and consumption, the burden of servicing the debt becomes an important factor in explaining the collapse in investment and output growth in Latin America. They also find that after the debt crisis of 1982, the decrease in capital inflows to Latin America affected investment, but not consumption. As a result, output growth decreased sharply.

2.2.3. Debt Overhang

Sachs (1989) is the first to attempt to give an explanation for the debt crisis puzzle in the form of the debt-overhang hypothesis. Debt overhang can be defined as a situation in which the expected repayment on foreign debt falls short of the contractual value of debt. The debt overhang hypothesis states that external debt burden provides a disincentive to domestic investment in developing countries and thus slow economic growth since any additional foreign-exchange earnings would have to be turned over to foreign creditors.

Krugman (1988) provides a straightforward definition of the problem of debt overhang: *A country has a debt overhang problem when the expected present value of potential future resource transfers is less than its debt*. In the paper, Krugman shows that the choice between financing and forgiveness represent a tradeoff. Financing gives the creditors an option value: if the country turns out to do relatively well, creditors will not have written down their claims unnecessarily. However, the burden of debt distorts the country's incentives, since the benefits of good performance go largely to creditors rather than itself.

Borenzstein (1990) distinguishes two channels through which foreign debt may affect investment, which can be termed the 'debt overhang' channel and the 'credit rationing' channel. Using a simulation method, he find that those two non mutually exclusive effects are significant in explaining the sharp decline in investment in the 1980s for heavily indebted countries. However, he also finds that credit rationing is a more important disincentive to investment than the debt overhang.

Warner (1992), using a forecasting method, concludes that debt overhang may not be an important factor in explaining the investment decline. Rather, shocks caused by falling export prices and high world real interest rates in the early 1980s have directly caused investment to decline. One important result from his study is that a debt crisis dummy added to panel regressions that pool the data on all of the heavily indebted countries in the sample not only fails to have a negative coefficient as the debt theories predict, but actually is positive and significant.

2.2.4. Highly Indebted Poor Countries

The World Bank and International Monetary Fund (IMF) proposed the Highly Indebted Poor Countries (HIPC) debt initiative and agreed by governments around the world in the fall of 1996. The initiative was the first comprehensive approach to reduce the external debt of the world's poorest, most heavily indebted countries by providing debt relieves. For the first time of debt relief efforts, poor countries with good policies will be provided debt writedowns of IMF and World Bank claims in present value terms. In the end of 1999, there are 40 countries classified as HIPCs. Among those, 32 are in Africa, 4 are in Latin America, 3 are in Asia, and 1 is in Middle East. Appendix G provides a complete list of countries that are currently under the HIPC program.

While debt overhang theory provides some explanations of the debt problem that HIPCs face, there are other reasons as well. Easterly (1999) tries to find the answers of why the HIPCs become highly indebted. The sample period covered in his study is 1979-1997, a period that include the first wave of debt crisis (early 1980s) and the second wave (early 1990s). The study casts doubts on the effectiveness of the program. A set of theoretical models used in the study predict that countries with unchanged long-run saving preferences will respond to debt relief with a mixture of asset decumulation and new borrowing. A review of the experience of the highly indebted poor countries compared to other developing countries conducted in the study finds direct and indirect evidence of asset decumulation and new borrowing associated with debt relief. Despite the debt relief efforts, the net present value of debt to exports ratio rose significantly over 1979-1999. Other significant finding is that there has been an important shift over time in financing HIPCs away from private and bilateral non-concessional sources to IDA and other multilateral concessional financing, but this implicit form of debt relief also failed to reduce debt in net present value terms.

Aid mismanagement by corrupt governments may also be significant contributor to high indebtedness of HIPCs. The study by Alesina and Weder (1999) shows that there is no evidence that less corrupt governments receive more foreign aid. On the contrary, according to some measure of corruption, more corrupt governments receive more foreign aid which, therefore, increase the probability of having debt problem. On the reverse causation, the study also finds no evidence that an increase in foreign aid reduces corruption.

CHAPTER III

THEORETICAL FRAMEWORK

This study incorporates the neoclassical growth model from Solow (1956), Swan (1956), and Ramsey (1928). Ramsey's classic article was published earlier than Solow-Swan's but his model is more general than the Solow-Swan's. Ramsey's model was several decades ahead of its time and was not widely used until 1960s. Ramsey's treatment of household optimization over time and intertemporally separable utility function is as widely used today as the Cobb-Douglas production function. This chapter explains the development of the theoretical framework in a neoclassical growth theory that start with the work of Solow and Swan, and evolve into Ramsey's more general growth model. This chapter draws heavily from Chiang (1992) and Barro and Sala-I-Martin (1995).

3.1. The Solow-Swan Model

The Solow-Swan growth model is the cornerstone of the neoclassical growth theory. It is considered the first growth model that uses mathematical exposition elegantly and, yet, still provide a good balance between theoretical and empirical applicability which is far superior to the Harrod-Domar model. The Solow-Swan model has not only been used in the field of growth theory, but also has been intensively applied for growth accounting studies.

Despite its limitation, variants of this model is still being used theoretically as well as empirically in the field of macroeconomics, development economics, and economic growth.

3.1.1. The Basic Properties of the Solow-Swan Model

It is assumed that the production function has two inputs, physical capital, K, and labor, L, and takes the form

$$Y = F(K, L) \tag{3.1}$$

output, Y, can be either consumed, C, or invested, I, through saving, S *(i.e.* $S = I$*)*, to create new units of physical capital, K. Let s be the fraction of output that is saved or *saving rate* such that $0 \leq s \leq 1$. Solow (1956) and Swan (1956) assume that s is positive, constant, and exogenously determined.

Capital, K, depreciates at a constant rate $\delta > 0$ such that

$$\dot{K} = I - \delta K = sY - \delta K \tag{3.2}$$

The labor force, L, varies over time because of population growth such that

$$L = e^{\mu t} \tag{3.3a}$$

where t is a time index and e is a natural number. This implies that

$$\frac{\dot{L}}{L} = \frac{dL / dt}{L} = \mu \tag{3.3b}$$

which means that labor force grows exponentially.

Equation (3.1) will be a neoclassical production function if for all $K > 0$ and $L > 0$, $F(\bullet)$ exhibits positive and diminishing marginal products with respect to each input:

$$\frac{\partial F}{\partial K} > 0 \qquad \frac{\partial^2 F}{\partial K^2} < 0$$

$$\frac{\partial F}{\partial L} > 0 \qquad \frac{\partial^2 F}{\partial L^2} < 0 \tag{3.4a}$$

it exhibits constant returns to scale :

$$F(\theta K, \theta L) = \theta \cdot F(K, L) \quad \text{for all } \theta > 0 \tag{3.4b}$$

and the marginal product of capital (or labor) approaches infinity as capital (or labor) goes to 0 and approaches 0 as capital (or labor) goes to infinity:

$$\frac{\lim}{K \to 0}(F_K) = \frac{\lim}{L \to 0}(F_L) = \infty$$

$$\frac{\lim}{K \to \infty}(F_k) = \frac{\lim}{L \to \infty}(F_l) = 0 \tag{3.4c}$$

Equations (3.4c) are the *Inada Conditions*, following Inada (1963).

Constant returns to scale implies that $Y = F(K, L) = L \cdot F(\frac{K}{L}, 1) = L \cdot f(k)$

where $k = K/L$ is the capital-labor ratio, $y = Y/L$ is per capita output, and the function $f(k)$ is defined to equal $F(k, 1)$. In intensive form, the production function can be expressed as:

$$y = f(k) \tag{3.5}$$

Properties (3.4a) - (3.4c) imply that each input is essential for production, that is, $F(0,L) = F(K,0) = f(0) = 0$. It also implies that as either input goes to infinity output goes to infinity as well.

The Solow-Swan model basically is the growth model derived from the dynamic behavior of the economy characterized by the neoclassical production function.

Dividing equation (3.2) by L we get:

$$\dot{K}/L = s \cdot f(k) - \delta k$$

and noting that

$$\dot{k} = \frac{d(K/L)}{dt} = \dot{K}/L - \mu k$$

we get

$$\dot{k} = s \cdot f(k) - (\mu + \delta)k \tag{3.6}$$

Since s, μ, and δ are all constants, this nonlinear equation depends only on k. Equation (3.6) is the fundamental differential equation of the Solow-Swan model.

The effective depreciation rate for the capital-labor ratio, $k \equiv K/L$ is the term $(\mu + \delta)$ on the right-hand side of equation (3.6). When the saving rate, s, is 0, k will decline partly

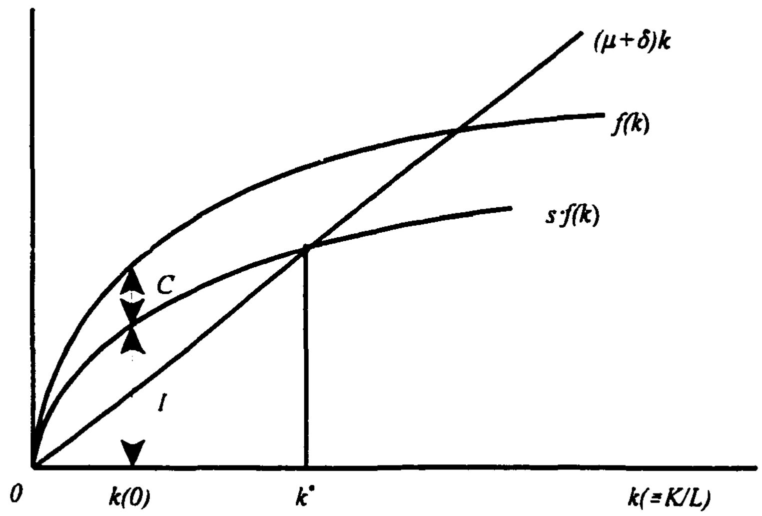

Figure 3.1a. The Solow-Swan Model.

due to depreciation of K at the rate δ and partly due to growth of L at the rate μ. The working of equation (3.6) can be shown graphically as in Figure 3.1a and 3.1b.

In Figure 3.1a, the upper curve is the production function $f(k)$ while $s \bullet f(k)$ is a constant fraction of the production curve. (Since $0 \leq s \leq 1$). The two curves start from the origin since when $K = 0$ and thus $k = 0$, Y must also be zero (each input is essential) as will be $f(k)$ and $s \bullet f(k)$.

For the economy with initial capital stock of $k(0)$ gross investment per person equals the height of the $s \bullet f(k)$ curve and consumption per person equals the vertical difference at this point between the $f(k)$ and $s \bullet f(k)$ curves since output can be either consumed or invested.

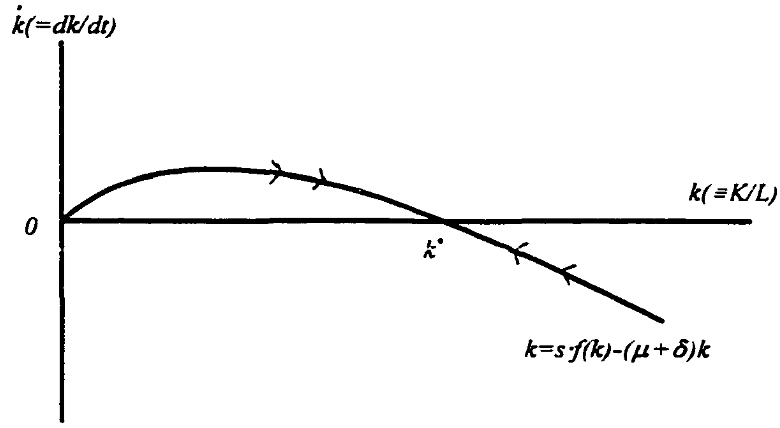

Figure 3.1b. The Phase Line of the Solow-Swan Model.

The value of $\dot{k}$ for each value of k can be measured by the vertical distance between the $s \bullet f(k)$ and $(\mu + \delta)k$ curves. Plotting the values of $\dot{k}$ against k, as in Figure 3.1b yields the phase line. By the assumptions of diminishing marginal product of each inputs, k^* (capital labor ratio when $\dot{k} = 0$) will be a stable equilibrium point. In the Solow-Swan model k^* corresponds to a *steady state* in which the various quantities grow at a constant rates. The steady state is achieved when $\dot{k} = 0$ or when

$$s \cdot f(k^*) = (\mu + \delta)k^* \tag{3.7}$$

In the neoclassical growth model, per capita quantity k, y, and c do not grow in the steady state. However, this implies that the levels of variables - K, Y, and C - grow in the steady state at the rate of population growth, μ.

If the level of technology; the saving rate, s; the rate of population growth, μ, and the depreciation rate, δ, change, the per capita *levels* of the various quantities in the steady-state will also change.[12] However, it will not affect the steady state growth rate of per capita output, capital, and consumption, all of which are equal to zero. For this reason, the model will not provide explanations of the determinants of long-run per capita growth. Long-run growth will only be possible if there is an exogenous shock.

3.1.2. Transitional Dynamics and Convergence

The Solow-Swan model can not explain the long-run growth since it is determined entirely by exogenous elements. The transitional dynamics of the model, however, is interesting to study. Dividing both sides of equation (3.6) by k we get the growth rate of k which is

$$g_k \equiv \dot{k}/k = s \cdot f(k)/k - (\mu + \delta) \tag{3.8}$$

Figure 3.2 plots the $s \cdot f(k)/k$ and $(\mu + \delta)$ curves. Since $(\mu + \delta) > 0$, and $s \cdot f(k)/k$ decreases monotonically (due to diminishing returns to capital) from infinity to 0, the curve

[12] Changes in the level of technology is represented by shifts of the production function, $f(\cdot)$.

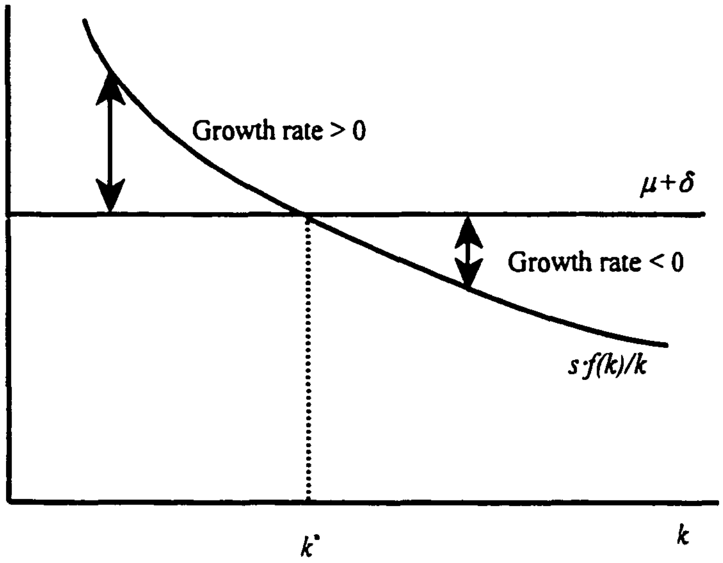

Figure 3.2. Dynamics of the Solow-Swan Model.

and the line intersect only at one point. Therefore, the steady state capital-labor ratio k^* exist and is unique.

From Figure 3.2, if $k < k^*$, the growth rate of k is positive since $s \bullet f(k)/k > (\mu + \delta)$; and if $k > k^*$ the growth rate of k is negative since $s \bullet f(k)/k < (\mu + \delta)$. If we start from any point to the left of k^*, the lower the k the higher the gap between the $s \bullet f(k)/k$ curve and $(\mu + \delta)$ curve.

Taking the first derivative of equation (3.8) with respect to k yields:

$$\partial g_k / \partial k = s \cdot \left[f'(k) - f(k) / k \right] / k < 0 \qquad (3.9)$$

The negative sign of equation (3.9) implies that the lower the k the larger the values of g_k. It also implies that economies with lower capital per person tend to grow faster in per capita terms. In other words, there tend to be *convergence* across economies since poor economies have higher growth rates than the rich ones.

As was mentioned earlier, there are two definitions of convergence, absolute and conditional convergence. *Absolute convergence* is a situation in which poor economies tend to grow faster per capita than rich ones, without conditioning on any other characteristics of economies. *Conditional convergence*, on the other hand, is related to situations in which countries who are further away from their steady state values will grow faster than countries closer to their steady state values. While absolute convergence is more likely to occur in a more homogenous group of economies, conditional convergence may also be applicable to a more heterogenous group of economies.

3.2. The Ramsey Model

Unlike the Solow-Swan model which has fixed and exogenous saving rate, the Ramsey model endogenizes saving rate by making representative agents (households) maximize their utility. The saving rate in the Ramsey model is not constant, instead, it will be a function of the per capita capital stock, k. The following exposition is the Ramsey growth model as constructed by Ramsey (1928) that has been refined by Cass (1965) and Koopmans (1965).

3.2.1. The Household Sector

In the economy, households receive wages for labor services they provide, receive interest income on assets, purchase goods for consumption, and save. The households model has inter-generational interaction whereby the current generation maximizes utility subject to a budget constraint over an infinite horizon. Each household contains at least one adult (working member) of the current generation. Assuming that the number of adults at time 0 are normalized to unity, the family size at time t is:

$$L(t) = e^{\mu t} \tag{3.10}$$

which is exactly the same as equation (3.3) except that the equation now can be interpreted differently.

Total consumption at time t is $C(t)$ and, therefore, consumption per adult person (or family) is $c(t) \equiv C(t)/L(t)$.

Household overall utility is given by

$$U = \int_0^{\infty} u\left[c(t)\right] \cdot e^{\mu t - \rho t} dt \tag{3.11}$$

The instantaneous utility function $u(c)$ is often called the *felicity function* that relates the flow of utility per person to the quantity of consumption per person, c. It is assumed that $u(c)$ is increasing in c and concave, i.e. $u'(c) > 0$, $u''(c) < 0$. It is also assumed that u(c) satisfies Inada conditions: $u'(c) \to \infty$ as $c \to 0$, and $u'(c) \to 0$ as $c \to \infty$.

The expression $e^{-\rho t}$ is the value of time preference with $\rho > 0$. A positive value of ρ implies that current utils are preferred to utils at a later time. It is also assumed that $\rho > \mu$ which implies that U is bounded if c is constant. The constant μ, as before, is the population growth rate.

It is assumed that households interact in a competitive environment with the labor market clears and each adult supplies inelastically 1 unit of labor service per unit of time. With the time subscripts suppressed, household budget constraint is

$$\dot{a} = w + ra - c - \mu a \tag{3.12}$$

where w is the wage rate, r is the interest rate, and a is the household's net assets per person. Equation (3.12) states that assets per person increase with per capita income, $w + ra$, decrease with per capita consumption, c, and decrease due to the expansion of the population in accordance with the term μa.

In order to rule out a form of chain letter or Ponzi game [13], it is necessary to assume that the present value of assets must be asymptotically nonnegative, that is

$$\lim_{t \to \infty} \left\{ a(t) \cdot \exp\left[- \int_0^t \left[r(v) - \mu \right] dv \right] \right\} \geq 0 \tag{3.13}$$

The above expression says that, in the long run, a household's debt per person cannot grow as fast as $r - \mu$, so that the level of debt cannot grow as fast as r.

---

[13]Ponzi game is a situation in which a household can borrow in such a way that it can use future borrowing to roll over the principal and pay all of the interest. In this case the household would be able to finance an arbitrarily high level of consumption in perpetuity.

The goal of the households is to maximize utility subject to their budget constraints. Since both utility and budget constraint equations have time variable in it, this is a dynamic optimization problem. In the literature, there are three ways to solve this problem, i.e. the calculus of variations, dynamic programming, and optimal control theory.[14] For the optimization problem in hand, the appropriate method will be optimal control theory.

Optimal control theory is the modern generalization of variational calculus. In optimal control theory, the dynamic constrained optimization problem is viewed as consisting of three types of variables, i.e. the time variable, the state variable, and a control variable that serve as the instrument of optimization.[15] The goal of the optimal control theory is to find the optimal time path for a control variable so that the optimal state path that corresponds to it can be found. The cookbook step by step procedure to solve dynamic optimization problem using optimal control theory is presented in Appendix C.

3.2.2. First Order Condition, The Euler Equation, and The Transversality Condition

From the Maximum Principle, the present value Hamiltonian of the dynamic optimization is

$$H = u(c)e^{-(\rho-\mu)t} + \lambda \cdot \left[w + (r - \mu)a - c\right] \qquad (3.14)$$

[14]Chiang, Alpha C., 1992, "Elements of Dynamic Optimization," McGraw-Hill, p. 17.

[15]The maximum principle which is commonly associated with L.S. Pontryagin is the most significant development in optimal control theory.

The constant λ is similar to *Lagrangian* constant and can be interpreted as the present value shadow price of income. The First Order Conditions for utility maximization are:

$$\frac{\partial H}{\partial c} = 0 \Rightarrow \lambda = u'(c)e^{-(\rho-\mu)t} \tag{3.15}$$

$$\dot{\lambda} = -\frac{\partial H}{\partial a} \Rightarrow \dot{\lambda} = -(r - \mu)\lambda \tag{3.16}$$

Equation (3.16) which says that the partial derivative of the Hamiltonian with respect to the state variable equals the negative of the derivative of the multiplier, $\dot{\lambda}$, is one of the Euler equations. The complete set of the Euler equations for this system would be equation (3.16) and the *transition equation* (*equation of motion*) in equation (3.12).

Differentiating equation (3.15) with respect to time and substitute for λ from this equation and for $\dot{\lambda}$ from equation (3.16) yields the basic condition for choosing consumption over time:

$$r = \rho - \left(\frac{du'/dt}{u'}\right) = \rho - \left[\frac{u''(c)\cdot c}{u'(c)}\right]\cdot(\dot{c}/c) \tag{3.17}$$

The above expression says that households choose consumption such that the rate of return, r, equals to the rate of time preference, ρ, plus the rate of decrease of the marginal utility of consumption, u', due to growing per capita consumption, c. Households prefer to consume today rather than tomorrow for two reasons, i.e. the time preference, ρ, and the assumption that $\dot{c}/c > 0$ which implies that c is low today relative to tomorrow.

The term $\left[\left(-\ u''(c)\cdot c\ /\ u'(c)\right)\right]$ is the magnitude of the elasticity of marginal utility which is sometimes also called the reciprocal of the elasticity of intertemporal substitution.

If we assume that the *felicity function* is

$$u(c) = \frac{c^{(1-\theta)} - 1}{(1-\theta)} \tag{3.18}$$

where $\theta > 0$ and the elasticity of marginal utility equals the constant $-\theta$, equation (3.17) simplifies to

$$\dot{c}/c = (1/\theta)\cdot(r-\rho) \tag{3.19}$$

Equation (3.18) is called the *constant intertemporal elasticity of substitution* (CIES) utility function. In equation (3.19), a higher value of θ (a lower willingness to substitute intertemporally) implies a smaller responsiveness of $\dot{c}\ /\ c$ to the gap between r and ρ.

The transversality condition of the dynamic optimization in hand is

$$\lim_{t\to\infty}\left[\lambda(t)\cdot a(t)\right] = 0 \tag{3.20}$$

It says that households do not want to have any valuable assets, which equals the quantity $a(t)$ times the shadow price $\lambda(t)$, left over at the end. The reason is because utility would increase if the assets, which are effectively being wasted, were used instead to raise consumption at some finite time.

The Euler equation of equation (3.17) shows the evolution of the shadow price λ over time. Integration of the Euler equation with respect to time yields:

$$\lambda(t) = \lambda(0) \cdot \exp\left\{ - \int_0^t \left[r(\lambda) - \mu \right] d\lambda \right\}$$

If we normalize $\lambda(0)$ to 1 and substitute the result for $\lambda(t)$ into the Transversality equation (3.20) we get

$$\lim_{t \to \infty} \left\{ a(t) \cdot \exp\left[- \int_0^t \left(r(\lambda) - \mu \right) d\lambda \right] \right\} = 0 \qquad (3.21)$$

The above expression implies that the level of assets does not grow at a rate as high as r. Households would be better off if assets were consumed in finite time instead of accumulating assets forever at the rate r or higher.

3.2.3. Firms and the Equilibrium

Firms which produce goods, pay wages for labor input, and make rental payments for capital input, have neoclassical production function of the form

$$Y = F(K, L, t) \tag{3.22}$$

where Y is output, K is capital input, L is labor input, and t is time representing the effect of exogenous technological progress.

Let $\hat{L} \equiv L \cdot A(t)$ be the effective amount of labor input where $A(t) = e^{xt}$ is the level of technology that grows at the constant rate $x \geq 0$ with $A(0) = 1$ (normalized). The production function can now be written as

$$Y = F(K, \hat{L})$$

In terms of quantities per unit of effective labor

$$\hat{y} \equiv Y/\hat{L} \quad \text{and} \quad \hat{k} \equiv K / \hat{L}$$

Using the above expression, the production function in intensive form is

$$\hat{y} = f(\hat{k}) \tag{3.23}$$

where $f(0) = 0$. The marginal products of the factors are:

$$\partial Y/\partial K = f'(\hat{k})$$

$$\partial Y/\partial L = \left[f(\hat{k}) - \hat{k} - f'(\hat{k})\right]e^{xt} \tag{3.24}$$

The Inada conditions for this production functions are that $f'(\hat{k}) \to \infty$ as $\hat{k} \to 0$ and $f'(\hat{k}) \to 0$ as $\hat{k} \to \infty$.

Firms rent the services of capital from the households that own the capital at the rental price for a unit of capital services, R. as before, capital stocks depreciate at the constant rate $\delta \geq 0$. Hence, the net rate of return to a household that owns a unit of capital is $R - \delta$. Since households can receive the interest rate, r, on funds lent to other households and since capital and loans are perfect substitutes as stores of value, we have $r = R - \delta$, or $R = r + \delta$.

The profit function for the firm is

$$\Pi = F(K, \hat{L}) - (r + \delta) \cdot K - wL \tag{3.25}$$

which says that profit equals gross revenue from the sale of output, $F(K, \hat{L})$, less the factor payments which are rentals to capital, $(r + \delta) \cdot K$, and wages to worker, wL. If the firm has a level of effective labor input $\hat{L} = L \cdot e^{-xt}$, the profit function will then be

$$\Pi = \hat{L} \cdot \left[f(\hat{k}) - (r - \delta) \cdot \hat{k} - we^{-xt} \right] \tag{3.26}$$

Under perfect competition, the conditions for profit maximization require that

$$f'(\hat{k}) = r + \delta \tag{3.27}$$

and

$$\left[f(\hat{k}) - \hat{k} \cdot f'(\hat{k}) \right] e^{xt} = w \tag{3.28}$$

that is firms would equate the marginal product of capital to the rental price, and the marginal product of labor to the wage rate.

The household budget constraint of equation (3.12) determines $\dot{a}$. Using $a = k$, $\hat{k} = ke^{-xt}$, and the conditions for r and w in equations (3.27) and (3.28) we get

$$\dot{\hat{k}} = f(\hat{k}) - \hat{c} - (x + \mu + \delta) \cdot \hat{k} \qquad (3.29)$$

where $\hat{c} = C/\hat{L} = ce^{-xt}$. Equation (3.29) says that change in the capital stock equals output less consumption and depreciation. It is also the key relation that determines the evolution of $\hat{k}$ and, hence, $\hat{y} = f(\hat{k})$ over time. The problem is that the evolution of $\hat{c}$ is not determined. However, from the household optimization, while assuming that we have CIES utility function, we know that c grows in a manner that is determined by equation (3.19). Using equation (3.19) and the conditions $r = f'(\hat{k}) - \delta$ and $\hat{c} = ce^{-xt}$, we get

$$\dot{\hat{c}}/\hat{c} = \dot{c}/c - x = (1/\theta) \cdot \left[f'(\hat{k}) - \delta - \rho - \theta x\right] \qquad (3.30)$$

Equations (3.29) and (3.30), together with the initial condition $\hat{k}(0)$, and transversality condition, determine the time path of $\hat{c}$ and $\hat{k}$.

The transversality condition of equation (3.21), using $a = k$, and $\hat{k} = ke^{-xt}$, is

$$\lim_{t \to \infty} \left\{\hat{k} \cdot \exp(-\int_0^t \left[f'(\hat{k}) - \delta - x - \mu\right] d\lambda\right\} = 0 \qquad (3.31)$$

Equation (3.31) can be interpreted as saying that $\hat{k}$ tends asymptotically to a constant steady-state value k^*, similar to the Solow-Swan model.

3.2.4. Steady-State and Transitional Dynamic

Let the steady state growth rate of $\hat{k}$ be $(g_{\hat{k}})^*$ and the steady-state growth rate of $\hat{c}$ be $(g_{\hat{c}})^*$. In the steady state, equation (3.29) implies

$$\hat{c} = f(\hat{k}) - (x + \mu + \delta)\cdot\hat{k} - \hat{k}\cdot(g_{\hat{k}})^* \tag{3.32}$$

Differentiating equation (3.32) with respect to time we get

$$\dot{\hat{c}} = \dot{\hat{k}}\cdot\left\{f'(\hat{k}) - \left[x + \mu + \delta + (g_k)^*\right]\right\} \tag{3.33}$$

The transversality condition of equation (3.31) implies that $f'(\hat{k}) - \left[x + \mu + \delta + (g_{\hat{k}})^*\right]$ is positive. Therefore, $(g_{\hat{k}})^*$ and $(g_{\hat{c}})^*$ must be of the same sign. This would then implies that $(g_{\hat{k}})^* = (g_{\hat{c}})^* = 0$.[16] It would also imply that

[16]Since, using equation (3.30), if one steady-state growth rate is positive (or negative) the other would be negative (or positive). For instance, if $(g_{\hat{k}})^*$ is positive, than $\hat{k} \to \infty$ and $f'(\hat{k}) \to 0$. Equation (3.30) then implies $(g_{\hat{c}})^* < 0$, which contradicts the result that $(g_{\hat{k}})^*$ and $(g_{\hat{c}})^*$ are of the same sign.

$(g_y)^* = 0$. Therefore, in the steady-state, the variables per unit of effective labor, $\hat{k}$, $\hat{c}$, and $\hat{y}$, are constant. However, per capita variables, k, c, and y, grow in the steady state at the rate x, and the level variables, K, C, and Y, grow in the steady-state at the rate $(\mu + x)$. These results are the same as those of the Solow-Swan model.

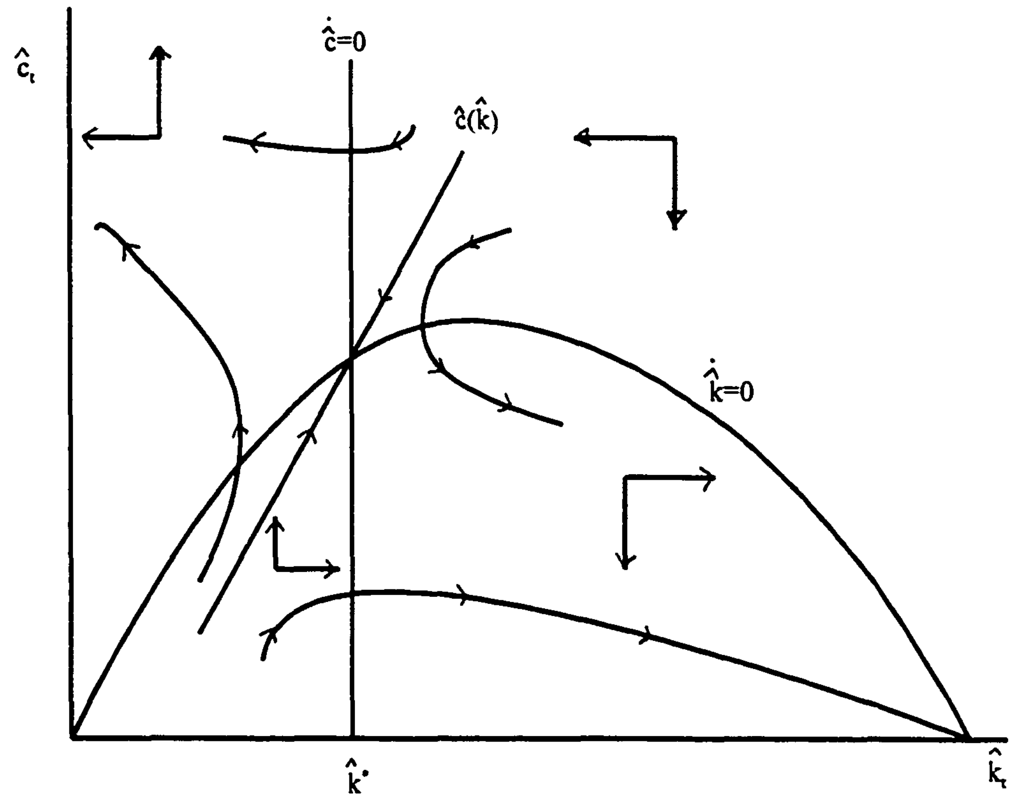

Figure 3.3. The Steady-State and Phase Diagram of the Ramsey Model.

Figure 3.3 shows the steady state conditions of the system. We get the steady state values for $\hat{c}$ and $\hat{k}$ by setting equations (3.29) and (3.30) to zero. In other words, the steady state occurs when $\dot{\hat{c}} = 0$ and $\dot{\hat{k}} = 0$.

Setting $\dot{\hat{k}} = 0$ in equation (3.29) yields $\hat{c} = f(\hat{k}) - (x + \mu + \delta) \cdot \hat{k}$ which shows that $\hat{c}$ is a non linear function of $\hat{k}$ and the curve is a parabolic as depicted in Figure 3.3.

Equation (3.30) and the condition $\dot{\hat{c}} / \hat{c} = 0$ in the steady-state imply

$$f'(\hat{k}^*) = \delta + \rho + \theta x \tag{3.34}$$

which says that the steady-state interest rate, $f'(\hat{k}) - \delta$, equals the effective discount rate, $\rho + \theta x$. The curve that corresponds to $\dot{\hat{c}} = 0$ will be vertical since it holds at the value of $\hat{k}$ that satisfies equation (3.34) independently of the value of $\hat{c}$.

The diminishing returns to capital, which make $f'(\hat{k}^*)$ a monotonically decreasing function of $\hat{k}^*$, is key to the determination of $\hat{k}^*$ in equation (3.34). Together with the Inada conditions, $f'(0) = \infty$ and $f'(\infty) = 0$, guarantee that equation (3.34) holds at a unique positive value of $\hat{k}^*$. In Figure 3.3. this value of $\hat{k}^*$ is determined by the intersection of the $\dot{\hat{c}} = 0$ curve and the $\dot{\hat{k}} = 0$ curve.

While the value of $\hat{k}^*$ is determined by equation (3.34), the value for $\hat{c}^*$ is determined by setting equation (3.29) to zero to get

$$\hat{c}^* = f(\hat{k}^*) - (x + \mu + \delta) \cdot k^* \tag{3.35}$$

And the steady state of $\hat{y}$ is found from $\hat{y}^* = f(\hat{k}^*)$.

Even though the determination of the long-run growth is exogenous, the Ramsey model, just as the Solow-Swan model, is interesting in showing the transitional dynamic. Beside the steady state condition, Figure 3.3. also shows the *phase diagram*[1] of the nature of the transitional dynamic.

The system exhibits saddle-path stability with $\hat{k}$ is falling for values of $\hat{c}$ above the solid curve and rising for values of $\hat{c}$ below the solid curve. Notice, however, that the pattern of arrows in Figure 3.3. is such that the economy can converge to the steady-state if it starts in two of the four quadrants in which the curves $\dot{\hat{c}} = 0$ and $\dot{\hat{k}} = 0$ divide the space.

3.2.5. Convergence in the Ramsey Model

The determination of the speed of convergence in the Ramsey model involves a two-variable system, that is $\hat{c}$ and $\hat{k}$. The method used in the assessment is *the log-linear*

[1]Phase diagram is a diagram that shows the direction of the movement of a point in the diagram and the steady state position where the point most likely ends up.

approximation around the steady state of equation (3.29) and (3.30). Appendix D explains the log-linearized version of equation (3.29) and (3.30) when expanded around the steady state position.

Using the log linearization approach, the time path for $\log[\hat{y}(t)]$ is given by

$$\log[\hat{y}(t)] = e^{-\beta t} \cdot \log[\hat{y}(0)] + (1 - e^{-\beta t}) \cdot \log(\hat{y}^*) \qquad (3.36)$$

where $\beta > 0$. Equation (3.36) says that, for $t \geq 0$, $\log[\hat{y}(t)]$ is a weighted average of the initial value, $\log[\hat{y}(0)]$, and steady-state value, $\log[\hat{y}^*]$. The weight on the initial value, $\log[\hat{y}(0)]$, is declining exponentially at the rate of β. The speed of convergence, β, depends on the parameters of technology and preferences. Assuming that we have a Cobb-Douglass technology, $f(\hat{k}) = A \cdot \hat{k}^{\alpha}$, the formula for the convergence coefficient is

$$2\beta = \left\{\xi^2 + 4 \cdot \left(\frac{1-\alpha}{\theta}\right) \cdot (\rho + \delta + \theta x) \cdot \left[\frac{\rho + \delta + \theta x}{\alpha} - (\mu + x + \delta)\right]\right\}^{1/2} - \xi \qquad (3.37)$$

where $\xi = \rho - \mu - (1 - \theta) \cdot x > 0$.

Using equation (3.36), the average growth rate of per capita output, y, over an interval from an initial time 0 to any future time $T \geq 0$ is

$$\left(1/T\right) \cdot \log\left[y(T) / y(0)\right] = x + \frac{(1 - e^{-\beta T})}{T} \cdot \log\left[\hat{y}^* / \hat{y}(0)\right] \tag{3.38}$$

If we hold fixed the steady-state growth rate, x, the speed of convergence, β, and time T, equation (3.38) says that the average per capita growth rate of output depends negatively on the ratio of $\hat{y}(0)$ and $\hat{y}^*$. Therefore, the effect of the initial position of $\hat{y}(0)$ on growth is conditioned on the steady-state position of $\hat{y}^*$. This result is the same as in the Solow-Swan model. In other words, the Ramsey growth model predicts conditional convergence, but not absolute convergence.

3.2.6. The Ramsey Model for a Credit-Constrained Open Economy

Assume that there are many countries with country i as domestic and others as foreign. The domestic country has assets per person a_i and capital per person k_r. If we define d_i to be the domestic country's net debt to foreigners, then

$$d_i = k_i - a_i \tag{3.39}$$

The budget constraint for the representative household in country i is

$$\dot{a}_i = w_i + (r - \mu_i) \cdot a_i - c_i \tag{3.40}$$

where r is the world interest rate.

Assuming that we have utility function as given by equation (3.11) and the CIES felicity function as given by equation (3.18, the first order condition from household optimization, like before, is

$$\dot{c}_i / c_i = (1/\theta_i) \cdot (r - \rho_i)$$

or, in terms of consumption per effective worker

$$\dot{\hat{c}}_i / \hat{c}_i = (1/\theta_i) \cdot (r - \rho_i - \theta_i x_i) \tag{3.41}$$

For firms, the optimization conditions involves the equalization of the marginal products and factor prices which yields

$$f'(\hat{k}_i) = r + \delta_i \tag{3.42}$$

$$\left[f(\hat{k}_i) - \hat{k}_i \cdot f'(\hat{k}_i) \right] \cdot e^{x_i t} = w_i \tag{3.43}$$

Equations (3.42) and (3.43) are the counterparts of equations (3.27) and (3.28) in closed economy. Substituting w_i from equation (3.43) into equation (3.40) and using equation (3.42) yields

$$\dot{\hat{a}}_i = f(\hat{k}_i) - (r + \delta_i) \cdot (\hat{k}_i - \hat{a}_i) - (x_i + \mu_i + \delta_i) \cdot \hat{a}_i - \hat{c}_i \tag{3.44}$$

which shows the change in assets per effective worker.

It is assumed that the world economy has a constraint on the availability of international credit. For tractability, it is also assumed that the production function is Cobb-Douglass with two kinds of capital:

$$\hat{y} = f(\hat{k}, \hat{h}) = A\hat{k}^{\alpha}\hat{h}^{\varepsilon} \tag{3.45}$$

where $\hat{k}$ is physical capital per unit of effective labor and $\hat{h}$ is human capital per unit of effective labor. Physical capital can be used as collateral on loans while human capital can not. In equation (3.45), α is the share of physical capital where $0 < \alpha < 1$, and ϵ is the share of human capital with $0 < \epsilon < 1$. In order to ensure diminishing returns in the accumulation of broad capital (physical and human), it is necessary to assume that $0 < \alpha + \epsilon < 1$.

The budget constraint of equation (3.44) can now be written as

$$\dot{\hat{a}} = \dot{\hat{k}} + \dot{\hat{h}} - \dot{\hat{d}} = A\hat{k}^{\alpha}\hat{h}^{\varepsilon} - (r + \delta) - (\hat{k} + \hat{h} - \hat{a}) - (x + \mu + \delta)\cdot \hat{a} - \hat{c} \tag{3.46}$$

where the subscript i is dropped and $\hat{a} = \hat{k} + \hat{h} - \hat{d}$. Both kinds of capital, physical and human, have the same depreciation rate, δ. It is assumed that the amount of foreign debt, d, can be positive but cannot exceed the quantity of physical capital, k. It is also assumed that the world interest rate, r, is constant and equal to the steady state interest rate in a closed economy, $\rho + \theta x$.

The initial quantity of assets per effective worker is $\hat{k}(0) + \hat{h}(0) - \hat{d}(0)$. It is assumed that $\hat{k}(0) + \hat{h}(0) - \hat{d}(0) < \hat{h}^{*}$ so that the constraint is binding, that is $d = k$.

The net return on physical capital, $f_k - \delta$, where f_k is the marginal product of capital, equals the world interest rate, r. Using the marginal product of capital formula and that $f_k - \delta = r$, equation (3.45) implies

$$\hat{k} = \alpha\hat{y} / (r + \delta) \tag{3.47}$$

Since α, r, and δ are all constant, equation (3.47) implies that the ratio of physical capital to GDP, k/y, will be constant throughout the transition to the steady state. Combining equation (3.45) and (3.47) yields

$$\hat{y} = B\hat{h}^{\eta} \tag{3.48}$$

where $B \equiv A^{1/(1-\alpha)} \cdot [\alpha / (r + \delta)]^{\alpha/(1-\alpha)}$ and $\eta \equiv \varepsilon / (1 - \alpha)$. The condition $0 < \alpha + \epsilon < 1$ implies $0 < \eta < \alpha + \epsilon < 1$. Equation (3.48), therefore, shows $\hat{y}$ as a function of $\hat{h}$ with positive and diminishing marginal product.

Combining equation (3.46), (3.47), (3.48), and the borrowing constraint $d = k$ (which implies $a = h$), yields the revised budget constraint:

$$\dot{\hat{h}} = (1 - \alpha) \cdot B\hat{h}^{\eta} - (\delta + \mu + x) \cdot \hat{h} - \hat{c} \tag{3.49}$$

The households' optimization problem is now to maximize utility

$$U = \int_0^{\infty} u[c(t)] \cdot e^{\mu t - \rho t} dt$$

with

$$u(c) = \frac{c^{(1-\theta)} - 1}{(1 - \theta)}$$

subject to the budget constraint in equation (3.49) and a given initial stock of human capital, $\hat{h}(0) > 0$.

The optimal condition for consumption over time is

$$\dot{\hat{c}}/\hat{c} = (1/\theta)\cdot\left[(1-\alpha)\cdot B\eta\hat{h}^{\eta-1} - (\delta + \rho + \theta x)\right] \tag{3.50}$$

where $(1-\alpha)\cdot B\eta\hat{h}^{\eta-1} = B\varepsilon\hat{h}^{\eta-1} = f_h$, the marginal product of human capital.

The system described by equation (3.49), (3.50), and the transversality condition has the usual transitional dynamics, i.e. saddle path stability. The steady state conditions and the phase diagram, however, are expressed in terms of $\hat{c}$ and $\hat{h}$.

The formula for the convergence coefficient, β, is similar to that for the closed economy in equation (3.37), except that the capital share parameter, $\alpha + \epsilon$, has to be replaced by $\eta = \epsilon/(1-\alpha)$. The convergence coefficient for the credit-constrained open economy is

$$2\beta = \left\{\xi^2 + 4\cdot\left(\frac{1-\eta}{\theta}\right)\cdot(\delta + \rho + \theta x)\cdot\left[\frac{\delta + \rho + \theta x}{\eta} - (\delta + \mu + x)\right]\right\}^{1/2} - \xi \tag{3.51}$$

where $\xi = \rho + \mu - (1-\theta)\cdot x > 0$

The Ramsey growth model for the credit-constrained open economy, therefore, shows the typical neoclassical (conditional) convergence. In equation (3.51) $\eta < \alpha + \epsilon$ since $\eta \equiv$

$\epsilon/(1 - \alpha)$. (And the condition $\alpha + \epsilon < 1$). This implies that the credit-constrained open economy behaves similar to closed economy with a broad capital share that is less than $\alpha + \epsilon$. Since the rate of convergence depends inversely on the capital share (a smaller capital share means that diminishing returns occur more rapidly), the credit constrained open economy, therefore, has a higher rate of convergence than the closed economy.

CHAPTER IV

DATA AND ESTIMATION

4.1. Data

There are three main sources of data used in this dissertation, namely the Penn-World Trade Table version 5.6, Barro-Lee data set compiled by Robert Barro and Jong-Wha Lee, and World Debt Table from World Bank. The Penn-World Trade (PWT) Tables are compilations of internationally comparable data that was originally developed by Robert Summers and Alan Heston and was best described in Summers and Heston (1991). The PWT Tables have evolved into several development starting from Mark 1 - Mark 5, version 5.5, and version 5.6. The tables use a common set of prices in a common currency as the denomination for its expenditure entries so that real international quantity comparisons can be made both between countries and over time. The Penn World Trade Table is derived from the benchmark studies of the United Nations International Comparison Project (ICP), which so far cover the years 1970, 1975, 1980, 1985, and 1990.

An ICP benchmark study basically is a pricing exercise. There are 150 standardized categories of goods and services that include approximately 110 for consumption, 35 for investment, and five for government consumption. The price comparisons of these goods and services are estimates of price parities for each country's currency at a number of aggregation levels, including an overall purchasing power parity (PPP). Using the price parities and PPPs, the countries' national currency expenditures are then converted to a common currency unit, thus making real quantity comparisons across countries possible. The most significant difficulty in ensuring comparability of prices across countries arises in the measurement of quality of services, especially general government, medical care, and education.

Barro-Lee data set covers 138 countries, mostly at five-year intervals over the period 1960 to 1985 (or 1990 for several variables). Some variables have incomplete coverage. The description and the use of this data set is as described in Barro and Lee (1994). Data are presented either quinquennially for the years 1960-1985, i.e., 1960, 1965, 1970, 1975, 1980, and 1985, or for averages of five years' sub-periods over 1960-1985. The documentation of the data is divided into eight broad categories, namely national accounts of income, education, population/fertility, government expenditures, PPP deflators, political variables, trade policy, and others. The education data supplement the U.N. figures on school-enrollment ratios to include the measures of school attainment. The data refer to male and female attainment of the adult population at four levels: no-schooling, primary, secondary, and higher. These education data are also broken down into male-female as well as age categories.

The World Debt Tables (WDT) are the World Bank's authoritative review of developing countries' external debt and financial flows. The data in the WDTs is extracted from statistics provided by countries who are mostly members of the World Bank's Debtor Reporting System. In 1997 the World Debt Tables (WDT) has been renamed Global Development Finance 1997 (GDF) to reflect the significant change in global capital flows. GDF 1997 contains key data on the states of the former Soviet Union and provides consolidated statistics for all developing countries, including those that do not report to the World Bank's Debtor Reporting System.

This dissertation uses total external debt as a measure of external debt of developing countries. Total external debt is the sum of public, publicly guaranteed, and private nonguaranteed long-term debt, use of IMF credit, and short-term debt. Long-term debt is defined as debt that has an original or extended maturity of more than one year and that is owed to nonresidents and repayable in foreign currency, goods, or services. Long-term debt has three components: public debt, which is an external obligation of a public debtor, including the national government, a political subdivision (or an agency of either), and autonomous public bodies; publicly guaranteed debt, which is an external obligation of a private debtor that is guaranteed for repayment by a public entity; and private nonguaranteed debt, which is an external obligation of a private debtor that is not guaranteed for repayment by a public entity.

Short-term debt is defined as debt that has an original maturity of one year or less. Available data permit no distinction between public and private nonguaranteed short-term debt. Short-term debt includes the following: interest in arrears on long-term debt, which is interest payment due but not paid, on a cumulative basis; principal in arrears on long-term debt, which is principal repayment due but not paid, on a cumulative basis; and export credits, which includes official export credits, suppliers' credits, and bank credits officially guaranteed or insured by an export credit agency.

Use of IMF credit denotes repurchase obligations to the IMF for all uses of IMF resources (excluding those resulting from drawings on the reserve tranche). It is shown for the end of the year specified. It comprises purchases outstanding under the credit tranches, including enlarged access resources, and all special facilities (the buffer stock, compensatory financing, extended fund, and oil facilities), trust fund loans, and operations under the structural adjustment and enhanced structural adjustment facilities.

These three principal data sources dictate the sample used in this study. Sample selection is determined by countries and periods (years) that fall in the domain of the three mutually inclusive data sets.

4.2. The Empirical Model and Estimation Method

This section of the dissertation describes the estimation methods used in the analysis. The setup of the model and the estimation methods are primarily driven by the theoretical framework, namely the Solow-Swan-Ramsey model and the implied mathematical tools used in their model, that is the optimal control theory. The estimation method is regression using 'Barro-type regression'. Following the works of Robert Barro and several other researchers[18], Barro-type regression is basically a regression in which the dependent variable is an average variable (3, 5, or 10 year averages) and the independent variables are average variables as well as initial level variables (data in the beginning of 3, 5, or 10 year period). In accordance with optimal control theory, initial level variables are intended to represent state variables while average variables in the independent variables are meant to represent control or

---

[18]Barro has used this method to do growth studies with co-authors like Xavier Sala-i-Martin, Jong-Wha Lee, and N. Gregory Mankiw.

environmental variables. Set of variables which are used in this dissertation that can be categorized as state variables or as control variables are explained below.

As explained in Chapter 2, the Solow-Swan-Ramsey model predicts that there will be an absolute or conditional convergence in the growth dynamic of countries in the world. This means that poorer countries tend to grow faster per capita than richer countries (absolute convergence) or countries that are further away from their income per capita at the steady state level will grow faster than the ones closer to it. This convergence feature of the neoclassical growth model is explored in the estimation.

The empirical framework, in relation with optimal control theory, relates the real per capita growth rate to two kinds of variables, initial levels of state variables and control or environmental variables. State variables such as physical and human capital, in a Cobb-Douglas two-input setting, will influence the evolution of national income which is a state variable itself. The evolution of these state variables over time depends on their initial values as well as on the control variables. Therefore, initial values of the stock of physical capital, human capital, and national income are critical in determining the time path of the national income and, hence, the growth rate. If y is a state variable, the evolution of y over time is dependent on $y(0)$, its initial value.

Control variables, on the other hands, influence the time path of the state variables by changing the environment in which the state variables evolve over time. In an economy, some of these variables are chosen by governments or private agents. Examples of these kinds of variables which are chosen by the government are the ratio of government expenditure to GDP, the ratio of domestic investment to GDP, the ratio of external debt to

GDP, tariff rate, etc. The private sector choices include saving rate, labor supply, and life expectancy. Control variables, however, are not *fully* controlled by agents. Fertility rate, political instability, and black market premium are examples of control variables that agents can influence but cannot control fully. Control variables guide the movement of the state variables toward their steady state or target values which are empirically unobservable.

Let us assume that the steady state or target value of the state variable is denoted by y^*. For a given initial level of per capita output, $y(0)$, an increase in the steady-state level, y^*, raises per capita growth rate over a transition interval. For example, if the government improves the climate for business activity by reducing corruption or taxation, the growth rate increases temporarily. The effects will be similar if people (private sectors) decide to save a larger fraction of their income. As output, y, rises, however, diminishing returns eventually kick in and restore the growth rate, g_y, to a steady state value (or a value determined by the rate of technological progress). The transition period from initial to steady state level takes quite some time and, therefore, the growth effects from shifts in government policy or private behavior are expected to persist for a long time.

If the control and environmental variables are fixed (hence, y^* is also fixed), a higher initial value of per capita output, y, implies a lower per capita growth rate.

The empirical model takes the following form

$$g_{y_t} = F(y_0, h_0, \text{control variables}) \tag{4.1}$$

where g_{y_t} is per capita growth rate[19], y_0 is initial per capita GDP, h_0 is initial human capital per person, and control variables are an array of control and environmental influences. The coefficient in front of y_0, the initial per capita GDP, is a measure of the speed of convergence.

The operationalization of the model, then, leads to the following form:

$$g_{yt} = \beta_0 + \beta_1 \, ln(GDP)_t + \beta_2 \, humanm_t + \beta_3 \, humanf_t + \beta_4 \, ln(lifee0)_t + \beta_5 \, open_t + \beta_6 \, geexp_t + \beta_7 \, pinstab_t + \beta_8 \, ln(bmp)_t + \beta_9 \, (d/GNP)_t + \epsilon_t \qquad (4.2)$$

where ϵ is assumed to be independently and identically normally distributed with mean vector zero and constant, non-singular covariance matrix Ω. Furthermore, i = 1, 2, 3, and

g_y	=	Growth rate of real per capita GDP (5 year average). *Source*: Summers-Heston PWT Table v.5.6.
ln(GDP)	=	Log value of real per capita GDP. *Source*: Summers-Heston PWT Table v.5.6.
humanm	=	Average schooling years in the male population over age 25. *Source*: Barro and Lee (1993).
humanf	=	Average schooling years in the female population over age of 25. *Source*: Barro and Lee (1993).
ln(lifee0)	=	Log value of life expectancy at age 0. *Source*: World Development Report, World Bank (various issues).
open	=	A measure of country openness. *Source*: Summers-Heston v.5.6.

[19]A five year average of the annual growth rates.

geexp = Ratio of total nominal government expenditure on education to nominal GDP. *Source*: UNESCO.

pinstab = Measure of political instability. *Source*: Barro and Lee. (0.5 x ASSASSP + 0.5 x REVOL)
(ASSASSP = number of assassinations per million per year)
(REVOL = number of revolution per year).

ln(bmp) = Log value of (1 + BMP). *Source*: Wood (1984) and World Development Report, World Bank (1988).
(BMP = Black Market Premium = Black Market Xrate/Official Xrate -1).
(Xrate = local currency per dollar)

(d/GNP) = Ratio of nominal external debt to nominal GNP. *Source*: Global Development Finance, World Bank (1997).

Subscript i=1 is for the first 5 year period, 1970-1974, i=2 is for the second 5 year period, 1975-1979, and i = 3 is for the third 5 year period, 1980-1984.

The regressors in equation (4.2) consist of two groups of variables, state variables and control variables. The detail is explained in the following section.

4.2.1. The State Variables

In equation (4.1), for given values of the control variables, a higher starting level of per capita output, y_0, and per capita human capital, h_0, relate to a lower per capita growth rate. This occurs because of diminishing returns to inputs. As a result, a richer country, with higher levels of y and h, tends to grow slower than the poorer one. As explained by the conditional convergence, however, these high or low levels of the state variables are measured relatively to their steady state values. In other words, for given values of the control variables, the higher the (positive) gap between the state variable and its steady state value, the higher the growth rate. Since, for positive gap, high gap occurs when the state variable is relatively low, this implies that poor countries tend to grow faster than the rich ones.

If per capita human capital, h_0 , is allowed to vary against physical capital, it is predicted that for given y_0, a higher value of h_0 in equation (4.1) tends to raise the growth rate. This prediction is the result of Uzawa (1965) and Lucas (1988) studies which predicts some influences on growth from imbalances between physical and human capital.

In equation (4.2), the operationalization of the variables shows that the state variables are the *GDP, humanm, humanf,* and *life expectancy* (*ln(lifee0)*). The coefficient on the *GDP*, which is also the speed of convergence, is expected to be negative since, due to diminishing returns to inputs, the higher the initial values of *GDP* the lower the growth rate. The coefficients in front of *humanm* and *humanf* are expected to be positive for the reason described above. The higher the value of life expectancy at age 0 the higher the productivity of each worker. We, therefore, expect positive correlation between this variable and the growth rate.

4.2.2. Control Variables

Control or environmental variables affect the steady state position and, therefore, influence the growth rate. In neoclassical growth models such as the Solow-Swan and Ramsey model, a change in a control or environmental variable affects the steady state level of output per effective worker will be affected by a change in a control or environmental variable, but not the long-term per capita growth rate.

A government policy that distort the market, for example, tends to lower the steady state level of output per effective worker and, therefore, reduce the growth rate for given values of the state variables. A higher value of life expectancy on the other hand, tends to increase the steady state level and increase the growth rate for given values of the state variables.

The empirical model of equation (4.2) shows that the control variables included in the study are *open, geexp, pinstab, ln(bmp)*, and *(d/GNP)*. In addition to that, second model is evaluated which adds a dummy variable to that array of control variables. The dummy variable takes the value of one for the Highly Indebted Poor Countries (HIPC) and zero otherwise.

The way the variable *open*, which reflects the degree of openness of a country to the international trade, is measured makes it possible that the sign of the coefficient in front of it can be either positive or negative. This variable is measured as a ratio between export plus import and GDP. If the numerator is dominated by export the coefficient will be positive since export generates international reserves that is necessary for growth and development. However, if import is dominant, the coefficient will be negative since import drains (depletes) domestic financial resource needed for economic growth. In other words, for a developing country, being 'open' can be *good* (increase growth) or *bad* (decrease growth) depending on whether openness induces export that outweigh import or vice versa.

The ratio of government expenditure on education and Gross Domestic Product (*geexp*) is used as a proxy of the school quality. High value of the ratio is interpreted as a high school quality which also means high worker productivity. Therefore, it is expected that there is a positive link between this ratio and the growth rate for given values of the state variables.

An increase in political instability, captured by the variable *pinstab*, will diminish the performance of the market. High political instability creates uncertainty among economic agents which will hamper the working of the market. This distortion of the market tends to lower the steady-state level of output per effective worker and, consequently, to reduce the growth rate for given values of the state variables. It is therefore expected that correlation between this variable and the growth rate variable is negative.

Black market premium is used as a proxy for market distortion in foreign exchange market. It is expected that a higher black market premium, like other governmental distortion, lowers the steady-state level of output per effective worker and, therefore, reduces the growth rate for given values of the state variables. The coefficient in front of the variable *ln(BMP)* is expected to be negative, i.e. it is expected that there is an inverse relationship between *ln(BMP)* and growth level.

The theoretical framework in chapter 3 predicts that the credit constrained open economy will likely converges faster than the close economy. The speed of convergence is likely to be higher when there is a limited amount of foreign capital available for development than when a country is isolated from the international capital market. The direct effect of external debt ratio to the growth level, however, is not predicted by the theoretical framework. The coefficient in front of the variable *ln(d/GNP)* will be positive if external debt is growth enhancing and negative if it is growth depriving. This variable, as well as other control variables, are assumed to be exogenous.[20]

4.3. Estimation

Recall that equation (4.2) is the equation to be estimated. Recall also that Barro-type regression is used in the estimation. Subscript *i* in equation (4.2) indicates sub-period, i.e. 1970-1974, 1975-1979, 1980-1984. Altogether there are 3 five-year sub-periods and, therefore, 3 sets of equations in equation (4.2).

The objective of the estimation is to get one set of vector of coefficients from those three equations. Therefore, cross equation restrictions are imposed. These cross equation restrictions make it unjustifiable for one to use ordinary least square (OLS) in the estimation

[20]A Hausman test for exogeneity using auxiliary equation for the "stacked data" with *ln(d/GNP)* as the dependent variable and *open,, geexp, pinstab, ln(BMP), ln(I/GDP), ln(C/GDP)* does not reject the exogeneity of the variable ln(d/GNP). (p-value=0.17)

of each individual equation since OLS, most likely, will yield three different sets of vector of coefficients. To impose these cross equation restrictions, it is necessary instead to use a system estimator.

One possibility is to use Zellner's seemingly unrelated regression (SUR) estimator. Even if there is no cross-equation restrictions, SUR estimator would provide more efficient estimates of parameters than OLS. The main reason is that in each equation of the equation (4.2) one would expect that the disturbance covariance matrix would not be diagonal if there is correlation among the three equations.

In practice, SUR estimator uses equation by equation OLS to obtain an estimate of the disturbance covariance matrix Ω and then does generalized least square, given this initial estimate of Ω, on an appropriately "stacked" set of equations. Furthermore, the estimate of Ω can be updated by doing iterative SUR (ISUR) until changes from one iteration to the next in the estimated parameters and the estimated Ω become arbitrarily small. This iterative SUR yields parameter estimates that are numerically equivalent to those of the maximum likelihood (ML) estimator.[21]

Maximum likelihood estimators are consistent, asymptotically unbiased, asymptotically normal, and asymptotically efficient. No other consistent and asymptotically normal estimator can have a smaller asymptotic variance. These properties, therefore, makes maximum likelihood estimators more appealing in large sample estimation. Hence, the choice of ISUR over standard SUR as a method of estimation in this dissertation is justifiable

[21]For a proof of this result, see Walter Oberhofer and Jan Kmenta (1974)

Table 4.1. Results of the Estimations

Regressors	Model 1	Model 2
Ln(GDP)	-0.0441* (-14.68)	-0.0448* (-15.41)
Humanm	0.00708* (2.054)	0.00641* (2.056)
Humanf	0.00405 (1.199)	0.000846 (0.2732)
Ln(lifee0)	0.0773* (14.97)	0.08199* (16.07)
Open	-0.000125* (-2.067)	-0.0000655 (-1.176)
Geexp	1.0617* (50.39)	1.0818* (59.41)
Pinstab	-0.02142 (-1.226)	-0.01182 (-0.7419)
Ln(BMP)	-0.0383* (-6.210)	-0.0290* (-4.316)
Debt/GNP	-0.03296* (-3.868)	-0.03708* (-4.120)
HIPC Dummy	-	-0.0344* (-6.742)

Note: Dependent variables in both models are the growth rate of real per capita GDP measured as a 5 year averages (g_y). The sample sizes are n_1 (first sub period) = 48; n_2 (second sub period) = 60; n_3 (third sub period) = 65. (Appendix A shows the complete list of samples). Numbers in parenthesis are t-ratios. The symbol * indicates significance at 5% level. Constants are estimated but not reported.

since it involves a large sample size. Both models, with and without HIPC dummy variable, are estimated by iterative SUR. The results of the estimation are presented in Table 4.1.

The variable *ln(GDP)* is (natural) log value of real per capita GDP observed for 1970 in the sub-period 1970-1974, for 1975 in the sub-period 1975-1979, and for 1980 in the sub-period 1980-1984. The estimated coefficient on *ln(GDP)* is -0.0441 (*t-ratio* = -14.68) for model 1. As explained in chapter 3, this coefficient shows conditional convergence similar to the ones that has been reported in various studies, such as Barro (1991) and Barro and Sala-I-Martin (1995). The coefficient is slightly higher than the one estimated by Barro and Sala-I-Martin since the environment setting for this study is a credit-constrained open economy. The convergence is conditional in that it predicts higher growth in responds to lower starting GDP per capita only if the other explanatory variables are held constant.

The effect of human resources in the production function is captured by the school-attainment and life expectancy variables. The variable ***humanm*** is average schooling years in the male population over age 25 and ***humanf*** is average schooling years in the female population over age 25. For model 1, the coefficient for the ***humanm*** is 0.00708 (t-ratio = 2.054) and for the ***humanf*** is 0.00405 (t-test = 1.199). The positive correlations of both control variables to the growth level are as expected, the higher the education attainment of male and female population over age 25 the higher the per capita growth rate. When joint together, to see the effect of both education attainment variables on growth rate, a test shows *p-value* of 0.000 which means that both variables (together) have significant effect on the growth rate. Despite the fact that the correct sign is achieved, the finding shows that female school attainment does not have significant effect on growth rate which also means that the finding does not support the hypothesis that education of women is a key to economic growth.[22]

The estimated coefficient means, for the sample period 1975-1979, that a one-standard-deviation increase in the average schooling years in the male population over age 25 (1.82 years, see Appendix B) raises the growth rate by 1.3 percentage points per year. For the variable average schooling years in the female population over age 25, for the same sample period, the estimated coefficient suggests that a one-standard-deviation increase in this variable raises the growth rate by 0.7 percentage points per year.

The variable life expectancy at birth (at age 0) is an average value measured in the beginning of every sub-period. In this study they are measured in the year 1970, 1975, and 1980. Therefore, in the context of the study, it is an initial value of a variable before it evolves over time. This variable has positive and highly significant effect (t-ratio=14.97) on the growth rate with the estimated coefficient of 0.0773. The estimated coefficient means, for the sample period 1975-1979, that a one-standard-deviation increase in life expectancy at birth (which is 1.2 years) raises the growth rate by 1.3 percentage points per year.

The variable *open* which measures the degree of openness of a country to international trade is a ratio index of export plus import to GDP. If export plus import is higher than GDP this index will be greater than one, but if GDP outweigh export plus import the ratio index will be less than one. A country which is an autarky will have an index of zero. The observation is taken as an average value for every 5 year sub period. The estimated

---

[22]Barro (1997) finds positive non-significant coefficient while Barro and Sala-I-Martin (1995) finds negative non-significant coefficient on similar variables.

coefficient in front of this variable is -0.000125 and the variable is significant (*t-ratio*=-2.067). The numerical value of the coefficient means, for the sample period 1975-1979, that a one-standard-deviation increase in this index (which is 45.28) decreases the growth rate by 0.6 percentage points per year.

The fact that the coefficient is negative implies that openness is a disincentive to economic growth for these (debtor) developing countries. One plausible explanation is that being open results in more import than export which may deprive Gross Domestic Product and hence slow economic growth. Being open will most likely stimulate domestic output when export outweigh import and the terms of trade is favorable. Using terms of trade change is one of the explanatory variables, Barro (1997) finds that terms of trade change (measured as a ratio of export to import prices) has positive and significant effect on growth level.

The variable *geexp* is public spending on education which is intended to capture the quality of education. This variable is the average value over each 5-year period of the ratio of nominal government spending on education to nominal GDP. Estimation gives an estimated coefficient of 1.0617 (*t-ratio*=50.39). This variable, therefore, has positive impact and highly significant on growth level. The numerical value of the coefficient means that a one-standard-deviation increase in geexp (which is 0.16 point for the sample period 1975-1979) increases the growth rate by 1.7 percentage points per year. Higher public spending on education which increases the quality of education results in an increase in productivity and, hence, an increase in domestic product.

The political instability variable is the average over each 5-year sub period of revolutions per year and political assassinations per million inhabitants per year.[23] The variable *pinstab*, as expected, has negative (but not significant) effect on growth level. Higher political instability lowers the incentive to invest and, hence, lowers the probability of domestic product to grow. The estimated coefficient is -0.02142 (*t-ratio* = -1.226). The inverse relationship between political instability and growth has also been reported in Barro (1991), Barro and Sala-I-Martin (1995), and Alesina and Perotti (1993). The numerical value of the coefficient suggests that a one-standard-deviation increase in political instability (which is 0.14 for the sample period 1975-1979) lowers the growth rate by 0.3 percentage points per year.[24] One of the reasons that this variable is not significant in affecting the growth rate maybe because the index does not accurately represent the true condition of political instability in a country. In this case a better index is called for.

The black market premium on foreign exchange variable, which is intended as a proxy of foreign exchange market distortions, is an average value for each 5 year sub period. The expected sign is negative since high market distortions hinder the working of the market and acts as a disincentive for growth. The variable *Ln(BMP)* has a significantly negative impact on growth with the estimated coefficient of -0.0383 (*t-ratio* = -6.21). The numerical

---

[23]The original data are as described in Bank (1979) and cover the period 1960-1985 for most countries. Following Barro and Lee, if a country's observations were missing for part of the sub-period, the average for the years that were available were used.

[24]Barro and Sala-I-Martin (1995) finds the standard deviation of 0.12 in the sample period 1965-1975 which lowers the growth rate by 0.4 percentage points per year.

value of the coefficient means that a one-standard-deviation increase in the log of black market on foreign exchange variable (which is 0.37 in the sample period 1975-1979) is estimated to reduce the growth rate by 1.4 percentage points per year.

The variable external debt is a ratio between nominal external debt to nominal gross national product (GNP) and is observed as an average value for each 5-year sub period. Similar to the variable *open*, the expected sign of the variable *(d/GNP)* can be either positive or negative. External debt, which is a supplement to domestic financial resource has a cost in the form of the usage of foreign exchange reserve (for debt repayment) accumulated mainly from export. If the cost outweigh the benefit of enhancing the overall production process, there will be an inverse relationship between this variable and growth.

The estimation shows that the variable *(d/GNP)* has a significantly negative impact on growth with the estimated coefficient of -0.03296 (*t-ratio* = -3.868). The estimated coefficient means that a one-standard-deviation increase in this variable (which is 0.16 in the sample period 1975-1979) lowers the growth rate by 0.5 percentage points per year.

As explained in Chapter I and Chapter II, several studies mostly show that there is no positive correlation between foreign aid and growth. The impact of foreign aid on growth is mostly non-significant. Only if certain requirements are met (for instance good fiscal, monetary, and trade policies), will foreign aid has a positive impact on growth. Even if there is a positive correlation, studies show that there are diminishing marginal returns to aid. Unlike foreign aid, the burden for debt repayment is higher in countries with external debt. Debt repayment requires the use of foreign exchange revenue which otherwise can be used for investment to stimulate growth. It is for this reason that the coefficient in front of the variable *(d/GNP)* has a negative sign. The indirect impact of external debt on growth predicted by the debt overhang hypothesis is examined in Chapter 5 to further investigate the effect of external debt on growth.

Model 2 has the same set of explanatory variables except that it adds one dummy variable which is intended to capture the differential intercept effect of countries in the highly indebted poor countries (HIPC). Even though overall looks very similar, several results of the estimation for model 2 worth mentioning. The variable *humanf* which is marginally significant in model 1 is clearly non-significant in model 2. Other variables have the same sign and the same significant/non-significant impact on the growth variable. The HIPC dummy is negatively significant with the estimated coefficient of -0.0344 (*t-ratio* = -6.74). Countries that belongs to HIPC have significantly lower growth rate than non-HIPC countries .

CHAPTER V

DEBT OVERHANG AND GROWTH: EVIDENCE FROM SEVERAL DEVELOPING COUNTRIES

Despite its benefit, foreign borrowing has its cost especially if it is not managed efficiently and prudently. The main cost of external debt is debt service, the payment of amortization and accumulated interest. Debt service payment has to be made by foreign exchange. For developing countries this implies that they have to use their export earnings, reduce their imports, or borrow some more to meet their debt service obligation. If they cannot provide enough foreign exchange to repay their debt service obligations, those developing countries will be in a debt crisis. Indeed, this is what happen to several developing countries during the 1980s.[25]

During this debt crisis, investment and growth rate (per capita income) have drop significantly. Kaminsky and Pereira (1996) calculate the drop in growth rate for Latin American countries is more than 4 percent (from around 6 percent in the 1970s to an average of 1.8 in the 1980s). They also call the 1980s the "lost decade" for these countries. Borensztein (1990a) observes the investment rate for the group of 15 heavily indebted countries have fallen dramatically. The average investment to GDP ratio in 1982-87 was 18 percent, compared to a 24 percent ratio in 1971-81. According to researchers like Jeffrey

---

[25]Countries like Argentina, Brazil, Mexico, Venezuela, Philippines, Ivory Coast, Morocco, Turkey, and Yugoslavia have tried to reschedule their foreign debt owed to commercial lenders between 1982 and 1987. *Source*: World Bank (1986, 1987).

Sachs, Paul Krugman, and Andreas Savvides, this decline in per capita income can be (partly) explained by the debt overhang hypothesis. The argument is that the external debt burden provides a disincentive to domestic investment in developing countries and thus slowed economic growth because any additional foreign-exchange earnings would have to be turned over to foreign creditors. According to the debt overhang hypothesis, the heavily indebted countries are in a situation where their expected present value of potential future transfer is smaller than the value of their external debt, which gives a rationale for debt forgiving schemes in the Brady Plan.[26]

There are several studies that try to explain the link between debt overhang and growth, directly or indirectly. However, most of those studies have been done using simulation method. Unlike those studies, the analysis in this chapter is intended to examine the more direct relationship between debt overhang, investment, and growth. By utilizing cross section and time series data (panel data), a simultaneous equation model is set up and estimated using an Error Component 2SLS (EC2SLS) developed by Badi H. Baltagi (1995). Developing Countries included in the sample are selected from Severely Indebted Low-income, Severely Indebted Middle-income, and Moderately Indebted Middle-income countries classified by the World Bank.[27]

---

[26]A good discussion of financing versus forgiving a debt overhang can be found in Krugman (1988a).

[27]These countries are in the Debtor Reporting System (DRS). *Source* World Bank (1996).

5.1. The Underlying Facts

In 1996, there are 136 countries, mostly developing countries, that report data to the World Bank's Debtor Reporting System. Using two ratios to classify indebtedness, i.e. the ratios of present value of total debt service to GNP and present value to exports, World Bank classifies the debtor countries into several groups. If either of these ratios exceeds a critical value - 80 percent for present value of debt service to GNP and 220 percent for present value to exports - the country is classified as *severely indebted.* The country is classified as *moderately indebted* if the critical value is not exceeded but either ratio is 60 percent or more. The country is *less indebted* if both ratios are less than 60 percent. Countries are further classified as *low income* if 1994 GNP per capita is $725 or less and as *middle income* if it is more than $725 but less than $8,956. The cross classification then yields 35 countries classified as severely indebted low-income countries (SILICs), 15 as severely indebted middle-income countries (SIMICs), 15 as moderately indebted low-income countries (MILICs), 15 as moderately indebted middle-income countries (MIMICs), 11 as less indebted low-income countries (LILICs), and 45 as less indebted middle-income countries (LIMICs). The complete list can be seen from Table A1 in the appendix.

Regionally, most of the SILICs are in Africa. The position of the SILICs relative to all developing countries during the two consecutive decades (1970-1980 and 1980-1990) can be seen from Table 5.1. below.

Table 5.1. SILICs and All Developing Countries Debt Position (US$ billion)

	1970	1980	1990	growth 1970-1980	growth 1980-1990
SILICs					
Total Debt Stocks[a]	6	60	201	29.15	14.38
Exports	8	56	44	24.14	-2.64
GNP	42	190	143	18.26	-3.11
Total Debt/Exports	75.00	107.14	456.82	4.04	17.48
Total Debt/GNP	14.29	31.58	140.56	9.21	18.05
All Developing Countries					
Total Debt Stocks	61	647	1510	30.00	9.87
Exports	93	733	934	25.78	2.73
GNP	541	2440	4546	18.22	7.16
Total Debt/Exports	65.59	88.27	161.67	3.35	6.96
Total Debt/GNP	11.28	26.52	33.22	9.96	2.53

[a]The values in 1970 are for Long-Term Debt.

Ratios and growths are in percentages.

Source: World Debt Table 1996, World Bank.

The important information that we can get from Table 5.1. is that total debt stocks grow faster than export and GNP for all developing countries as well as for SILICs. The ratios and the growth rates show that the debt performance of the developing countries was relatively better during the first decade (1970-1980) than the second one (1980-1990). For SILICs, the situation was even worse during the second decade as can be seen by the negative values of the growth rate of exports and GNP, while the growth rate of debt was still positive.

Countries included in the sample are taken from the SILICs, SIMICs, and MIMICs. The fourteen countries in the sample are the same as those sampled by Warner (1992) with the addition of Indonesia. Hence, the sample represents a non exhaustive combination of samples by Warner (1992) and Sawada (1994).

5.2. The Model and The Estimation Method

The models used in this analysis basically are ad-hoc models. There are two main equations used in the model, namely the investment equation and the growth equation. The development of the investment equation follows previous studies in the field of debt overhang hypothesis. The growth equation, on the other hand, follows the Solow neoclassical growth model.

5.2.1. The Model

Cohen (1990) pools data for 81 developing countries and regresses investment as a percent of GDP on population growth, inflation, the ratio of exports to GDP, income per capita, the share of the population in primary school, time and regional dummies, and the debt to export ratio in 1982. He finds that both the 82-87 dummy and the debt to export variable have negative coefficients (-1.67 and -0.13) but are not significant (standard errors are 1.90 and 0.69).

Borensztein (1990b), analyzes one country only (the Philippines), regresses investment on the relative price of investment goods, an estimate of the marginal product of capital, an estimate of the expected real interest rate, and several alternative debt variables. A representative result from his study is that a 1.3 billion dollar debt reduction, equivalent to 3.7 percent of GDP in 1987, is estimated to increase the ratio of investment to GDP by one percentage point.

Warner (1992) regresses investment to GDP ratio on its own lag, terms of trade (defined as the ratio of dollar export prices to dollar import prices), a proxy of world real interest rate, and the world growth rate measured by the growth rate of developed countries. Using fixed effect for the panel data, he finds that all of the independent variables are positive and significant at 5% level of significance.

For the growth equation, using Ramsey and Solow-Swan Neoclassical Growth model, Barro (1994) regresses average growth rate on Log of initial GDP, Log of Schooling, the average of the ratio of real government consumption (exclusive of education and defense) to real GDP, a measure of trade opennes, indicator of political stability (frequency of revolution and coup), the ratio of real gross domestic investment to real GDP, fertility rate, and two regional dummies. Using SUR for four alternative form of equations, he finds that most of the independent variables are significant.

In this analysis, it is assumed that investment ratio, the ratio of investment to GDP, and the growth rate are endogenous and are simultaneously determined in the model. Equations 5-1 and 5-2 show the structural model of investment and growth. Both equations are over-identified.

$$(I/GDP)_{it} = \alpha_0 + \alpha_1\, g_{it} + \alpha_2\ (I/GDP)_{it-1} + \alpha_3\, Infl_{it} + \alpha_4 \ln(Debt/GNP)_{it} + \alpha_5\, Pinstab + u_{1it} \qquad (5\text{-}1)$$

$$g_{it} = \beta_0 + \beta_1 (I/GDP)_{it} + \beta_2\, Open + \beta_3\, Infl + \beta_4\, Stliv + \beta_5\, Henroll + u_{2it} \qquad (5.2.)$$

where : $u_{1it} = \mu_{1i} + \nu_{1it}$

$u_{2it} = \mu_{2i} + \nu_{2it}$

μ_{ji} and ν_{jit} have all the necessary properties for a one-way error component model.

The detail structure of the errors are explained in Appendix F.

Brief explanation of the variables are as follow :

(I/GDP)	: real investment to real GDP ratio (x100%)
Infl	: rate of inflation (%)
Debt/GNP	: ratio of nominal debt to nominal GNP (%)
Pinstab	: index of political instability; this is a time invariant variable
g	: rate of growth (%)
Open	: index of openness (ratio of exports and imports over GDP)
Stliv	: standard of living index
Henroll	: highschool enrollment (x100%); this is a time invariant variable

5.2.2. The Estimation Method

The model described above is a simultaneous equations model involving the investment and growth equations with panel data. For this kind of model, the usual estimation methods for panel data, such as fixed-effect or random-effect models, can not be employed since this estimation technique will suffer a simultaneous equation bias. The standard methods for estimating a simultaneous equations, such as two-stage least-square (2SLS) or three-stage least-square (3SLS), can not be employed either since these methods ignore the dynamic nature of the data that differs across units. As a consequence, it requires a method that takes into account the simultaneity as well as the time-series cross-section feature of the data. Fortunately, recently, there have been several methods proposed to deal with this type of problem.[28]

Most of the panel data applications utilize a one-way error component model for the disturbances. By assuming that the error terms follow a one-way error component model, and that the estimation is done for a single equation only (not a system of equations), two simple methods of estimations can be used, namely the error component two-stage least squares (EC2SLS) developed by Baltagi (1995) and the generalized two-stage least squares (G2SLS) developed by Balestra and Varadharajan-Krishnakumar (1987). The derivation of the Baltagi's EC2SLS can be found in Baltagi (1981). Baltagi and Li (1992) proved that Balestra and Varadharajan-Krishnakumar G2SLS uses "redundant" instruments in the estimation.

[28]The book written by Baltagi (1995) is a good starting point for referencing the problem of simultaneity in a panel data.

Redundant instruments can be interpreted loosely as additional sets of instruments that do not yield extra gains in asymptotic efficiency. Based on the above arguments, and since EC2SLS is easier to implement, this analysis uses EC2SLS as the estimation methods. A brief explanation of the EC2SLS is provided in Appendix F.

5.3. Data and Results of Estimation

The data used in this analysis are extracted from Penn-World Trade Tables v. 5.6[29], Barro-Lee data set compiled by Robert Barro and Jong-Wha Lee, and *World Debt Table* of the World Bank. A more detailed description of the data and its sources is in the appendix. Each set of variable in the panel will have 280 observations since it contains 20 annual data and there are 14 countries in the sample. Several variable, for instance the variable which measure the political instability, will be time invariant. This means that there is only one observation for each unit (country) in the sample. This kind of variables will be wiped out during the Within-2SLS estimation. The period covered by this study is 20 years, i.e. from 1970 to 1990. The purpose is to cover the time before and during the debt crisis.

The results of the estimation using Baltagi's EC2SLS are presented in Table 5.2. The estimation involves two dependent variables, and six predetermined variables. Both the investment and the growth equation are over-identified. Each variable in the panel data contains fourteen units (countries) and 20 annual data. The lagged variable, i.e. lagged

---

[29]This data set, which can be downloaded from the internet, is the internationally comparable data provided by Robert Summers and Alan Heston as described in Summers and Heston (1991).

Table 5.2. Results of the Estimations

	2SLS	W2SLS	B2SLS	EC2SLS
Investment Equation	**Dependent variable is investment ratio *I/GDP***			
Growth	18.732 (1.729)	62.988* (2.829)	12.296* (6.478)	19.467* (4.075)
Inv_{-1}	0.8730* (31.16)	0.8146* (15.30)	0.9889* (155.9)	0.9506* (54.71)
Inflation	-0.7164 (-0.5176)	-5.1482* (-2.066)	-2.0551 (-1.251)	-0.4720 (-0.4528)
Debt/GNP	-0.8048 (-1.346)	0.61038 (0.4683)	0.0792 (0.6038)	-0.1496 (-0.4336)
Pol. Instability	-0.10406 (-0.1131	-	-0.6489* (-4.038)	-0.3296 (-0.7331)
	$\theta_1 = -1.5396$		SE Within = $\sigma_{v1} = 3.524$	
Growth Equation	**Dependent variable is growth rate, *g***			
Investment ratio	-0.0153 (-1.036)	0.0685 (0.5437)	-0.0029 (-1.246)	0.0011 (1.613)
Opennes	-0.0010 (-0.7977)	0.0010 (0.5460)	0.0004* (2.826)	0.0002* (2.763)
Inflation	0.0996* (2.127)	0.3552 (0.7430)	0.7362* (2.129)	0.1147* (3.484)
Stnd. of living Index	-0.0183 (-1.149)	0.1091 (0.5329)	-0.0039* (-2.222)	-0.0009 (-1.959)
Highschool Enroll.	0.0054 (0.0327)	-	-0.1299* (-7.397)	-0.1462* (-11.36)
	$\theta_2 = -5.5960$		SE Within = $\sigma_{v2} = 0.4375$	

Note: Numbers in parenthesis are t-ratios. n = 280 (i.e. 14 countries and 20 annual data). The Symbol * indicates significance at 5% level. Constants are estimated but not reported.

investment ratio, is constructed such that the time length is not affected (20 years) so that all the original time series can be used.

The standard 2SLS shows that, in the investment equation, only lag investment has a significant effect. Growth, inflation, debt ratio, and political instability, all have the expected signs; however, all are insignificant. In the growth equation, only inflation is significant. Other variables are not only insignificant, but seems to have the wrong sign also. This standard 2SLS, however, does not take into account the panel structure of the data, and therefore, it may suffer some kind of inconsistency and/or bias.

The last column in Table 5.2. shows the results from implementing Baltagi's EC2SLS. In the first equation, i.e. investment, growth and lagged investment are significant while the other three independent variables are not. The coefficient in front of the growth variable tells us that a one percent increase in growth, ceteris paribus, will approximately increase the investment ratio by 0.2 percent. Inflation, which may also be viewed as an instrument for interest rate, has negative but insignificant effect on investment. Similarly, the debt ratio also has a negative and non-significant effect on investment. This directly implies that empirically, using fourteen developing countries and twenty years of coverage, the debt overhang hypothesis is not supported. This result is in parallel of the findings by Borenzstein (1990a) and Warner (1992). Borenzstein (1990a) shows that credit rationing is a more important channel for external debt in causing investment to decline. Warner (1992), on the other hand, shows that the decrease in investment during the 1980s were mainly caused by the high world interest rate and the decrease in terms of trade of developing countries.

Political instability, captured by a time invariant index for each country, has a negative but insignificant effect on investment.

In the growth equation, country openness, inflation, and highschool enrollment have significant effect on growth while investment ratio and standard of living index do not. Investment ratio has the expected sign but insignificant in affecting growth. Empirical support for the debt overhang hypothesis is achieved if the debt ratio has a negative and significant effect on investment in equation (1), and investment has a positive and significant effect on growth in equation (2). The study finds only the correct relationships (signs) among the variables but not the significance. The positive and significant effect of inflation on growth seems puzzling. However, this maybe interpreted that inflation is regarded as an incentive for production. Level of education, proxied by percentage of highschool enrollment, also gives unexpected result, i.e. negative and significant. Further investigation of this variable is required. One possibility is to replace this variable by years of schooling for primary or secondary school. This, however, cannot be done for the sample used in this study since the required data for Nigeria and Morocco are not available.

5.4. Discussion on Findings

Previous studies on the investigation of the debt overhang hypothesis found mixed results. Most of those studies have been done by simulation methods using a combination of actual (historical) and non-actual data (for instance by setting several benchmark figures). If actual data was used, the estimation was done on a single equation only. Studies that took into account the cross-section time series characteristic of data ignored the simultaneity problem. This analysis add to the literature by considering the panel structure of the data and, at the same time, addressing the problem of simultaneous bias (endogeneity) that may exist in the relationship among variables involved in the study.

The method of estimation is Baltagi's error component two-stage least squares (EC2SLS). This method is chosen because it is easy to implement, and yet, it is capable of handling the problems in hand. The method involves transformation of the data, similar to the generalized least squares, and running 2SLS three times for each equation. Within two-stage least squares (W2SLS) and between two-stage least squares (B2SLS) are run first, and the final EC2SLS resumes the procedure.

The analysis finds no empirical support of the debt overhang hypothesis. The debt ratio in the investment equation, even though has the correct sign (negative), does not show evidence of significant effect (t-ratio = -0.4336). Investment is affected mainly by the growth of output and previous investment. Investment in the growth equation, on the other hand, also shows little evidence of significant effect on growth (t-ratio=1.613) even though, again, it has the expected sign (positive). Openness (measured by the ratio of exports and imports to output), rate of inflation, and education (proxied by highschool enrollment) are all significant in affecting the growth rate. Education, however, does not have the expected sign and this may suggest the use of other proxy variable for education such as years of schooling in primary education.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The availability of financial resources have been a chronic problem in developing countries. Propelled by the idea of financing gap developing countries rely on foreign capital resources, mostly external debt, to supplement the lack of domestic saving. Financing gap model predicts that by injecting foreign capital (even in the form of external debt) into the economy the goal of achieving certain level of growth can be accomplished. The idea of financing gap itself is based on Harrod-Domar model which predicts that growth will be proportional to investment rate. The Harrod-Domar model, however, has been heavily criticized for its shortcoming that the equilibrium is unstable since it requires the equalization of warranted and natural growth rate. Other weakness of the Harrod-Domar model is that it uses production functions with little substitutability among the inputs. The production functions used in their model are of Leontief type fixed proportion of inputs.

The work of Solow (1956) and Swan (1956) which has been categorically defined as a neoclassical growth theory is an attempt to solve the Harrod-Domar dilemma. Their production functions exhibit constant returns to scale, diminishing returns to each input, and positive substitutability among inputs. By assuming a constant saving rate the model predicts that growth in the long run is a function only of technical change and not of saving or investment. Saving will have an effect on the level of income but not on its growth rate. Increases in saving, reflected in investment, will spark additional growth only temporarily.

When the diminishing returns kick in the economy will move back to its long-run or steady-state level.

The Solow-Swan model predicts the occurrence of absolute as well as conditional convergence. Absolute convergence is a situation whereas a country with a lower capital-labor ratio has a higher per capita growth rate than a country with a high capital-labor ratio. Conditional convergence, on the other hand, is a situation in which a country has a higher growth rate when that particular country has a lower starting level of real per capita income relative to its long run or steady-state position.

The Ramsey model, also a neoclassical model, is regarded as a refinement of the Solow-Swan model. Ramsey model basically is an inter-temporal model with one of the key feature is the assumption that households optimize their utility over time. This assumption essentially makes the model dynamic. The saving rate, which is exogenous in the Solow-Swan model, is endogenous and not constant in the Ramsey model. As in the Solow-Swan model, Ramsey model also predicts the occurrence of conditional convergence.

Dynamic optimization technique for constrained optimization is needed to solve the Ramsey model since the model is dynamic. In this case, optimal control theory is more popular to solve the Ramsey model than calculus of variation even though either one can be appropriately used. The application of optimal control theory for Ramsey model leads the independent variables in the empirical model fall into two categories, i.e. state variables and control or environmental variables. In optimal control theory the state variables evolve over time whereas their time paths are controlled by control variables which also serve as the instrument of optimization. In empirical work, the state variables are initial values of the variables over certain sub-period while control variables are average values of the variables over the same sub-period.

Due to his extensive works on this subject, regressions guided by Solow-Swan-Ramsey models and the application of optimal control theory are popularly known as Barro-type regression. Barro -type regression is basically a regression in which the dependent variable is an average measure and the independent variable are a mix of initial values and average variables of sub-periods. In the spirit of optimal control theory, the initial values are the state variables while the average variables are the control or environmental variables.

In this dissertation, the impact of external debt on growth is investigated using Solow-Swan-Ramsey model and optimal control theory as the environmental setting. Barro-type regression is used. Three main data source are used, namely the Penn-World Trade Table version 5.6, Barro-Lee data set, and World Debt Table from World Bank. The method of estimation is iterative seemingly unrelated regression which yields parameter estimates that are numerically equivalent (for large sample) to those of the maximum likelihood (ML) estimator. Maximum likelihood estimators are consistent, asymptotically unbiased, asymptotically normal, and asymptotically efficient which are desirable properties for large sample estimations.

The empirical model has an average growth rate as the dependent variable, four state variables represented by their initial values, and five control or environmental variables represented by their average values. Similar model with the addition of a Highly Indebted Poor Countries (HIPC) dummy is also estimated.

Initial value of real per capita GDP has significantly negative impact on growth. The estimated coefficient which is also the speed of convergence is -0.0441 which is higher (in absolute value) then the finding of Barro (1997) of -0.026. The speed of convergence is higher since the estimation is conducted in a credit-constrained open economy setting.

School attainment for male and female population over age 25 have positive correlation with the growth level. The coefficient for the male variable, ***humanm***, is 0.00708 while for the female variable, ***humanf***, is 0.00405. While *humanm* is significant (*p-value* = 0.041), *humanf* is not (*p-value* = 0.232). Life expectancy at birth has positive and significant effect (p-value = 0.000) on the growth rate with the estimated coefficient of 0.0773. The human resource variables, namely humanm, humanf, and ln(lifee0) all have the expected signs.

The first control variable, *open* which measures the degree of openness of a country to international trade, has an inverse relationship with growth. The estimated coefficient is -0.000125 and is significant (p-value = 0.04). The fact that the coefficient is negative implies that openness is a disincentive to economic growth for those (debtor) developing countries.

Public spending on education *geexp*, which is intended to capture the quality of education, has a positive and significant effect on the growth level. The estimated coefficient is 1.0617 with the *p-value* of 0.000. Higher public spending on education which increase the quality of education results in an increase in productivity and, hence, an increase in domestic product and growth.

The political instability variable *pinstab*, as expected, has an inverse relationship with the growth level. The estimated coefficient is -0.02142 with the *p-value* of 0.222. Hence, this variable is not significant. The black market premium on foreign exchange, *ln(bmp)*, has negative and significant effect on the growth level. The estimated coefficient is -0.0383 with the *p-value* of 0.000. Distortion in the foreign exchange market hinders the performance of the economy and slow down the production process.

External debt ratio, *d/GNP*, has a negative and significant effect on the growth level. The estimated coefficient is -0.03296 with the p-value of 0.000. Debt repayment by debtor developing countries which requires the use of foreign exchange reserve may hinder developing countries to grow faster. This finding is more direct than the results of others who use foreign aid as the independent variable. The general finding is that foreign aid does not have significant effect on growth.

An addition of HIPC dummy variable yields similar estimated coefficient for the state and control variables. The dummy variable itself has an estimated coefficient of -0.0344 and is highly significant (*p-value* = 0.000). This shows that countries which are members of HIPC on average have lower rate of growth.

The effect os external debt to growth may take an indirect route. Therefore, in order to supplement the main analysis, debt overhang hypothesis is tested using simultaneous equations and panel data from fourteen developing countries. The debt overhang hypothesis states that the external debt burden provides a disincentive to domestic investment in developing countries and thus slow economic growth since any additional foreign exchange earnings would have to be turned over to foreign creditors. Assuming that the panel data has a one-way error component model, Baltagi's error component two stage least square

(EC2SLS) is used as a method of estimation. Two over-identified equations are used in the estimation, namely investment and growth equations.

The estimation shows modest support of debt overhang hypothesis. In the investment equation, the debt ratio has the correct sign but insignificant in affecting investment. The estimated coefficient is -0.1496 with the *t-ratio* of -0.4336. The effect of investment on growth, in the growth equation, is also insignificant even though the expected sign is achieved. The estimated coefficient is 0.0011 with the *t-ratio* of 1.613.

The general finding that external debt tends to have an inverse relationship with growth suggests that relying on external debt to boost economic growth is not a good policy. Instead, developing countries may be better off by trying to reduce their external debt and supplement their lack of domestic saving with other forms of foreign capital such as foreign direct investment.

REFERENCES

Alesina, Alberto and Beatrice Weder, 1999, "Do Corrupt Governments Receive Less Foreign Aid?" NBER working paper, No. W7108.

Balestra, P. and J. Varadharajan-Krishnakumar, 1987, "Full Information Estimations of a System of Simultaneous Equations With Error Component Structure," *Econometric Theory*, 3, 223-246.

Baltagi, Badi H., 1981, "Simultaneous Equations With Error Component," *Journal of Econometrics*, 17, 189-200.

Baltagi, Badi H., 1995, "Econometric Analysis of Panel Data," John Wiley & Sons.

Baltagi, Badi H. and Q. Li, 1992, "A Note on The Estimation of Simultaneous Equations With Error Components," *Econometric Theory*, 8, 113-119.

Baltagi, Badi H. and Sophon Khanti-Akom, 1990, "On Efficient Estimation With Panel Data: An Empirical *Comparison* of Instrumental Variables Estimators," *Journal of Applied Econometrics*, 5, 401-406.

Banks, Arthur S., 1979, "Cross-National Time Series Data Archive," Center for Social Analysis, State University of New York, Binghamton.

Barro, Robert J., 1997, "Determinants of Economic Growth: A Cross-Country Empirical Study," The MIT Press, Cambridge, Massachusetts.

Barro, Robert J., 1994, "Economic Growth and Convergence," Occasional Papers No. 46, International Center for Economic Growth, San Francisco, California.

Barro, Robert J., and Jong-Wha Lee, 1994, "International Comparisons of Educational Attainment," *Journal of Monetary Economics*, 32, 3, 363-394.

Barro, Robert J., and Xavier Sala-I-Martin, 1992, "Convergence," *Journal of Political Economy*, 100, 2 (April), 223-251.

Barro, Robert J., and Xavier Sala-I-Martin, 1995, "Economic Growth," McGraw-Hill Inc.

Bauer, P.T., 1972, "Dissent on Development: Studies and Debates in Development Economics," Harvard University Press.

Berg, Andrew and Jeffrey Sachs, 1988, "The Debt Crisis: Structural Explanations of Country Performance," *Journal of Development Economics*, 29, 271-306.

Bhagwati, Jagdish, 1966, "The Economics of Underdeveloped Countries," McGraw Hill, New York.

Borensztein, Eduardo, 1990, "Debt Overhang, Credit Rationing and Investment," *Journal of Development Economics*, 32, 315-335.

Borensztein, Eduardo, 1990, "Debt Overhang, Debt Reduction and Investment: The Case of the Philippines," Working Paper 90/77, International Monetary Fund.

Cass, David, 1965, "Optimum Growth in an Aggregative Model of Capital Accumulation," *Review of Economic Studies*, 32 (July), 233-240.

Chenery, Hollis B. and Alan M. Strout, 1966, "Foreign Assistance and Economic Development," *The American Economic Review*, Vol. LVI, Number 4, Part I.

Chiang, Alpha C., 1984, "Fundamental Methods of Mathematical Economics, third edition, New York, McGraw-Hill, Inc.

Chiang, Alpha C., 1992, "Elements of Dynamic Optimization," New York, McGraw-Hill, Inc.

Cohen, Daniel, 1990, "Slow Growth and Large LDC Debt in the Eighties: An Update," CEPREMAP unpublished manuscript, Paris.

Cornwell, Christopher and Peter Rupert, 1988, "Efficient Estimation With Panel Data: An Empirical Comparison of Instrumental Variables Estimators," *Journal of Applied Econometrics*, 3, 149-155.

Cornwell, C., P. Schmidt and D. Wyhowski, 1992, "Simultaneous Equations and Panel Data," *Journal of Econometrics*, 51, 151-181.

Domar, Evsey, 1946, "Capital Expansion, Rate of Growth, and Employment," *Econometrica*, 14, 137-147.

Easterly, William, 1999, "How Did Highly Indebted Poor Countries Become Highly Indebted?," the World Bank working paper, September 1999.

Harrod, Roy F., 1939, "An Essay in Dynamic Theory," *Economic Journal*, 49 (June), 14-33.

Harrod, Roy F., 1942, "Toward a Dynamic Economics: Some Recent Development of Economic Theory and Their Application to Policy," London, Macmillan.

Inada, Ken-Ichi, 1963, "On a Two-Sector Model of Economic Growth: Comments and Generalization," *Review of Economic Studies*, 30 (June), 119-127.

Kaminsky, Graciela L. and Alfredo Pereira, 1996, "The Debt Crisis: lessons of the 1980s for the 1990s," *Journal of Development Economics*, 50, 1-24.

Koopmans, Tjalling C., 1965, "On the Concept of Optimal Economic Growth," in *The Econometric Approach to Development Planning*, Amsterdam, North Holland.

Krugman, Paul, 1988a, "Financing vs. Forgiving a Debt Overhang," *Journal of Development Economics*, 29, 253-268.

Krugman, Paul, 1988b, "Market-Based Debt Reduction Schemes," NBER Working Paper No. 2587.

Leme, Maria Carolina da Silva, 1993, "External Debt and Foreign Direct Investment: The Brazilian Experience," dissertation, *The University of California, Los Angeles.*

Leontief, Wassily, 1941, "The Structure of the American Economy: 1919-1929," Cambridge MA., Hardvard University Press.

Lucas, Robert E., Jr., 1988, "On the Mechanics of Economic Development," *Journal of Monetary Economics*, 22, 1 (July), 3-42.

Oberhofer, Walter and Jan Kmenta, 1974, "A General Procedure for Obtaining Maximum Likelihood Estimates in Generalized Regression Models," Econometrica, 42:3 (May), 579-590.

Ramsey, Frank, 1928, "A Mathematical Theory of Saving," *Economic Journal*, 38 (December), 543-559.

Rostow, W.W., 1960, "The Stages of Economic Growth: A Non Communist Manifesto," Cambridge.

Sachs, Jeffrey, 1988, The Debt Overhang of Developing Countries," in Ronald Findlay, ed., *Debt, Growth and Stabilization: Essay in Memory of Carlos Diaz Alejandro*, Oxford, UK: Blackwell.

Sawada, Yasuyuki, 1994, "Are the Heavily Indebted Countries Solvent?: Tests of Intertemporal Borrowing Constraints," *Journal of Development Economics*, 45, 325-337.

Summers, Robert and Alan Heston, 1991, "The Penn World Tables (Mark 5): An Expanded Set of International Comparisons, 1950-1988," *Quarterly Journal of Economics*, 106, 1, 327-368.

Todaro, Michael P., 1997, "Economic Development," 6th edition, Addison-Wesley Publishing Company.

Uzawa, Hirofumi, 1965, "Optimal Technical Change in an Aggregative Model of Economic Growth," *International Economic Review*, 6 (January), 18-31.

Warner, Andrew, 1992, "Did the Debt Crisis Cause the Investment Crisis?," *Quarterly Journal of Economics*, 107, 4, 1161-1186.

World Bank, 1986, "World Debt Tables," 1985-1986 edition (World Bank, Washington, DC).

World Bank, 1987, "World Debt Tables, " 1986-1987 edition (World Bank, Washington, DC).

World Bank, 1996, "World Debt Tables," 1996 edition (World Bank, Washington, DC).

APPENDIX

Appendix A. Countries in the Sample

Table A1. Countries in the Sample for the Estimation of Model 1 and Model 2

No.	SH Code	Country	1970-1974	1975-1979	1980-1984
1	1	Algeria	√	√	√
2	4	Botswana	√	√	√
3	7	Cameroon	-	√	√
4	9	Central Africa R.	-	√	√
5	12	Congo	-	-	√
6	17	Gambia	-	√	√
7	18	Ghana	√	√	√
8	22	Kenya	√	√	√
9	23	Lesotho	√	-	√
10	24	Liberia	√	√	√
11	26	Malawi	√	√	√
12	27	Mali	-	√	√
13	29	Mauritius	-	√	√
14	33	Niger	-	-	√
15	36	Rwanda	-	√	√
16	37	Senegal	√	-	-
17	39	Sierra Leone	-	√	√
18	42	Sudan	-	-	√
19	43	Swaziland	-	√	√
20	44	Tanzania	√	√	√
21	45	Togo	√	√	√
22	46	Tunisia	-	-	√
23	47	Uganda	√	√	√

No.	SH Code	Country	1970-1974	1975-1979	1980-1984
24	49	Zambia	√	√	√
25	50	Zimbabwe	-	-	√
26	55	Costa Rica	√	√	√
27	57	Dominican Rep.	√	√	√
28	58	El Salvador	√	√	√
29	60	Guatemala	√	√	√
30	61	Haiti	√	√	√
31	62	Honduras	√	√	√
32	63	Jamaica	√	√	√
33	64	Mexico	√	√	√
34	65	Nicaragua	√	√	√
35	66	Panama	√	√	√
36	71	Trinidad & Tobago	-	√	√
37	73	Argentina	√	√	√
38	74	Bolivia	√	√	√
39	75	Brazil	√	√	√
40	76	Chile	√	√	√
41	77	Colombia	√	√	√
42	78	Ecuador	√	√	√
43	79	Guyana	-	√	√
44	80	Paraguay	-	√	√
45	81	Peru	√	√	√
46	83	Uruguay	√	√	√
47	84	Venezuela	√	√	√
48	86	Bangladesh	√	√	√

No.	SH Code	Country	1970-1974	1975-1979	1980-1984
49	90	India	√	√	√
50	91	Indonesia	√	√	√
51	96	Jordan	√	√	√
52	97	Korea, Rep.	√	√	√
53	100	Malaysia	√	√	√
54	103	Nepal	√	√	√
55	105	Pakistan	√	√	√
56	106	Philippines	√	√	√
57	109	Singapore	√	√	-
58	110	Sri Lanka	-	-	√
59	111	Syria	√	√	√
60	113	Thailand	√	√	√
61	115	Yemen	-	√	√
62	119	Cyprus	-	√	√
63	126	Greece	√	√	√
64	132	Malta	√	√	√
65	136	Portugal	√	√	√
66	141	Turkey	√	√	√
67	144	Yugoslavia	√	√	√
68	148	Papua New Guinea	-	√	-

Note: SH Code is the code in the Summer and Heston's Penn World Trade Table v. 5.6.

Appendix B. The Means and Standard Deviations of the Dependent and Explanatory Variables

Table A2. The Means and Standard Deviations of the Dependent and Explanatory Variables in Model 1 and Model 2

Variables	Means 1970-1974 Sample (48 Observ.)	Standard Deviations 1970-1974 Sample (48 Observ.)	Means 1975-1979 Sample (60 Observ.)	Standard Deviations 1975-1979 Sample (60 Observ.)	Means 1980-1984 Sample (65 Observ.)	Standard Deviations 1980-1984 Sample (65 Observ.)
Growth Rate	0.0309	0.0379	0.0272	0.0341	0.0081	0.1245
Ln(GDP)	7.3890	0.6946	7.5175	0.7368	7.5824	0.7582
Humanm	3.2561	1.5922	3.5027	1.8239	3.9236	1.8968
Humanf	2.2150	1.5679	2.4621	1.8428	2.8203	1.9752
Ln(lifee0)	3.9997	0.1546	4.0283	0.1687	4.0508	0.1615
Open	50.351	36.220	65.418	45.277	69.214	39.114
Geexp	0.0348	0.0129	0.0376	0.0165	0.0411	0.0173
Pinstab	0.1238	0.2039	0.1111	0.1427	0.1249	0.2143
Ln(BMP)	0.2244	0.2990	0.2216	0.3671	0.3342	0.4622
Debt/GNP	0.2069	0.1310	0.2495	0.1613	0.4654	0.3235

Note: The numbers for *Ln(GDP)*, *Humanm*, *Humanf*, and *Ln(lifee0)* refer to initial values for each 5-year sub periods while *Growth Rate*, *Open*, *Geexp*, *Pinstab*, *Ln(BMP)*, and *Debt/GNP* are 5-year averages for each 5-year sub periods.

Appendix C. Cookbook Procedure for Solving Dynamic Optimization Using Optimal Control Theory

The typical problem would be a representative agent chooses a number of variables, called *control variable*, so as to maximize an objective function subject to some constraints. These constraints are dynamic and are represented by a set of *state variables* that evolve over time. The problem is given by

$$\max_{c(t)} U(0) = \int_0^T u[y(t), c(t), t] \cdot dt \tag{A-1}$$

subject to

$$\text{(a)} \quad \dot{y}(t) = g[y(t), c(t), t] \tag{A-2}$$

$$\text{(b)} \quad y(0) = k_0 > 0 \tag{A-3}$$

$$\text{(c)} \quad y(T) \cdot e^{-\bar{\rho}(T) \cdot T} \geq 0 \tag{A-4}$$

where *U(0)* is the value of the objective function at $t = 0$ (initial moment), $\bar{\rho}$ is an average discount rate that applies between dates *0* and *t*, and *T* is the terminal planning date, which could be finite or infinite. If the problem is minimization, simply change the objective function into $U(0) = \int_0^T u[y(t), c(t), t] \cdot dt$. The variable *y(t)* is the *state variable* and the variable c(t) is the *control variable*. *u(·)* is the instantaneous felicity function that depends on the state variable, control variable, and on time t. Equation (a) is the *transition equation* or *equation of motion*. Equation (b) is the initial condition which says that the state variable, $y(t)$, start at a given value, y_0. Equation (c), the last constraint, is the final (terminal) condition which says that the chosen value of the state variable at the end of the planning horizon, $y(t)$, discounted at the rate $\bar{\rho}(T)$, must be nonnegative.

The cookbook procedure to solve this problem involves the following steps:

Step 1: A Hamiltonian function is constructed by adding to the felicity function, $u(\cdot)$, a Lagrange multiplier times the right-hand side of the transition equation:

$$H = u(y,c,t) + \lambda(t)\cdot g(y,c,t) \tag{A-5}$$

Step 2: Take the first derivative of the Hamiltonian, equation (A-5), with respect to the control variable and set it to 0:

$$\partial H/\partial c = \partial u/\partial c + \lambda(t)\cdot \partial g/\partial c = 0 \tag{A-6}$$

Step 3: Take the first derivative of the Hamiltonian with respect to the state variable and set it to equal the negative of the derivative of the Lagrange multiplier with respect to tine:

$$\partial H/\partial y = \partial u/\partial k + \lambda \cdot \partial g/\partial y = -\dot{\lambda} \tag{A-7}$$

Step 4: This step involves the tranversality condition with three possibilities,

Case a: Finite horizons. Set the product of the shadow price and the capital stock at the end of the planning horizon to 0:

$$\lambda(T)\cdot y(T) = 0 \tag{A-8}$$

Case b: Infinite horizons with discounting. The transversality condition is

$$\lim_{t \to \infty} \left[\lambda(t) \cdot y(t) \right] = 0 \qquad \text{(A-9)}$$

Case c: Infinite horizons without discounting. Use Michel's condition which is

$$\lim_{t \to \infty} \left[H(t) \right] = 0 \qquad \text{(A-10)}$$

Step 5: Equation (A-2), (A-6), and (A-7) can be combined to form a system of two differential equations in the variables λ and y. Alternatively, equation (A-6) can be used to transform the ordinary differential equation for $\dot{\lambda}$ into an ordinary differential equation for $\dot{c}$. Two boundary conditions are needed for the system to be determinate. Equation (A-3) provides the initial condition of the state variable, *y(0)*. Depending on the nature of the problem, one terminal condition is given by the transversality condition, equation (A-8), (A-9), or (A-10).

Appendix D. Log-Linearization of the Ramsey Model[30]

The Ramsey model is characterized by the system of differential equations given from equation (3.29) and (3.30) by

$$\dot{\hat{k}} = f(\hat{k}) - \hat{c} - (x + \mu + \delta)\cdot\hat{k} \tag{A-11}$$

and $$\dot{\hat{c}}/\hat{c} = \dot{c}/c - x = (1/\theta)\cdot\left[f'(\hat{k}) - \delta - \rho - \theta x\right] \tag{A-12}$$

Assuming that the production function is Cobb-Douglas, $f(\hat{k}) = A\cdot k^{\alpha}$, equations (A-11) and (A-12) can be rewritten in terms of logs of $\hat{k}$ and $\hat{c}$ as

$$d\left[\log(\hat{k})\right]/dt = A\cdot e^{-(1-\alpha)\cdot\log(\hat{k})} - e^{\log(\hat{c}/\hat{k})} - (x + \mu + \delta) \tag{A-13}$$

$$d\left[\log(\hat{c})\right]/dt = (1/\theta)\cdot\left[\alpha A\cdot e^{-(1-\alpha)\cdot\log(\hat{k})} - (\rho + \theta x + \delta)\right] \tag{A-14}$$

In the steady-state, where $d\left[\log(\hat{k})\right]/dt = d\left[\log(\hat{c})\right]/dt = 0$, we get

$$A\cdot e^{-(1-\alpha)\cdot\log(\hat{k}^{*})} - e^{\log(\hat{c}^{*}/\hat{k}^{*})} = (x + \mu + \delta) \tag{A-15}$$

$$\alpha A\cdot e^{-(1-\alpha)\cdot\log(\hat{k}^{*})} = (\rho + \theta x + \delta) \tag{A-16}$$

[30]As explained in Barro and Sala-i-Martin (1992) and Barro and Sala-i-Martin (1995), 87-88.

First-order Taylor expansion of equations (A-13) and (A-14) around the steady state values determined by equations (A-15) and (A-16) yields,

$$\begin{bmatrix} d\left[\log(\hat{k})\right]/dt \\ d\left[\log(\hat{c})\right]/dt \end{bmatrix} =$$

$$\begin{bmatrix} \zeta & x+\mu+\delta-(\rho+\theta x+\delta)/\alpha \\ -(1-\alpha)\cdot(\rho+\theta x+\delta)/\theta & 0 \end{bmatrix} \cdot \begin{bmatrix} \log(\hat{k}/\hat{k}^{*}) \\ \log(\hat{c}/\hat{c}^{*}) \end{bmatrix} \qquad \text{(A-17)}$$

where $\zeta \equiv \rho - \mu - (1-\theta)\cdot x$. The determinant of the characteristic matrix equals

$$-\left[(\rho+\theta x+\delta)/\alpha - (x+\mu+\delta)\right]\cdot(\rho+\theta x+\delta)\cdot(1-\alpha)/\theta$$

This determinant is negative since $\alpha < 1$ and $\rho + \theta x > x + \mu$ (from the transversality condition in equations (3.31) and (3.34)). This condition implies that the two eigenvalues of the system have opposite signs which, then, implies a saddle-path stability.

The eigenvalues, denoted by ϵ, is computed by assuming that

$$\det\begin{bmatrix} \zeta-\varepsilon & x+\mu+\delta-(\rho+\theta x+\delta)/\alpha \\ -(1-\alpha)\cdot(\rho+\theta x+\delta)/\theta & 0 \end{bmatrix} = 0 \qquad \text{(A-18)}$$

which corresponds to a quadratic equation in ϵ:

$$\varepsilon^2 - \zeta\cdot\varepsilon - \left[(\rho+\theta x+\delta)/\alpha - (x+\mu+\delta\right]\cdot\left[(\rho+\theta x+\delta)\cdot(1-\alpha)/\theta\right] = 0 \qquad \text{(A-19)}$$

with two solutions:

$$2\varepsilon = \zeta \pm \left[\zeta^2 + 4\cdot\left(\frac{1-\alpha}{\theta}\right)\cdot(\rho+\theta x+\delta)\cdot\left[(\rho+\theta x+\delta)/\alpha-(x+\mu+\delta)\right]\right]^{1/2} \quad \text{(A-20)}$$

where ϵ_1 is positive and ϵ_2 is negative.

The log-linearized solution for $\log(\hat{k})$ takes the form

$$\log\left[\hat{k}(t)\right] = \log(\hat{k}^*) + \psi_1 \cdot e^{\varepsilon_1 t} + \psi_2 \cdot e^{\varepsilon_2 t} \quad \text{(A-21)}$$

where ψ_1 and ψ_2 are arbitrary constants of integration. Since $\epsilon_1 > 0$, $\psi_1 = 0$ must hold for $\log\left[\hat{k}(t)\right]$ to tend asymptotically to $\log(\hat{k}^*)$. ($\psi_1 > 0$ violates the transversality condition, and $\psi_1 < 0$ leads to $\hat{k} \rightarrow 0$, which corresponds to cases in which the system hits the vertical axis in Figure 3.3.). The other constant, ψ_2, is determined from the initial condition:

$$\psi_2 = \log\left[\hat{k}(0)\right] - \log(\hat{k}^*) \quad \text{(A-22)}$$

Substituting $\psi_1 = 0$, the value of ψ_2 from equation (A-22), and $\epsilon_2 = -\beta$ into equation (A-21), we get the time path for $\log\left[\hat{k}(t)\right]$:

$$\log\left[\hat{k}(t)\right] = (1-e^{-\beta t})\cdot\log(\hat{k}^*) + e^{-\beta t}\cdot\log\left[\hat{k}(0)\right] \quad \text{(A-23)}$$

Since $\log\left[\hat{y}(t)\right] = \log(A) + \alpha \cdot \log\left[\hat{k}(t)\right]$, the time path for $\log\left[\hat{y}(t)\right]$ is given by

$$\log\left[\hat{y}(t)\right] = e^{-\beta t} \cdot \log\left[\hat{y}(0)\right] + (1 - e^{-\beta t}) \cdot \log(\hat{y}^{*}) \tag{A-24}$$

which is equation (3.36).

Appendix E. Countries and Variables in the Debt Overhang Hypothesis

Table A3. Classification of DRS Economies

SILICs		SIMICs	MILICs	MIMICs
Burundi	Mozambique	Algeria	Albania	Cape Verde
Cambodia	Myanmar	Angola	Bangladesh	Chile
Cameroon	Nicaragua	Argentina	Benin	Colombia
Central Africa	Niger	Bolivia	Chad	Dominican Rep.
Rep	Nigeria	Brazil	Comoros	Hungary
Congo	Rwanda	Bulgaria	Egypt, Arab Rep.	Indonesia
Cote d'Ivoire	Sao Tome & Pr.	Ecuador	Gambia, The	Morocco
Equatorial Guinea	Sierra Leone	Gabon	Haiti	Papua New
Ethiopia	Somalia	Jamaica	India	Guinea
Ghana	Sudan	Jordan	Lao PDR	Philippines
Guinea	Tanzania	Mexico	Malawi	Russian
Guinea-Bissau	Togo	Panama	Nepal	Federation
Guyana	Uganda	Peru	Pakistan	Tunisia
Honduras	Vietnam	Poland	Senegal	Turkey
Kenya	Yemen, Rep. of	Syrian Arab Rep.	Zimbabwe	Uruguay
Liberia	Zaire			Venezuela
Madagaskar	Zambia			Western Samoa
Mali				
Mauritania				

LILICs	LIMICs			
Armenia	Barbados	Grenada	Mauritius	Swaziland
Azerbaijan	Belarus	Guatemala	Moldova	Thailand
Bhutan	Belize	Iran, Islamic Rep.	Oman	Tonga
Burkina Faso	Botswana	Kazakstan	Paraguay	Trinidad &
China	Costa Rica	Korea, Rep. of	Romania	Tobago
Georgia	Croatia	Latvia	Seychelles	Turkmenistan
Kyrgyz Rep.	Czech Rep.	Lebanon	Slovak Rep.	Ukraine
Lesotho	Djibouti	Lithuania	Slovenia	Uzbekistan
Mongolia	Dominica	Macedonia, FYR	Solomon Islands	Vanuatu
Sri Lanka	El Salvador	Malaysia	St. Kitts and	Yugoslavia
Tajikistan	Estonia	Maldives	Nevis	
	Fiji	Malta	St. Lucia	
			St. Vincent	

Source : World Bank, Debtor Reporting System

Table A4. Developing Countries in the Sample for Debt Overhang Analysis

Countries	Classification
Argentina	SIMIC
Bolivia	SIMIC
Brazil	SIMIC
Chile	MIMIC
Colombia	MIMIC
Equador	SIMIC
Indonesia	MIMIC
Mexico	SIMIC
Morocco	MIMIC
Nigeria	SILIC
Peru	SIMIC
Philippines	MIMIC
Uruguay	MIMIC
Venezuela	MIMIC

Table A5. Variables and its Source in the Debt Overhang Analysis

Variables	Source
(I/GDP)	Penn World Table
Inflation	Penn World Table
(Debt/GNP)	World Debt Tables, World Bank
Pinstab.	Barro & Lee
Growth	Penn World Table
Open	Penn World Table
STLIV	Penn World Table
Henroll	Barro & Lee

Appendix F. Error Component Two-Stage Least-Squares (EC2SLS) as explained by Baltagi (1995).

In a simultaneous equation model, consider the first structural equation, i.e.

$$y_1 = Z_1\delta_1 + u_1 \tag{A-11}$$

where $Z_1 = [Y_1,X_1]$ and $\delta_1' = (\gamma_1',\beta_1')$. Y_1 is the set of g_1 right-hand side endogenous variables, and X_1 is the set of k_1 included exogenous variables. Let $X = [X_1,X_2]$ be the set of all exogenous variables in the system. The identification requires that k_2 the number of excluded exogenous variables from the first equation (X_2) being larger than or equal to g_1.

In equation (A-11), the disturbance (u_1) is assumed to follow a one-way error component model of the form:

$$u_1 = Z_\mu \mu_1 + \nu_1 \tag{A-12}$$

where $Z_\mu = (I_N \otimes \iota_T)$ and $\mu_1' = (\mu_{11}, \ldots\ldots\ldots, \mu_{N1})$ and $\nu_1' = (\nu_{111}, \ldots\ldots\ldots\ldots, \nu_{NT1})$ are random vectors with zero means and covariance matrix

$$E\begin{pmatrix}\mu_1\\ \nu_1\end{pmatrix}(\mu_1', \nu_1') = \begin{bmatrix}\sigma^2_{\mu_{11}} I_N & 0\\ 0 & \sigma^2_{\nu_{11}} I_{NT}\end{bmatrix} \tag{A-13}$$

and

$$E(u_1u_1') = \Omega_{11} = \sigma^2_{\nu_{11}} I_{NT} + \sigma^2_{\mu_{11}}(I_N \otimes J_T) \tag{A-14}$$

We can, then, transform (A-11) by $Q = I_{NT} - P$ with $P = I_N \otimes \bar{J}_T$, to get

$$Qy_1 = QZ_1\delta_1 + Qu_1 \tag{A-15}$$

Let $\tilde{y}_1 = Qy_1$ and $\tilde{Z}_1 = QZ_1$. Performing 2SLS on (A-15) with $\tilde{X} = QX$ as the set of instrument, we get the Within 2SLS

$$\tilde{\delta}_{1,W2SLS} = (\tilde{Z}_1' P_{\tilde{X}} \tilde{Z}_1)^{-1} \tilde{Z}_1' P_{\tilde{X}} \tilde{y}_1 \tag{A-16}$$

with $\operatorname{var}(\hat{\delta}_{1,W2SLS}) = \sigma^2_{\nu_{11}} (\tilde{Z}_1' P_{\tilde{X}} \tilde{Z}_1)^{-1}$.

Similarly, if we let $\bar{y}_1 = Py_1$ and $\bar{Z}_1 = PZ_1$, we can transform (A-11) by P and perform 2SLS with $\bar{X} = PX$ as the set of instruments. In this case, we get the Between 2SLS estimator of δ_1

$$\hat{\delta}_{1,B2SLS} = (\bar{Z}_1' P_{\bar{X}} \bar{Z}_1)^{-1} \bar{Z}_1' P_{\bar{X}} \bar{y}_1 \tag{A-17}$$

with $\operatorname{var}(\hat{\delta}_{1,B2SLS}) = \sigma^2_{1_{11}} (\bar{Z}_1' P_{\bar{X}} \bar{Z}_1)^{-1}$. Where $\sigma^2_{1_{11}} = T\sigma^2_{\mu_{11}} + \sigma^2_{\nu_{11}}$.

Stacking these two transformed equations in (A-16) and (A-17), and noting that δ_1 is the same for these two transformed equations, we get

$$\begin{pmatrix} \tilde{X}'\tilde{y}_1 \\ \bar{X}'\bar{y}_1 \end{pmatrix} = \begin{pmatrix} \tilde{X}'\tilde{Z}_1 \\ \bar{X}'\bar{Z}_1 \end{pmatrix} \delta_1 + \begin{pmatrix} \tilde{X}'\tilde{u}_1 \\ \bar{X}'\bar{u}_1 \end{pmatrix} \tag{A-18}$$

where

$$E\begin{pmatrix}\widetilde{X}'\widetilde{u}_1\\ \overline{X}'\overline{u}_1\end{pmatrix}=0 \quad \text{and} \quad var\begin{pmatrix}\widetilde{X}'\widetilde{u}_1\\ \overline{X}'\overline{u}_1\end{pmatrix}=\begin{bmatrix}\sigma^2_{\nu_{11}}\widetilde{X}'\widetilde{X} & 0\\ 0 & \sigma^2_{1_{11}}\overline{X}'\overline{X}\end{bmatrix}$$

The error component two-stage least squares (EC2SLS) estimator of δ_1 derived by Baltagi (1981) can be calculated by performing GLS on (A-18) which yield:

$$\hat{\delta}_{1,EC2SLS}=\left[\frac{\widetilde{Z}_1'P_{\widetilde{X}}\widetilde{Z}_1}{\sigma^2_{\nu_{11}}}+\frac{\overline{Z}_1'P_{\overline{X}}\overline{Z}_1}{\sigma^2_{1_{11}}}\right]^{-1}\left[\frac{\widetilde{Z}_1'P_{\widetilde{X}}\widetilde{y}_1}{\sigma^2_{\nu_{11}}}+\frac{\overline{Z}_1'P_{\overline{X}}\overline{y}_1}{\sigma^2_{1_{11}}}\right] \tag{A-19}$$

and the $var(\hat{\delta}_{1,EC2SLS})$ is given by the first inverted bracket in (A-19).

Using the residuals from W2SLS and B2SLS, we can get the consistent estimates of $\sigma^2_{\nu_{11}}$ and $\sigma^2_{1_{11}}$ with the following expression:

$$\hat{\sigma}^2_{\nu_{11}} = (y_1 - Z_1\widetilde{\delta}_{1,W2SLS})'Q(y_1 - Z_1\widetilde{\delta}_{1,W2SLS})/N(T-1) \tag{A-20}$$

$$\hat{\sigma}^2_{1_{11}} = (y_1 - Z_1\hat{\delta}_{1,B2SLS})'P(y_1 - Z_1\hat{\delta}_{1,B2SLS})/N \tag{A-21}$$

Feasible estimate of EC2SLS can be obtained by substituting these variance components estimates in equation (A-19). From this it is apparent that the difference between the standard 2SLS procedure and EC2SLS is that the later requires estimates of the variance component.

An alternative way to get the vector estimates of EC2SLS is by premultiplying (A-11) by $\Omega_{11}^{-1/2}$, where Ω_{11} is given in (A-14), to get

$$y_1^* = Z_1^*\delta_1 + u_1^* \tag{A-22}$$

with $y_1^* = \Omega_{11}^{-1/2} y_1$, $Z_1^* = \Omega_{11}^{-1/2} Z_1$, and $u_1^* = \Omega_{11}^{-1/2} u_1$. In this case, $\Omega_{11}^{-1/2}$ is given by the following expression:

$$\Omega_{11}^{-1/2} = (Q/\sigma_{\nu_{11}}) + (P/\sigma_{1_{11}}) \tag{A-23}$$

Hence, the typical element of y_1^* is $y_{1_{it}}^* = (y_{1_{it}} - \theta_1 \bar{y}_{1_i})/\sigma_{\nu_{11}}$ where

$\theta_1 = 1 - (\sigma_{\nu_{11}} / \sigma_{1_{11}})$ and

$\bar{y}_{1_i} = \sum_{t=1}^{T} y_{1_{it}} / T$.

Given a set of instrument A, then 2SLS on (A-22) using A gives:

$$\delta_{1,2SLS} = (Z_1^{*\prime} P_A Z_1^*)^{-1} Z_1^* P_A y_1^* \tag{A-24}$$

Cornwell, Schmidt and Wyhowski (1992) shows that Baltagi's EC2SLS can be obtained from (A-24), i.e. using a 2SLS package on the transformed equation (A-22) with the set of instruments A = [QX, PX] = $[\tilde{X}, \bar{X}]$. In practice, we run W2SLS and B2SLS using a standard 2SLS package that computes equations (A-16) and (A-17). Then we compute $\hat{\sigma}_{\nu_{11}}$ and $\hat{\sigma}_{1_{11}}$ from (A-20) and (A-21). We, then, transform (A-11) by $\Omega_{11}^{-1/2}$ to get

(A-22) and run 2SLS on this transformed equation using the instrument set A = [QX, PX].

The overall procedure involves simple transformation on the data and the application of 2SLS three times.

Appendix G. The Heavily Indebted PoorCountries (As of October 1999)

Table A6. HIPC

Africa		Latin America	Asia	Middle East
Angola	Malawi	Bolivia	Lao, Peoples Dem. Rep.	Yemen, Rep. of
Benin	Mali	Guyana	Myanmar	
Burkina Faso	Mauritania	Honduras	Vietnam	
Burundi	Mozambique	Nicaragua		
Cameroon	Niger			
Cntrl. African Rep	Rwanda			
Chad	Sierra Leone			
Congo	Sao Tome and Principe			
Congo, Dem. Rep.	Senegal			
Cote d'Ivoire	Somalia			
Ethiopia	Sudan			
Ghana	Tanzania			
Guinea	Togo			
Guinea-Bissau	Uganda			
Kenya	Zambia			
Liberia				
Madagaskar				

Source : The World Bank