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The impact of improved nutrition on labor productivity and GDP growth rate in low- and middle-income countries

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The impact of improved nutrition on labor productivity and GDP growth rate in low- and middle-income countries

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Signatures have been redacted for privacy

Table of Contents

List of Figures

List of Tables

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Abstract

This study examined the effects of nutrition on the growth rate of country economies over time. Previous studies on this topic have resulted in debates among researchers over how significant nutritional effects are on individual country economies. For this study, data were collected for four decades (1960s, 1970, 1980s, and 1990s) for 43 low- and middle-income countries. The data were analyzed to determine the effect of nutrition, represented by dietary energy supply (DES), on the growth rate of gross domestic product (GDP) per worker and on labor productivity. The research utilized ordinary least squares, instrumental variables, and random effects regressions in the context of the Solow growth rate model. The research revealed that nutrition did, indeed, have an effect on the economies, but the impact was not very significant for GDP growth rate per worker and labor productivity. The t-statistic for the nutrition variable did not support the contribution of DES to growth rate GDP per worker. On the contrary, other variables such as capital per worker and literacy rate showed stronger impacts than did the DES variable.

Introduction

Economic development plays an important role in improving population health (Pan American Health Organization [PAHO]). Food and nutrition needs are determined by an individual's age and gender and by the amount of work they do. Food and beverages are the sources of energy, protein, vitamins, and mineral to meet these energy needs. In low-income countries, the average available dietary energy is frequently below the energy requirement, and this shortfall leads to low intensity of effort at work or short work days. Hence, as (DES) Dietary Energy Supply increases, it is an interesting issue to determine how economic growth is affected. Fogel was the first to raise this issue as a concern to the economic growth of the U.S. South before 1965.

Health and economic outcomes are linked to each other in a causality way in both directions. First, higher income leads to higher human capital investment, of which health is one aspect. Second, a good health causes an increase in productivity because the worker is more energetic and less vulnerable to disease (Thomas and Frankenberg).

The PAHO tried to answer the question of how important the long-term effects of good nutrition and human health are on the formation and the accumulation of human capital, labor productivity, and the competitiveness of the labor force, and on long-term economic growth.

Strauss and Thomas (1998) stated that an improvement in health results in an improvement in functionality and productivity of labor. Moreover, they argued that adults in poorer countries are more likely to be affected with health problems than are those in richer countries, which results in reduced labor productivity because the work in poorer countries relies on strength and endurance, which requires good health. In PAHO, Suarez noted that, "We suspected that certain populations rank low in human capital not only for reasons of genetic heritage but also because of the cumulative effect of generations of poverty, poor nutrition and poor health" (PAHO, press release). From another point of view, many studies have shown that deficiencies in the nutrients iron, potassium, and vitamin A also lower labor productivity.

In this study, the impact of nutrition will be studied as DES per person. The purpose of this research is to examine the effect of dietary energy supply (DES) on growth of gross domestic product (GDP) per capita of low- and middle-income countries between 1960 to1990. Using observations on decadal average growth rate, we find only mild support for the contribution of dietary energy supply to GDP growth. The results were sensitive to specification of the growth equation, and literacy rates were a stronger explanatory variable than was DES.

In the following discussion, I first review available evidence on the contribution of improved health to economic growth, which can be viewed from a nutrition point of view.

Chapter One

Literature Review

The impact of food and nutrition on economic growth and labor productivity is almost certainly positive. However, an imbalance of energy intakes relative to energy uses leads to weight gain and obesity.

Height at maturity is one proxy of good health, although an individual's height has a genetic component. And, good nutrition of a mother during pregnancy is an important determinant of a newborn child's birth weight.

Fogal has shown that, on average, heavier babies have a more highly developed set of vital organs and immune system. An individual's diet during the first three years of life and at puberty are influential in allowing a child to reach his mature height. Furthermore, individuals who are taller at birth in both developing and developed countries have been shown to earn more than shorter do their counterparts. The relationship is that they are, on average, healthier, missing fewer days of work due to illness and being more productive while at work (Strauss and Thomas 1998)

Body mass index

Body mass index (BMI) is one index of short-term dietary quality, given an individual's genetic potential, and is related to energy intake and work, given an individual's height (Strauss and Thomas1998). BMI is the ratio of a person's weight (w) to the square of his/her height (h) (James, Ferro-Luzzi, and Waterlow, 1988; James et al., 1992).[1] BMI has

[1] English formula for calculating BMI: BMI = (weight in pounds/square of height in inches) * 703.
Metric formula for calculating BMI: BMI = (weight in kilograms/square of height in meters) * 10,000.

been found to be an index of both the principal stores of energy (i.e., fats) and the active tissue mass (Dasgupta 1997, p. 13).

According to this measure, the ideal BMI (weight in kilograms and height in meters) range is between 18.5 and 25.0 (Table 1). So, if BMI is over 25.0, an individual is overweight, consuming too many calories relative to the number of calories used for physiological reasons and work. Obesity in adults occurs when BMI equals 30.0 or more. For a 6'2" male or 5'4" female, this index translates into weighing at least 220 lbs. or 180 lbs., respectively.

On the other hand, if BMI is less than 18.5, an individual is most likely undernourished (National Center for Chronic Disease Prevention and health promotion CDC). An individual will be at risk if BMI is less than 17.0. Low BMI is a concern in very poor countries because individuals do not have enough income to purchase enough calories. BMI is sensitive to both short- and long-term imbalances between an individual's energy intake and energy expended in work (Strauss and Thomas).

Table 1.1. The relationship of body mass index and weight status.

BMI	Weight Status
Below 18.5	Underweight
18.5 – 24.9	Normal
25.0 – 29.9	Overweight
30.0 and Above	Obese

It is also useful to view the food balance sheet for a population, which indicates the secular trend in calorie consumption. The Food and Agricultural Organization, United

Nations; United Nation University, and the World Health Organization (FAO, UNU, WHO, 1985), define the energy required to keep the body functioning while at rest as 1,794 cal, and that required for baseline maintenance at 2,279 cal. Fogel also estimated the minimum average number of calories that an individual should have in order to do productive work at 2,000 calories per day.

Mortality rate

The relationship between income and mortality can run in both directions. Earlier studies mainly focused on the relationship between the mortality rate and famine (i.e., the short-term effects). The focus of later studies shifted to nutrition and the decline in mortality rate (i.e., long-term effects) (Sen, 1981). Many studies could not show the exact relationship or the causal effects between income and mortality rate. For instance, in the 18th century, it was not disease that caused the high rate of mortality; on the contrary, it was the increasingly poor diets due to the low level of food availability or poverty in that era (Fogal, 1984). Preston (1975) and Schultz (1990) argued that an increase in income causes improvement in health and reduction in mortality.

Life expectancy

Life expectancy at birth is a measure of early human capital investment by one's parents in health given heredity, which is strongly correlated with the level of economic development. Health is not of interest only because it leads to a higher economic growth rate, but also because it is a marker for the individual's well being. Maddison (2001) mentions that life expectancy at birth in the Middle Ages was only 24 years, and this short expected length of life was correlated with the low subsistence level of GDP per capita. A large share of newborns did not live beyond three years of age (Huffman).

Life expectancy and GDP per capita both increased between 1985 and 1990, and the gap between developing and developed countries narrowed. Over the same period, the gap in GDP per capita between developing and developed countries widened (Perkins, et al.). Currently, life expectancy in Organization for Economic Cooperation and Development (OECD) countries is about 78 years, whereas life expectancy in Africa is only 52 years and in some African countries is approximately 42 years (Huffman and Orazem).

Low Income

Income is an important determinant of the demand for good health when good health is a normal good. Also, studies have shown that food diversity is a luxury food. Hence, poor people tend to have a diet with little variety, which contributes to protean, vitamin, and mineral deficiencies.

Deaton (2003) concluded that people who are income poor are likely to be health poor. Huffman and Orazem examined the relationship between population growth rates and the economic growth rates and concluded that low per capita income led to a persistently low level of labor productivity. Marmot (1994, 2002) suggests that income can be considered as a marker for underlying causes of poor health, the reason being that per capita income is related to the level of consumption, health care, and education level. In poor countries, for example, malnutrition remains a major issue, and most researchers agree that income is a major factor (Case 2001, 2002).

Income inequality

We can also view income inequality as a cause of poor health. Poor people can impose a health externality on others in a society when they catch and spread contagions diseases. Deaton (2003) emphasized that health is the major determinant of well-being. If health status is affected by income inequality, market policies such as tax and transfer policies, which affect income distribution, would also affect the distribution of good health in a society. If a country with a high average income has a high share of inequality in income, then there may be many people with low levels of income who are very poor. (Angus Deaton, 2003)

Education level

Schooling is the single most important form of human capital. Higher education level enhances labor quality and productivity at most jobs and leads to improve decision-making. For example, an individual with more education can better interpret the likely negative outcomes of smoking and overeating on good health. Also, a mother with more education can better read the likely consequences of her child's illness. This is important in poor countries where medical services may be some distance away. Also, individuals can better interpret the effects of diet, including breast-feeding, on good health. Lucas (1988) and Barro (1991) pointed out that better educated people could learn faster. Thus, nutrition is a fundamental condition for human welfare (Johnson.2000).

Labor force participation

Good nutrition leads to more energy and to higher labor force participation and earnings. In contrast, seriously ill people earn less when they work, and they tend to retire earlier than do healthy people (Deaton, 2003). People who consider their health to be their first priority will, on average, postpone the onset of traditional diseases of old age and retirement, and they will be able to earn more and be more creative and more productive.

Based on these studies, we can conclude that nutrition is a very important issue to be studied not only by nutritionists, but also by economists because it affects economic growth.

Chapter Two

Data and Conceptual Framework

Data

The main interest of this study is to examine the effect of dietary energy supply on aggregate labor productivity and the GDP growth rate. The data needed for this study are (a) dietary energy supply (DES) pre capita, (b) average annual growth rate, (c) population growth rate, (d) production level of four main staple crops in the countries (wheat, rice, maize, and milk); (e) capital investment per worker, (f) literacy level, and (g) labor force.

Since serious malnutrition is primarily a concern of developing countries, our analysis is based on data from 43 low- and middle-income countries (Table 2.1). According to the World Bank in 1990, 29 of these countries are low-income countries (Bangladesh, Benin, Burundi, Burkina Faso, Burma, Central Africa, Ethiopia, Guinea, China, India, Indonesia, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Nepal, Niger, Nigeria, Pakistan, Sri Lanka, Sudan, Togo, Uganda, Yemen, Zambia and Ghana), and 14 are middle-income countries (Brazil, Chile, Colombia, Egypt, Jamaica, Mexico, Poland, Turkey, Zimbabwe, Senegal, Argentina, Hungary, South Africa, and Venezuela).

Data Sources

The source of data on DES per capita for each of the 43 countries is the FAO. Statistics on annual GDP and capital investment are from the World Bank Internet site (World Development Report 2000/2001, 1980, 1970), and the labor force growth rate and literacy rate statistics are from the UNESCO database (http://www.uis.unesco.org/TEMPLATE/html/Exceltables/education/View_Table_Literacy_Country_Age15+. Xls).

Table 2.1. Low- and middle-income countries used in this study

	Low-income countries	Middle-income countries
1	Bangladesh	Brazil
2	Benin	Chile
3	Burundi	Colombia
4	Burkina Faso (Upper Volta)	Egypt
5	Burma (Myanmar	Jamaica
6	Central Africa	Mexico
7	Ethiopia	Poland
8	Guinea	Turkey
9	China	Zimbabwe
10	India	Senegal
11	Indonesia	Argentina
12	Kenya	Hungary
13	Liberia	South Africa
14	Madagascar	Venezuela
15	Malawi	
16	Mali	
17	Mauritania	
18	Mozambique	
19	Nepal	
20	Niger	
21	Nigeria	
22	Pakistan	
23	Sri Lanka	
24	Sudan	
25	Togo	
26	Uganda	
27	Yemen	
28	Zambia	
29	Ghana	

The population growth rate is from the U.S. Census Bureau Internet site (http://www.census.gov/cgi-bin/ipc/idbsum?cty=AF). Finally, the production data are from the FAO Internet site (http://faostat.fao.org/faostat/form?collection=Production.

Crops.Primary&Domain=Production&servlet=1&hasbulk=0&version=ext&language=EN).

Overview of the Data

Population growth rate

The population growth rate is an important determinant of the aggregate labor supply.

Population growth rate in low-income countries

During the 1960s, the mean of the average annual growth rate of population for this income subgroup was 2.3 percent per annum with a standard deviation of 0.4 (see Table 2.2). Over the decade of the 1970s, the mean increased to 2.45 percent per annum, with a standard deviation of 0.5y. Over the 1980s, the mean of population growth rate for this subgroup was 2.7 percent per annum, with a standard deviation of 0.6. Over the 1990s, the mean decreased to 2.4 percent per annum, with a standard deviation of 0.8.

Table 2.2. Average annual population growth rate, by decade

	Mean		Standard Deviation	
Decade	LIC	MIC	LIC	MIC
1960s	2.293	2.307	0.44	0.926
1970s	2.451	2.180	0.532	0.807
1980s	2.717	2.042	0.603	0.955
1990s	2.408	1.468	0.796	0.797

Note: LIC = low-income countries; MIC = middle-income countries.

Population growth rate in middle-income countries

The mean of the population growth rate for the middle-income countries for the decades of the 1960s through the 1980s has a negative trend. The mean over the 1960s was 2.3 percent per annum, with a standard deviation of 0.9; over the 1970s, the mean was 2.2 percent per annum, with a standard deviation of 0.8. For the 1980s, the mean was 2.04 percent per annum, with a standard deviation 0.9. For the 1990s, the mean of the average annual growth rate of population was 1.5 percent per annum, with a standard deviation of 0.8.

Annual gross domestic product (GDP)

Annual GDP is an important variable because it represents the value of all final products (goods and services) produced in a country. Personal income is an important part of GDP as well as an important factor in mortality (Leibenstein and Nelson).

GDP must grow faster than population grows for real per capita income to rise and faster than the labor force grows if labor productivity is to increase. For example, some of the countries in this study that experienced an increase in population growth rate also experienced significant decreases in GDP. Over the decades 1990s, the GDP in Burkina Faso decreased from 4.4 percent per year to -2.9 percent per year, and population growth rate increased from 1.5 percent per year to 2.98 percent per year (see Appendix Table 2).

Meanwhile, some of the 43 countries experienced a decrease in population growth rate and an increase in GDP growth (e.g., Argentina, Chile, China, India Bangladesh, Burma, Indonesia, Pakistan Sri Lanka, and Malawi). The highest annual rate of growth occurred in China over the decades of the 1990s, where GDP grew at 10.7 percent per annum. By contrast, the lowest GDP growth rate occurred in Burkina Faso, at -2.9 percent per annum.

From a statistical point of view, which is summarized in Table 2.3, the mean for the low-income countries over the decade of the 1960s was 3.8 percent per annum, with a standard deviation of 2.05. This mean decreased over the decades of the 1970s and 1980s to 3.3 percent and 2.99 percent per annum, respectively. The mean then increased over the decades of the 1990s, to 3.7 percent per annum

For the middle-income countries, the mean of GDP growth rate was 4.9 percent per annum over the decade of the 1960s, with a standard deviation of 2.0 percent. The mean decreased over the decade of the1980s to 2.6 percent, with a standard deviation of 1.8. As in the low-income countries, the mean average growth rate increased over the decade of the 1990s, to 3.69 percent per annum, with a standard deviation of 1.8 percent.

Table 2.3. Average annual growth of gross domestic product, by decade

Decade	Mean		Standard Deviation	
	LIC	MIC	LIC	MIC
1960s	3.789	4.892	2.0506	1.198
1970s	3.30	4.614	2.5869	2.831
1980s	2.993	2.571	2.4300	1.768
1990s	3.686	3.178	2.8695	1.813

Note: LIC = low-income countries; MIC = middle-income countries.

Labor force growth rate

The growth rate of labor force is computed based on the number of individual over the age of 15 working in the labor force in each country (see Appendix Table 2). For each of the groups of countries, on average, the labor force grew over the period of 1960 through 1999 (see Table 2.4). For the low-income countries, the average rate of growth of the labor force over the decades of the 1960s was 2.1 percent per year, increasing to 2.2 percent per annum for the decade of the 1970s, to 2.4 percent for the decade of the 1980s, and to 2.5 percent for the decades of the 1990s. For these countries, the standard deviation was lowest over the decade of the 1960s and the 1970s, at about 0.4 percent per annum. However, the standard deviation over the decade of the 1980s jumped to 0.7 percent per annum and remained at this level in the 1990s.

Table 2.4. Average annual growth rate of labor force, by decade

	Mean		Standard Deviation	
Decade	LIC	MIC	LIC	MIC
1960s	2.086	2.102	0.4023	0.825
1970s	2.223	2.294	0.4210	0.912
1980s	2.440	2.110	0.7158	0.993
1990s	2.451	1.827	0.7086	0.721

Note: LIC = low-income countries; MIC = middle-income countries.

For the middle-income countries, the labor force growth rate was slightly higher than for low-income countries over the decade of the 1960s, at 2.1 percent per annum. The labor force growth rate for the decade of the 1970s was slightly higher than for the 1960s, at 2.3 percent per annum, but then the growth rate dropped slowly during the 1980s, to 2.1 percent per annum. Over the decade of the 1990s, the labor force of the middle-income countries grew substantially more slowly, at 1.8 percent per annum. For these countries, the standard deviation of the labor force growth rate was 0.8 percent per annum in the 1960s, increasing to 0.91 percent per annum in the 1970s and to 1 percent per annum in the 1980s. However, for the decade of the 1990s, the standard deviation of labor force growth rate was substantially lower, at 0.7 percent per year.

Output per worker

Output per worker is an aggregate measure of labor productivity. Output per worker can be computed as follows: Output per worker = Percentage change in GDP per person + percentage change in population - percentage change in the labor force.

For the low-income countries, GDP per worker grew at the annual average rate of 4.0 percent over the decade of the 1960s, 3.5 percent per annum over the decade of the 1970s, 3.4 percent over the decade of the 1980s, and 3.6 percent over the decade of the 1990s. For the middle-income countries, output per worker grew at 5.1 percent per annum over the decade of the 1960s, 4.5 percent over the decade of the 1970s, 2.5 percent over the decade of the 1980s, and 2.8 percent over the 1990s (see Table 2.5).

The variability of GDP per capita growth is high across both low- and middle-income countries. For the low-income countries, the standard deviation of per capita GDP was 2.1 percent per year over the decade of the 1960s, 2.6 percent per year over the decade of the 1970s, 2.3 percent per year over the decade of the 1980s, and 2.8 percent per year over the decade of the 1990s

Table 2.5. Average annual growth rate of GDP per worker, by decade

	Mean		Standard Deviation	
Decade	LIC	MIC	LIC	MIC
1960s	4.018	5.09	2.08	1.242
1970s	3.456	4.500	2.648	2.888
1980s	3.367	2.502	2.265	1.742
1990s	3.641	2.818	2.826	1.910

Note: LIC = low-income countries; MIC = middle-income countries.

For the middle-income countries, variability of GDP per worker was generally less than for the low-income countries (Table 2.5).

Dietary energy supply

Per capita energy availability is measured by DES, which indicates the number of calories per day available per person. Countries with the highest DES levels are Hungary (3,710.8), Turkey (3,564.6), Poland (3,343.3), Egypt (3,176.4), and Mexico (3,103), all of which are middle-income countries. For the low-income countries, the average growth rate of DES per worker was 0.6 percent per annum over the decade of the 1960s, but DES was -0.2 percent per annum over the decade of the 1970s. Growth rate of DES per worker remained positive over the decades of the 1980s and the 1990s, at 0.3 percent per year and 0.6 percent per year, respectively. In the low-income countries, the variability of the DES growth rate per worker tended to increase over time. The standard deviation was 0.8 percent per annum over the decade of the 1960s, 1.14 and 1.2 percent per annum over the decade of the 1970s and of the 1980s, respectively, and a somewhat lower 1 percent per annum over the decade of the 1990s.

For the middle-income countries, DES per worker grew at 0.6 percent per annum over the decade of the 1960s and 0.6 percent per annum over the 1970s, but growth was -0.1 percent per annum over the decade of 1980s. Over the decade of the 1990s, DES growth per worker returned to a positive value of 0.2 percent per annum. The variability of DES per worker for these countries was much lower than for the low-income countries, at about 0.7 percent per year in 1960s, 1970s, and 1980s and 0.6 percent per year in the 1990s (see Table 2.6).

Table 2.6. Average annual growth rate of DES per worker, by decade

	Mean		Standard Deviation	
Decade	LIC	MIC	LIC	MIC
1960s	0.613	0.6214	0.810	0.730
1970s	-0.151	0.546	1.1425	0.659
1980s	0.275	-0.114	1.193	0.701
1990s	0.606	0.157	0.988	0.598

Note: LIC = low-income countries; MIC = middle-income countries.

Growth rate of investment per labor

The other important variable used in this study is the growth rate of investment per worker, which is calculated by this formula: Growth rate of investment per worker = Domestic investment growth rate - growth rate of labor force.

In both the low- and middle-income countries, the mean for the annual average growth rate of investment per worker decreased over the 1960s, 1970s, 1980s. In the 1990s, the mean increased from –3.3 percent per year in the 1980s to 2.5 percent in the 1990s. The variability in the annual average growth rate of investment per worker varied substantially over all four decades in both group of countries. In low-income countries, it was 2.7 percent per year in the 1960s, 1.9 percent per year in the 1970s, and –3.5 percent per year in the 1980s, increasing to 3.8 percent per year in the 1990s (see Table 2.7).

In the middle-income countries, the standard deviation was 3.3 percent per year for the decade of the 1960s, 7.9 percent per year for the 1970s, 3.8 percent per year for the 1980s, and 4.1 percent per year for the 1990s.

Table 2.7. Growth rate of investment per labor, by decade

	Mean		Standard Deviation	
Decade	LIC	MIC	LIC	MIC
1960s	2.11	2.65	4.74	3.31
1970s	1.16	1.93	7.92	7.91
1980s	-3.33	-3.50	6.89	3.80
1990s	2.50	3.80	5.98	4.08

Note: LIC = low-income countries; MIC = middle-income countries.

Literacy rate

Because human capital is important in improving human health, the literacy rate is a factor that can contribute positively to improving health levels. Apparently, the average annual growth rate of literacy rate increased annually in the countries, although it varied among countries in both the low- and middle-income countries (see Appendix Table 4).

In the low-income countries, the mean of the annual average growth rate of literacy increased over the four decades studies. Over the decade of the 1960s, it was 0.7 percent per year, with a standard deviation of 0.3 percent. The growth rate increased to 0.8 percent per year for the 1990s, with a standard deviation of.0.3 percent. In the middle-income countries, the situation was opposite to the situation in the low-income countries. The mean of the annual average growth rate of literacy started decreasing over the decade of the 1970s, from 0.6 percent per year, with a standard deviation of 0.3 percent, to a growth rate of 0.4 percent for the 1990s, with a standard deviation 0.3 percent.

Table 2.8. Average annual change in literacy rate, by decade

	Mean		Standard Deviation	
Decade	LIC	MIC	LIC	MIC
1960s	0.730	0.58	0.320	0.33
1970s	0.730	0.58	0.320	0.33
1980s	0.829	0.47	0.290	0.28
1990s	0.852	0.39	0.301	0.27

Note: LIC = low-income countries; MIC = middle-income countries.

Production

Four staple crops were used as instrumental variables in the model for this study (wheat, barley, rice, and milk). The data on production for each of the foods covers the 1960s, 1970s, 1980s, and 1990s. Production per capita for each crop was calculated by dividing the production quantity over the population (see Appendix B for more details). After reviewing the data that are used in this study we will try to analyze these data in economic growth rate model. The economic growth model, which we are going to use, is the Solow model.

Chapter 3 reviews the assumptions of this model, the equations on which the model is built, and the Solow diagram depicting all the seniors that an economy can experience.

Chapter Three

The Economic Model

The economic model used in this study is a neoclassical economic growth model. The growth model presented is the Solow model. The following discussion about the Solow model is taken from Charles I. Jones book, *Introduction to Economic Growth*. The Solow model imposes the following assumptions that facilitate solving the problem of the growth rate model.

1. Countries are producers and consumers of a single homogenous product (output), which is unit of countries' gross domestic product (GDP).
2. There is no international trade in this model because there is only a single product.
3. Technology is exogenous, meaning that the technology available to firms in this model is unaffected by the actions of the firms, including research and development.
4. Individuals save a constant fraction of their income and spend a constant fraction of their time-accumulating skills.
5. The economy is closed.
6. The only used of investment is to accumulate capital.
7. Firms pay worker a wage (w).
8. Firms pay capital rent (r).
9. The economy consists of so many firms that perfect competition prevails.
10. Firms are price takers.
11. The production function is $Y = F(K,L) = K^{\alpha} L^{\alpha-1}$

The profit maximization problem for a firm is $Max_{K,L}\ F(K,L) - rK - wL$. According to this equation, the firm will hire labor until the marginal product of labor is equal to the wage, and the firm will rent capital until the marginal product of capital equals the rent on capital given the production function $F(K,L) = Y = K^{\alpha} L^{(1-\alpha)}$.

$$\frac{\partial F}{\partial L} = 0 = (1-\alpha)L^{-\alpha}K^{\alpha} - w$$

$$w = (1-\alpha)\frac{K^{\alpha}}{L^{\alpha}}$$

$$w = \frac{\partial F}{\partial L} = (1-\alpha)\frac{Y}{L}$$

in the same way we can obtain the rent on capital equation.

$$r = \frac{\partial F}{\partial K} = (1-\alpha)\frac{Y}{K}$$

where $wL + rK = Y$, which means that payment to the input completely exhausts the value of output produced, so there is no economic profit to be earned. This is because we assume that the production function exhibits constant return to scale.

The Solow model is built around two equations: the production equation and the capital accumulation equation. The production equation describes how inputs combine together to produce output. We group these inputs into three categories:

Capital K

Labor L

Output Y

The assumptions of this equation follow:

1. The production function is assumed to take the Cobb-Douglas form

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

2. The production function exhibits constant return to scale since α is between 0 and 1.

Because we are interested in explaining the output per worker or per capita output, we can write the production function (1) in terms of output per worker:

$$y = \frac{Y}{L} \tag{2}$$

and capital per worker:

$$k = \frac{K}{L} \tag{3}$$

From equations (2) and (3), we can rewrite output per worker as follows:

$$y = \frac{Y}{L} = \frac{K^{\alpha} L^{(1-\alpha)}}{L} = \frac{K^{\alpha}}{L^{\alpha}} = k^{\alpha}$$

$$y = k^{\alpha} \tag{4}$$

Equation (4) indicates that with more capital per worker, firms produce more output per worker. This function exhibits diminishing return to scale. Graphically, Equation (4) can be presented as shown in Figure 3.1.

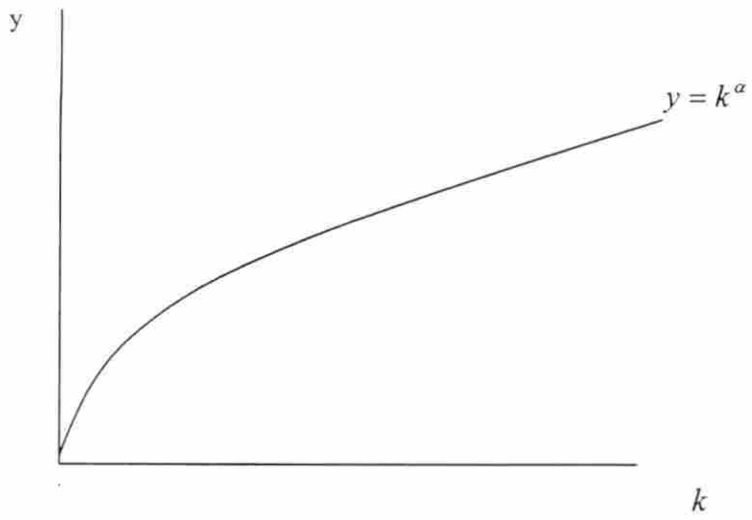

Figure 3.1.A Cobb-Douglas production functionn.

The capital accumulation equation can be written as follows:

$$\dot{K} = sY - dK$$

where:

$\dot{K}$ = change in capital stock by time $\frac{dK}{dt}$,

sY = gross investment,

dK = depreciation that occurs during the production process,

s = constant fraction of the worker's wage and rental income ($Y = wL + rK$), and

d = constant fraction of the capital stock depreciates every period regardless of how much output is produced.

To study the evaluation of output per person in this economy, we rewrite the capital accumulation equation in terms of capital per worker:

$$\dot{K} = \frac{dK}{dt} = sy - (n+d)k \qquad (5)$$

$$(n+d)k$$

where:

$sy =$ investment per worker,

$dk =$ depreciation, and

$nd =$ reduction in capital due to the population growth.

$n =$ the population growth rate

Every year there will be new nL workers who were not there during the last period.

The Solow diagram

Equation 1: output per worker

$$y = k^{\alpha}$$

Equation 2: capital accumulation per worker

$$\dot{K} = \frac{dK}{dt} = sy - (n+d)k$$

given:

Stock of capital per worker $= k^0$,

Population growth rate = n,

Depreciation rate = d, and

Investment rate $= s$

The output per worker evolves over time in this economy according to the diagram shown in

Figure 3.2.

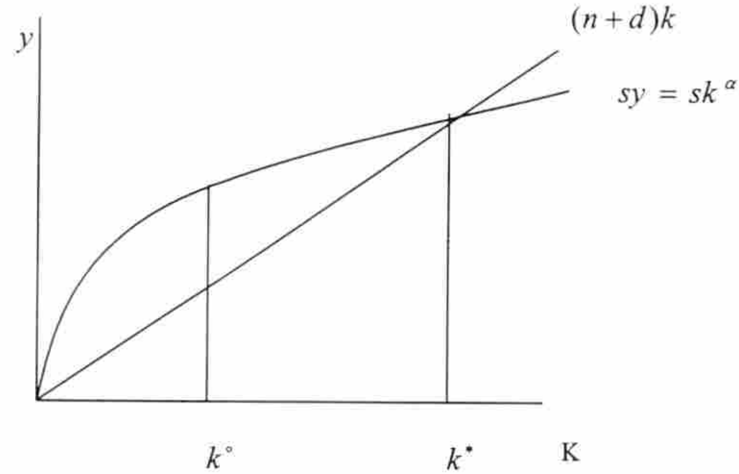

Figure 3.2. The Basic Solow Diagram.

The curved line $(n+d)k$ in Figure 3.2 represents the amount of new investment per person required to keep the amount of capital per worker constant. Both the depreciation and the growing labor force tend to reduce the amount of capital per person in the economy, while the curved line $sy = sk^{\alpha}$ represents the amount of savings, or the investment per person to maintain a given K. The difference between these two curves is the change in the amount of capital per worker. From this point, using the Solow diagram, we can define the steady state[2] value of capital per worker.

To determine the steady-state value of output per worker, y^{*} as a function of k^{*}, we include the production function in the Solow diagram as shown in Figure 3.3.

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2 The steady state occurs when k^{0} in an economy is equal to the amount of investment per worker at $k*$.

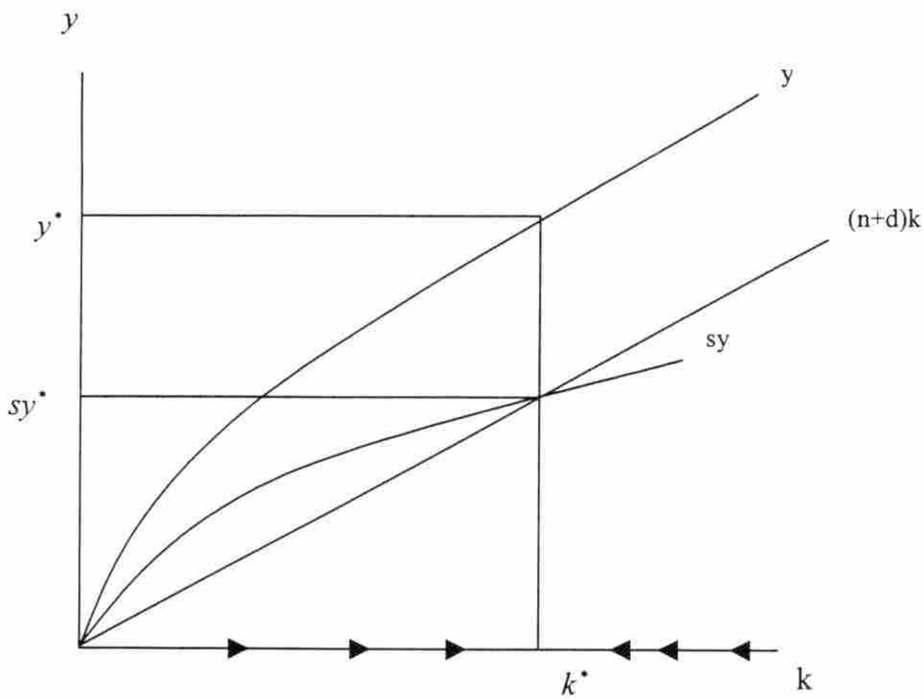

Figure 3.3 The Solow Diagram and the Production Function

The steady-state consumption per worker is given by the difference between steady state output per worker, y^*, and steady-state investment per worker, sy^*.

Comparative static

"Comparative statistics are used to examine the response of the model to changes in the value of various parameters" (see Charles I. Jones, *Introduction to Economic Growth*), meaning that comparative statistics help us to figure out the economy (in a steady-state) parameters such as income per capita response to "shocks" such as an increase in the investment rate or the population growth rate.

Graphically, an increase in investment rate will cause a shift upward the (sy) curve to ($s'y$) when the investment rate increases from s to s', and the capital stock, k^*, or investment per worker, exceeds the amount required to keep capital per worker constant.

Therefore, k^{*} will be increased so that $s'y = (n+d)k$, and this equality will occur in the new level of investment per worker at k^{**} as it revealed in Figure 3.5.

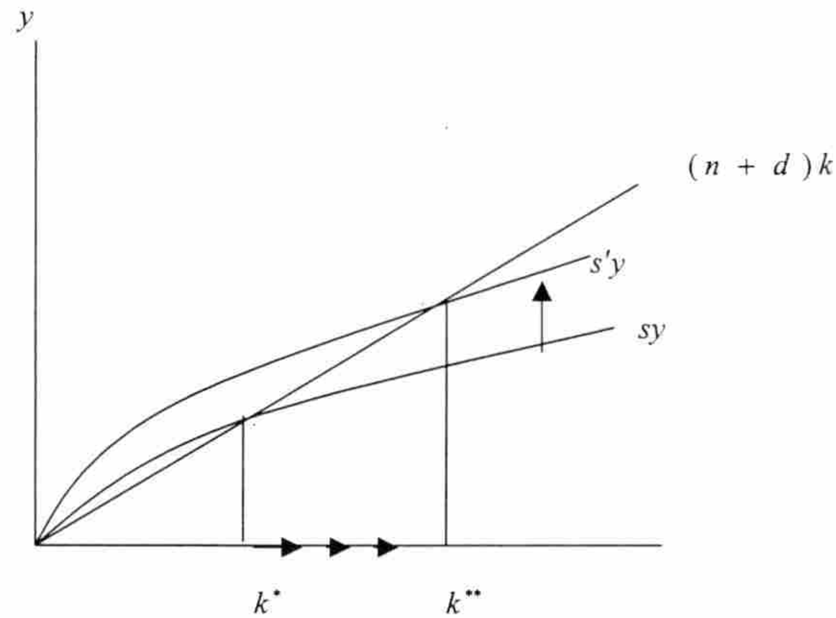

Figure 3.5 An increase in investment rate.

In contrast, an increase in population growth rate from n to n' causes the capital-labor ratio to fall until a new equilibrium point is reached where $sy = (n'+d)k$, which indicates that the society now has less capital per worker, as shown in Figure 3.6.

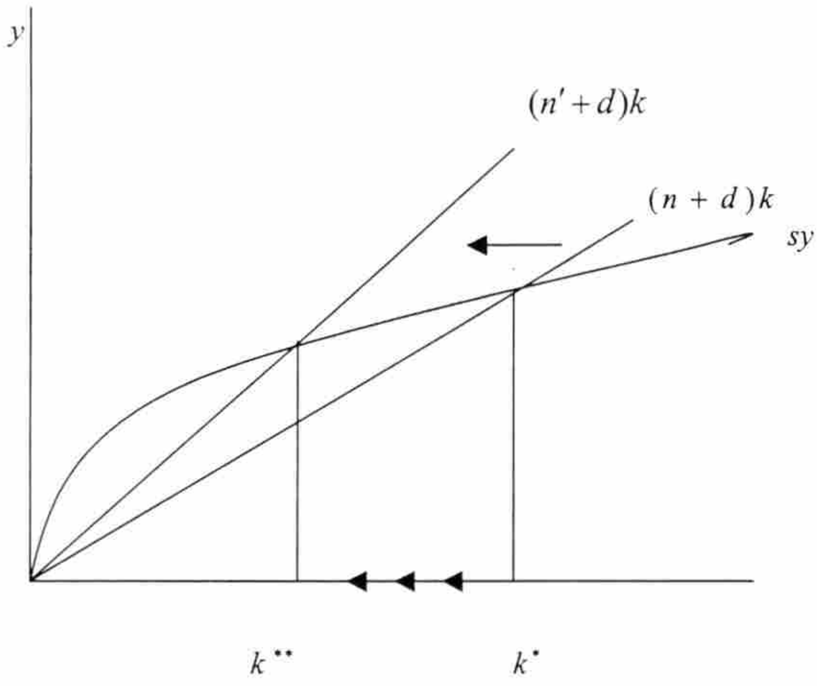

Figure 3.6. Effects of an increase in population growth rate.

Properties of the steady-state model

The steady-state condition is $\frac{dK}{dt} = 0$. According to this condition, we can define the capital per capita and the output per worker. Using Equations (4) $y = k^{\alpha}$ and Equation (5) $K^{\cdot} = \frac{dK}{dt} = sy - (n + d)k$, and using the previous condition, we can define capital per worker as follows:

$$K^{\cdot} = sk^{\alpha} - (n + d)k$$
$$K^{\cdot} = 0 \Rightarrow sk^{\alpha} - (n + d)k = 0$$

$$sk^{\alpha} = (n+d)k$$

$$\frac{k^{\alpha}}{k} = \frac{(n+d)}{s}$$

$$\frac{1}{k^{(1-\alpha)}} = \frac{(n+d)}{s}$$

$$k^{*} = (\frac{s}{n+d})^{\frac{1}{1-\alpha}} \tag{6}$$

where:

k^{*} = capital per worker.

Output per worker, y^{*}, can be defined by the following:

$$y = k^{\alpha}$$

$$y^{*} = (\frac{s}{n+d})^{\frac{\alpha}{1-\alpha}} \tag{7}$$

From Equations (6) and (7) and according to the Solow model, the countries with high rates of saving (which means high rates of capital per worker) tend to be richer and have higher output per worker than do countries with lower rates of saving. On the other hand, the countries with high rates of population growth tend to be poorer, on average.

The Solow model with technology

By adding the technology variable to the Solow model, we generate sustained growth in per capita income in this model. So, the Solow model production function after adding the technology variable will be:

$$Y = F(K, AL) = K^{\alpha}(AL)^{(1-\alpha)}$$

A is said to be "labor augmenting" and works as a booster to increase labor productivity. More improvement in technology leads to more production per worker. Based on the Solow model assumption, A is exogenous and is growing at a constant rate.

$$\frac{A^{\cdot}}{A} = g \Leftrightarrow A = A_{o}e^{gt}$$

where:

$g :=$ growth rate of technology.

After adding A to the model, the capital accumulation function will be:

$$\frac{K^{\cdot}}{K} = s\frac{Y}{K} - d$$

Production in terms of output per worker will be:

$$y = k^{\alpha} A^{1-\alpha}$$

Taking the log and differentiating yields:

$$\frac{y^{\cdot}}{y} = \alpha\frac{k^{\cdot}}{k} + (1-\alpha)\frac{A^{\cdot}}{A}$$

According to the capital accumulation and production equations, the growth rate of K will be constant if and only if $\frac{Y}{K}$ is constant. And if $\frac{Y}{K}$ is constant then $\frac{y}{k}$ is constant and k and y are growing at the same rate as the population growth rate and consumption rate,

$g_{y} = g_{K} = g$, where $g = \frac{A^{\cdot}}{A}$.

When capital, output, consumption, and population grow at the same rate, the economic model is called a "balanced growth path." An example of this is the U.S. economy given that: 1-the real rate of return to capital, r, shows on trend upward or downward

2-the shares of income devoted to capital, rK/Y, and labor wL/Y, shows on trend, and

3-the average growth rate of output per person has been positive and relatively constant over time-i.e. the United States exhibits steady, sustained per capita income growth.

The Solow diagram with technology

The Solow model with a technology variable indicates that technological progress is a source of sustained growth. The only difference between the Solow model with and without a technology variable is that the improvement in technology will offset the diminishing return to capital accumulation, which leads to increased labor productivity.

Specifically, capital is not any more constant in the long run. The new state variable will be

$$\widetilde{k} \equiv \frac{K}{AL} = \frac{k}{A}.$$

$\frac{k}{A}$ is a constant along the balanced growth path because $g_K = g_A = g$.

The variable $\widetilde{K}$, therefore, represents the "capital-technology ratio" $\widetilde{k} = \frac{k}{A}$, where k refers to capital per worker.

The production function will be:

$$\widetilde{y} = \widetilde{k}^{\alpha}$$

where

$$\widetilde{y} = \frac{Y}{AL} = \frac{y}{A}$$ and $\widetilde{y}$ is the "output-technology ratio."

Given the output-technology ratio equation we can rewrite the capital accumulation equation in terms of $\widetilde{K}$ yields

$$\frac{\tilde{k}^{\cdot}}{\tilde{k}} = \frac{K^{\cdot}}{K} - \frac{A^{\cdot}}{A} - \frac{L^{\cdot}}{L}$$

$$\tilde{k}^{\cdot} = s\tilde{y} - (n + d + g)\tilde{k}$$

With these new equations of capital and production, we can draw the diagram shown in Figure 3.7.

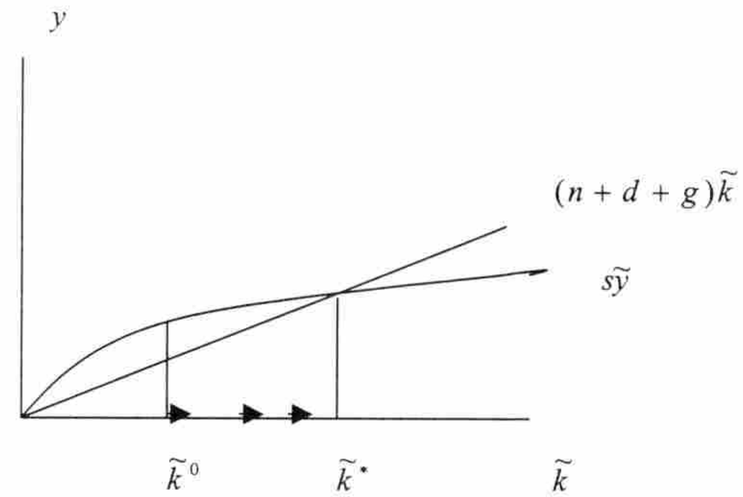

Figure 3.7. The Solow Diagram with Technological progress

If the economy starts with a capital-technology ratio less than the steady state value, it will rise until it reaches the steady-state ratio at the point $(n + d + g)\tilde{k} = s\tilde{y}$ and it grows along a balanced growth path. Solving for the steady-state situation in the Solow model uses the assumption that $\tilde{k} = 0$, where $\tilde{k}$ is the growth rate of capital with technology equal zero.

So, $\tilde{k}^* = (\frac{s}{n + g + d})^{\frac{1}{(1-\alpha)}}$ substituting in the production function yields:

$$\tilde{y}^* = (\frac{s}{n + d + g})^{\frac{\alpha}{(1-\alpha)}}$$

We can write the production function in another way to reveal the dependency of y and A on time:

$$y^*(t) = A(t)\left(\frac{s}{n+g+d}\right)^{\frac{\alpha}{(1-\alpha)}}$$

Finally, the Solow model with technological progress guarantees the sustained growth rate in an economy by offsetting the diminishing return to capital accumulation, which boosts the labor productivity, while without technological progress, capital runs into diminishing returns.

The Solow model with human capital

Because labor in different economies may possess different levels of education and different skills, the Solow model is extended to include human capital of skilled labor as a main factor to boost economic growth.

Assume that output, Y, in an economy is produced by a combination of physical capital, K, and skilled labor, H. The constant returns of the Cobb-Douglas production function can be rewritten as:

$$Y = K^{\alpha}(AH)^{1-\alpha}$$

where:

Y = output,

K = capital (total),

A = labor-augmenting technology that grows exogenously at rate g, and

H = skilled labor.

Skilled labor can be defined by the equation:

$$H = e^{\Psi u}L$$

where:

u = the fraction of an individual's time spent in acquiring skill,

L = total labor, and

ψ = the percentage that (H) will be increased if (u) increases by a small amount according to the following:

$$H = e^{\psi u} L .$$

Taking the log and differentiating yields:

$$\log H = \mu\psi \log e + \log L$$
$$\frac{\partial \log H}{\partial u} = \psi$$

This equation states that a small increase in u leads to an increase in H by the percentage ψ or $\psi * 100$. This result matches the fact that labor economists have found that an additional year of school increases wages by about 10 percent.

In this model, we assume that u is constant and given exogenously. The physical capital is accumulated by investment of some of the output, and the growth rate of capital will be:

$$K^{\cdot} = skY - dK$$

where

sk = the investment rate of physical capital, and

d = constant depreciation rate.

The production function per worker can be rewritten as:

$$y = k^{\alpha} (Ah)^{1-\alpha}$$

where:

$$h = e^{\psi u}.$$

We assume in this equation that an individual saves as in the Solow model with technology, so we assume h is constant and k and y will grow at the constant rate, and g is the rate of technological progress.

Given this review of the analytical framework, the following section introduces the hypothesis and expectations of this study.

Hypotheses to be tested in this study

The hypothesis to be tested is that the coefficient of the DES is positively correlated with real GDP and is statistically significant. Moreover, we expect that capital per worker is positively correlated with real GDP and statistically significant. For literacy rate, as with the other variables, we expected its coefficients to be positive and statistically significant.

Chapter Four

Empirical Economic Growth Rate Model and Results -

The Econometric Model

Method of Analysis

1- The Ordinary Least Square (OLS), The Linear Model

The assumption of this model

Consider the linear multiple regression model of growth where y is GDP growth rate, x's are the regressors or explanatory variables, and e_i is a stochastic country-specific effect,

and:

$$y = \beta_0 + \beta_1 x_{ti1} + \beta_2 x_{ti2} + ... + \beta_k x_{tik} + e_i + \mu_{ti}$$

where

$\mu_{ti} : t = 1,2,...,n$ is the sequence of errors or disturbance, and

n = the number of observations.

Zero conditional mean

This assumption means that for each t, the expected value of the error terms, μ, given all the explanatory variables for all time periods, is zero.

$$\mathrm{E}(u_{ti}|X) = 0, t = 1,2,....,n$$

No perfect collinearity

In the sample, none of the independent variables is constant and there are no exact linear relationships among the independent variables. In other words, an independent variable is not an exact linear combination of the other independent variables.

Homoskedasticity

The variance in the error term μ_t, conditional on the explanatory variables, is the same for all $t : Var(\mu_t|X) = Var(\mu_t) = \sigma^2, t = 1,2,...,n$, which means that μ, and, X, are independent. In other words, the variance of the unobserved error does not depend on the levels of any of the explanatory variables.

No serial correlation

The error in two different time periods is uncorrelated: $Corr(\mu_t, \mu_s|X) = 0$ for all $t \neq s$.

Normality

The errors μ_t, are independent of X, and are independently and identically distributed as normal $(0, \sigma^2)$. To obtain the distribution of the test statistics, the structural empirical model for explaining growth in real GDP per worker using decade average data is:

$d \ln RGDP = \beta_1 + \beta_2 d \ln(capital / wor\text{ker}) + \beta_3 d \ln(DES / wor\text{ker}) + \beta_4 literacylevel + \mu$ (1)

For the identification of the variables, see Table 4.1.

2-Potential endogeneity of regressor

Although Equation (1) can be fitted by ordinary least square (OLS), some complications exist. First, there may be endogeneity of one or more explanatory variables. If so, the OLS estimate is inconsistent and we then use the instrumental variable method, or two-stage least squares (2SLS). To create instruments, we assumed that the agricultural production of wheat, rice, corn, and milk per worker were correlated with DES but not with μ in Equation (1); that is,

$$\operatorname{cov}(z_i, \mu) = 0$$

and,

$$\operatorname{cov}(z_i, x) \neq 0$$

Then, the instrumental variable estimator, or 2SLS estimators, will be consistent.

Table 4.1. Definition of variables

Variable	Definition
DlnRGDP	Average rate of change in the log real GDP per worker, by decade (1960s, 1970s, 1980s, 1990s)
$d \ln capital / worker$:	Average rate of change in the log capital per worker, by decade (1960s, 1970s, 1980s, 1990s)
$d \ln DES / worker$:	Average rate of change in the log of DES per worker, by decade (1960s, 1970s, 1980s, 1990s)
$dliteracylevel$:	Change in literacy rate, by decade (1960s, 1970s, 1980s, 1990s)
$\ln(DES)_t$	The log of DES at the beginning of each decade (1960s, 1970s, 1980s, and 1990s)
$\ln(cornprod)_t$	The log of the production of corn per worker at the beginning of each decade (1960s, 1970s, 1980s, and 1990s)
$\ln(riceprod)_t$	The log of the production of rice per worker at the beginning of each decade (1960s, 1970s, 1980s, and 1990s)
$\ln(wheatprod)_t$	The log of the production of wheat per worker at the beginning of each decade (1960s, 1970s, 1980s, and 1990s)
$\ln(milk)_t$	The log of the production of milk per worker at the beginning of each decade (1960s, 1970s, 1980s, and 1990s)

First stage

Regressing the growth rate of DES on the growth rate of the agricultural production activity yields:

$$gDES = \alpha_1 + \alpha_2 p_i + \mu$$

where:

$gDES$:= the average growth rate of DES over the decade,

P_i : = the production level for the four staple foods (rice, wheat, corn, milk) at the beginning of the decade, and the level of DES at the beginning of the decade.

μ : = the error term.

To instrument the first-stage equation is then:

$$\ln(DES/worker)_t - \ln(DES/worker)_{t-10} = d\ln(DES/worker) = \alpha_1 + \alpha_2 \ln(DES)_{t-10} + \alpha_3 \ln(cornprod)_{t-10} + \alpha_4 \ln(wheatprod)_{t-10} + \alpha_5 \ln(riceprod)_{t-10} + \alpha_6 \ln(milkprod)_{t-10} + \mu_t$$

After fitting Equation (2) to the data, we obtain the predicted value:

$$d\ln(D\widehat{ES}/worker) = \widehat{\alpha}_1 + \widehat{\alpha}_2 \ln(DES) + \widehat{\alpha}_3 \ln(cornprod) + \widehat{\alpha}_4 \ln(wheatprod) + \widehat{\alpha}_5 \ln(riceprod) + + \widehat{\alpha}_6 \ln(milkprod)$$

Second stage

Substituting $d\ln(DE\hat{S}/worker)$ for the actual value in Equation (1), and then fitting the following equation, yields:

$$d\ln(RGDP/worker) = \beta^*_1 + \beta^*_2 d\ln(capital/worker) + \beta^*_3 d\ln(DE\widehat{S}/worker) + \beta^*_4 d\ln(literacylevel)$$

where:

The new coefficients β^{*}'s are the IV estimators and they are consistent.

3-The Random Effect

With a random stochastic country-specific effect present, estimation of Equation (1) by least squares leads to a left-out variable bias problem when e_i is correlated with the other regressors. When the correlation is non-zero, we can improve the estimation by fitting a random effects model, which at least adjusts the variance of $e_i + \mu_{ti}$ for the fact that $\sigma_{e_i} \neq 0$, and we control for the fact that the country-specific noise has different variances.

$$Cov(x_{tij}, e_i) = 0$$

$$t = 1,2,3,4$$

$$j = 1,2,3,4$$

The results are presented in the next section.

Empirical Results

In this chapter, we report the empirical result for the growth rate equation, Equation (1), paying attention to both the potential for a linear random country-specific observed effect and endogeneity of DES. We choose two different subgroups of countries: one group comprised of low-income countries and one group comprised of middle-income countries. We have a total of 168 observations, or 42 per decade, and we first report results for an OLS estimate of Equation (1) ignoring the implication of $e_i \neq 0$. Next, we apply the random-effects least square estimator, followed by the IV estimator and IV with random effects. The results are reported in Table 4.2.

In regression (1), the estimate of β_2 is 0.111 and is significantly different from zero at the 5 percent level. Hence, a higher capital-to-labor ratio increases GDP per worker. The estimate of β_3 is 0.003, which suggests that a higher availability of energy per worker increases the growth rate of GDP per worker. This effect is significantly positive at the 10 percent level. An increase of the literacy level also increases GDP per worker. The effect is significantly positive at the 5 percent level. The equation has modest explanatory power with an R^2 of 0.13, but the dependant variable is in percentage form, which elevates the importance of noise and tends to lead to a small R^2.

Table 4.2. Model explaining average rates of growth of real GDP per worker for 42 low- and middle-income countries, by decade (1960s and 1970s)

	Estimated Coefficients							
Dependent variable	Intercept	dln(capital /worker)	dln(DES /worker)	d(literate)	dln (litrate)	R^2	N	
1.dln(RGP/ worker)	0.030 (8.86)	0.111 (4.03)	0.003 (1.64)	0.007 (1.86)	----------	0.136	168	OLS
2.dln(RGP/ worker)	0.032 (10.29)	0.108 (3.92)	0.004 (1.81)	--------	0.121 (0.96)	0.123	168	OLS
3.dln(RGP/ worker)	0.035 (16.6)	0.106 (3.84)	0.004 (1.85)	--------	---------	0.118	168	OLS
4.dln(RGP/ worker)	0.030 (8.85)	0.110 (3.24)	0.003 (1.18).	0.007 (1.61)	----------	0.163	168	Random effect GLS by country
5.dln(RGP/ worker)	0.029 (8.45)	0.102 (3.24)	0.006 (1.18)	0.007 (1.61)	----------	-------	168	IVinstrument for dln(DES/worker)
6.dln(RGP/ worker)	0.029 (8.42)	0.117 (4.35)	0.008 (1.47)	0.006 (1.49)	----------	------	168	IV for dln (DES/worker) and random effects GLS by country

In Equation (2), β_2 is 0.108, which is positive and significantly different from zero at the 5 percent level. The same result could be concluded: that increasing the capital-labor ratio increases GDP per worker by approximately 10 percent. β_3 is 0.004, which is positive and significantly different from zero at the 5 percent level. This result implies that higher energy levels lead to increase GDP per worker, although in a small percentage. Literacy in this regression, even though positive, is not significant at the 5 percent or 10 percent level.

In Equation (3), using only the capital-labor ratio and DES in the OLS regression model, β_2 is 0.106, positive, statistically significant at the 5 percent level, and different from zero. This result reveals the importance of the capital-labor ratio for growth, which was predicted by the Solow model. Likewise, DES has a positive effect on GDP per worker, where β_3 is 0.004, which is significantly different from zero at the 5 percent level. We obtained the same conclusion: that an increase in the energy level per worker provokes GDP per worker, even at a modest percentage.

In Equation (4), we apply the random effect model and the estimated β_2 is 0.110, positive, and significantly different from zero. This equation supports our result in the previous equation that an increase in the capital-labor ratio leads to an increase in GDP per worker. β_3 is 0.003, which is positive and statistically significant at the 10 percent level. As mentioned, energy intakes boost the growth of GDP per worker. In addition, literacy has a positive impact on increasing GDP per worker.

Likewise, for the previous regressions in Equation (5), after getting the predicted value for DES by running the instrumental variable model and running the OLS , β_2 is 0.102, positive, and significantly different from zero at the 5 percent level . β_3 is 0.006, positive, and statically significant at 10 percent. β_4 , the literacy coefficient, is also positive and significantly different from zero. Among the three variables, the capital-labor ratio still plays the most important role in increasing GDP per worker.

In Equation (6), we control for the stochastic error and the result improved. β_2 is 0.117, positive, and significantly different from zero at the 5 percent level. Likewise, the coefficient of DES is 0.008, positive, and significant at the 5 percent level. The coefficient of literacy in this regression has a larger effect than in the previous regression; here, β_4 is 0.006, which is positive and significantly different from zero at the 5 percent level, even though the effect is a smaller percentage increase in GDP per worker.

Chapter Five

Conclusion

The effect of nutrition has been applied by many researchers to determine the importance of the role it can play in terms of both health improvement and changes in economies. As such, nutrition is of interest not only to nutritionists, but to economists as well because it is related to an individual's labor, work ability, productivity.

Interestingly, as our results revealed, the nutrition variable does not have a strong impact on the growth rate of GDP per worker. In our results, in first equation an increase of 1 percent in DES leads to an increase in the growth rate of GDP per worker by 0.003 percent, which is a modest effect on GDP per worker, especially with a 5 percent level of confidence. The effects of an increase in DES in all the regressions we ran range between 0.003 percent and 0.008 percent

However, in comparison with other variables, the growth rate of capital per worker played a very important and significant role in boosting the growth rate of GDP per worker in all the regressions we ran, where an increase of 1 percent of capital per worker leads to an increase in GDP per worker of approximately 0.11 percent, which is a significant effect as it is revealed by the first equation, while in the second equation it led to an increase in GDP per worker by 0.108 percent. In the last equation the result improved and an increase of 1% in the growth rate of capital per worker led to 0.117 % increase in the growth rate of real GDP per worker.

Literacy also played a more important role than did DES, whereby an increase of 1 percent in literacy rate caused the growth rate of GDP per worker to increase by 0.07-percentage points change.

Thus, we can conclude that nutrition might have an impact on growth rate of GDP per worker and labor productivity, but this impact is not very significant, as our data and results explained.

An earlier study, conducted by Jean Luois Arcand for the ESAE and FAO of the United Nations, revealed that the impact of nutrition measured by DES has a significant and strong impact on the growth rate of GDP per capita directly through the impact of nutrition on labor productivity and indirectly through improvement in life expectancy. The difference in results between Arcand's study and this study might be due to data the way that the empirical variables are constructed, e.g., because we use GDP per worker while he defines his growth variable as GDP per capita.

Finally, according to our data and statistical analysis, the role that nutrition plays in boosting the growth rate of GDP per worker is positive but generally not statically significant. From another point of view, DES is nutrition availability based on domestic production of calories only, and hence it fails to account for food imports, including food aid or food exports. As a result DES per worker may be noisy measure of total available calories of a country.

Furthermore, form another point of view; DES takes no account for the non-calorie attributes of the food supply, e.g., protein, vitamin, and essential mineral content or the distribution of food in the population. For instant poop people depend mainly in their diet on bread and sugar, which are carbohydrate, to get the whole require amount of calories and sometimes more than what required. In this case essential minerals, which are very important to body function like Iron, Protein, Calcium, etc are missing in their diet. As a result this can affect their labor productivity and hours of work

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Appendix A

Table A1. Population, GDP, labor force, and GDP/worker growth rates by decade for a set of low and middle-income countries, 1960-1999.

Countries	Code	Years	Population growth rate	Average Annual Growth Rate GDP%	Average Annual Growth rate of labor force rate (%)	Average annual growth rate of GDP per worker (%)
Argentina	1	1960s	1.50	4.20	1.37	4.33
		1970s	3.13	2.30	1.30	4.13
		1980s	2.20	-0.70	1.32	0.18
		1990s	1.29	4.90	1.55	4.63
Brazil	2	1960s	2.90	5.30	2.62	5.58
		1970s	2.50	9.20	2.80	8.90
		1980s	2.09	2.70	2.27	2.52
		1990s	1.52	2.90	2.07	2.35
Chile	3	1960s	2.10	4.50	1.92	4.68
		1970s	1.70	0.80	2.27	0.23
		1980s	1.57	4.20	1.93	3.84
		1990s	1.46	7.20	1.57	7.10
China	4	1960s	2.30	5.00	2.11	5.19
		1970s	1.80	6.00	2.29	5.51
		1980s	1.41	10.10	2.36	9.14
		1990s	1.06	10.70	1.25	10.51
Colombia	5	1960s	3.00	5.10	2.68	5.42
		1970s	2.20	6.00	2.92	5.28
		1980s	2.12	3.60	2.56	3.16
		1990s	1.91	3.30	2.14	3.07
Egypt	6	1960s	2.20	4.50	2.03	4.67
		1970s	2.40	7.80	2.24	7.96
		1980s	2.57	5.40	2.22	5.75
		1990s	2.19	4.40	2.38	4.21
Hungary	7	1960s	0.30	3.80	0.32	3.78
		1970s	0.40	5.40	0.19	5.61
		1980s	-0.27	1.30	-0.10	1.13
		1990s	-0.21	1.00	0.01	0.77
India	8	1960s	2.20	3.60	1.99	3.81
		1970s	2.10	3.70	2.25	3.55
		1980s	2.08	5.80	2.17	5.71
		1990s	1.77	6.10	2.02	5.85
Jamaica	9	1960s	1.70	4.60	1.59	4.71

		1970s	1.40	-0.80	2.29	-1.69
		1980s	1.38	2.00	1.69	1.68
		1990s	0.77	0.10	1.27	-0.40
Kenya	10	1960s	3.20	6.00	2.94	6.26
		1970s	3.90	6.70	3.08	7.52
		1980s	3.76	4.20	3.42	4.54
		1990s	2.44	2.20	3.42	1.22
Mexico	11	1960s	3.10	7.20	2.85	7.45
		1970s	2.60	5.00	2.86	4.74
		1980s	2.18	1.10	2.92	0.36
		1990s	1.75	2.70	2.34	2.11
Nigeria	12	1960s	2.50	3.10	2.25	3.35
		1970s	3.10	6.20	2.61	6.69
		1980s	2.84	1.60	2.45	1.99
		1990s	2.92	2.40	2.76	2.56
Poland	13	1960s	0.90	4.30	0.86	4.34
		1970s	0.90	7.00	1.11	6.79
		1980s	0.85	2.20	0.52	2.53
		1990s	0.16	4.70	0.81	4.04
Senegal	14	1960s	2.80	2.50	2.53	2.77
		1970s	2.70	2.20	2.48	2.42
		1980s	2.82	3.10	2.52	3.39
		1990s	2.86	3.20	2.47	3.59
South Africa	15	1960s	2.70	6.40	2.42	6.68
		1970s	2.50	3.60	2.41	3.69
		1980s	2.37	1.00	2.56	0.81
		1990s	1.36	1.90	2.20	1.07
Turkey	16	1960s	2.40	6.00	2.15	6.25
		1970s	2.30	7.10	2.42	6.98
		1980s	2.38	5.40	2.69	5.10
		1990s	1.61	4.10	2.24	3.47
Venezuela	17	1960s	3.50	5.90	3.21	6.19
		1970s	3.20	5.60	3.90	4.90
		1980s	2.55	1.10	2.71	0.94
		1990s	2.01	1.70	2.54	1.18
Zambia	18	1960s	2.70	5.00	2.43	5.27
		1970s	2.90	2.30	2.80	2.40
		1980s	3.23	1.00	3.15	1.08
		1990s	2.19	1.00	2.26	0.93
Zimbabwe	19	1960s	3.20	4.20	2.89	4.51
		1970s	2.60	3.40	2.93	3.07

		1980s	3.78	3.60	3.73	3.65
		1990s	1.88	2.40	2.00	2.27
Bangladesh	20	1960s	2.10	3.60	1.91	3.79
		1970s	2.70	2.90	2.51	3.09
		1980s	2.55	4.30	2.63	4.22
		1990s	1.69	4.80	2.54	3.95
Burma (Myanmar)	21	1960s	1.80	2.60	1.65	2.75
		1970s	2.00	4.00	2.11	3.89
		1980s	1.92	0.60	2.18	0.34
		1990s	0.82	6.30	2.06	5.07
Indonesia	22	1960s	2.00	3.50	1.81	3.69
		1970s	2.30	7.80	2.30	7.80
		1980s	2.03	6.10	2.41	5.71
		1990s	1.76	4.70	2.08	4.38
Nepal	23	1960s	1.70	6.70	1.56	6.84
		1970s	2.30	4.40	1.77	4.93
		1980s	2.14	6.30	1.94	6.50
		1990s	2.47	4.00	2.18	4.29
Pakistan	24	1960s	2.70	4.60	2.41	4.89
		1970s	2.60	3.40	2.49	3.51
		1980s	3.13	4.00	2.71	4.41
		1990s	2.17	5.30	2.32	5.14
Sri Lanka	25	1960s	2.40	0.00	2.16	0.24
		1970s	1.70	0.00	2.29	-0.59
		1980s	1.50	4.60	1.77	4.33
		1990s	1.15	8.10	1.72	7.53
Yemen, PDR	26	1960s	1.90	2.60	1.72	2.78
		1970s	2.50	3.80	1.23	5.07
		1980s	3.29	2.50	3.38	2.40
		1990s	3.43	4.70	3.95	4.18
Benin	27	1960s	2.40	3.00	2.21	3.19
		1970s	2.70	-0.20	2.42	0.08
		1980s	2.98	3.60	2.16	4.41
		1990s	3.22	3.80	3.03	3.99
Burkina Faso (upper Volta)	28	1960s	1.50	4.40	1.32	4.58
		1970s	2.10	2.90	1.70	3.30
		1980s	2.48	4.40	2.37	4.51
		1990s	2.98	-2.90	2.23	-2.14

Burundi	29	1960s	2.20	1.90	2.02	2.08
		1970s	1.60	3.20	1.44	3.36
		1980s	3.31	1.40	2.76	1.94
		1990s	0.65	1.80	0.68	1.77
Central Africa Rep.	30	1960s	2.20	0.50	2.00	0.70
		1970s	2.10	1.70	1.80	2.00
		1980s	2.65	6.10	1.91	6.84
		1990s	2.28	2.30	2.19	2.39
Ethiopia	31	1960s	2.00	2.10	1.83	2.27
		1970s	2.00	0.40	1.79	0.61
		1980s	2.89	3.00	2.73	3.16
		1990s	2.73	4.30	2.44	4.58
Ghana	32	1960s	2.30	3.20	2.12	3.38
		1970s	2.30	5.40	2.16	5.54
		1980s	3.50	0.00	3.01	0.49
		1990s	2.43	4.20	2.92	3.71
Guinea	33	1960s	1.90	4.60	1.73	4.77
		1970s	2.10	6.50	2.32	6.28
		1980s	2.59	4.60	1.75	5.44
		1990s	3.28	4.40	1.98	5.70
Liberia	34	1960s	2.80	2.90	2.55	3.15
		1970s	3.00	-0.70	2.59	-0.29
		1980s	2.75	1.10	0.07	3.77
		1990s	3.41	1.70	4.18	0.92
Madagascar	35	1960s	2.10	4.90	1.91	5.09
		1970s	2.50	6.50	2.45	6.55
		1980s	2.79	2.50	2.52	2.77
		1990s	2.96	4.00	2.65	4.32
Malawi	36	1960s	2.60	3.30	2.39	3.51
		1970s	3.10	4.60	2.71	4.99
		1980s	3.55	0.80	3.92	0.44
		1990s	1.57	3.60	1.77	3.40
Mali	37	1960s	2.10	8.10	1.89	8.31
		1970s	2.00	2.30	1.82	2.48
		1980s	2.44	1.80	2.41	1.84
		1990s	2.56	4.10	2.31	4.35
Mauritania	38	1960s	1.40	4.60	1.30	4.70
		1970s	1.80	-3.20	2.03	-3.43
		1980s	2.57	-0.10	2.08	0.40
		1990s	2.97	6.30	2.77	6.49

Mozambique	39	1960s	2.20	2.90	1.99	3.11
		1970s	2.60	2.40	2.07	2.93
		1980s	1.95	-0.10	1.34	0.51
		1990s	3.09	2.50	2.68	2.91
Niger	40	1960s	2.80	2.70	2.52	2.98
		1970s	3.00	4.80	2.54	5.26
		1980s	3.15	2.20	2.74	2.61
		1990s	2.88	-1.50	3.10	-1.72
Sudan	41	1960s	2.60	8.50	2.40	8.70
		1970s	3.20	4.20	2.65	4.75
		1980s	2.87	1.70	2.63	1.94
		1990s	2.74	2.50	2.36	2.89
Togo	42	1960s	3.00	5.90	2.72	6.18
		1970s	2.80	-0.20	1.88	0.72
		1980s	3.33	2.90	2.89	3.34
		1990s	3.10	7.20	2.69	7.61
Uganda	43	1960s	2.90	0.10	2.66	0.34
		1970s	2.30	3.90	2.37	3.83
		1980s	3.12	-0.20	2.90	0.01
		1990s	3.13	-1.70	2.54	-1.11

Note: population data of the year1978 from FAO database. We use the 1978, and 1970 population data to calculate the growth rate of population in 1980. The other data is from US census bureau.

Table A2. The dietary energy supply (DES) by decades

Countries	Code	Years	DES (beginning of each decade) (Kcal/person/day)	DES in LN Form
Argentina	1	1961	3116.00	8.04
		1970	3327.30	8.11
		1980	3212.80	8.07
		1990	2909.90	7.98
Brazil	2	1961	2215.90	7.70
		1970	2411.40	7.79
		1980	2697.50	7.90
		1990	2754.60	7.92
Chile	3	1961	2475.80	7.81
		1970	2637.20	7.88
		1980	2667.30	7.89
		1990	2553.30	7.85
China		1961	1621.90	7.39
		1970	2010.90	7.61
		1980	2310.70	7.75
		1990	2705.80	7.90
Colombia	4	1961	2074.80	7.64
		1970	1938.30	7.57
		1980	2307.70	7.74
		1990	2418.80	7.79
Egypt	5	1961	2122.60	7.66
		1970	2355.90	7.76
		1980	2902.60	7.97
		1990	3176.40	8.06
Hungary		1961	3082.40	8.03
		1970	3330.00	8.11
		1980	3491.60	8.16
		1990	3710.80	8.22
India	6	1961	2073.40	7.64
		1970	2086.40	7.64
		1980	1965.70	7.58
		1990	2291.70	7.74

Jamaica	7	1961	1953.50	7.58
		1970	2537.80	7.84
		1980	2684.20	7.90
		1990	2620.20	7.87
Kenya	8	1961	2141.00	7.67
		1970	2211.30	7.70
		1980	2185.00	7.69
		1990	1888.80	7.54
Mexico	9	1961	2525.30	7.83
		1970	2705.70	7.90
		1980	3139.30	8.05
		1990	3103.00	8.04
Nigeria	10	1961	2284.60	7.73
		1970	2308.60	7.74
		1980	2046.90	7.62
		1990	2376.20	7.77
Poland		1961	3281.70	8.10
		1970	3430.10	8.14
		1980	3596.80	8.19
		1990	3343.30	8.11
Senegal	11	1961	2290.10	7.74
		1970	2232.60	7.71
		1980	2207.10	7.70
		1990	2316.50	7.75
South Africa	12	1961	2658.40	7.89
		1970	2790.40	7.93
		1980	2837.50	7.95
		1990	2919.90	7.98
Turkey	13	1961	2898.00	7.97
		1970	3053.00	8.02
		1980	3363.20	8.12
		1990	3564.60	8.18
Venezuela	14	1961	2165.40	7.68
		1970	2352.30	7.76
		1980	2845.60	7.95
		1990	2389.90	7.78
Zambia	15	1961	2146.60	7.67

		1970	2243.60	7.72
		1980	2272.60	7.73
		1990	2044.20	7.62
Zimbabwe	16	1961	2201.70	7.70
		1970	2265.10	7.73
		1980	2330.40	7.75
		1990	2110.50	7.65
Bangladesh	17	1961	2085.60	7.64
		1970	2202.80	7.70
		1980	1964.60	7.58
		1990	2081.80	7.64
Burma (Myanmar)	18	1961	1743.40	7.46
		1970	2039.20	7.62
		1980	2326.20	7.75
		1990	2620.20	7.87
Indonesia	19	1961	1727.70	7.45
		1970	1861.10	7.53
		1980	2198.20	7.70
		1990	2624.20	7.87
Nepal	20	1961	1847.20	7.52
		1970	1867.10	7.53
		1980	1877.60	7.54
		1990	2481.20	7.82
Pakistan	21	1961	1747.70	7.47
		1970	2263.80	7.72
		1980	2156.50	7.68
		1990	2412.30	7.79
Sri Lanka	22	1961	2110.90	7.65
		1970	2304.20	7.74
		1980	2351.60	7.76
		1990	2203.20	7.70
Yemen, PDR	23	1961	1730.20	7.46
		1970	1767.90	7.48
		1980	1937.10	7.57
		1990	2018.00	7.61
Benin	24	1961	1951.80	7.58
		1970	1958.40	7.58

		1980	2022.80	7.61
		1990	2318.20	7.75
Burkina Faso (upper Volta)	25	1961	1563.20	7.35
		1970	1756.90	7.47
		1980	1671.40	7.42
		1990	2084.10	7.64
Burundi	26	1961	2104.70	7.65
		1970	2106.20	7.65
		1980	2022.20	7.61
		1990	1877.20	7.54
Central Africa Rep.	27	1961	2313.20	7.75
		1970	2386.70	7.78
		1980	2300.70	7.74
		1990	1923.20	7.56
Ethiopia	28	1961	0.00	0.00
		1970	0.00	0.00
		1980	1865.90	7.53
		1990	0.00	0.00
Ghana	29	1961	2107.40	7.65
		1970	2348.90	7.76
		1980	1704.60	7.44
		1990	1831.00	7.51
Guinea	30	1961	2194.10	7.69
		1970	2190.40	7.69
		1980	2268.70	7.73
		1990	1987.50	7.59
Liberia	31	1961	2164.20	7.68
		1970	2444.40	7.80
		1980	2504.20	7.83
		1990	2100.50	7.65
Madagascar	32	1961	2325.00	7.75
		1970	2396.90	7.78
		1980	2374.00	7.77
		1990	2138.60	7.67
Malawi	33	1961	2015.20	7.61

		1970	2359.50	7.77
		1980	2246.20	7.72
		1990	1935.20	7.57
Mali	34	1961	2173.40	7.68
		1970	2196.10	7.69
		1980	1745.60	7.46
		1990	2313.40	7.75
Mauritania	35	1961	1996.00	7.60
		1970	1910.20	7.55
		1980	2118.10	7.66
		1990	2561.80	7.85
Mozambique	36	1961	1918.40	7.56
		1970	1873.60	7.54
		1980	1939.60	7.57
		1990	1840.30	7.52
Niger	37	1961	1660.40	7.41
		1970	1997.30	7.60
		1980	2139.40	7.67
		1990	2152.90	7.67
Sudan	38	1961	1729.50	7.46
		1970	2093.10	7.65
		1980	2201.00	7.70
		1990	2139.10	7.67
Togo	39	1961	2216.60	7.70
		1970	2299.30	7.74
		1980	2281.40	7.73
		1990	2468.60	7.81
Uganda	40	1961	2311.00	7.75
		1970	2419.50	7.79
		1980	2056.20	7.63
		1990	2324.30	7.75

Table A3. Literacy rate, investment growth rate per worker, and the annual growth rate of production for four crops (wheat, rice, maize, and milk) for a set of low and middle-income countries by decades, 1961-1999

Countries	Years	Literacy rate	Annual Average Change in lit level	Growth rate of investment per worker	A.G.R.of maize per capita %	A.G.R.of Rice per capita %	A.G.R.of wheat per capita %	A.G.R.of Milk per capita %
Argentina	1960s	92.97	0.13	2.73	0.00	0.00	0.00	0.00
	1970s	94.36	0.13	-0.10	4.61	7.77	-2.74	-1.28
	1980s	95.73	0.12	-9.02	-4.99	-5.40	2.86	0.61
	1990s	96.83	0.10	7.55	-2.92	2.95	1.57	0.15
Brazil	1960s	68.40	0.69	4.38	0.00	0.00	0.00	0.00
	1970s	76.04	0.69	7.90	1.50	0.44	8.46	0.45
	1980s	82.03	0.54	-2.27	0.99	0.07	1.19	2.13
	1990s	86.91	0.44	1.03	-1.45	-4.38	-0.64	0.16
Chile	1960s	87.62	0.34	1.78	0.00	0.00	0.00	0.00
	1970s	91.40	0.34	-4.97	1.57	-4.81	0.24	1.35
	1980s	94.00	0.24	-2.43	3.26	0.51	-4.28	-1.47
	1990s	95.76	0.16	9.83	4.91	1.69	3.70	0.40
China	1960s	29.50	1.29	-2.11	0.00	0.00	0.00	0.00
	1970s	67.06	1.29	-2.29	3.41	4.25	4.38	-1.56
	1980s	78.29	1.02	12.04	4.15	0.46	4.13	1.99
	1990s	85.19	0.63	11.55	2.66	1.35	3.92	6.65
Colombia	1960s	77.83	0.56	1.82	0.00	0.00	0.00	0.00
	1970s	84.03	0.56	3.38	-1.35	1.53	-11.53	-0.46
	1980s	88.45	0.40	-2.26	-2.20	5.89	-3.43	-2.32
	1990s	91.63	0.29	5.36	1.27	-0.37	5.62	3.75
Egypt	1960s	31.59	0.70	1.07	0.00	0.00	0.00	0.00
	1970s	39.29	0.70	21.06	1.55	5.46	-1.52	0.84
	1980s	47.10	0.71	-0.72	0.54	-2.98	-0.96	-0.49
	1990s	55.30	0.75	4.32	1.00	0.00	5.58	-0.93
Hungary	1960s	98.08	0.04	-0.32	0.00	0.00	0.00	0.00
	1970s	98.57	0.04	-0.19	3.30	1.10	2.78	-1.26
	1980s	99.06	0.04	-0.90	4.17	-6.00	6.98	3.14
	1990s	99.32	0.02	8.39	-3.29	4.82	0.47	1.30
India	1960s	33.10	0.72	3.61	0.00	0.00	0.00	0.00
	1970s	41.03	0.72	3.85	3.02	-0.46	3.49	-1.80
	1980s	49.32	0.75	2.13	-2.61	0.22	2.24	1.85

	1990s	57.24	0.72	5.38	0.46	1.14	2.23	2.98
Jamaica	1960s	68.14	0.74	6.21	0.00	0.00	0.00	0.00
	1970s	76.27	0.74	-12.69	0.35	-20.49	0.00	4.45
	1980s	82.18	0.54	-2.89	-1.26	11.17	0.00	-0.77
	1990s	86.92	0.43	2.63	-7.36	-22.59	0.00	-0.27
Kenya	1960s	40.62	1.41	4.06	0.00	0.00	0.00	0.00
	1970s	56.15	1.41	-0.78	1.12	3.18	3.47	-1.27
	1980s	70.76	1.33	-4.52	-2.69	-0.51	-3.81	-2.24
	1990s	82.42	1.06	1.48	-0.13	-5.04	-4.42	4.71
Mexico	1960s	73.49	0.71	6.75	0.00	0.00	0.00	0.00
	1970s	81.33	0.71	4.24	0.35	-1.06	3.03	1.67
	1980s	87.35	0.55	-9.82	0.62	-1.54	-2.03	2.74
	1990s	91.16	0.35	1.56	-0.35	-2.98	1.26	-2.91
Nigeria	1960s	20.14	1.16	5.15	0.00	0.00	0.00	0.00
	1970s	32.94	1.16	20.69	0.16	6.37	-0.68	1.31
	1980s	48.66	1.43	-16.95	-10.61	7.70	-0.69	-0.01
	1990s	64.02	1.40	3.04	17.81	4.96	4.08	-0.85
Poland	1960s	98.20	0.08	-0.86	0.00	0.00	0.00	0.00
	1970s	99.07	0.08	-1.11	-10.06	0.00	3.69	0.57
	1980s	99.58	0.05	1.08	13.48	0.00	-1.71	0.07
	1990s	99.73	0.01	11.09	14.03	0.00	6.38	-0.99
Senegal	1960s	14.68	0.58	-1.43	0.00	0.00	0.00	0.00
	1970s	21.01	0.58	0.02	0.32	-1.75	0.00	0.73
	1980s	28.35	0.67	-0.52	1.05	-5.48	0.00	-2.94
	1990s	37.37	0.82	0.63	5.33	6.94	0.00	-1.10
South Africa	1960s	69.71	0.59	7.08	0.00	0.00	0.00	0.00
	1970s	76.15	0.59	-2.41	-1.02	-4.60	1.86	-1.24
	1980s	81.21	0.46	-8.36	2.99	1.40	-1.81	-3.39
	1990s	85.24	0.37	0.80	-3.86	-2.18	-0.83	-2.56
Turkey	1960s	56.48	1.08	6.65	0.00	0.00	0.00	0.00
	1970s	68.41	1.08	7.78	-1.95	-0.94	0.99	-1.05
	1980s	77.85	0.86	1.71	-0.52	-3.14	2.39	0.34
	1990s	85.01	0.65	2.36	2.81	-2.30	-0.25	-1.98
Venezuela	1960s	76.27	0.69	4.09	0.00	0.00	0.00	0.00
	1970s	83.90	0.69	7.90	1.57	6.16	-11.20	3.44
	1980s	88.89	0.45	-7.41	-4.79	6.27	-4.28	0.30
	1990s	92.54	0.33	0.36	2.60	-4.48	-5.57	-1.51
Zambia	1960s	47.65	0.99	8.17	0.00	0.00	0.00	0.00

	1970s	58.57	0.99	-5.70	-3.76	0.00	-18.75	-1.38
	1980s	68.15	0.87	-7.65	1.86	11.74	38.89	0.01
	1990s	78.19	0.91	9.04	-1.54	10.03	12.78	-0.41
Zimbabwe	1960s	57.58	1.14	-2.89	0.00	0.00	0.00	0.00
	1970s	70.10	1.14	-3.73	-2.28	11.22	35.34	-1.90
	1980s	80.70	0.96	-5.13	0.62	-26.05	9.09	1.20
	1990s	88.67	0.72	-2.70	-0.74	-0.52	1.69	-2.35
Bangladesh	1960s	24.57	0.40	9.19	0.00	0.00	0.00	0.00
	1970s	28.93	0.40	-3.91	-9.76	-0.57	8.72	-0.53
	1980s	34.22	0.48	-0.13	-9.51	-0.44	16.31	-1.64
	1990s	39.99	0.52	4.46	6.07	0.28	-1.30	0.86
Burma (Myanmar)	1960s	69.78	0.53	4.65	0.00	0.00	0.00	0.00
	1970s	75.56	0.53	2.09	-2.97	-0.04	12.01	0.80
	1980s	80.71	0.47	-2.18	9.63	2.68	7.32	5.29
	1990s	84.67	0.36	12.64	-0.26	-0.89	1.51	2.78
Indonesia	1960s	56.06	1.18	2.99	0.00	0.00	0.00	0.00
	1970s	69.04	1.18	13.00	0.12	2.45	0.00	-3.13
	1980s	79.51	0.95	-0.51	1.02	1.77	0.00	1.06
	1990s	86.81	0.66	3.02	2.96	2.04	0.00	6.26
Nepal	1960s	16.36	0.55	-1.56	0.00	0.00	0.00	0.00
	1970s	22.41	0.55	-1.77	-1.67	-0.76	4.56	-0.34
	1980s	30.44	0.73	-1.94	-3.14	-1.49	2.52	-0.49
	1990s	41.70	1.02	3.52	2.30	0.90	3.75	-0.37
Pakistan	1960s	20.90	0.63	4.49	0.00	0.00	0.00	0.00
	1970s	27.82	0.63	2.31	1.09	3.67	3.48	-0.45
	1980s	35.38	0.69	3.79	0.38	0.83	1.25	-0.63
	1990s	43.21	0.71	-0.22	-0.83	-2.25	-0.13	1.82
Sri Lanka	1960s	80.46	0.44	4.44	0.00	0.00	0.00	0.00
	1970s	85.29	0.44	1.31	1.70	2.93	0.00	0.59
	1980s	88.72	0.31	-2.67	1.94	0.95	0.00	3.36
	1990s	91.63	0.26	4.48	2.83	0.28	0.00	-0.96
Yemen, PDR	1960s	14.15	0.53	-1.72	0.00	0.00	0.00	0.00
	1970s	19.98	0.53	-1.23	-1.15	0.00	-0.59	-4.67
	1980s	32.68	1.15	-3.38	10.31	0.00	3.52	-1.57
	1990s	46.36	1.24	3.75	-0.67	0.00	4.05	3.30
Benin	1960s	10.93	0.63	1.99	0.00	0.00	0.00	0.00
	1970s	17.87	0.63	5.98	-1.76	14.67	0.00	2.06
	1980s	26.45	0.78	-13.66	-1.01	4.28	0.00	1.45

	1990s	37.42	0.58	2.27	1.00	-2.10	0.00	-0.98
Burkina Faso (upper Volta)	1960s	6.98	0.35	-1.32	0.00	0.00	0.00	0.00
	1970s	10.80	0.35	0.10	-4.08	0.36	0.00	1.86
	1980s	16.35	0.50	1.93	3.87	-0.98	0.00	-2.21
	1990s	23.90	0.69	2.57	5.76	-0.88	0.00	-0.22
Burundi	1960s	20.24	0.68	2.28	0.00	0.00	0.00	0.00
	1970s	27.74	0.68	15.46	0.83	2.71	0.01	1.70
	1980s	36.99	0.84	6.04	-0.81	4.73	-0.46	-0.88
	1990s	47.97	1.00	-13.08	-0.57	10.38	1.68	-3.36
Central Africa Rep.	1960s	14.03	0.80	-0.70	0.00	0.00	0.00	0.00
	1970s	22.88	0.80	-1.10	-1.51	5.71	0.00	4.42
	1980s	33.21	0.94	6.89	-2.16	3.76	0.00	9.29
	1990s	46.72	1.23	-3.89	0.01	-6.65	0.00	4.12
Ethiopia	1960s	12.88	0.64	3.87	0.00	0.00	0.00	0.00
	1970s	19.88	0.64	-3.39	0.20	0.00	0.14	-0.56
	1980s	28.60	0.79	-0.73	2.84	0.00	-5.57	-0.63
	1990s	39.10	0.95	10.96	0.22	0.00	1.10	-1.17
Ghana	1960s	29.50	1.30	-5.32	0.00	0.00	0.00	0.00
	1970s	43.77	1.30	-10.46	4.75	2.18	0.00	3.25
	1980s	58.46	1.33	1.89	3.96	10.33	0.00	4.97
	1990s	71.60	1.20	1.28	-7.81	-10.84	0.00	-8.55
Guinea	1960s	12.02	0.60	-1.73	0.00	0.00	0.00	0.00
	1970s	18.61	0.60	3.28	-4.77	2.54	0.00	-1.00
	1980s	27.18	0.78	-1.75	0.66	0.98	0.00	0.73
	1990s	38.41	1.02	0.42	-4.83	-4.15	0.00	-2.62
Liberia	1960s	18.44	0.86	-7.15	0.00	0.00	0.00	0.00
	1970s	27.86	0.86	3.51	0.00	2.01	0.00	0.98
	1980s	39.22	1.03	-16.77	0.00	-0.52	0.00	0.25
	1990s	53.54	1.30	-4.18	0.00	-4.05	0.00	-1.56
Madagascar	1960s	38.49	0.82	-1.91	0.00	0.00	0.00	0.00
	1970s	47.55	0.82	-4.95	-2.57	0.67	0.00	-0.20
	1980s	57.96	0.95	-3.22	-0.82	-1.53	0.00	-0.31
	1990s	66.50	0.78	-1.75	-0.81	-1.33	22.33	-1.84
Malawi	1960s	37.93	0.60	13.01	0.00	0.00	0.00	0.00
	1970s	44.53	0.60	-1.61	-1.49	5.24	20.27	1.18
	1980s	51.83	0.66	-12.22	-0.32	2.23	-14.55	3.99
	1990s	60.15	0.76	-9.27	-2.58	-2.52	7.09	-2.96

Mali	1960s	9.14	0.39	1.61	0.00	0.00	0.00	0.00
	1970s	13.42	0.39	-0.02	-3.60	-2.69	-7.61	1.22
	1980s	18.84	0.49	0.39	-4.00	-4.09	-1.79	-0.88
	1990s	25.64	0.62	-3.11	11.50	5.12	-1.53	-2.52
Mauritania	1960s	26.79	0.18	-3.40	0.00	0.00	0.00	0.00
	1970s	28.74	0.18	3.07	0.26	7.86	6.66	0.48
	1980s	34.83	0.55	-7.38	0.82	17.09	-2.89	-2.23
	1990s	40.23	0.49	4.03	-8.89	12.01	6.67	-0.84
Mozambique	1960s	16.60	0.71	6.31	0.00	0.00	0.00	0.00
	1970s	24.44	0.71	-11.67	-1.91	-0.63	-1.59	0.77
	1980s	33.48	0.82	-7.94	-2.23	-4.89	-12.58	-2.16
	1990s	44.02	0.96	10.42	1.19	1.88	4.24	-0.37
Niger	1960s	5.75	0.20	0.48	0.00	0.00	0.00	0.00
	1970s	7.95	0.20	2.66	-5.62	9.81	-11.08	-1.11
	1980s	11.40	0.31	-12.94	14.19	-4.66	5.86	-2.43
	1990s	15.96	0.41	2.30	-18.57	5.26	20.55	-2.75
Sudan	1960s	24.78	0.86	-3.70	0.00	0.00	0.00	0.00
	1970s	34.21	0.86	7.15	13.63	8.05	11.00	-1.31
	1980s	45.77	1.05	-7.73	-2.73	-0.48	3.37	2.98
	1990s	57.67	1.08	-2.36	-7.27	-21.94	2.16	0.11
Togo	1960s	22.11	0.94	8.38	0.00	0.00	0.00	0.00
	1970s	32.41	0.94	14.12	5.97	-5.13	0.00	0.03
	1980s	44.24	1.08	-4.49	-5.03	-2.46	0.00	-1.39
	1990s	57.14	1.17	8.91	3.35	1.65	0.00	-2.36
Uganda	1960s	36.38	0.86	7.14	0.00	0.00	0.00	0.00
	1970s	45.87	0.86	-16.17	-17.39	8.92	0.00	-1.13
	1980s	56.15	0.93	-2.90	-4.90	1.47	4.81	0.60
	1990s	67.03	0.99	7.36	3.69	7.44	-16.23	-0.78

Appendix B

Data review of the production variables

Maize

In low-income countries, the mean of the annual average growth rate of maize production per capita was almost the same throughout the period of this study. Over the decade of the 1960s, the mean was 2.68 percent per year, with a standard deviation of 1.95 percent. Over the decade of the 1990s, the mean was 2.62 percent per year, with a standard deviation of 2.03. For the middle-income countries, the situation was the same, with means ranging between 3.85 percent per year in the 1960s and 4.04 percent per year over the1990s (see Table B1.)

Table B1. Growth rate for maize production per capita, by decade

	Mean		Standard Deviation	
Decade	LIC	MIC	LIC	MIC
1960s	2.68	3.85	1.95	1.79
1970s	2.58	3.84	1.99	2.03
1980s	2.59	3.95	1.92	1.83
1990s	2.62	4.04	2.03	1.62

Note: LIC refers to low-income countries; MIC refers to middle-income countries.

Rice

In the low-income countries, the mean of the annual average growth rate of rice production was the same over the entire period covered by the study. For the middle-income countries, the mean was decreasing. Over the decade of the 1960s, the mean of the annual average growth rate of rice production was 1.79 percent per year, with a standard deviation of 1.83 percent, while over the decade of the1990s the mean decreased to 1.407 percent per year, with a standard deviation of 2.5 percent (see Table B.2).

Table B2. Growth rate of rice production per capita, by decade

	Mean		Standard Deviation	
Decade	LIC	MIC	LIC	MIC
1960s	2.263310	1.789787	2.356517	1.839715
1970s	2.502135	1.790163	2.273824	2.045234
1980s	2.688642	1.591352	2.111792	2.292734
1990s	2.696374	1.407470	2.228186	2.504757

Note: LIC refers to low-income countries; MIC refers to middle-income countries.

Wheat

In the low-income countries, the mean of annual average growth rate of wheat production over the decade of the 1960s was 0.38 percent per year, with a standard deviation of 1.74 percent. In the 1990s, the mean increased to 0.87 percent per year, with a standard deviation of 0.87 percent.

The situation in the middle-income countries was better in terms of production in the two decades of the 1960s and 1970s, but over the decade of the 1980s and the 1990s the mean decreased to 0.87 percent per year, with a standard deviation of 2.94 percent (see Table B3).

Table B3. Growth rate of wheat production per capita, by decade

	Mean		Standard Deviation	
Decade	LIC	MIC	LIC	MIC
1960s	0.38	2.73	1.74	2.62
1970s	0.52	2.96	1.74	2.61
1980s	0.59	2.99	0.59	2.78
1990s	0.87	3.138	0.87	2.94

Note: LIC refers to low-income countries; MIC refers to middle-income countries.

Milk

In the low-income countries, the mean of the annual average growth rate of milk production was increasing during the decade of the 1960s through the 1990s. Over the decade of the 1960s, the mean was 0.38 percent per year, with a standard deviation of 1.47 percent. In the 1990s, the mean of the average annual growth rate of milk production increased to 0.87 percent per year, with a standard deviation of 0.87 percent (see Table B4).

In the middle-income countries, the situation was the same. The mean was increased during the 1960s, 1970s, 1980s, and 1990s by approximately 0.2 percent.

Table B4. Growth rate of milk production per capita, by decade

	Mean		Standard Deviation	
Decade	LIC	MIC	LIC	MIC
1960s	2.5491	4.48295	1.552464	0.920262
1970s	2.5499	4.53240	1.490729	0.810759
1980s	2.6187	4.525842	1.396111	0.885041
1990s	2.6115	4.45641	1.44727	0.917835

Note: LIC refers to low-income countries; MIC refers to middle-income countries.

Appendix C

The Correlation Matrix

	Annual Average Change in literacy level	Growth rate of investment per worker	A.G.R.*of maize per capita %	A.G.R.* of Rice per capita %	A.G.R.* of wheat per capita %	A.G.R.* of Milk per capita %	Population growth rate	Average A.G.R.* of labor force rate %	Average A.G.R.* of GDP per worker
Annual Average Change in literacy level	1	-0.06	-0.01	0.01	0.02	-0.01	0.57	0.51	0.11
Growth rate of investment per worker	-0.06	1	0.19	0.10	0.00	0.09	-0.08	0.00	0.32
A.G.R.* of maize per capita %	-0.01	0.19	1	0.05	-0.04	0.09	-0.06	-0.07	0.04
A.G.R.* of Rice per capita %	0.01	0.10	0.05	1	0.11	0.00	0.10	0.01	0.05
A.G.R.*.o f wheat per capita %	0.02	0.00	-0.04	0.11	1	-0.05	0.01	0.05	0.02
A.G.R.* of Milk per capita %	-0.01	0.09	0.09	0.00	-0.05	1	-0.11	-0.03	0.01
Population growth rate	0.57	-0.08	-0.06	0.10	0.01	-0.11	1	0.79	0.02
Average A.G.R.* of labor force rate %	0.51	0.00	-0.07	0.01	0.05	-0.03	0.79	1	-0.03
Average A.G.R.* of GDP per worker	0.11	0.32	0.04	0.05	0.02	0.01	0.02	-0.03	1

A.G.R.* = Annual Growth Rate