Master's Thesis in Economics
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Nutrition Intake and Economic Growth:
A causality study on five countries in Southern Africa

Abstract

The relationship between a population's nutrition intake and economic growth has been receiving an increasing amount of attention in economic literature. Although the correlation of these factors has been quite well established, the direction of the causality remains somewhat unclear: Is it nutrition intake that leads to economic growth or does economic growth lead to improved nutrition levels, or does the causality run in both directions in a self-reinforcing mechanism? It is reasonable to believe that the causal direction could have significant policy implications, particularly for developing economies in which the level of nutrition still lies significantly below recommended levels. This study uses time series of GDP/capita and two indicators of nutrition intake (average daily calorie intake per capita and average daily protein intake per capita) to test the direction of the growth-nutrition causality in five countries in the region of Southern Africa, which all display relatively severe rates of malnutrition. The Granger causality test is employed for this purpose. The obtained results reveal some evidence for that nutrition Granger-causes economic growth. The opposite relationship, i.e. that of growth Granger-causing nutrition, receives however very little support.

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TABLE OF CONTENTS

1. Introduction

The United Nations Millennium Development Goals (MDGs) deem income poverty and malnutrition as indicators of poverty that should, relative to their 1990 levels, be halved by 2015.[1] This raises the question of how these two measures of a globally adopted development strategy are related and interlinked. To what extent is an adequate level of nutrition intake a necessary component of a sound and realistic growth strategy to combat poverty? Further, would a growth strategy that aims to achieve a significant increase in the gross domestic product per capita, be sufficient to attain the nutrition MDGs? Are there reasons to believe that nutrition might respond inadequately to income growth, or vice versa? While sufficient nutrition and the reduction of malnutrition can be justified on their purely intrinsic grounds, it is the potential gains in productivity and the contributions to economic growth that are the background and focus of this paper.

Economic theory explains that greater incomes would allow families to spend more on food, clean water, hygiene and health care. Along the same line of thought, one would also expect families to attempt to obtain a more diversified diet. The links between individual nutritional status and health and survival, physical and cognitive functions, and thus work capacity and productivity, are well acknowledged and empirically established. Empirical links relating individual productivity to household income and in turn to the capacity for economic growth at a national level are, however, weaker.

While much research has shown a positive correlation between economic growth and nutrition intake, economic literature is somewhat ambiguous on the causal relationship between the two. A common assumption is that income has a strong effect on the demand for health and nutrition. There has been less agreement on the reverse relationship: the causal impact of health, including the nutritional status, on productivity and national income in low-income countries. In a Western historical framework, as the economies of the developed nations grew, nutrition and health

[1] For more information see the United Nations MDG website on http://www.un.org/millenniumgoals/.

improved. Indeed, the perception seems to be that the industrial revolution preceded and caused improvements in nutrition and health status of the population. However, only in recent years, has progress been made inferring this relationship through both experimental and non-experimental methods. Yet relatively little empirical evidence has critically analysed the causal links between economic performance and nutrition. Instead, many studies seem to interpret correlation as though it were causality, despite the fact that knowing the correct causal relationship is clearly of outmost importance in determining and advocating effective public policy interventions.

This paper aims to examine the nature of the causality between nutrition intake and economic growth in five of the most malnourished countries in Sub-Saharan Southern Africa. The study focuses on the relationship in a short-term perspective.[2] Given the relative lack of research on the relationship from national income to nutrition, we are specifically interested in the plausible causal relationship from economic growth to nutrition intake.

The study uses data on five Southern African countries from 1961 to 1999. After a check of the availability of data and its suitability to the selected econometric procedure, the studied countries include Lesotho, Madagascar, Malawi, Zambia, and Zimbabwe. One of the reasons for that these countries are studied is that each of these countries have relatively high undernourishment rates, ranging from 12 percent to 47 percent of the total population. These estimates are based on calculations of the amount of food available in each country (national dietary energy supply or DES). This also implies that the population is likely to suffer from high rates of malnutrition, defined as a "state in which the physical function of an individual is impaired to the point where he or she can no longer maintain adequate bodily performance processes such as growth, pregnancy, lactation, physical work, and resisting and recovering from disease".[3]

The remainder of the paper is as follows. The next section provides a brief background to the area and countries of our study. Section three discusses the

[2] The meaning of short-term in this study related to the theoretical understanding of the potential impact of nutrition on GDP and vice versa. This will be discussed later in the paper.
[3] World Food Programme (2000), *Food and Nutrition Handbook,* p. 18.

theoretical background to the relationship between malnutrition and economic growth. Section four presents the data selection and the requirements and workings of the Granger causality test, the procedure used for testing the causality between economic growth and malnutrition. Section five provides the results from the econometric tests performed. Section six presents a discussion of the results of the two-way causality test between nutrition intake and economic growth, also addresses the limitations of the study. Finally, concluding remarks are made in section seven.

2. Regional Background

The countries investigated in this thesis are all located in the region of Southern Africa.[4] Although the original aim of the study was to include as many countries of this region as possible, the availability of trustworthy data restricted the extent of the study to five countries[5]:

- Lesotho
- Madagascar
- Malawi
- Zambia
- Zimbabwe

An advantage of restricting the study to a certain geographical region is that the countries are less likely to differ markedly in terms of factors that could have a possible impact on the relationship between nutrition and economic performance. It seems for example reasonable to expect that the countries selected have in common a fair share of similarities in terms of culture, history and climate. Most importantly, however, all of the countries studied are at this point far from having tackled the problem of malnutrition.

As a general background, Table 1 gives a basic overview of a few relevant statistics. The low per capita income levels that most of Africa suffers from are also prevalent in the studied countries. Apart from Zimbabwe, which gained official independence in 1982, there is a shared history of colonial rule and independence in the 1960's, followed by a brief spell of post-independence growth and optimism that by the 1980's was dashed by a rapid and severe decline. Agriculture is by far the most important preoccupation and inequality of income is large (a Gini coefficient ranging

[4] "Southern Africa" usually includes Angola, Botswana, Lesotho, Malawi Mozambique, Namibia, South Africa, Swaziland, Zambia and Zimbabwe. Although Madagascar displays somewhat different characteristics (see Table 1 on p.7), it is nevertheless sometimes included into Southern Africa, as for example in the United Nations Food and Agriculture report on food security for 2006.

[5] The choice of countries had to in the end be based upon the availability of World Bank data for the GDP for the entire period studied. South Africa (the country) was never considered on the basis of it not being considered a developing country.

between 47 and 63, by comparison, Sweden has a Gini coefficient of 25.0 and the USA 40.8; a higher value indicates greater inequality). Besides these issues, more or less prevalent in all of Africa, Southern Africa stands out in one particularly gloomy department: the region is the world's most afflicted by HIV/AIDS.[6] This has made the governments face a completely new set of challenges to preserve the afflicted labour force, including the need for a better understanding of the relationship between the virus and nutrition both in terms of supply and intake.[7]

Finally, what is most relevant for this study, the levels of undernourishment are consistently very high in all the countries. Taking the daily calorie intake per capita as a crude measure, only Lesotho lies above the approximate minimum daily requirement of 2300 kcal per capita, with the recommended value being higher, around 2700 kcal/cap.[8] By comparison, Sweden averages 3208 kcal/cap, whiles the USA 3754 kcal/cap.

[6] Madagascar is an exception to this, with a substantially lower affliction rate.
[7] Nutrition and HIV are inextricably linked. HIV causes repeated illness which reduces the ability to produce and/or buy sufficient food. The virus also affects the ability to eat and absorb food and thus leads to nutrient losses. See for example the WHO report *Nutrient requirements for people living with HIV/AIDS: report of a technical consultation*, World Health Organization (2003).
[8] These numbers are simply rough estimation because the energy requirements vary greatly between individuals and countries. See Haddad (1997), p.18-19; Perkins et al. (2001), p.359.

Table 1. Development Indicators

	Lesotho	Madagascar	Malawi	Zambia	Zimbabwe
Population (million)	2,1	19,4	13,6	11,5	12,3
GDP/cap (PPP US$) 2003	2561	809	605	877	2443
Population below income poverty line 1$ a day (1990-2003)	36.4	61	41.7	63.7	56.1
Inequality - Gini index	63.2	47.5	50.3	52.6	56.8
Aids - adult prevalence rate (2003 est.)	28.90	1.70	14.20	16.50	24.6 (2001)
Literacy - ages 15 and above (%)	81.4	70.6	64.1	67.9	90.0
Population undernourished (%)	12	38	34	47	45
Dietary Energy Supply Kcal/person/day (2003)	2620	2040	2140	1930	2010
Rural population (% of total)	82	73	83	64	65

Source: UNDP Human Development Report 2005 and The FAO Report on the State of Food Insecurity in the World 2006.

3. Theoretical Background and Earlier Research

In this section, we present the theoretical and empirical evidence relevant to the relationship between nutrition intake and economic performance.

3.1. Theoretical background

This section is based on Perkins et al. (2001) chapters 2 and 10.

The level of a population's nutrition has not received significant interest from economists until relatively recently; nutrition did not figure much in the early growth theory. The basic Solow (neoclassical) growth model developed in the 1950's explained growth in terms of the capital and labour endowments. The model predicts that eventually a steady state capital level will be reached after which capital accumulation will no longer be able to affect the absolute growth rate and income will thus only increase in proportion to the population, i.e. per capita income will be unaffected. The steady growth experienced in the developed world even without population growth can instead be explained by technological change. In this setting, as technology advances the productivity of labour increases. This can derive either from better equipment (e.g. more advanced machinery), or, what is more relevant to this thesis, by the way of increased human capital.

The concept of human capital received a greater attention from economists who tried to extend the basic Solow model into the so called endogenous growth theory. The idea behind this theory is to treat parameters taken as granted by the Solow model as possible to influence. As a consequence, the development of human capital is no longer simply given by the rate of technological change, but can be influenced through policy. The issue that is more difficult to agree upon is which variables constitute human capital and what relative weights they should be given.

The most prominent part of the human capital has normally been reserved for education. A more educated population yields a better skilled and more productive work force. In the late 1960's, health economics appeared as a growing discipline and the importance of health for economic growth received greater attention. The study of nutrition as a variable that can possibly explain growth rate emerged slowly as part of this discipline.

The above points give a basic overview of the theory used to explain the effect of nutrition on growth. It is suitable here to also mention the theoretical background for the opposite causality, i.e. how growth may induce improved nutrition intake. Arguably, this causality is more straightforward and has raised less debate. It is anchored in basic microeconomic theory, more specifically the so called Engel's Law. This states that when a household's income increases, more food will be purchased, although the proportion of the income that goes to food will gradually decrease. Expressed even more simply, since food is a normal good, it is right to expect that its consumption will increase when income increases. Effectively, assuming that the quantity of food is a sufficient proxy for nutrition, higher income should be creating better nourished populations.

3.2. Earlier research

The literature on the bi-directional relationship between nutrition intake and economic growth dates back to the 1960s and includes inputs from a range of different disciplines.[9] In the below section we present the most relevant theories and empirical evidence in order to clarify important distinctions and concepts such as correlation and causality, short-term versus long-term, and the links between micro - and macroeconomic approaches.

[9] As an example, a food security study conducted at the University of Zimbabwe claimed inputs from "anthropologists, sorghum and millet breeders, agronomists, microeconomists, agricultural engineers, macroeconomists and food scientists". Rukuni & Eicher (1987), p.20.

3.2.1 The impact of nutrition intake on economic performance

While much literature and empirical evidence assert that income and nutrition intake are strongly correlated, there is no intuitively straightforward causal relationship between the two variables. For this reason, several economists have offered a set of explanations and empirical studies on the multiple mechanisms which link the two together. These studies can be separated into microeconomic and macroeconomic approaches. Microeconomic studies mainly use data from household surveys and focus on the impact of nutrition intake upon the health of individuals, whereas the macro or aggregate alternatives typically investigate gains/losses from nutrition/malnutrition in terms of growth in national income.

There are multiple channels through which gains from improved nutrition intake may operate - from conception through childhood and into adulthood. Behrman et al. (2004) provides a helpful categorization of these channels through the following grouping: (1) saving of resources that are currently used towards diseases and other problems related to malnutrition; (2) direct gains arising from an improved physical stature; and 3) indirect gains arising from correlations between nutritional status and schooling and cognitive development, and the resulting links to cognitive ability and worker productivity.

A thorough presentation of the available microeconomic evidence about the impact of improved nutrition intake is clearly beyond this study. Rather, given our focus on the possibility of a short-term causal relationship, a key question is whether it is possible to discern an immediate to short-term relationship from nutrition intake to income. Given the above groupings of channels, the most relevant channel for our study would appear to be the effects of the physical and cognitive losses arising from a period of malnutrition.

The direct harmful physical and cognitive effects arising from undernutrition have been both well researched and acknowledged.[10] Evidence is, however, most of all

[10] This acknowledgement is also supported by one of the most influential models of wage-setting in low-income countries, the Nutrition Efficiency Wage Theory. One of the main points of the theory posits that

based upon research on the effect of early child malnutrition. In terms of the short term impact, evidence for the effect of current consumption on current work capacity is strong, but support for the subsequent effect on economic productivity and income is more mixed, yet still persuasive.[11] First, as stated in Strauss & Thomas (1998), it is reasonable to suggest that a human body can adapt to inadequate nutrition in the very short run, and so there is only a weak link between intakes and output over some time range. A study conducted on the labour productivity of rural Indian workers indicates this point since neither farm output nor market wages were responsive to daily energy intake of workers (Deolalikar 1988). However, once a lower nutritional threshold has been passed, adaptation mechanisms are likely to be insufficient.[12] This seems reasonable given that there must be a biological limit to the extent to which a human body can adapt to inadequate nutrition. Several empirical studies confirm this by finding that increased calorie consumption does significantly affect worker productivity both in the medium and long-term perspective (Deolalikar 1988), (Strauss & Thomas 1997) and (Foster & Rosenzweig 1993*).*

Given the above, reductions of nutrition levels in low-income and already poorly nourished populations should potentially have a more sizeable and harmful impact. Along the same reasoning, additional dietary energy intake would be associated with a relatively larger impact on higher productivity than in already well nourished populated countries (Behrman et al. 2004). Indeed, in recent years substantial progress in documenting the existence of a causal impact of health on wages and worker productivity in low-income countries has been made. This impact has also proven to be stronger in countries with low levels of health and with jobs requiring more physical strength as is the case in the countries in this study (Strauss & Thomas 1998).

Evidence showing the impact of nutrition on an aggregate level often is combined with estimations of the economic benefits of a generally improved health status of a population.[13] Most macro-level studies estimate the relationship between cross-country or panel data on economic growth and some duly selected measure of

there is a significant relationship between worker productivity and food consumption. For more readings on this topic, see Strauss & Thomas (1998).

[11] For a review of the development of nutrition studies, see Rogers B. L. (2002) p. 29-34.

[12] Strauss & Thomas (1998), p. 807.

[13] See for example the *Commission on Macroeconomics and Health* by the World Health Organization (2001).

malnutrition. The results subsequently indicate an estimate of aggregate productivity losses, the accumulated losses over time and reduced potential rates of GDP growth. Other studies emphasize how a low nutrition level may lower life expectancy, thereby negatively affecting the input of average human capital.

An often-quoted historical study was conducted by Fogel (1997) who elucidated the relationship between body size and food supply and found it to be a critical binding constraint on economic productivity and development. Several publications on behalf of the international food organizations (e.g. United Nations Food and Agriculture Organization (FAO)) have also pointed out the importance of nutrition for economic performance. One of these studies was made by Arcand (2001) who employs time series methods and data from 129 countries and thereby concludes that inadequate nutrition is causing losses of 0.16 to 4.0 percentage point of GDP in sub-Saharan Africa. Wang & Taniguchi (2003) build on the latter study, and conclude that there is both a significant short-term and long-term correlation indicating a strong influence of nutrition on economic growth and vice versa. Fewer studies investigate the macro relationship at a country level. One such case is the study by Ganegodage et al (2003) on Sri Lanka where evidence shows both a significant short-run and long-run the relationship between nutrition intake and economic growth, indicating that 1 percent increase in protein intake increases GDP by 0.49 percent in the long run, and a relatively strong short-term relationship.

On a more cautious note, these findings should not be taken out of proportion. Despite the many studies supporting the argument of a strong correlation from nutrition to income, there exist studies that find little support of this impact. An example is a study made by Edmundson & Sukhatme (1990) suggesting that the health effect of malnutrition has been overstated because the human body has a strong potential to adapt to low nutrition intakes. After all, research sponsored by the FAO, UNICEF and other food agencies may have somewhat of a vested interest in proving the economic importance of nutrition. As a counterexample, an organization such as the International Monetary Fund traditionally attributes far less attention to the impact of nutrition and even human capital in general in the analysis of macro economic performance.[14] This needs not imply the existence of any self-serving bias, but it does provide an indication that research is still quite far away from universal agreement on the point of the importance of human capital.

3.2.2. The impact of economic performance on nutrition intake

According to classical economic theory, it seems reasonable to suggest that income growth, specifically at low levels of real per capita income, will lead to increased food consumption. The magnitude of this effect has however been much debated. Several studies have attempted to measure the elasticity of the demand for calories and found that the income elasticity of demand for calories fluctuates around 0.2 to 0.3, though Behrman et al (2004) points out that other studies have also found estimates both higher and lower than this range. Furthermore, Rogers (2002) mentions studies which show that in an undernourished population increases in income translate into increases in food consumption at a lower rate than what might be expected. From this it seems clear that at a household level, private income growth does not guarantee improved or increased nutrition intake for several reasons. In part, this is a result of individual preference but also combined with different biological needs for nutrition intake due to various genetic make-ups (Behrman et al. 2004). Individual preferences would for example be influenced by factors such as knowledge and skills regarding nutrition, culture, religion and general food habits. Further, the very fact that a household holds an increased income, does not guarantee the access to the food available. This could particularly be the case in developing countries characterized by lack of properly functioning food market distribution channels, infrastructure, and most of all a large rural and informal sector without the available cash income.

Haddad et al. (2003) uses household survey data from 12 countries to estimate the magnitude of the response between weight-for-age values to income growth. The results show that a scenario of sustained per capita income growth of 2.5 per cent per annum, would reduce the average in the fraction of underweight children between 27 per cent and 34 per cent. Nevertheless, a more recent study by Alderman et al. (2005)

[14] Basu et al. (2000), p.4.

concludes that while income growth does matter to the reduction of malnutrition, the effect is only noteworthy *in connection with* nutrition programs. Subsequently, the study suggests that income growth alone is insufficient to attain the nutrition level stated in the MDGs.

Concluding this section, it is clear that several studies provide regression analyses and interpretations of coefficients of the independent variables as a means of investigating the effect that changes in nutrition intake have on income growth and vice versa. However, there is of yet no conclusive evidence on the causal directions. As with other health phenomena, all the mechanisms involved in nutrition's relationship with economic performance are genuinely difficult to assess. From an economist's point of view, it should be acknowledged that the issue of nutrition intake may be better considered in a multi-disciplinary and institutional framework, even when investigating the seemingly more straightforward causality from income to nutrition intake. As was suitably pointed out in one of the earlier economic studies of nutrition: "The roots of malnutrition are found in economics, education, agriculture and health."[15]

[15] Austin (1978), p. 811.

4. Data Selection and Testing Procedure

This section presents the data selection process and the workings of the econometric method to be employed.

4.1 Data selection

The data selection and methodology mirrors the fact that any macroeconomic study on developing countries is bound to be restricted by the limited data availability. The data variables used for this study are: 1) annual GDP per capita measured in year 2000's US dollars to measure economic performance and 2) both average daily calorie and average daily protein intake per capita calculated on an annual basis as proxies for nutritional intake.

The GDP per capita data was taken from the World Bank Indicators and the data on nutrition intake from the United Nations Food and Agriculture Organization Statistical database (FAOSTAT database) for all the five countries studied.[16]

The selection and implications of testing two different proxies for nutrition intake for this study, namely average daily calorie and protein intake per capita, deserve some more attention (hereafter the two variables are jointly referred to as nutrition intake). Perhaps the biggest problem in the area of nutrition and nutrition studies involves constructing consistent measures of nutrition intake for a range of countries over several decades. Firstly, there are very few indicators of nutrition intake available as annual observations on a global basis. Indeed, the FAO statistics provides the only data available for the countries in question over a relatively long time period.

The most commonly used indicators of malnutrition can be divided into two categories: the first category represents the actual intake of nutrition; the second category represents the health impact of malnutrition. On the one hand, daily calorie

[16] The GDP per capita for Malawi is taken from the "Africa Development Indicators 2006: from the World Bank Africa Database".

and/or protein intake per capita have been favoured as measurements by FAO macro studies. An important measurement issue should be noted here: the concepts of both the protein and calorie intake here refer to food acquired by (or available to) the households rather than the actual food intake of the individual members of the households.[17] Using these measures of nutritional status has good reasons, as deficiency of these is a common malnourishment condition. This measure does, however, not take into account a deficiency of micronutrients, such as vitamins and minerals, which also can result in malnutrition (WFP Food and Nutrition Handbook, 2000). Furthermore, it is arguably easier to prove that stunting or deficient body weight impair productivity than to show that a deficient diet does so, as the human body can be efficient even if the energy requirements are not fulfilled for some time. For these reasons, an alternative and perhaps more adequate measure of malnutrition is the so called stunting (low height for age), wasting (low weight for height) and underweight (low weight for age). While this might be preferable, the data is rarely available in a long-time series, and particularly not in the countries studied. Another point is that the very existence of stunting and wasting may be confused with interaction effects of other health problems.

Despite the problems mentioned, the relative strengths and weaknesses of protein and calories as proxies for nutritional status seem to have a complementary effect which to some extent covers both quality and quantity of nutrition. Measuring protein has the advantage in that it is a better indicator of the quality of food, as opposed to calories which only convey information about the quantity. A diet with sufficient calorific content but insufficient protein would not be considered satisfactory. On the other hand, an abundance of protein in a diet that does not contain enough calories would likewise fail to improve an individual's nutritional status, because the body would use up the protein not as a building block (i.e. in the way that protein should ideally be used up), but rather as energy, much in the way it uses up carbohydrates and fat. Finally, empirical evidence thus far seems to infer that protein consumption is more responsive to income changes than general calorie consumption.[18] This is

[17] These estimates, also referred to as Dietary Energy Supply, are calculations of the amount of food potentially available for human consumption derived by considering the sources of supply and the specific purposes for which they are meant to be utilized.
[18] Interview with Pushpa Acharaya, Senior Programme Advisor, Nutrition Service, World Food Programme.

because animal protein is a relatively more expensive good and households that obtain a higher income are likely to switch away from carbohydrate-rich staples to protein-rich meat/fish.

4.2 Testing procedure

As discussed in section three, a variety of studies have looked at the correlation between nutrition intake and economic growth, but few have tested the causality of the relation. One of the reasons for this may very well be the complexity of the relationship in question.

For the purpose of this study, there are however clear advantages in doing a causality test as opposed to building an econometric model and running a regular regression.[19] Firstly, the knowledge of the process of economic growth is far from conclusive, particularly in the case of developing economies. A causality test is thus a useful method of studying the nature of the possible relationship between economic performance and another macroeconomic variable. Secondly, even if a comprehensive model of economic growth could be specified for the purpose of our study, the lack of reliable data for African developing economies would make the estimation of such a model virtually impossible. Finally, to the best of our knowledge, the Granger test has so far rarely been used to test the causality between nutrition intake and GDP on a macro level.

A test that has been extensively studied and applied for a wide array of short-term economic relationships is the Granger (1969) Causality framework. Notable examples of the use of the Granger methodology include the adoption of the model to justify monetary and fiscal interventions by the US Federal Reserve System and the Federal Government by testing the causality between the interest rates or the public spending and aggregate income measures.[20] Other examples where the Granger test has been used include investigations of interest rate linkages within the EMU and examinations

[19] Similar points were made by Gyapong & Karikari (1999) who chose to use the Granger causality test to study the relationship between foreign investment and economic performance in sub-Sahara Africa (p. 137).
[20] Brinkley (2001) p.7.

of the causal impact of foreign investment on economic growth.[21] More recently, the test has also been employed to investigate the relationship between macroeconomic fluctuations and the health sector. One example is the case study by Brinkley (1999) who employed the bivariate Granger Causality test on the relationship between aggregate health indicators and GNP growth in the US economy. The test was similarly used in a multivariate approach to show the impact from the aids epidemic on economic growth in 17 African countries (Ukpolo 2004).

In order to test for parametric causality between two events, Granger insisted that two criteria must be met. One is that a mechanism must exist that is intuitive or logical explaining why one variable would influence another (Granger 1988). In practice, this means that the causality should have backing in economic theory. The other crucial criterion is that one event must precede the other in time. It seems reasonable to suggest that both of these criteria hold in our case; as discussed above there is a theoretically supported mechanism by which nutrition intake and economic growth would influence the other, and at the same time one should expect that the influence would run from one of the variables preceding the other.

4.3 Granger causality test

This section is based largely upon Gujarati (2003), unless otherwise stated.

The present study uses the Granger-Causality framework to determine the causal direction between GDP growth and changes in nutrition levels. The Granger (1969) test for causality between two variables indicates that, for two time-series variables, X_t and Y_t, if *X* improves the prediction of *Y*, then *X* Granger-causes *Y*. The test is based on the following regressions:

Let X_t and Y_t be the variables tested and stationary time series with zero means.

[21] Karfakis & Moschos (1990) and Karikari & Gyapong (1999).

Then

$$X_t = \sum_{i=1}^{n} \alpha_i Y_{t-i} + \sum_{j=1}^{n} \beta_j X_{t-j} + u_{1t} \qquad \text{(eq. 1)}$$

$$Y_t = \sum_{i=1}^{n} \lambda_i Y_{t-i} + \sum_{j=1}^{n} \delta_j X_{t-j} + u_{2t} \qquad \text{(eq. 2)}$$

where u_{1t} and u_{2t} are random error terms.

The test of causality between nutrition intake and GDP requires that nutrition intake is regressed on its own past values and on the past values of GDP. Similarly, GDP is regressed on its past values and on the past values of nutrition intake.

An F-test is then conducted for the following hypotheses[22]:
$H_0 =$ lagged Nutrition Intake variables do not belong in the regression
$H_1 =$ lagged Nutrition Intake variables do belong in the regression

And for the reverse relationship:
$H_0 =$ lagged GDP variables do not belong in the regression
$H_1 =$ lagged GDP variables do belong in the regression

There are four possible outcomes:

1. *Unidirectional causality from Y to X* occurs if the estimated coefficients of the lagged *Y* in (eq.1) are statistically different from zero and the set of the estimated coefficients on the lagged *X* in (eq.2) is not statistically different from zero.
2. *Unidirectional causality from X to Y* occurs if the set of lagged *Y* coefficients in (eq.1) is not statistically different from zero and the set of the lagged *X* coefficients in (eq.2) is statistically different from zero.
3. *Bilateral causality* occurs when the sets of *X* and *Y* coefficients are statistically different from zero in both regressions.

[22] Note that we here conducted separate tests for both daily calorie and protein intake against GDP, but we refer to these as Nutrition Intake to simplify the explanation.

4. *Independence* occurs when the sets of *X* and *Y* coefficients are not statistically significant in both regressions.

Given the discussion in the theory section, if both the traditional theory (i.e. income affects nutrition) and the studies confirming nutrition's impact on growth hold, bilateral causality is what should be suspected.

Before going more in depth on the causality concept and testing procedure, it is useful to note some of the recent improvements which highlighted important limitations of the standard Granger (1969) framework. First, as noted by for example Frimpong & Oteng-Abayie (2006), one issue is that the concept itself abstracts from philosophical issues of causality suggesting that that temporal precedence is sufficient to have *X* Granger-cause *Y*. This also means that the test results are hugely dependent upon the choice of the length of lags tested. Another limitation is that the framework is only valid for stationary variables that are not bound together in the long-run by a co-integrating relationship. As outlined below, the testing procedure thus needs to account for these potential problems.

Requirements of the Granger test

Gujarati (2003) mentions a few requirements needed for a reliable Granger test. These are:

- The variables used need to be stationary, or have to be made stationary through appropriate transformation (e.g. by taking the first differences of the variables).
- The variables used should not be cointegrated, i.e. the error terms of the variables entering the causality test have to be uncorrelated; if they are, appropriate transformation may become necessary.
- The number of lags introduced to the causality test is of great importance to the outcome. This necessitates a test for the selection of the appropriate number of lags.

Below follows a description of the methods used to test whether the above requirements are fulfilled.

Testing for stationarity

The first precondition for the causality test is that the variables are stationary. We must thus determine whether the variables follow a non-stationary trend and are of the order of 1 denoted as $I(1)$ or whether the series are stationary, i.e. of the order of 0 denoted as $I(0)$. To do this, we perform the stationarity tests on the series for Nutrition Intake and GDP, and use the Dickey-Fuller (DF) test for unit root:

The Dickey-Fuller test used is based upon the following equation:

(DF) $\Delta Y_t = \beta_1 + \beta_2 T + \delta Y_{t-1} + u_t$

Where Y_t denotes the variables GDP/cap, calories/cap/day or protein/cap/day, all being in log form, and T is a trend variable. The t-value of the estimated δ-variable is then compared with the critical value found in the Dickey-Fuller table. If the t-value is smaller than the critical value, the null hypothesis of a unit root is rejected (i.e. the series is stationary).

Testing for cointegration

In order to use the Granger Causality test it might also become necessary to examine whether a stable long-run relationship exists between the series used in a study. This is done using a cointegration test. Two variables are said to be cointegrated if they on their own are non-stationary, but the error terms resulting from a regression of a variable on the other are stationary.[23] There is a number of procedures for testing co-integration, common test include the Co-integrating Regression Durbin-Watson (CRDW), the Dickey-Fuller (DF) and the Engle-Granger Augmented Dickey-Fuller (EG-ADF) tests. We tested our data using the CRDW and DF method.

[23] For a full explanation of the concept of cointegration, see Gujarati (2003) p.822.

Simply put, a test for cointegration is based upon the error terms (residuals) obtained through a regression of one variable upon the other. So, first a regression (eq.3) is run:

$$Y_t = a_0 + a_1 X_t + Z_t \qquad \text{(eq. 3)}$$

Where X and Y are the used variables (e.g. Y is GDP/cap and X is kcal/cap). In the second step of the test, the series of residuals obtained from equation (3) is examined by applying the DF test, i.e. the obtained residuals, Z_t, are subjected to the DF test:

$$\text{(DF)} \quad \Delta Z_t = \beta_1 + \beta_2 T + \delta Z_{t-1} + u_t$$

If the calculated DF statistic (i.e. the t-value of δ) is less than the critical values from MacKinnon (1991), then the series is stationary and the null hypothesis of no cointegration is rejected.[24] If this happens, there is a long run relationship between the two variables. According to Granger (1988), this would make the use of the standard Granger test inappropriate.

We also perform a quick check whether the variables in the model are cointegrated by using the Cointegration Regression Durbin-Watson (CRDW). The null hypothesis is that the Durbin-Watson *d*-statistic equals 0 and the critical values are found in Sargan and Bhargava (1983). Again, the *d* statistic value is obtained from the equation (3) in question. If observed *d* is greater than critical value, we reject the null hypothesis of no cointegration.

If there is evidence of a long run stable relationship (i.e. cointegration) between the two variables, the causality between them should be tested by an error correction mechanism. On the other hand, if the variables are not cointegrated then the standard Granger causality test is appropriate.

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[24] It should be mentioned here that the traditional critical values for unit root tests are not valid since the cointegration test is applied to *estimated* residuals.

Choosing the lag length

Finally, a crucial issue in the test of causality is determining the appropriate lengths of the lags in equations (1) and (2). Arbitrarily selected lag lengths can lead to differing outcomes of the Granger test. As noted by Aqeel and Butt (2001), if choosing a lag length that is less than the true lag length, the omission of relevant lags can cause bias. If choosing a lag length that is more, the irrelevant lags in the equation will cause the estimates to be inefficient. There are several different procedures for selecting optimal lag lengths; in this study, the Akaike Information Criterion was used.[25]

[25] For a more thorough description of the Akaike Information Criterion, see Gujarati (2003) p. 537.

5. Empirical Results

In this section we present our results from the tests before proceeding with the discussion and analysis.

5.1 Testing for stationarity

The stationarity tests for the three variables in question all fail to reject that the series contains a unit root at the one-percent significance level. As such, the variables are well characterized by I(1) processes, and are consequently non-stationary. All the variables are first-difference stationary, at the 1 percent significance level. We therefore judge the Calorie, Protein and GDP series to be first-difference stationary. The results of the stationarity tests are reported in Table 2. Conclusive evidence of autocorrelation was not found for any country at the 5 percent significance level (Appendix II). Given these results, it is possible to proceed to the next step which involves the test for cointegration.

Table 2. Stationarity Test Results

		Dickey-Fuller	
Country	**Variable**	**Level**	**First diff.**
Lesotho	GDP/cap	-3.228*	-5.433***
	kcal/cap/day	-2.171	-6.929***
	protein/cap/day	-2.894	-7.246***
Madagascar	GDP/cap	-2.043	-5.086***
	kcal/cap/day	-1.896	-7.410***
	protein/cap/day	-2.950	-9.053***
Malawi	GDP/cap	-1.959	-7.046***
	kcal/cap/day	-2.045	-5.849***
	protein/cap/day	-2.396	-6.457***
Zambia	GDP/cap	-2.697	-7.576***
	kcal/cap/day	-1.534	-5.481***
	protein/cap/day	-1.878	-6.257***
Zimbabwe	GDP/cap	-1.861	-4.545***
	kcal/cap/day	-2.887	-6.892***
	protein/cap/day	-2.699	-6.534***

Notes: *, **, and * denote statistical significance at the 10%, 5% and 1% levels respectively. Critical values for the Dickey-Fuller test are -3.195 (10%), -3.528 (5%), -4.209 (1%). The critical values are based on Dickey & Fuller (1981).**

5.2 Testing for cointegration

According to Granger (1988), the variables must not be cointegrated in order for the standard Granger Causality test to be valid. The results of the DF and CRDW co-integration tests are presented in Table 3. The DF tests suggest no presence of co-integration between Calorie Intake and GDP as well as between Protein Intake and GDP at the 1 percent significance level. The CRDW test largely confirms this result, although it should be noted that there is indication of cointegration between Protein Intake and GDP for Madagascar and Zambia. Nevertheless, given the predominance of evidence against cointegration, we conclude that the standard Granger causality test is appropriate for our purpose.

Table 3. Cointegration Test Results

Country	Cointegration Equation	CRDW	Calculated DF for residuals
Lesotho	GDP = f (Kcal)	0.4885	-2.729
	GDP = f(Prot)	0.2460	-3.21
Madagascar	GDP = f (Kcal)	0.2810	-1.768
	GDP = f(Prot)	0.7710**	-2.874
Malawi	GDP = f (Kcal)	0.1358	-1.949
	GDP = f(Prot)	0.1650	-1.873
Zambia	GDP = f (Kcal)	0.3589	-2.647
	GDP = f(Prot)	0.8806**	-3.402
Zimbabwe	GDP = f (Kcal)	0.2162	-1.856
	GDP = f(Prot)	0.2875	-1.799

Notes: *, **, and * denote statistical significance at the 10%, 5% and 1% levels respectively. Sargan & Bhargava critical values for 31 observations are 0.770 (5%) and 1.081 (1%). MacKinnon critical values for 40 observations are -3.68 (10%), -4.03 (5%), -4.74 (1%). Overall we find that the values of the calculated test statistics in the table are higher than the critical values, which indicates acceptance of the null hypothesis of no cointegration. Sources for critical values include MacKinnon (1991) and Sargan & Bhargava (1983).**

5.3 Granger causality test

The test results of the Granger causality tests between GDP and nutrition intake are reported in Table 4a-b. The table also indicates the optimal lag lengths tested (see Appendix II for the results of the Akaike Information Criterion). With one exception, the lag lengths vary between 1 and 4 years which seems reasonable given the theory. The *F*- value indicates whether the H_0 was rejected or not, i.e. in the case that the H_0 was rejected, the implication is that there is a granger-causal relationship between the two variables in question. We provide the results at both 5 per cent and 10 per cent significance level.

Table 4a. Granger-Causality Test Results

Country	Direction of causality	Lags	F-value	Decision at 5%	Decision at 10%
Lesotho	Kcal → GDP	2/2	3.815	Reject	Reject
	Prot → GDP	1/2	0.436	Do not reject	Do not reject
Madagascar	Kcal → GDP	3/1	3.169	Reject	Reject
	Prot → GDP	4/1	2.309	Do not reject	Reject
Malawi	Kcal → GDP	2/1	8.588	Reject	Reject
	Prot → GDP	2/9	1.424	Do not reject	Do not reject
Zambia	Kcal → GDP	1/1	1.519	Do not reject	Do not reject
	Prot → GDP	4/1	8.069	Reject	Reject
Zimbabwe	Kcal → GDP	3/2	1.063	Do not reject	Do not reject
	Prot → GDP	3/1	1.269	Do not reject	Do not reject

Notes: The lags reported denote the number of years of lags of the respective variables in the equations tested. A summary of all the optimal lags according to the Akaike Information Criterion is available in Appendix II.

Table 4b. Granger-Causality Test Results

Country	Direction of causality	Lags	F-value	Decision at 5%	Decision at 10%
Lesotho	GDP → Kcal	2/2	3.308	Do not reject	Reject
	GDP → Prot	2/1	11.899	Reject	Reject
Madagascar	GDP → Kcal	1/3	0.414	Do not reject	Do not reject
	GDP → Prot	1/4	0.019	Do not reject	Do not reject
Malawi	GDP → Kcal	1/2	4.022	Do not reject	Reject
	GDP → Prot	9/3	2.654	Reject	Reject
Zambia	GDP → Kcal	1/1	0.447	Do not reject	Do not reject
	GDP → Prot	1/4	2.890	Do not reject	Do not reject
Zimbabwe	GDP → Kcal	2/3	0.286	Do not reject	Do not reject
	GDP → Prot	1/3	0.007	Do not reject	Do not reject

Notes: The lags reported denote the number of years of lags of the respective variables in the equations tested. A summary of all the optimal lags according to the Akaike Information Criterion is available in Appendix II.

To summarize, we find evidence for that daily calorie intake granger-causes GDP in Lesotho, Madagascar and Malawi, and that daily protein intake granger-causes GDP in Zambia, all at the 5 percent significance level. This means that we find evidence for that nutrition intake granger-causes GDP in all countries studied, except for Zimbabwe, with the precaution that the causality is never simultaneously found for *both* calorie and protein intake at five percent level. In terms of the reverse relationship, the results are somewhat more surprising. Only in the case of Malawi and Lesotho are we able to infer evidence for that nutrition intake responds to an increased aggregate income at a 5 percent significance level. In both cases the relationship is found from protein intake to GDP, but not when calorie intake is used as the nutritional indicator.

6. Discussion

In this thesis we have set out to investigate the causal relationship between nutrition intake and economic growth, specifically in a short-term causality framework. Based on the evidence provided by the Granger causality test, the causal relationships only partially conform to what could be expected from the economic theory and evidence presented earlier. Though a causal relationship from nutrition intake to growth can be suggested, the evidence is not very strong since we would expect both protein and calorie intake to prove significant at the five percent level. More importantly, the causality from growth to nutrition is almost non-existent. Indeed, only in the case of Malawi and Lesotho are we able to discern a causal direction from economic growth to nutrition intake (and specifically with the measurement of protein intake, which as noted on page 17, could be expected to display a stronger responsiveness to income growth).

Because of the observed disparity between the results and the result expected from theory, it would be relevant at this stage to take a brief look at what the cause of this disparity could be. This section is not intended to be an in-depth analysis of such causes; given the complexity of the subject and the rather different socio-political conditions of each African country, such an analysis would require some extensive on-the-spot and household survey based research. Nevertheless, based on existing literature in development economics, it is possible to identify a few general issues that could provide an explanation for the results presented.

Starting with the "nutrition → growth" causality, a question that comes to mind is why the evidence for this causality is not stronger. The results are somewhat ambiguous and inconclusive; causality can be discerned in many cases, but not in all. It seems quite possible that an important reason for this may have to do with a substantial amount of "white noise" in the data, i.e. a phenomenon where the data is hiding the influences of many mechanisms other than the particular one that is studied.

One of the explanations could thus lie in the ambiguous interaction between nutrition, productivity growth and population growth. One argument (Wang & Taniguchi 2003) states that in a typical developing country, with a high prevalence of malnourishment, population growth tends to be reduced due to high child mortality and malnutrition-related diseases. Increased nutrition intake tends to have a positive influence on both worker productivity and population growth. This in turns means that the even though one may expect an increase in the productivity of labour and an augmenting of human capital, such positive productivity effects may in the short-run be overridden by the effects of decreased mortality, which are likely to increase the population. One may also mention that this effect works in much the same way as the improving health care was able to generate a population explosion in the poorer countries in the mid-20th century.[26] What follows is that the increased population may very well "consume" the additional nutrition, and subsequently not only reduce the overall average per capita nutritional status, but also any positive short-term impact on productivity and economic growth. At the same time, improvements in income will not be visible in per capita form, because higher income is spread out over a larger population. The phenomenon in which the improvement in nutrition is not large enough to be transformed into productivity quickly enough has been named a nutritional trap and is also supported by other empirical research on Sub-Saharan Africa (Wang & Taniguchi 2003).

Also, it should be remembered that this study has been based upon results from Southern Africa, a region where HIV/AIDS has had momentous and devastating socio-economic impact.[27] In economic terms, this means not only increased costs and a direct reduction in the productive labour force, and thus economic output; but it also changes the potential positive impact of increased nutrition intake.[28] This effect is mainly induced because the virus reduces the ability of the human body to absorb essential nutrients. Thus, unless income increases substantially to allow for acquisition of proper medicine, any small increases in nutrition intake are unlikely to have any significant impact upon productivity. Our results may therefore reflect the very fact that the potential positive causal effect of nutrition on productivity and

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[26] Perkins et al. (2001), p. 357.
[27] See for example a case study on Malawi by Arrehag et al (2006).
[28] World Health Organization (2003) *Nutrient requirements for people living with HIV/AIDS: report of a technical consultation*.

economic growth may be offset by the multifaceted effects of the HIV/AIDS virus combined with the increased population growth on the short-run average nutrition intake.

Furthermore, as was pointed out in the theory section, nutrition can affect growth through several different mechanisms and these effects may not be differentiated well with the application of the Granger causality framework. Theory is somewhat ambiguous in the distinction between the instantaneous, the medium-term and the long-term impact of malnutrition. The effect of increased nutrition may thus be instantaneous, as is the case of increased productivity following a meal, or it may stretch over generations, as in the case of a malnourished mother giving birth to a stunted baby who in the future may not be as productive as his colleagues. Thus since the Granger test works by choosing an “optimal” lag through the Akaike Information Criterion, this subsequently incorporates and makes a compromise between both the long-run and short-run effects. Adding to this complexity, is that the nutritional status is an individual characteristic which means that its effects depend on how the individual functions within the household, and in turn how the household functions as a determinant of national productivity and the national economy. In summary, the Granger test may be somewhat too simplistic a test to be able to correctly deal with all the mechanisms that in interconnection make nutrition affect income.

Turning now to the somewhat more surprising finding of our study, namely that income does not appear to granger-cause improvements of nutrition. This is indeed rather unexpected, because it goes against some very basic and well-established economic theory. Unlike the case with the “nutrition → growth” causality, the mechanisms that could be expected for the “growth → nutrition” causality are more straightforward; higher income should according to theory cause households, and at the macro level also countries, to increase their food consumption. Given the almost non-existent causality in the results, however, it seems that at some point the mechanism of transforming income to nutrition fails, which hinders the population from reacting to changes in income. Below follow a few possible explanations to this transmission failure.

An issue that takes up an important place in development economics deals with the detrimental effects of income inequality and it might also be very relevant for this study. To begin with, there is the problem of measurement: per capita measures of GDP and calories/protein are based on the entire population, which includes members of the elite. It is first after considering measures such as the Lorenz curve or the Gini coefficient that one gets a more complete idea of where the true income level for the different sections of the population may lie. As the countries in the study are very unequal by international standards, there is a small group of very rich people who are quite likely to be benefiting disproportionately from any income rise. However, although income can increase indefinitely, nutritional intake cannot. The rich are likely to lie around the "bliss point" for nutrition intake already. As was hinted at in the theory section, Engel's Law suggest that even though the rich receive most of the newly formed income, their income elasticity of demand for calories is low, meaning that their food consumption does not change markedly.[29] At the same time, although national accounting might display income growth, the poor majority which can be expected to transform the income into increased nutrition, does not benefit and are thus unable to increase actual nutrition intake. In an often used expression within development economics, the income growth fails to "trickle down" to the lower strata of the society.

This effect seems to be aggravated by an urban bias implying that there are major socio-economic disparities between capital cities and major urban areas versus the population in rural areas.[30] One key reason would be that the countries studied have substantial proportions of the rural population mostly self-employed through the informal sector and subsequently unlikely to benefit equally from growth in aggregate income (which reflects only the formal economy). It is thus evident that the use of national income growth in this investigation would infer only a partial effect of the relationship between income growth and nutrition intake in the general population.[31] Likewise, mention should here also be made of a problem of a more logistical nature. Even though the food supply can theoretically be available for additional consumption in the country, the substandard infrastructure and the difficulty of supplying food to

[29] Leathers H.D. & Foster Phillips (2004), p.165-7.
[30] The concept of urban bias is discussed by Perkins et al. (2001), p.368.
[31] Interview with Margaret Phiri, Policy Consultant, Economic Analysis Unit, World Food Programme.

certain areas can make peripheral areas suffer sustained food deficits for undefined periods of time. This becomes particularly noticeable during natural disasters (usually droughts, occasionally flooding) that regularly beset the region.[32]

On a similar note, an often-quoted work by the development economist Amartya Sen (1981) has presented the theory that what matters is not the actual availability of food, but rather the entitlement of individuals to food. By drawing on examples of famines in Asia and Africa, Sen argues that is possible for people to starve even when the total amount of food available in the country is unchanged, because they do not have the ability to "command food through the legal means available to that society (including the use of production possibilities, trade opportunities, entitlements vis-à-vis the state, etc.)".[33]

One final issue, quite possibly correlated to the exposed position of the poor, is that of the absence of appropriate education and the predominance of potentially harmful influence of customs and culturally ordained behaviour. Therefore, food agencies often complement their food provision programmes with providing information about proper nutrition.[34] Even though people may be able to produce or consume more nutrients than they currently do, and thereby reach an adequate nutrition status, they may fail to do so because they lack the knowledge about the effect of malnutrition on their lives. Finally, as some research has pointed out, food consumption represents to some degree choices by the individual, which means that the presumption that higher income should lead to higher nutrition intake may be overstated because it may in fact be some other, unobserved, factors that cause this outcome.

[32] Clay et al (2003).
[33] Sen (1981), p.433.
[34] WFP, *Food and Nutrition Handbook*, p.25-7.

6.1 Limitations of the study

The primary weakness of this study must be tied to the lack of quality data. Time series data for developing countries that goes back long enough to warrant satisfactory econometric specification is hard to come by. The data used for this study had a relatively good time span, but, as had been pointed out at times, the amount of white noise present must be considered quite substantial.[35] The difficulty of measuring malnutrition cannot easily be overcome and any measure used is likely to introduce an error term of unknown proportions. On the same note, it is not impossible to find a debate about the appropriateness of nutritional data and claims that several of the performed studies do not fulfil adequate criteria for robustness.[36] It is in view of such issues that the need for interdisciplinary approaches becomes apparent.

In addition, as in any other econometric study, the results must be taken with caution. Analyses of this type of relationships have been proven very difficult. Although it is reasonable that better nutrition enhances economic growth, and that improved incomes should increase food consumption, more explanatory conclusions should perhaps only be drawn from the specification of an appropriate model. This is evident since the two variables are obviously related to many factors that are difficult, if not, impossible to measure (such as the general health level and its interaction effects on the population). In this regard, there are clearly limitations with using the bivariate Granger causality test. Perhaps most importantly because the use of the Granger framework means that there is a lack of a true specification, i.e. there may as well be a third factor influencing each of the two variables.

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[35] Interview with Joyce Luma, Chief of the Vulnerability and Assessment Unit, World Food Programme.

[36] Arcand (2001), p.19.

6.2 Relevance and further research

How relevant are the results of the study for policymakers or donor organizations involved in promoting economic growth and development in Southern Africa? If the results indeed are solid enough to infer the true nature of the growth-nutrition causality, this study re-enforces that adequate nutrition levels can be seen as key in economic growth, and that policy makers cannot rely upon the trickle-down effect in order to improve current undernutrition conditions. Perhaps a more important issue that should be of great interest to involved parties is the identification of what exactly has gone wrong in the "growth → nutrition" mechanism. The theoretical foundation, together with the previous empirical studies, seems to present a rather strong case for the existence of a bi-directional causality between growth and nutrition, i.e. in the ideal state of affairs, this circular flow could become a source of great economic value. With this in mind, it is quite possible that a developing country could actually achieve greater benefits from the improvement of the mechanism that channels income into nutrition, rather than from focusing solely upon income growth in the belief that this will trickle down and automatically cause the desired improvement of the nutrition level. Similarly, the above presents an important argument in favour of nutrition programs and other interventions as a way of targeting malnutrition as opposed to relying solely on growth.

The question of what further research can be undertaken depends heavily upon the availability and quality of data. Given the suggested impact of inequality on the results, it seems reasonable to assume that if the malnourished population is the true object of the study, better conclusions would be drawn from excluding the top echelons of society. The measurement of both the per capita economic status and the nutritional level should then be more in line with what truly is the case for the poor majority. If trustworthy data can be compiled on a macro level, a Granger causality test could be expected to give a more reliable result.

Finally, given the nature of the study, it is impossible to overstate the need for a multidisciplinary approach that transcends purely economic analysis. There are many poorly understood aspects of the health-productivity relationship that are likely to affect the returns to health and nutritional investment, including the shape of the relationship, the time frame over which nutritional intake affects productivity, the extent to which the body operates as a storage mechanism, and the seasonality of income for cultivating households (Behrman et al. 1994). Work also needs to be done to understand which population groups are mostly affected by malnutrition/nutrition, and under what low-income conditions the causal relationship between nutrition and labour productivity are most likely.

7. Conclusion

This thesis has attempted to investigate the direction of the causality between economic growth and nutrition intake in five Southern African countries. This was done by the way of the Granger causality test employing GDP/capita and two proxies for nutritional intake: the average daily calorie intake per capita and the average daily protein intake per capita.

The obtained results gave a somewhat inconclusive indication that nutrition Granger-causes economic growth. Evidence in favour of the opposite causality was, however, very weak. These results suggest an interesting check of mainstream economic theory. The literature that includes nutrition in the stock of human capital is still relatively young; yet a fair amount of studies have showed that, particularly on the individual level, nutrition can in many circumstances affect economic performance. The results presented here seem to give a moderate backing for this view on the macroeconomic level. On the other hand, the causality running from economic growth to improved nutrition, so often just simply assumed in texts on economic growth, has failed to emerge in the results. Although it is impossible to make any accurate statements about why this "trickle down" mechanism of converting new income to favourable nutrition has broken down, a few possible issues have been briefly hinted at. Since many of such issues are, however, prevalent in many developing countries, this raises some suspicion about whether income growth really can be relied upon to improve nutrition in the developing world.

All of the countries studied have committed to the Millennium Development Goals of by the year 2015 reducing both malnutrition and income poverty by half from their 1990 levels. Given the findings of this thesis, it seems that in order to reduce malnutrition, a complete reliance on income growth may not be sufficient. At first instance, this calls for complementary nutrition programs tailored for the region in which they are implemented. Secondly, it also calls for an interdisciplinary and more thorough investigation of exactly at what stage the trickle-down mechanism may be failing.

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Interviews

- **Joyce Luma**, Chief of the Vulnerability and Assessment Unit, United Nations World Food Programme, Rome 14 May 2007.

- **Pushpa Acharaya**, Senior Programme Advisor, Nutrition Service Unit, United Nations World Food Programme, Rome 18 May 2007.

- **Margaret Phiri**, Policy Consultant, Economic Analysis Unit, United Nations World Food Programme, Rome 27 April 2007.

Appendix

I. Descriptive Statistics

Table A. Descriptive Statistics for all Five Countries

Country	Variable	Mean	St.deviation	Min	Max
Lesotho	GDP/cap	298.769	104.819	141.00	511.00
	kcal/cap/day	2135.021	161.985	1861.90	2321.80
	protein/cap/day	62.500	3.638	56.40	70.60
Madagascar	GDP/cap	316.103	62.446	228.00	410.00
	kcal/cap/day	2278.562	164.327	1990.60	2513.80
	protein/cap/day	55.697	5.284	46.70	63.40
Malawi	GDP/cap	141.871	20.046	98.00	170.00
	kcal/cap/day	2169.451	176.642	1795.50	2452.40
	protein/cap/day	62.341	7.644	49.10	74.20
Zambia	GDP/cap	446.204	95.927	295.04	604.43
	kcal/cap/day	2136.459	143.730	1928.10	2424.00
	protein/cap/day	57.736	6.337	47.70	67.40
Zimbabwe	GDP/cap	589.385	69.940	463.00	690.00
	kcal/cap/day	2174.644	123.225	1860.60	2376.60
	protein/cap/day	57.615	6.297	46.50	66.40

II. Akaike Information Criterion

The Akaike Information Criterion (AIC) is calculated using the following formula:

$$\ln AIC = \left(\frac{2k}{n}\right) + \ln\left(\frac{RSS}{n}\right)$$

where *n* is the number of observations, *k*, is the number of regressors and *RSS* is the residual sum of squares. The lowest value of AIC is preferred. The results are reported below in Tables B-F. The lowest values of the AIC are highlighted in order to indicate the respective lag lenghts chosen.

Table B. The Akaike Information Criteria for Lesotho

Country	First difference Variables	p	*RSS*	*2k/n*	*ln (RSS/n)*	*ln AIC*
Lesotho	GDP/calories	1	0.173	0.108	-5.364	-5.256
		2	0.143	0.111	-5.531	**-5.420**
		3	0.167	0.114	-5.344	-5.230
		4	0.153	0.118	-5.403	-5.285
		5	0.164	0.121	-5.303	-5.182
	Calories/GDP	1	0.026	0.108	-7.265	-7.156
		2	0.024	0.111	-7.320	**-7.209**
		3	0.025	0.114	-7.233	-7.119
		4	0.025	0.118	-7.206	-7.088
		5	0.022	0.121	-7.295	-7.174
	GDP/proteins	1	0.174	0.108	-5.361	-5.252
		2	0.107	0.111	-5.822	**-5.710**
		3	0.166	0.114	-5.349	-5.235
		4	0.148	0.118	-5.438	-5.321
		5	0.165	0.121	-5.299	-5.177
	Proteins/GDP	1	0.068	0.108	-6.303	**-6.195**
		2	0.068	0.111	-6.279	-6.168
		3	0.067	0.114	-6.261	-6.147
		4	0.067	0.118	-6.235	-6.117
		5	0.064	0.121	-6.251	-6.130

Table C. The Akaike Information Criteria for Madagascar

Country	First difference Variables	p	RSS	2k/n	ln (RSS/n)	ln AIC
Madagascar	GDP/calories	1	0.045	0.108	-6.708	**-6.600**
		2	0.045	0.111	-6.685	-6.574
		3	0.043	0.114	-6.701	-6.587
		4	0.044	0.118	-6.643	-6.526
		5	0.044	0.121	-6.612	-6.491
	Calories/GDP	1	0.014	0.108	-7.886	-7.778
		2	0.013	0.111	-7.951	-7.839
		3	0.012	0.114	-7.963	**-7.849**
		4	0.012	0.118	-7.909	-7.792
		5	0.013	0.121	-7.822	-7.700
	GDP/proteins	1	0.045	0.108	-6.702	**-6.594**
		2	0.045	0.111	-6.688	-6.577
		3	0.043	0.114	-6.694	-6.579
		4	0.044	0.118	-6.641	-6.524
		5	0.043	0.121	-6.643	-6.522
	Proteins/GDP	1	0.019	0.108	-7.552	-7.443
		2	0.021	0.111	-7.469	-7.357
		3	0.020	0.114	-7.452	-7.338
		4	0.018	0.118	-7.566	**-7.448**
		5	0.020	0.121	-7.424	-7.303

Table D. The Akaike Information Criteria for Malawi

Country	First difference Variables	p	RSS	2k/n	ln (RSS/n)	ln AIC
Malawi	GDP/calories	1	0.101	0.108	-5.908	**-5.800**
		2	0.112	0.111	-5.775	-5.664
		3	0.101	0.114	-5.847	-5.733
		4	0.112	0.118	-5.720	-5.602
		5	0.092	0.121	-5.888	-5.767
	Calories/GDP	1	0.033	0.108	-7.023	-6.915
		2	0.021	0.111	-7.442	**-7.331**
		3	0.029	0.114	-7.087	-6.973
		4	0.028	0.118	-7.095	-6.978
		5	0.026	0.121	-7.132	-7.011
	GDP/proteins	1	0.104	0.108	-5.874	-5.766
		2	0.112	0.111	-5.771	-5.660
		3	0.099	0.114	-5.866	-5.752
		4	0.112	0.118	-5.719	-5.602
		5	0.090	0.121	-5.908	-5.787
		6	0.077	0.125	-6.032	-5.907
		7	0.072	0.129	-6.067	-5.938
		8	0.062	0.133	-6.180	-6.047
		9	0.059	0.138	-6.205	**-6.067**
		10	0.059	0.143	-6.165	-6.022
	Proteins/GDP	1	0.043	0.108	-6.746	-6.638
		2	0.035	0.111	-6.944	**-6.833**
		3	0.036	0.114	-6.872	-6.758
		4	0.036	0.118	-6.843	-6.726
		5	0.036	0.121	-6.827	-6.706

Table E. The Akaike Information Criteria for Zambia

Country	First difference Variables	p	RSS	2k/n	ln (RSS/n)	ln AIC
Zambia	GDP/calories	1	0.073	0.108	-6.226	**-6.118**
		2	0.081	0.111	-6.101	-5.990
		3	0.077	0.114	-6.116	-6.001
		4	0.081	0.118	-6.035	-5.917
		5	0.081	0.121	-6.015	-5.894
	Calories/GDP	1	0.015	0.108	-7.806	**-7.698**
		2	0.015	0.111	-7.780	-7.669
		3	0.015	0.114	-7.758	-7.644
		4	0.015	0.118	-7.738	-7.621
		5	0.015	0.121	-7.706	-7.584
	GDP/proteins	1	0.079	0.108	-6.152	**-6.043**
		2	0.080	0.111	-6.107	-5.995
		3	0.086	0.114	-6.015	-5.900
		4	0.083	0.118	-6.012	-5.894
		5	0.073	0.121	-6.110	-5.989
	Proteins/GDP	1	0.019	0.108	-7.559	-7.451
		2	0.019	0.111	-7.562	-7.451
		3	0.019	0.114	-7.529	-7.414
		4	0.017	0.118	-7.614	**-7.496**
		5	0.019	0.121	-7.470	-7.349

Table F. The Akaike Information Criteria for Zimbabwe

Country	First difference Variables	p	RSS	2k/n	ln (RSS/n)	ln AIC
Zimbabwe	GDP/calories	1	0.115	0.108	-5.778	-5.670
		2	0.110	0.111	-5.786	**-5.675**
		3	0.114	0.114	-5.723	-5.608
		4	0.107	0.118	-5.766	-5.648
		5	0.107	0.121	-5.732	-5.611
	Calories/GDP	1	0.057	0.108	-6.472	-6.364
		2	0.057	0.111	-6.450	-6.339
		3	0.052	0.114	-6.506	**-6.391**
		4	0.054	0.118	-6.437	-6.319
		5	0.052	0.121	-6.445	-6.324
	GDP/proteins	1	0.115	0.108	-5.778	**-5.669**
		2	0.114	0.111	-5.751	-5.640
		3	0.114	0.114	-5.726	-5.611
		4	0.105	0.118	-5.782	-5.664
		5	0.107	0.121	-5.732	-5.610
	Proteins/GDP	1	0.074	0.108	-6.221	-6.113
		2	0.073	0.111	-6.199	-6.088
		3	0.068	0.114	-6.239	**-6.125**
		4	0.068	0.118	-6.217	-6.100
		5	0.066	0.121	-6.222	-6.101

III. Autocorrelation Test Results

The procedure for the Durbin-Watson test is based on Edlund (1997) ch.7.

Autocorrelation occurs when a series of data has observations that are not independent of each other. We first use the Durbin-Watson *d*-statistic, which tests the first order autocorrelation in the residuals of the regression equation. The *d*-statistic is obtained using:

$$d = \frac{\sum_{t=1}^{n} (\hat{u}_t - \hat{u}_{t-1})^2}{\sum_{t=1}^{n} \hat{u}_t^2}$$

The *d*-statistic is then used to estimate the first-order autocorrelation coefficient ρ which is given by

$$\rho \approx 1 - \frac{d}{2}$$

The null hypothesis of no autocorrelation is tested depending on the size of the *d*-statistic:

Since $d < 2$ indicates positive autocorrelation, the hypotheses in this case are:
H_0: $\rho \leq 0$ (i.e. no positive autocorrelation present)
H_1: $\rho > 0$ (i.e. positive autocorrelation)

Since $d > 2$ indicates negative autocorrelation, the hypotheses in this case are:
H_0: $\rho \geq 0$ (i.e. no negative autocorrelation present)
H_1: $\rho < 0$ (i.e. negative autocorrelation)

If $d < d_L$ or $d > 4 - d_L$, the null hypothesis is rejected. If $d_U < d < 4 - d_U$, the null hypothesis is not rejected. If *d* is in the intervals $d_L \leq d \leq d_U$ and $4 - d_U \leq d \leq 4 - d_L$, the test is considered inconclusive.

The critical values for 39 obervations at 5 per cent significance level are:[37]

$d_L = 1.435$
$d_U = 1.540$

Tables G and H indicate that there is no autocorrelation at 5 per cent significance level, with the exception of Zimbabwe, for which the test is inconclusive.

[37] Gujarati (2003), Appendix D

Table G. The Durbin-Watson autocorrelation test on GDP and Kcal

Country	Durbin-Watson
Lesotho	1.773
Madagascar	1.747
Malawi	2.112
Zambia	2.127
Zimbabwe	1.491

Table H. The Durbin-Watson autocorrelation test on GDP and Protein

Country	Durbin-Watson
Lesotho	1.776
Madagascar	1.698
Malawi	2.162
Zambia	2.209
Zimbabwe	1.491