The Geographic Basis of Food Insecurity in Sub-Saharan Africa

Honors Thesis
Presented to the College of Agriculture and Life Sciences, Social Science
of Cornell University
in Partial Fulfillment of the Requirements for the
Research Honors Program

by
Vivian Merker
May 2007

Professor David Lee

Acknowledgments

Table of Contents

CHAPTER ONE

INTRODUCTION

In the 1960s and 1970s, agricultural economists predicted that population growth would dramatically outpace food production in a doomsday scenario of worldwide starvation. Instead, agricultural productivity has grown rapidly enough that the world still produces sufficient food for its expanding population. Unfortunately, development inequality has also increased, leaving us no closer to a solution for the problem of world hunger. Even if productivity growth continues to be strong, there is no guarantee that the nutritional needs of the poorest and most vulnerable people will be met any better than they are now. This realization has expanded and diversified international approaches to hunger reduction.

At the turn of the millennium, the members of the United Nations issued the Millennium Declaration, stating their joint commitment to eliminate poverty and build a secure and peaceful world conducive to human development. The Millennium Development Goals (MDGs) quantify this commitment. The very first goal is to eradiate extreme poverty and hunger, with a target of halving the proportion of undernourished people by 2015 from the level in 1990. The 185 countries who met in 1996 at the World Food Summit (WFS) in Rome generated an even more ambitious goal of halving the absolute number of hungry people in the world in the same period.

Of all the regions in the world, sub-Saharan Africa has progressed the least towards hunger reduction. In the region, one out of every three people lacks sufficient access to food. Ghana is the only country that has already met the WFS and MDG nourishment targets (FAO, *State of Food Insecurity in the World*, 2006). Many other

countries are not on pace to reach them at all. Opportunity exists for the international community to facilitate food security improvements in sub-Saharan Africa by reducing and eliminating barriers to nourishment.

The fundamental agents of food insecurity in Africa are political, socioeconomic, and physical. Political causes of undernourishment include weak, corrupt, and ineffective governments plagued by conflicts. Without a stable environment, investment is curtailed because outcomes of development efforts are uncertain. The region suffers from a lack of infrastructure connecting agricultural producers to markets and consumers. In many other regions, public-private partnerships, especially with external investors, drive investment, but in sub-Saharan Africa, the network of partnerships is weak (Paarlberg, 1999).

Socioeconomic conditions generate food insecurity. Poverty is a primary cause of hunger because it affects both production and consumption. Lack of wealth prevents households from purchasing food and limits investments in productivity-enhancing agricultural technologies and inputs. Poverty contributes to a host of other social ailments that also affect food insecurity. HIV/AIDS strains social resources, disrupts the earning potential of primary food providers, and increases nutritional demands of the 28.9 million people infected with the virus in Africa, where it is the leading cause of mortality and morbidity (Rosegrant, et al., 2005). In sub-Saharan Africa, women play a central role in food production and use a larger percentage of their incomes for household food than men, but they are often excluded from food and agriculture policy-making (Laier, et al., 1996).

The physical roots of food insecurity and hunger include climate, resource endowments, and geography. Africa is an enormous continent with diverse challenges to food security. Much of sub-Saharan Africa is located between the Tropic of Cancer and the Tropic of Capricorn, a geographic band which has notoriously low soil quality and crop yields. Agriculture in the region is dependent primarily on inconsistent rainfall; only slightly more than one percent of agricultural land is irrigated (Rosegrant, et al. 2005). Another consequence of tropical climate is the prevalence of diseases, especially malaria, which drain economic resources and reduce incomes. Finally, low endowments of natural resources in many countries limit national incomes. Alternately, conflicts over harvesting rights in countries with abundant natural resources, especially diamonds, also restrict development.

The above contributors to food insecurity in Africa have been studied in depth and are generally well understood by scholars. However, these explanations focus solely on African characteristics and endowments. They ignore the effect of the region's physical location within the global community/marketplace.

I believe that Africa's spatial context contributes greatly to food insecurity. Transportation costs isolate the region, prohibitively increasing the cost of international trade and exacerbating the effects of other agents of underdevelopment. This thesis attempts to quantify the relationship between geography, prices of imported foods, and undernourishment.

Geography and Food Imports

Poverty and lack of resources in combination with depleted soil quality result in low agricultural productivity in sub-Saharan Africa. As population grows at a rate of

2.28 percent per year, the highest in the world, annual crop yield growth rates ranging from 1.5 to 2 percent cannot keep pace with food demand (Rosegrant, et al., 2005). Food imports from outside the continent have the potential to counter shortfalls in domestic production. However, poverty prohibits many people from purchasing food, imported or not. Nevertheless, if future nutritional needs are to be met, obstacles to trade must be reduced so that the potential of food imports can be realized.

Sub-Saharan Africa faces massive geographical challenges to importing food. It is distant from major food exporters including United States, Canada, Southeast Asia, Argentina, and Western Europe. The region has the highest proportion of landlocked countries in the world. These inland countries are frequently centers of population growth. As a result, food imports must travel long distances overland to reach many cities. Overland transport is more expensive than transport on waterways, and the region suffers from very poor infrastructure. Landlocked countries' imports must pass through at least one transit country, incurring customs charges and administrative delays, which can take as long as two weeks (Faye, et al., 2004). Grains and other food crops are high volume and low value, so additional transportation costs significantly increase import unit prices for geographically isolated countries.

In brief, African countries must import food to meet their populations' food needs, but they are at a geographic disadvantage in international trade, and many lack the economic resources to compensate for inflated import prices.

The Future of Food Prices

Rich countries have subsidized farmer income with programs that artificially increase production and lower world commodity prices. These market-distorting

measures range from guaranteed prices, to loan programs, to export credits. This has created a competitive disadvantage for developing countries, which are unable or unwilling to subsidize their domestic agriculture in similar ways. Developing countries, including those in sub-Saharan Africa, suffer reduced farm incomes and lower returns to agricultural investment as a result of developed country subsidies. However, countries that are net importers may have benefited from market-distorting subsidies since consumers commonly experience lower food prices. As a whole, the region of sub-Saharan Africa is a net agricultural exporter and has likely been made worse off by developed countries' subsidies (FAO, *State of Food in Agriculture*, 2005).

Reducing market-distorting agricultural subsidies has been a goal for the Doha Round of the World Trade Organization (WTO) negotiations, supported by developing countries with export-driven economies. According to the objectives in the Doha Declaration, export subsidies will be phased out, barriers to market access will be reduced, and domestic subsidies that distort production will be decreased (*Ministerial Declaration*, 2001). However, developing countries will likely continue to have the leeway to pursue policies necessary for food security and rural development. A probable outcome of agricultural subsidy reduction in developed countries will be increased global commodity prices (FAO, *State of Food in Agriculture*, 2005). This will drive up the already-inflated import prices that many sub-Saharan African countries face. The result of the policy course of the Doha Round may be worsening food security in some countries, especially before the income effects of higher prices have been realized. For a clearer understanding of the consequences of agricultural subsidy reductions, the

relationship between food security and the price of food imports must be better understood.

Hypotheses

This thesis clarifies the effect of geography on the prices of imported foods and explains how the prices of import foods influence food security. I hypothesize the following:

1. Geographically isolated countries in sub-Saharan Africa face higher prices on imported foods than maritime countries due to increased transport and administrative costs.

2. Food import prices are negatively related to nourishment and food security in sub-Saharan African countries since consumers may not have sufficient income to meet their food needs.

To test these hypotheses, I create two econometric models and several estimation alternatives of each basic model. The first model explains the deviation of a country's unit value of grain imports from the world market level based on geographical and demographical factors. The second model explains country-level undernourishment using food import prices as well as economic, political, agricultural, and demographic variables whose importance other studies have demonstrated.

While addressing these hypotheses, I define the spatial challenge facing food-importing African countries. This knowledge should help inform developmental aid policies of the international community as well as domestic policies of food insecure countries as they struggle to allocate scare resources to effectively combat hunger. The unique complexity of food security in each country should drive policy. Geography is a

neglected characteristic of food-insecure countries that can be addressed only when it is understood. In particular, affirming the influence of geography on food import prices and prices on food insecurity helps demonstrate the importance of particular development strategies. Investments in infrastructure can reduce transportation expenses, and improved relations between transit countries can alleviate administrative burdens that hurt landlocked countries. Also, investments in domestic agriculture may have greater returns to food security in isolated countries than in countries with easy access to food imports.

Since price is the primary mechanism through which I measure the effects of geography on food security, my models will be useful at anticipating the consequences of agricultural subsidy reduction. Many international groups and nongovernmental organizations acknowledge the need to craft trade policy which will promote pro-poor economic development. Implicit in this is the need to understand and eradicate food insecurity. This requires through exploration of the consequences of trade policy. The above-mentioned agenda of the Doha round could have far-reaching effects which must be understood so that policy is informed, and negative food security consequences are handled proactively. This thesis contributes to the call for enlightened policy by increasing understanding of the geography, international trade, and food security relationships.

Organization

The second chapter of this thesis is a literature review that offers an overview of the important concepts driving this work, including African development economics, food security, geographical and spatial economics, and agricultural trade policy. In the

third chapter of the thesis I present models used by other scholars to explain trade prices and food security, and I describe the construction of the import price and nourishment models I create to support my hypotheses. In the fourth chapter of the thesis, I present the results of the models and offer my interpretations and how they connect to the original hypothesis. Finally, in the conclusion of the thesis, I locate my findings within the food security scenario driving my research and describe how geography should inform food aid and policy prescriptions for undernourishment.

CHAPTER TWO

LITERATURE REVIEW

In this thesis, I draw from four particular areas of study: African development, food security, geography, and agricultural trade. This chapter successively examines noteworthy works and recent trends in these subjects in order to build a foundation the models in Chapter Three.

African Development

To study African food insecurity, it is important to understand the state of development in the continent. In particular, there are many factors that may contribute to undernourishment, and they should inform analysis and shape possible solutions.

Africa is the second largest and second most populous continent in the world, with a population approaching one billion people, but it is the poorest inhabited continent.   During the past two decades, the portion of the population living on less than one dollar a day rose continuously, reaching almost 50 percent by 2000 (Rosegrant, et al. 2005), and 16 of the 20 poorest countries in the world are in sub-Saharan Africa (Paarlberg, 1999). While researching African countries' gross domestic products, David Bloom and Jeffrey Sachs summarize six common explanations for Africa's economic plight (1998). They are:

1. External manipulations such as the slave trade, colonial rule, and political exploitation during the Cold War.

2. Heavy dependence on relatively few primary exports which have declining and volatile terms of trade.

3. Unstable internal politics plagued by conflict and corruption.

4. Domestic economies characterized by extravagant spending, protectionism, and heavy state involvement.

5. Rapid population growth.

6. Diverse populations deeply divided religiously and ethnically, along with low levels of social capital.

The continent was shaped by European colonial control from the late 1800s until after World War II, and many of the region's current challenges stem from the vestiges of colonialism. Colonial powers capriciously divided the continent into what are now 53 independent countries, many of which contain a variety of ethnic and linguistic groups.

By marginalizing local people and manipulating local governments during their rule, the colonial powers left no foundations for sound governance. Present-day political instability and conflict discourage both foreign and domestic investment in infrastructure, productivity-enhancing technologies, and social programs. Without sufficient guarantees of private property protection, investors choose to direct their money to other regions and deprive Africa of the building blocks of economic growth (Paarlberg, 1999). Infrastructure built during colonial times served to efficiently harvest natural resources from the land, without regard for the need to connect populations to each other and to the rest of the world. In some countries, remaining natural resources have fueled impressive development, such as diamond wealth in Botswana, but in other countries they incite resource wars, such as disputes over diamond harvesting in Sierra Leone.

Agriculture forms the basis of many African economies, especially those lacking diamond wealth. Agriculture accounts directly and indirectly for 80 percent of employment and the bulk of export earnings, but less than 10 percent of government

expenditures in Africa are directed toward the farm sector (Paarlberg, 1999). Governments have adopted many policies hostile to the interests of farmers and agricultural development, ranging from the aforementioned lack of private property protection, to high tariffs on agricultural inputs, to overvalued domestic currencies that make agricultural exports relatively more expensive and less competitive on the world market. The rural sector is weak and poorly organized. In 1994, the World Bank concluded that "no country [in Africa] has good macroeconomic policies and agricultural policies" (World Bank, 1994, pp. 1-2, quoted in Paarlberg, p. 506).

In the second half of the 20th century, many African countries became indebted to the developed powers. As countries defaulted on their loans during the financial crisis of the 1980s, lenders insisted on rigorous structural adjustment programs, many of which would have benefited agriculture, but the level of implementation has been spotty. Many countries remain financially crippled by debt service.

Poverty is a reality in households as well as at the macroeconomic level. The relationship between poverty and food insecurity is well documented, and the cycle they form is extremely hard to break. Without money, families cannot buy food, and without adequate nourishment, workers cannot earn income. Although overall levels of poverty are very high, sub-Saharan Africa has less income inequality than many other developing regions (Paarlberg, 1999). Gender inequality is a more serious social division and possible barrier to food security, especially in rural areas where women will cope with food shortages by forgoing consumption in order to feed their families (Laier, et al., 1996).

Africa has been hardest hit by the HIV virus. In Swaziland, one third of the population 15 to 49 is HIV positive (World Bank, 2003). HIV strains weak health resources, and people infected with the virus require more calories and special diets. In a recent examination of hunger in Zambia, the *New York Times*' reporter interviewed an HIV positive woman receiving treatment and reported, "Mrs. Mubita assumes her children are also HIV positive, she said, but has not had them tested because if they, too, go on the drugs, they will be as hungry as she is" (Dugger, 2007). HIV reduces the ability of adults to work, when they should be at the peak of their earning potential, and it generates orphaned children. Families making their living from agriculture may be unable to tend high yield crops and switch to crops of lower value and lower nutrients when they are coping with HIV, so agricultural productivity declines.

Despite the bleak picture painted by some of the factors above, it is important to remember that the continent of Africa is very large and diverse. Generalizations about the continent have some truth but also many exceptions, and I do not profess expertise in the unique circumstances of every country. However, an overall understanding of the development scenario in the region is a prerequisite to in-depth analysis of the high rates of undernourishment in sub-Saharan Africa, depicted in Figure 1. It also roots policy recommendations in reality.

Figure One: African Food Insecurity

African Food Insecurity

Percent of total population suffering from undernourishment

	1 - 9
	9 - 19
	19 - 36
	36 - 50
	50 - 73
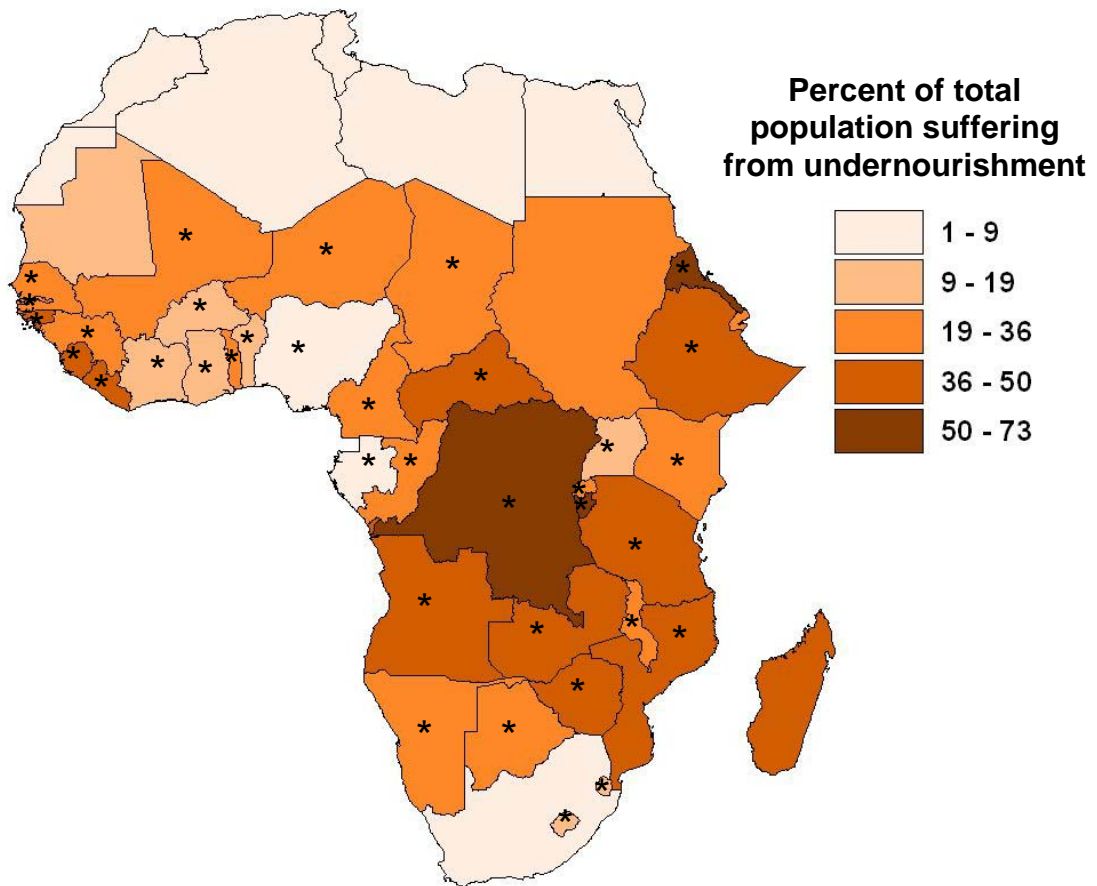
* starred countries are included in the analysis, and countries without data are omitted from the map

In this thesis, I focus on 36 continental sub-Saharan countries (starred in Figure 1). I exclude the nation of South Africa because its unique history and relatively developed status make it an outlier in many ways. Similarly, many of the countries of North Africa possess distinct characteristics, particularly geographic proximity to Europe. Below, I explore in depth three issues critical to this thesis: food security, geography, and agricultural trade. In addition to reviewing important literature and scholarship on these topics, I consider the three issues in the context of these 36 countries.

Food Security

Over time, the concept of food security has evolved from a basic concern of production capacity to an array of definitions whose complexities reflect the multi-faceted problem of hunger itself. The food security paradigm has shifted in three ways: from global/national to a household/individual perspective, from food to livelihood concerns, and from objective indicators to subjective perceptions (Maxwell, 1996).

Prior to the 1980s, food security was generally synonymous with food supply. Malthusian scholars worried that the food needs of the rapidly growing world population would exceed the quantity that could be produced. For example, in the 1968 book, *The Population Bomb*, Paul Ehrlich predicted a scenario of massive famines in the 1970s and 1980s as population growth outstripped food supply. The global think-tank Club of Rome commissioned *The Limits to Growth* to model the resource shortages its members viewed as imminent (Meadows, 1974).   Although correct about the rapidly growing population, the scholars' scenarios of global starvation were not realized. Immense growth in agricultural productivity created the global capacity to feed all people.

Aggregate cereal yields increased 87 percent from 1970 to 2004 (Falcon, 2005). Nevertheless, food security remains a pressing concern. In 1970, almost one billion people were undernourished, and thirty years later, the number still exceeded 800 million (FAO, *State of Food Insecurity in the World*, 2006). At least five times as many people die annually from food insecurity than from war (Falcon, 2005).

In 1981, Amartya Sen published an extremely influential paper, "Poverty and Famines: An Essay on Entitlement and Deprivation," which popularized the concept of food access as a vital component to food security. Sen recognized that the ability of agriculture to produce sufficient foodstuffs does not prevent hunger, and he wrote that every person is entitled to have his or her basic food needs met. To foster development, all people must be able to consume the food they need to be healthy. Poverty reduction is virtually impossible without first alleviating hunger since undernourished people suffer diminished work capacity (FAO, *State of Food Insecurity in the World*, 2006). Sen's contribution has become a permanent part of the conversation surrounding food security.

The food security dialogue continued to evolve in the 1980s as scholars recognized that starving people will forgo food in the present to preserve their livelihoods and maintain access to their assets in the future (see: Oshaug, 1985; de Wall, 1991.) For example, during a drought a household may undergo substantial hunger to avoid slaughtering animals or selling assets which will contribute to its future livelihood.

Most recently, food security scholars have recognized that objective, quantitative measures of food security such as per capital daily caloric consumption neglect to address the realities of the people who suffer food insecurity and instead impose the views of the researchers upon them. Scholars have developed indicators that reflect the subjectivity of

insecurity (Radimer, et al., 1992). These indicators include feelings of depravation and lack of food choice as well as the employment of coping strategies. Maxwell writes that "Policy will …need to recognize the diversity of food insecurity causes, situations and strategies, and be contingent on particular circumstances" in order for the expansive concept of food security to be ensured (1996, pp. 162-3).

Currently, the United Nations' Food and Agriculture Organization (FAO) defines foods security as follows:

> **Food security** can be said to exist when all people have access at all times to sufficient, nutritionally adequate and safe food, without undue risk of losing such access.
> (*State of Food in Agriculture*, 2006)

The original concept of an available food supply is still an important component of food security, but the FAO definition also encompasses individual access to and utilization of such food and the continuing stability of the food supply. Although FAO data often fails to address the subjectivity of food insecurity, its definition is an accurate reflection of the changes that have taken place in food security scholarship in the past thirty years.

Other groups continue to view food security through lenses colored by their own self-interest. For example, farmers in developed countries argue that food security requires their countries to be able to meet food needs domestically as a way to justify agricultural subsidies. Fear of bio-terrorism influences government officials, and safety of the food supply has emerged as a security concern for them. Falcon and Nayler explore linkages between hunger and conflict. They believe that food insecurity in developing countries can spur civil clashes and possibly influence international terrorism, and increasing food security would help spread democracy and improve U.S. national

security (2005). In this thesis, I follow the FAO food security definition with special emphasis on the fundamental component of food supply.

Future of Food Security

Much of the current literature on food trade and security focuses on "demand-pull" from developing countries due to population growth. According to the International Food Policy Research Institute (IFPRI), virtually all the increase in food demand in the next 15 years will come from developing countries (Pinstrup-Andersen, 1999). While population growth exceeds economic growth, the poor economies of many developing countries will continue to struggle with access to food.

In 1965, Ester Boserup introduced a hotly contested theory contrary to the popular Malthusian view of population dependence on food supply, suggesting that population growth in developing communities drives agricultural intensification and technological innovations which will lead to increased productivity. Time has proven her belief in productivity increases to be correct, but the direction of the causal relationship she proposed is still debated among scholars. With the expansion of global trade, agricultural imports must be included to update her theory. As the population grows and requires more nourishment, the global incentives for technological innovation do indeed rise, but importing food may be more feasible then technological adoption in some developing countries.

The OECD-FAO *Agricultural Outlook Report 2006-2015* predicts that yield increases in developing countries will not grow quickly enough to meet rising food demand domestically. However, most scholars, though not all, now believe that the global capacity of agriculture will be able to produce sufficient food for the world's

population. D. Gale Johnson predicted that continued improvements in productivity will cause supply growth to outpace demand growth and provoke a decline in international food prices (1998).

If food productivity gains exceed population gains globally, foreign food sources have the potential to satisfy rising food demand in developing countries. The *Agricultural Outlook Report* predicts greater reliance on imports and emphasizes the necessity of infrastructure for efficient transportation (2006). IFPRI's International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) predicts that developing countries' cereal imports will double by 2025 and triple by 2050 from their level in 2000 (Rosegrant, 2003). The result is a substantial increase in international trade.

Often people look down upon the importation of food into developing countries since foreign-produced foods do not contribute directly to domestic agriculture production, rural development, or general economic goals. Import taxes, tariffs, quotas, and other regulatory barriers all hinder international food trade, often to protect or promote domestic agriculture. Yet, both domestic-produced and foreign-produced food can contribute to food security. The FAO stresses the need for complementary policies, including public investments in pro-poor growth strategies and safety nets, in order for imports to support food security without excessive negative side effects (2005).

Food Security Policy

The broad discussion of food security must be tailored to address individual countries and communities since each has its own food security situation. Many communities' primary challenge to food security is poverty. Other groups rely very

heavily on a limited number of trading partners to meet their populations' nutritional needs and are vulnerable to economic fluctuations experienced by those partners. Still other groups produce certain crops domestically that fill most of their food needs, but bad weather during the growing season makes food security impossible. Finally, the pursuit of food security in some regions is compromised by human conflict.

Each country's policy makers must adequately understand their particular food security profile to develop strategies to eliminate undernourishment. They must be able to predict food shortfalls and minimize disruptions to the population's consumption. International actors must also understand food security profiles to help fight huger, understand the impact of trade reform on the poor, and offer effective food aid in the event of famine.

Food Security in Africa

In this thesis, I choose to consider food security in sub-Saharan Africa because of the great challenges facing many countries' food security profiles. People lack economic access to food, climates can be inhospitable to many types of agriculture, population growth is large, diseases including HIV/AIDS and malaria strain resources, and many countries face challenging geographic locations for trade. As a result of these impediments, over 200 million Africans suffer from malnutrition, and the proportion of malnourished individuals has remained consistently high since 1970, in contrast to other regions which have increased food security (Rosegrant, 2005.)

In sub-Saharan Africa, one in three people lack access to sufficient food. The region contains 13 percent of the population of the developing world but 25 percent of

22

the under nourished people.   No other region in the world has such a high prevalence of undernourishment (FAO, *State of Food and Agriculture*, 2006).

The United Nation's Millennium Development Goals (MDG) and the World Food Summit (WFS) of 1996 created goals for hunger reduction using 1990 as the base year and 2015 as the target for completion. The MDG proposed halving the proportion of people who suffer from hunger while the WFS more ambitiously proposed halving the number of undernourished people. In Sub-Saharan Africa, the number of undernourished people actually increased from 169 million at the beginning of the period to 206 million at the turn of the millennium. An annual population growth rate of 2.5 percent has caused the proportion of hungry people to decline during that same period from 35 percent to 32 percent. The region is far from achieving the benchmarks set at the two conferences. Out of 39 countries with data in the region, 21 have seen growth in the number of undernourished and only Ghana has exceeded the MDG and WFS goals (FAO, *State of Food and Agriculture*, 2006).

In the countries which have made progress towards MDG/WFS goals, the drivers of hunger reduction appear to be economic growth and expansion of the food producing component of the agricultural sector. The countries straying furthest from the MDG/WFS goals were plagued by war and human conflict during the 1990s. The most striking example is the Democratic Republic of the Congo in which the prevalence of hunger rose from 31 percent to 72 percent of the population during the period of the goals (FAO, *State of Food and Agriculture*, 2006).

Sub-Saharan African food insecurity has a gendered nature. Women play a central role in food production but not in food policy-making (Laier et al., 1996).

Women use more of their income for household food, so if the production of crops grown by women were to increase and women were to retain control over the income from the sale of the crops, the nutritional status of children would improve more than with an increase in productivity of crops grown by men. In the face of food shortages, women's coping strategies greatly affect the fate of the household due to their responsibility for children, and they are first to forgo consumption when food is scarce. Women rely on social networks to maintain their households and sometimes assume all responsibility for property and family when men migrate to look for work.

Food insecurity in Africa has a strong geographic component. Extreme poverty and hunger are concentrated in rural areas due to the inhabitants' reliance on subsistence agriculture and isolation from markets. The phenomena of rural poverty and hunger drive urban migration, as wage-earners or entire families move to cities looking for better circumstances. The next section explores other contributions of geography to food security and development in general.

Geography

Recently economists have begun to consider spatial implications on economic development with sensitivity and insight. A division has arisen between the theoretical and empirical scholars of spatial economics. Theoretical scholars are primarily concerned with modeling and predicting spatial agglomeration of resources while 'Physical Economic Geographers' (my term) have occupied themselves with the effects of particular natural situations and endowments on countries and regions.

Spatial Economic Theory

Although the scope of this thesis is primarily empirical, I will briefly review the work of the theoretical spatial economists. Theoretical work usually attempts to model the patterns of aggregation of trade and industry into markets. In his article, "Economic Geography, Industry Location and Trade: The Evidence," Marius Brülhart believes there are three categories of location theory (1998). Neo-Classical Theory assumes that location of industry and trade is determined exogenously by natural endowments, technologies or other factors, and the spatial distribution of demand only influences trade patterns, not production locations. The New Trade Theory takes market size as fixed, but other features of market development, such as level of competition vary. Within New Economic Geography, all factors are mobile so even market size is determined within a model and the system tends to be unstable. All of the paradigms offer some valid insights which can fuel empirical analysis.

Brülhart goes on to comment on empirical studies which tend to compare predicted and observed outcomes of spatial theory. Specialization and location clustering are observable phenomena which can be evaluated. Papers often use trade data as a proxy for production instead of employment or output data. Rising evidence of intra-industry trade (the simultaneous importing and exporting of goods with similar production requirements) fits better with the latter two theories of spatial economics, New Trade Theory and New Economic Geography. However, Brülhart notes that it is important to consider industries separately as there are some exceptions to the general trends.

Physical Economic Geography

Physical Economic Geography has been rooted in observations of specific geographic conditions on the economies of different regions with less emphasis on the theoretical foundations of markets. Championed by well-known scholar Jeffrey Sachs of Columbia University's Earth Institute and former director of the U.N. Millennium Project, Physical Economic Geography begins with the premise that physical geography is highly differentiated in a way which affects economic development (see *Geography and Economic Development*, 1999). Differences in coastal access and climate influence many other economic factors such as transportation costs, disease burdens, and agricultural productivity. Sachs's insights inspired my questions that led to this project. Some of these insights are detailed below.

Tropical Countries

One notable observation regarding economic geography is the difference between tropical and non-tropical countries. Upon dividing the 150 countries with populations greater than one million in 1995 into tropical and non-tropical categories, Gallup, Sachs, and Mellinger find an average GDP per capita of $3,326 for tropical countries and $9,027 for non-tropical countries (1999). In fact, only two tropical economies find themselves in the top thirty richest economies ranked by 1995 PPP-adjusted GDP per capita: Hong Kong and Singapore, both of which are very small (Gallup, Sachs, and Mellinger).

Explanations for the economic plight of tropical countries are numerous. One is the distance many tropical countries find themselves from the world's major goods markets in Europe, North America, and East Asia. This distance significantly raises transportation costs. The transition to industry and manufacturing and the subsequent

wealth which many countries have undergone requires the import of many inputs as well as the export of final products. In effect, the cost of transportation works two-fold against tropical countries.

Life expectancy in tropical zones is lower than temperate zones, even after controlling for per capita income levels. The human body adapts well to heat, but the high temperatures and moist climate of the tropics affect nutrition and disease ecology (Bloom, 1998). Many tropical countries face large infectious and parasitic disease burdens. The "Big Three" diseases of malaria, tuberculosis, and HIV/AIDS cause about 5.6 million deaths a year and occur primarily in tropical countries (Hotez, 2006). Additionally, they cause a loss of 166 million disability-adjusted life years (DALYs) which measure the total amount of healthy life lost to disease. A host of other "neglected" tropical diseases account for another half million deaths per year and the loss of over 50 million DALYs.

Economically, health challenges and shorter life expectancies have many effects. Tropical diseases and morbidity certainly generate enormous healthcare costs. Prevention efforts are also expensive. Diseases reduce productivity by decimating working adult population and generate the cost of care for orphaned children. Even children's schooling is hampered by disease and illness. Furthermore, fear of disease reduces travel to tropical countries and discourages beneficial foreign investment.

In tropical countries, agricultural productivity tends to be low. Measured by output per worker, non-tropical countries' agriculture is 8.8 times more productive than that of tropical countries (Gallup and Sachs, 2000). One hypothesis is that lower wages in low-income countries creates an equilibrium of comparatively high labor and low

capital use in production. However, even controlling for income, Gallup and Sachs find agricultural labor productivity in the tropics to be just 51 percent of that in non-tropical agriculture (2000). Although this seems contrary to the image of lush, diverse rainforests found in the tropics, the conditions for biodiversity need not be related to those for optimal plant growth. In fact, yields of cereal crops are lowest in tropical ecozones, approximately 50 percent of what they are in temperate ecozones (Gallup, 1999). Low nutrient content of tropical soil offers one explanation. The soil may initially possess high organic content, but the heat and humidity of wet tropics quickly decompose the organic matter and decrease the rate of return on fertilizer investments which are generally already more expensive in the tropics due to transportation costs. Further, when cleared of its naturally occurring cover, tropical soil tends to erode quickly. Dry ecozones occurring within the geographic bounds of the tropics generally have higher soil fertility but must be irrigated to produce. Irrigation infrastructure may exacerbate water resource conflicts or simply be impractical or prohibitively expensive.

Gollin, Parente, and Rogerson believe that agricultural productivity growth is central to development (2002). With a simple model, they show that low agricultural productivity delays the onset of industrialization and cause countries' per capita income to fall behind those of industrialized leaders. When countries are able to increase agricultural productivity, labor shifts from agriculture to other industries which experience higher output per worker, and total productivity increases.

Landlocked and Coastal Countries

Strong differences exist between the economic well-being of costal and landlocked countries. Outside of Western and Central Europe, where landlocked

countries enjoy close integration with the European regional market, landlocked

countries' per capita income in 1995 averaged $1,771 compared with $5,567 for coastal

countries (Gallup, Sachs, and Mellinger, 1999). Nine of the 12 countries with the lowest

Human Development Scores in 2002 were landlocked (Faye et al., 2004). Even when

populations in landlocked countries enjoy closer absolute distance to the coast than inland

populations of coastal countries, they still suffer economic disadvantages due to their

dependence on neighboring countries as transit thoroughfares for imports and exports.

Faye and his collaborators identify four elements to transit dependence: transit

infrastructure, political relations with neighbor countries, peace and stability within

neighbor countries, and dependence on administrative processes in transit (2004). The

entirety of landlocked countries' trade must pass through neighboring countries to reach

ports (excepting the minuscule amount shipped by air). Weak infrastructure in

neighboring countries from lack of resources, natural disasters, conflict, and government

neglect all increase the transport costs ultimately born by producers and consumers in

landlocked countries. Since many developing countries export low margin raw goods,

even small increases in transport costs can eliminate profits.

Coastal countries can easily block port access or impose strict, expensive

regulations on transit goods if the relationship between the landlocked and coastal

country is poor, and coastal countries may have geo-strategic incentives to do so. Even

when they have a stable political relationship with their neighbors, landlocked countries

are still dependent on peace within the coastal countries and may face damaged or closed

transit routes when the coastal countries experience conflict. Rerouting transit can be

prohibitively expensive. For example, during the Mozambican civil war, Malawi

rerouted its freight at a cost of 4 to 6 percent of its GDP (Faye, et al., 2004). Finally, border crossings result in delay, administrative hassle, paperwork, the cost of bribes, and direct and indirect customs charges.

As if the additional shipping and customs costs were not significant enough, the above factors also increase the cost of insuring shipped goods. Radellet and Sachs create a model that shows landlocked countries face shipping and insurances costs 63 percent higher than coastal countries (1998). Not only are the above hindrances facing landlocked countries expensive, they can disrupt shippers' abilities to satisfy contracts reliably.

Not all scholars concur with the importance of geographic variables. Easterly and Levine examine the influence of geographic endowments including latitude, coastal access, disease, and the possibility of growing certain grains and cash crops on economic development in 72 former colonies (2003). Their regression estimate finds strong evidence that these endowments exert a large impact on economic development. Endowments also have the power to explain the institutions (rule of law, political stability, private property protections, etc) in the sample countries.   Easterly and Levine run a two stage least squares (2SLS) regression to address whether endowments affect economic development beyond their ability to explain institutions, and they fail to reject the hypothesis that endowments affect economic development solely through their influence on institutions. Although the authors use their result to discount the importance of geographic variables, their result is weak (simply failing to reject a null hypothesis) and actually confirms the importance of geographic endowments on development by

highlighting a mechanism through which their effect is generated. They demonstrate that geographic characteristics manifest themselves in countries' institutions.

In this paper, I will examine the effects of geographic endowments of coastal access and agricultural productivity on import prices and food security.

African Geography

Africa, the region of focus for this thesis, has immense geographic diversity, stretching from northern temperate zones all the way to southern temperate zones.   It contains the world's largest river as well as the world's largest desert.   It suffers from several characteristics associated with low income, including a high proportion of land in the tropics and an inland population, 81 percent of which lives 100 kilometers or further from the coast, and 25 percent of which resides in landlocked countries (Gallup, 1999).

Approximately two thirds of the continent of Africa is subject to high risk of drought (Paarlberg, 1999). Despite the uncertainty of agriculture that relies on rainfall, less than one percent of African agricultural land is irrigated, primarily due to the high capital costs (Rosegrant. et al. 2005). Due to its tropic location, soil in much of Africa is weathered, acidic, and lacks fertility, and high temperatures break down organic matter components quickly (Paarlberg, 1999).   Modern plant geneticists can partially compensate for lack of water and poor soil nutrients with new plant varieties, but no one has successfully created a plant or animal that does not need water.

In Africa, landlocked countries experience different degrees of difficulty from their landlocked status, depending on their region. In Southern Africa, landlocked countries have multiple routing channels available to them, including several through South Africa which maintains excellent infrastructure (Faye, et al., 2004). Several groups

promote intraregional trade and transportation agreements. With the exception of

Zimbabwe, the Southern Africa region has enjoyed relatively stable conditions which

have facilitated trade and transit. In Eastern Africa, Burundi, Rwanda, and Uganda have

extremely limited transit options and virtually no railways. Regional tensions are high

and infrastructure is weak as a result of conflict, although recent efforts have been

extended to improve intraregional cooperation. Maritime transit countries, Kenya and

Tanzania, have underinvested in infrastructure. Ethiopia, in the northeast of Africa, lost

its coastline to Eritrea in 1991. Somalia, due to conflict and poor infrastructure, is not a

viable trade path. The majority of Ethiopia's trade, after traversing its weak

transportation network, passes through Djibouti. In West Africa, six of eight possible

transit countries have experienced at least one civil conflict severe enough to block transit

in the past 12 years. Border crossing in remaining routes can take as long as two weeks.

Both the landlocked and coastal countries in the region have weak infrastructure and

heavy rainy seasons that flood roads, while dry seasons render rivers impassible (Faye, et

al.).

Agricultural Trade and Policy

> "To the extent that agriculture is affected by trade, trade will
> necessarily affect the livelihoods and food security of the world's
> most vulnerable people. . . FAO has long recognized that agricultural
> trade is vital for food security, poverty alleviation and economic
> growth. Food imports are a fundamental means of supplementing
> local production in ensuring the provision of minimum supplies of
> basic foodstuffs in many countries"
> (FAO, *State of Food in Agriculture*, 2005).

As the world develops, agriculture plays a proportionately smaller role in

economies and trade, but it grows in absolute importance. Agriculture's share in total

merchandise trade has trended downward since the trade in manufactured goods has grown more quickly. In the early 1960s, agriculture trade comprised 25 percent of the value of merchandise trade, but it has declined to about seven percent in recent years (FAO, *State of Food in Agriculture,* 2006). The drop in developing countries has been even greater, from about 50 percent in 1960 to less than seven percent in 2000 (FAO). However, focusing manufacturing trade obscures both the growing volume and increasing value of agricultural trade overall. The value of agricultural trade reached a high of over $700 billion (U.S.) in 2003. Contrary to popular belief, most developing countries are net importers of agricultural products. In the least developed countries, the value of agricultural imports was more than twice as high as exports by the end of the 1990s (FAO).

Globalization trends mean that more people will be eating food produced outside of their own country. Agricultural trade and food security are now linked in a relationship which will only become more complex in the future.

Agricultural trade policies affect food security in a fundamental way, as a driver of price. As policies distort markets, both the income generated from food exports as well as the price of imported food change. Within countries, marketing margins, geographic factors, and infrastructure also influence the final price paid by consumers of imported foods. If policies raise commodity prices of traded food, consumer eventually bear those costs. In poor communities, higher imported food prices can have a strong, negative effect on food security.

A number of problems affect the competitive environment of international agricultural trade. Countries transition from promoting policies that discriminate against

agriculture to adopting policies that subsidize agriculture as they undergo the process of development (Anderson, 2006). Government subsidies to benefit domestic farmers in developed countries distort markets and lower international commodity prices. Low prices reduce the return on agricultural investment in developing countries to the detriment of rural economies. Protectionist policies and import tariffs in developing countries further harm their farmers by increasing the prices of agricultural inputs such as fertilizer. Finally, developing countries have overvalued their domestic currencies at the expense of their agricultural exports (generally remedied in countries which underwent structural adjustment). Past estimates show that global trade-distorting policies have caused the volume of international food trade to reach only half its potential level, to the detriment of farmers in developing countries (Anderson, 2006).

In the Doha round of WTO negotiations, member countries tackled agricultural subsidies. They agreed to eliminate all export subsidies and export-restrictive regulations by the end of 2013 (FAO, 2006). However, developing countries will retain the right to self-designate appropriate tariffs for special products essential to food and livelihood security and rural development.

Anderson, Martin, and van der Mensbrugghe take the study of subsidy reduction further in their paper, "Distortion to World Trade: Impacts on Agricultural Markets and Farm Incomes," as they attempt to predict the effects of gradually removing all merchandise trade distortions including agricultural subsidies (2006). Using the LINKAGE model and data from the Global Trade Analysis Project, they predict global gains of $287 billion per year by 2015. Although the bulk of this gain would be for high-income countries, developing countries' national incomes would increase by a greater

percentage, 0.8 percent compared with 0.6 percent in developed countries (Anderson, et

al.). Despite the relatively small role of agriculture in merchandise trade, 63 percent of

the effect of trade liberalization would come from agriculture and food markets

(Anderson, et al).

African Trade

In sub-Saharan Africa, the marketing channels for international trade and

domestic production are shown in simplified form in Figure 2. The exact composition of

the marketing channels and the specific role of the government marketing boards differ

from country to country and from commodity to commodity (Coulter and Poulton, 2001).

A variety of shortcomings stem from marketing channels. In many countries, multiple

levels of players and transactions raise consumer prices. A lack of capital and trust for

financing arrangements restricts producers, while imperfectly liberalized governmental

marketing boards sometimes adopt producer-unfriendly practices such as uniform

producer prices that do not vary based on season and geography. Finally, storage

facilities shortages prevent the accumulation of agricultural stocks which could be used to

regulate seasonal price fluctuations (Coulter and Poulton; Fafchamps, 2004).

Sub-Saharan Africa is not a net agricultural importer, so in the face of trade

liberalization, the positive effects of higher agricultural incomes may offset increases in

food prices.   The primary agricultural exports include cocoa, cotton, and coffee, none of

which are dietary energy staples. In contrast, the region is a net importer of cereal crops,

importing approximately 19 times as much as it exported in 1998 (Coulter and Poulton,

2001). For this reason, Anderson, et al. predict that total consumption would decline 1.3

percent in sub-Saharan Africa (excluding South Africa) in the face of total trade

liberalization (2006). Agriculture and food exports would increase 45.4 percent from their current level under the proposed policies changes, while imports would increase 79.2 percent, and total consumption would decline 1.3 percent (Anderson, et al.). Although Anderson's simulation is extreme, it highlights the fact that trade liberalization trends may be harmful for sub-Saharan consumers. There is need for simultaneous increases in agricultural productivity and food aid or the implementation of other pro-poor development strategies to counteract the harmful effects of trade liberalization. In fact, increases in food prices from trade liberalization could be offset by reductions in import prices due to more efficient transport and marketing channels.

The four topics reviewed in the chapter form a network of relationships that help to explain food insecurity in sub-Saharan Africa. Undernourishment can be considered one of many development challenges facing the continent, along with poverty, conflict, residual effects of colonialism, poor governance, and disadvantageous location. Increasingly, food insecurity is seen as a consequence of other development challenges, as scholars' concept of food insecurity focuses on access to nutrition rather than production capacity. Geographic isolation in particular may increase the price of imported food and contribute to undernourishment. In the next chapter, I explore the last relationship, between geography, import prices, and undernourishment, using models informed by the literature reviewed in this chapter.

Figure Two: Sub-Saharan Africa Agricultural Marketing Channels
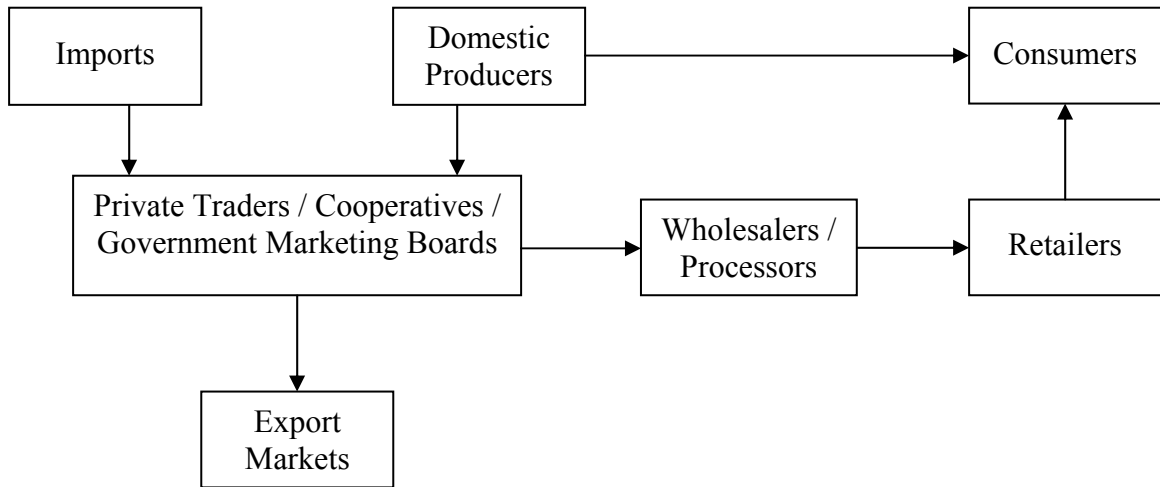
Based on information reported in Coulter and Poulton, 2001; Fafchamps, 2004

CHAPTER THREE

MODEL FORMULATION AND DATA SPECIFICATION

The work of many spatial economists has justified the importance of geography in economic development. Development economists have demonstrated that economic development is vital to food security. I hope to clarify a linkage between geography and food security through the use of import prices. Given the challenging geographic situation and the widespread undernourishment in sub-Saharan Africa, I hope that the results of the estimations made with the models presented here will allow for a better understanding of the effects of isolation on nutrition.

As I present the models used to support my hypotheses, I justify the inclusion of explanatory variables and describe their expected effects on the dependent variables. I also give the sources of the data set used in the analysis. I rely extensively on data sets from the FAO and the World Bank. To a lesser extent, I use data from other sources as well as created my own measures.

Spatial Price Differential Model

Trade prices have been widely analyzed in a variety of contexts. With my first model, I aim to identify the determinants of import prices of major cereal crops by explaining deviations from world prices for they year 2003, the most recent data available. Although this is a somewhat specific goal for a trade model, several well-known econometric studies of trade do contribute to the formation of my model.

IFPRI developed one of the best known agricultural trade models, the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) (Rosegrant, et al, April 2005). The model is a complex system of equations

for analyzing global food demand, supply, and trade, as well as income and demographic trends. Country and regional-level sub-models determine supply, demand, and prices for agricultural commodities (including maize, wheat, and rice). Then the sub-models are linked through trade. The optimal values of the system of equations are determined with the Gauss-Seidel method algorithm that minimizes the sum of net trade at international levels and seeks a market-clearing world commodity price (PW) which serves as the equilibrating mechanism in the system. IMPACT operates on the assumption that prices are endogenous in the system of equation for food. Domestic consumer prices (PD) by commodity are derived from the market-clearing world price by adding a spatial price differential (MI) reflecting transport and marketing costs and subtracting a consumer subsidy equivalent (CSE) measuring implicit levels of taxation or subsidy borne by consumers relative to the world prices.

$$PD = PW(1 + MI)](1 - CSE) \tag{1}$$

In this model, the determinants of price are assumed to be the same whether the crop is domestically produced or imported, and volume of trade is simply the difference between domestic supply and domestic demand of a specific quantity

Similar in theory to IMPACT but extending beyond agriculture, the Global Trade Analysis Project (GTAP) is a large-scale community effort to model trade centered at Purdue University. It incorporates separate functions for the behavior of many actors including producers, private households, governments, global banks, and the rest of the world. Then the model establishes partial equilibriums between the different functions based on input values (Hertel, 1997).

Abbot takes a simplified approach to modeling commodity trade (1979). He creates a model to observe the effects of changes in government policy on net import demand for grain:

Imports-exports = f [border (world) price, production, population, income, policy] (2)

This is a reduced-form model of the balance between estimated supply and estimated demand. It measures the marginal effects of exogenous variables on trade and allows the equation to be estimated with an Ordinary Least Squares (OLS) model. I am interested in using an inverse form of this equation to model border prices of imported grain.

Model and Theory

To support my hypothesis that geography is an important determinant of grain import prices, I create a model rooted in basic microeconomic theory where aggregate demand for good j is a function of all prices (p) and the aggregate income in the country (Y).

$$q_j = f(p,Y) \tag{3}$$

The price p includes the price of the good j as well as the prices of all other goods. Thus the demand for good j can be further specified as a function it price, p_j, and all other prices, p_0.

$$q_j = f(p_j,p_0,Y) \tag{4}$$

When good j is a cereal, in most countries it can be cultivated domestically and sold at price p_{dj} or imported and sold at price p_{mj}.

$$q_j = f(p_{dj},p_{mj},p_0,Y) \tag{5}$$

Since cereals are considered non-differentiated goods, consumers will see p_{dj} equal to p_{mj}. If the importing country is small and a price-taker, the consumer price will be equal

to the world price (p_{wj}) plus country-specific transportation and insurance charges known as the spatial price differential (spd), which is similar to a marketing margin.

$$q_j = f(p_{wj} + spd_j, Y) \tag{6}$$

I am interested in the influence of geography on this spatial price differential, so it makes sense to consider an inverse demand function, with spatial price differential as the dependent variable. It is a function of the quantity of good imported (due to economies of scale) and other factors including transport and insurance costs (x):

$$p_{wj} + spd_j = f(q_j, x_j) \tag{7}$$

Transport and insurance costs can both be considered functions of distance, d, but costs differ greatly by shipping method (sea or land), so x is replaced by d_s and d_l. When considering cross-country variation in spatial price differentials, the subscript i identifies the country. The world price does not change across countries, so I drop it from the model.

$$spd_{ij} = f(q_{ij}, d_{is}, d_{il}) \tag{8}$$

I create several iterations of a model in the general form given in equation eight to derive the importance of geography on inter-country import price differentials in the model outlined below.

Dependent Variable

The dependent variable in equation eight is the spatial price differential generated in international trade between the exporting and importing country. When defining the marketing, it is important to consider the crops and measures of price from which it is defined. Considering the international trade of livestock or other perishable foods would introduce other explanatory variables beyond the scope of this work. Aggregate

measures of import values would obscure the effects of price. Therefore, I elect to consider the three major grain crops: wheat, maize, and rice. Together these three crops account for the majority of all grain trade. Directly and indirectly (as inputs in livestock production), these grains provide a bulk of nourishment to the human population. Data documenting trade in rice, wheat, and maize is readily available, which also accounts for their popularity in food security research.

The specific data I use are derivations of import unit values. Although unit values are not a perfect measure of import price, the unit value was readily available from the FAO's FAOSTAT database. It is measured in the current year U.S. dollars for each country which facilitates cross-country analysis. Unit value is calculated as the total Cost Insurance and Freight (CIF) dollar value of the commodity imported divided by the quantity in metric tons (MTs) of commodity imported. From here on, price and unit value are used interchangeably. To interpret the unit value, it is important to understand CIF values. CIF incorporates the farm-gate value of the product itself plus the value of transporting it to the port in the exporting country, (which alone comprise the Free On Board [FOB] price), plus the cost of the international transportation to the border of the import country, including labor, insurance, and freight. However, CIF values do not include the cost of clearing customs in the importing country or any domestic transportation costs within the destination country.

I create a weighted average spatial price differential (SPD) for each country's grain imports in 2003. I considered constructing three separate models, representing rice, wheat, and maize separately, but not all sub-Saharan Africa countries import each crop in

significant quantities. By aggregating the trade of the three cereals into grain trade, the data set has a larger degree of freedom and permits more intricate analysis.

I calculated the SPD in several steps. First I gathered the import unit values for each African country and crop. Next I identified the world price for each of the three grain crops. There is no definitive 2003 international price for agricultural commodities since prices fluctuate continually. I generate my own measures of world price using information from the Global Information and Early Warning System of the FAO. It publishes a twice-yearly *Food Outlook* report with prices and trade information for major crops, using FAO and International Grains Council data.

To determine the 2003 international price for maize which has a market year reaching from July to June, I used the quarterly price information for 2002-3 and 2003-4. I averaged the U.S. Number Two Yellow maize price (FOB at Gulf of Mexico ports) and the Argentinean maize price (upriver FOB). The resulting value was $108.95 per MT (U.S.). Unfortunately, I could not weight the average because I did not have information about the aggregate quantities exported by each country for the same periods of the values, although I do know that the U.S. was the largest maize exporter, followed by Argentina. Since the highest price in the average was $115 per MT, and the lowest price was $102, the overall change of a correct weight would have been minimal. In fact, the FAO does not bother to weight the prices in its world price estimations either.

For wheat, I performed a similar procedure on data from the same source, *Food Outlook*. Three international FOB prices were reported, for U.S. Number Two hard and U.S. Number Two soft red winter wheat, and for Argentina Trigo Pan. The market year

is the same as for maize, but I did have export quantity information, so I weighted each price by its quantity. The resulting international price was $152.16 per MT (U.S.).

The *Food Outlook* reports FOB rice prices for Thai 100 percent B rice, Thai Broken rice, U.S. Long grain rice, and Pakistani Basmati rice. The price is for the calendar year, and I was able to determine export quantities for each country in order to weight the prices when I determined the average international price. The resulting price was $235.57 per MT (U.S.).

After determining the world prices for each crop, I calculated the average spatial price differential facing each country. First I subtracted the world price from the import unit value of each crop. Then I multiplied the SPD for each crop by its relative importance (quantity of that grain divided by total quantity of rice, wheat, and maize imported). I added the weighted rice, wheat, and maize SPD together to get a total spatial price differential value for the insurance and transportation costs born by each country on its grain crop imports. This value should vary by distance between the export and import ports. The number of transit countries, the quality of their infrastructure, and the customs charges they assess also affect the SPD.

Independent Variables

Price and quantity of goods imported are related endogenously since economies of scale create lower unit values as volume increases by distributing transaction costs across a greater volume of good, and by giving the buyer greater negotiating power. In this model, I take world price as given, but spatial price differentials, the price differential between countries will also be influenced by economies of scale, and thus share the same complex, endogenous relationship to quantity. Therefore, I do not include quantity as an

explanatory variable in my price differential model. If I were to create a system of equations, I could simultaneously model price and spatial price differentials along with quantity, but that is beyond the scope of this thesis. Instead, I use three alternative variables that can be interpreted, to some extent, as proxies of quantity: population, per capita annual cereal consumption, and openness to trade. The other variables in the model are land and sea distance to the major population center of the importing country from major world markets. Each variable is described below.

<u>Population</u>

Population, along with other demographic variables, determines the required dietary energy consumption of a country.   I use it as a measure of food market potential, which may or may not be realized due to economic or access constraints. Although population does not take into account the relative dietary preferences of each country for each type of grain, it does drive total grains consumption, and secondarily, import demand.   Nigeria, with a population of 125 million people, will almost certainly import more grain than Swaziland where the population barely exceeds one million, despite differences in domestic agricultural capacity and food preferences. Population brings economies of scale into the spatial price differential model. Since population was not normally distributed in my sample of countries, I took the natural log of population in thousands in order to make population's influence on price clearer.   I expect a negative relationship between population and spatial price differential.

<u>Openness to Trade</u>

A country's openness to trade will affect the quantity of cereals it imports. A county with high tariffs (or low quotas) on traded goods will import less than a similar

country with lower market barriers. Non-monetary customs procedures and delays can also reduce openness to trade. In landlocked countries, domestic policies may be very market-oriented, but transit countries' customs can create barriers of cost and corruption which reduce the landlocked destination countries' propensity to trade.

I use the sum of the values of imports and exports, divided by total GDP, as a measure of openness to trade. The resulting percentage allows comparison across disparately sized economies. It is a popular measure of openness to trade (for example, Yahikkaya, 2003; Rose, 2002; Miller and Upadhyay, 2000). Although rice, maize, and wheat imported will affect aggregate imports, they are generally a small percent of the total value.   Furthermore, the measure is a percent of total GDP, so endogeneity concerns are avoided. Barriers to openness will increase the import price countries experience, and a history of low openness will result in higher returns to agricultural investment and an increased domestic food production capacity. Therefore I predict a negative relationship between openness and spatial price differentials.

Cereal Consumption

Countries which consume more cereal per capita each year will likely import more cereal than a similarly endowed country that consumes less cereal. I include kilograms of cereal per capita per year as an explanatory variable because of this relationship with quantity. Kilograms of cereal consumed per year would have a stronger relationship with import quantity than the per capita measures I use, but the endogeneity of the variable with spatial price differential would have risen.   Even still, there is risk of endogeneity between spatial price differential and kilograms of cereal per capita since per-capita consumption will tend to increase with lower prices, the relationship

represented in basic microeconomic supply and demand curves. In order to exclude this endogeneity but retain a measure of the importance of cereals to countries' diets, I lagged the data by one year, using a measure of kilograms of cereal consumption for the 2001-2002 marketing year.

It is interesting to note that kilograms of cereal consumed per capita per year has a complex relationship with wealth. As countries develop and wealth increases, people tend to consume more calories up to a certain point, at which dietary energy intake levels off. However, consumption patterns continue to evolve towards a Western dietary standard heavy in meat and prepackaged foods. In the countries in my sample, I expect that kilograms of cereal per capita per year will indicate greater quantity of cereals imported, and a lower MM, but it may be partially confounded by the wealth effect where countries in which people consume more cereal have smaller economic power and purchase less imports.

<u>Transport distance</u>

I make a key assumption in this thesis that most grain imports in sub-Saharan Africa come from other continents. Grains like rice, wheat, and corn are generally shipped in large containers by truck, train, and ship. Shipping by air is prohibitively expensive for such a low value, high volume product. The journey to the destination country for African grain imports is made in several legs. The beginning of the journey is from the point of production to the exporting port. Then the grain is shipped by ocean liner to an African port which may or may not be within the destination country. In some instances, the importing port is the destination. Otherwise, the grain is trucked or trained to the final destination. Road transport is more fuel-intensive than rail, but much of sub-

Saharan Africa lacks decent rail infrastructure. The ships carrying the containers are more fuel efficient than overland transport by truck which is why this model divides total transport distance into two legs: sea distance and land distance.

Sea distance

Oceanic distance is not an absolute measure. Country of origin varies, and different shipping companies use slightly different routes which they protect as proprietary information. I use different measures of sea distance in three iterations of my model, explained in the next chapter. The first is a measure of sea distance from Faye, et al. They identify the main ports used for each country's imports. They also produce a measure for sea distance to reach that point, which appears to be the closest of the distances from New York, Amsterdam, and Tokyo, none of which is a major grain exporting port. Unfortunately, they do not provide detailed information about the data set, which also has a large number of missing values, so I use the information with caution.

As an alternate measure, I use the absolute distance from New Orleans which is assumed to represent U.S. Gulf ports, through which a large portion of the world's grain trade pass (representing the major grain traffic from the Mississippi though the U.S. Gulf Ports to the global destinations). This "as the crow flies" distance will slightly underestimate actual shipping distances to West and South African countries, and significantly underestimate distances for East Africa since it does not include the distance of traveling around the Cape of Good Hope in South Africa. For this reason, I also include a dummy variable for East African countries to account for the added distance to the region.

When generating the absolute distances, I use the importing ports determined by Faye, et al. when available. For the missing sub-Saharan countries, all of which are coastal, I use the largest oceanic city as the importing port.

Land distance

Land transportation takes place from the port of arrival by truck or train, with truck being more common but also more expensive due to high fuel costs and neglected roads. I expect land distance to be positively related to spatial price differentials, with a greater effect on the margins than the one for sea distance. This relationship is the basis of my first hypothesis. The farther a country is located from the arrival port, the more it must pay for imported grain, due to the increased fuel and labor costs, likelihood of additional border crossings and customs costs, and higher insurance prices.

Faye, et al. measure the distance from the point of arrival in Africa to the major population center of the destination country. Land distance is measured in kilometers along the most popular transportation routes. For many of the coastal countries not accounted for in Faye, the major population center is the same as the point of disembarkation, for a total land distance of zero. For two countries, I estimated land distance from maps.

Models

The coefficients of the above variables, summarized in table one, are estimated in linear equations of the general form defined in equation eight:

$$SPD_{ti} = \alpha_0 + \alpha_1 POP_{ti} + \alpha_2 OPEN_{ti} + \alpha_3 CER_{(t-1)i} + \alpha_4 LAND_{ti} + \alpha_5 SEA_{ti} + \varepsilon_{ti} \qquad (9)$$

$$SPD_{ti} = \beta_0 + \beta_1 POP_{ti} + \beta_2 OPEN_{ti} + \beta_3 CER_{(t-1)i} + \beta_4 LAND_{ti} + \beta_5 AIR_{ti} + \beta_6 EAST_{ti} + \upsilon_{ti}$$

$$(10)$$

where: SPD = spatial price differential
POP = population
$OPEN$ = openness to trade
CER = cereal consumption, kilograms per capita per year
$LAND$ = land shipping distance
SEA = sea shipping distance
AIR = absolute distance from New Orleans
$EAST$ = dummy variable where 1 equals country in East Africa

In the model, ε and υ are the residuals and the subscript t indicates the time period and i indicates the country.

Data Sources

I have found the FAO to be a very useful source of data. I used the TRADESTAT section of the FAOSTAT database to find import unit values for each country. I create world prices with data from the FAO's *Food Outlook* reports, as described above, and combine them with import unit values to determine the spatial price differentials. All values are in 2003 U.S. dollars per MT, using the FAO conversions when necessary. The cereal consumption in kilograms per capita per year variable comes from the FAO as well. The FAO publishes a semiannual *Africa Outlook* report with this measure for every African country. Since it is reported on a market year basis, which varies across country and frequently differs from calendar year, I used the data from which ever market year included the majority of 2002 (due to the one year lag).

The population and openness data are from the World Bank's *World Development Indicators* data set. The WDI calculates the sum of import and exports divided by GDP directly.

As described above, the land and sea distance variables come from the data set associated with Faye, et al,'s paper, *The Challenges Facing Landlocked Developing Countries*. The distances are in kilograms, and the process of identifying trade routes is

described in the paper. I create the absolute distance from New Orleans using the

distance calculator at http://www.timeanddate.com/worldclock/distance.html which uses

city latitude and longitude to produce distances. I also assign the countries to the east

dummy variable using regions defined by Faye, et al.

The data used in the spatial price differential model is summarized in Table 1.

Table One: Summary Statistics for Price Differential Model

Variable	Description	Units	Number of Observations	Mean (St. Dev.)	Number of Observations	Mean (St. Dev.)
SPD	Spatial Price Differential	Dollars per Metric Ton	25	53.19 (55.96)	34	49.85 (56.62)
POP	Population	Natural Log of Real Population	25	16.21 (1.10)	34	15.97 (1.19)
OPEN	Openness to Trade	Percentage of GDP	25	0.73 (0.37)	34	0.76 (0.35)
CER	Cereal Consumption	Kilograms per Capita per Year	25	136.6 (49.25)	34	127.38 (49.22)
LAND	Land Transport Distance	Kilometers	25	608.6 (539.08)	34	466.26 (523.73)
SEA	Sea Transport Distance	Kilometers	25	11624.16 (3125.33)	—	— —
AIR	New Orleans to Port Distance	Kilometers	—	— —	34	11063.06 (2819.72)
EAST	East Africa	0 or 1 [dummy]	—	— —	34	0.18 (0.39)

Undernourishment Model

Development scholars are very interested in modeling food consumption and shortfalls in order to measure progress towards development and to analyze the effects of changes in various factors such as population growth, climate change, and trade policy. Most food security empirical models are developed at the household level. Although microeconomic work is not the focus of this thesis, the research still offers insight into nutrition modeling methodology.

Garrett and Ruel observe striking differences in micro-level food security in Mozambique between urban and rural areas (1999). They hypothesize that the determinants of nutritional status are different in the two areas. To test their hypothesis, they create two sets of models based on household survey data from a Mozambique census. Their dependent variable is a high-for-age Z-score for children, and they use twenty four independent variables including adult family member education, household demographic information, land ownership, agricultural production and yields, infrastructure and development indicators, and household expenditures per capita. They perform Ordinary Least Squares (OLS) regressions, but concern over endogeneity between household expenditures and nutritional status led them to calculate 2SLS regressions with an index of household assets as an instrument for household expenditures. Testing to see if the two equations had significantly different coefficients (indicating that 2SLS fixed endogeneity) was inconclusive. Overall, Garrett and Ruel determined that the variables in the rural and urban equations had the same signs with approximately the same coefficient values. This indicates that the same determinants of undernourishment acted in both rural and urban areas; nutritional differences stemmed

from differences in levels of the determinants in the two regions, thus rejecting their original hypothesis.

IFPRI uses its IMPACT model to explore food security effects of agricultural policy and trade by calculating country-level undernourishment (Rosegrant, et al., February 2005). The estimated functional relationship for malnourishment is a simple linear equation. The dependent variable is the percentage of malnourished preschool children (MAL) in developing countries. The definition of a malnourished child is based on a weight-for-age standard. The independent variables used in the IMPACT model are the natural log of per capital kilocalorie availability (KCAL) derived from the model's demand projections, the ratio of female to male life expectancy at birth (LFEXPRAT), the percentage of females enrolled in secondary education (SCH), and the percentage of population with access to safe water (WATER).

$$MAL = -.25.24 * \ln(KCAL) - 71.75 LFEXPRAT - 0.22 SCH - 0.08 WATER \quad (11)$$

To determine the absolute number of malnourished children, MAL is simply multiplied by the population.

Model and Theory

Although I am performing a cross-country macroeconomic analysis of nutrition, it is important to understand the microeconomic theory behind nutrition and health modeling. In the *Handbook of Development Economics*, Behrman and Deolalikar introduce a theoretical model for nutrition and health which has become a standard in the field (1988). Health and nutrition are produced at the household level according to a production function. The household utility maximization function of preferences is constrained by the production of health and nutrition, along with prices of goods.

Behrman and Deolalikar emphasize that consumption and production are often inseparable, especially in rural communities where households produce a significant portion of the food they consume and the food consumed affects productivity. They also note that, "Testable predictions can be derived only if one is willing to simplify the model considerably and probably unrealistically" (Behrman and Deolalikar, 1988, p. 639). I do indeed simplify the model considerably, but I attempt to do so realistically.

Of particular interest to me is the reduced-form of the Behrman and Deolalikar demand relationship, in which the constrained maximization of preferences leads to a set of reduced-form demand functions.

$$Z = f(V) \qquad (12)$$

where: $Z =$ all endogenous variables including nourishment in the system for the household or individual
$V =$ all exogenous prices, endowments, transfers minus taxes, and predetermined wealth (p. 646)

This model provides a framework in which to assess the impact of changes in market price, endowments, and policies on health and nutrition-related consumption. In the case of this macro-level thesis, Z is the food security of the individuals in a country and V represents the endowments and factors unique to the country.

I create two models in the form of equation twelve to assess the validity of my second hypothesis: countries experiencing relatively high grain import prices suffer relatively worse undernourishment. The first model explains the prevalence of undernourishment:

$$UN_c = f(EXP_c, PR_c RQ_c, AL_c, YL_c, MP_c, MPC_c) \qquad (13)$$

where: $UN_c =$ percent of people undernourished in country c
$EXP_c =$ expenditures per capita in country c

PR_c = rural population percentage in country c

RQ_c = regulatory quality in country c

AL_c = hectares arable land per capita in country c

YL_c = cereal yield in country c

MP_c = import price of cereals in country c

MPC_c = percent of consumption from imported cereals in country c

The second model explains the percent of malnourished children.

$$UNC_c = f(PR_c, IW_c, KCAL_c, MP_c) \tag{11}$$

where: UNC_c = percent of malnourished children in country c

PRc = rural population percentage in country c

IW_c = percent of people with access to improved water in country c

$KCAL_c$ = kilocalories per capita consumed per day in country c

MP_c = import price of cereals in country c

Dependent Variables

Undernourishment is an effective measure of food insecurity used by the United Nations to track progress towards the MDGs. It is also used in many food insecurity studies (see Rosegrant, 2005), and it is an appropriate variable choice to test my second hypothesis. Undernourishment is defined as the proportion of the population whose food intake falls below the minimum level of dietary energy consumption requirement, and it ranges from 0.00 to 1.00. The FAO prepares the undernourishment estimate at the national level using country statistics on local food production, trade, stocks, and non-food use, along with food consumption information from household surveys to determine per-capita food consumption patterns. Anthropometric data from national surveys and population estimates from the United Nations allow the FAO to determine the appropriate minimum energy requirement level for each country. Since food insecurity is not equal across all regions and all populations within a country, this aggregate measure is

somewhat limited. It does not reflect intrahousehold differences in food security across gender or age lines either, simply food acquired by households. However, prevalence of undernourishment is readily available for many countries, and it is easy to compare across the sample.

Due to the above limitations of data regarding the prevalence of undernourishment, the U.N. also monitors the percent of child malnutrition judged by weight for a given age. The United Nations Children's Fund and the World Health Organization (WHO) use national household surveys to determine the percentage of children under five whose weights are more than two standard deviations below the median for a reference population adopted by the WHO. A benefit of the measure is that it is based on a symptom of food insecurity rather than a formula for the expected level of undernourishment, and many food insecurity studies choose to use it (Garrett and Ruel, 1999; Rosegrant, et al, February 2005). However, the child weight measure also captures effects from non-food security determinants of low weights including poor health and environmental conditions and shortfalls in quality of caregiving. The data set is also less complete than that for undernourishment. Therefore, I create two food insecurity models in order to use both undernourishment and childhood malnutrition as dependent variables. In concert, the two variables provide a more complex scenario in which to analyze food security.

Independent Variables

The variables I use to explain food insecurity cover a wide range of subjects including wealth and endowments, development, government, demography, and import

prices and behavior. I justify their inclusion and explain the potential relationships

between them and food insecurity.

Expenditures

The link between poverty and food insecurity is indisputable, but incorporating a measure

of poverty into the model is not a simple task.   Perhaps the most common measure of

poverty is Gross Domestic Product per capita. However, GDP per capita may not reflect

household-level purchases very accurately due to the non-expenditure portion of the

amount. The percentage of people living on less than $1 (U.S.)per day is another popular

measure of a country's economy, and it relates to inequality of income distribution, but

the data is spotty. Furthermore, since it is a percent rather than a dollar measure, it

obscures the details of the extent of poverty and nutrition shortfalls. I include

expenditures per capita as an explanatory variable indicating the economic power of

countries. Poor countries will have lower per capita expenditures than relatively

wealthier countries which may reduce food purchasing and subsequent food

consumption, leading to undernourishment. Low expenditures also indicate inability to

purchase inputs such as genetically engineered seeds, irrigation systems, and fertilizer

needed to cultivate high-yield crops which could reduce undernourishment.

There is some justification to the argument that expenditures and food insecurity

are endogenous. Undernourishment negatively affects the earning potential of adult and

reduces the ability to spend. The FAO notes that reducing poverty without first

alleviating food insecurity is virtually impossible (FAO, *State of Food Insecurity*, 2006).

For this reason, fighting hunger is a vital task for the global community. However, I

focus on the causal relationship of poverty on food insecurity to support my hypothesis.

In the context of my model, I expect expenditures per capita to have a significant negative relationship with the prevalence of undernourishment. Due to the skewed distribution of values across the countries in my data set, I took the natural log of the expenditures to better represent their influence on undernourishment.

Rural Population

The FAO observes that food insecurity is more common in rural communities than urban areas. Many other works observe that food insecurity is a relatively greater concern in rural areas (Laier, et al., 1996). In fact, rural food insecurity is a primary cause of urban migration trends. A larger percentage of rural residents produce food for their own households, leaving them vulnerable to seasonal fluctuations in consumption. Drought or other causes of crop failure can severely affect food security in rural areas which may lack infrastructure connecting populations to other food markets, as well as the means to purchase food.

Given the relationship between rural situation and undernourishment, I have included the percentage of population that lives in rural areas as an explanatory variable for food insecurity in the second models. I expect it to be positively correlated with the prevalence of undernourishment.

Governance and Regulatory Effectiveness

A country's governance influences many aspects of its development. Robert L. Paarlberg, a professor of political science at Wellesley College and a collaborator with IFPRI explores linkages between institutions of governance and food security at length (1999). He believes that the importance of governance cannot be overstated due to the many ways in which it contributes to food security, from ensuring stability that promotes

agricultural investment, to creating market friendly policies that do not punish rural

producers. Furthermore, economic aid is believed to be more effective in countries with

good governance (Kaufmann, 2005). For these reasons, Kaufmann et al., from the World

Bank, have undertaken a project of measuring the traditions and institutions through

which authority is exercised by creating six indices used to evaluate governance in 216

countries (2005).   The authors create indicators that

> "reflect the statistical compilation of responses on the quality of
>
> governance given by a large number of enterprise, citizen and
>
> expert survey respondents in industrial and developing countries,
>
> as reported by a number of survey institutes, think tanks, non-
>
> governmental organizations, and international organizations."
>
> (Kaufmann, *Intro*, 2006).

As noted, the indicators are not objective measures, but given the credibility of the

evaluators and the comprehensiveness of the data set, they are very useful.   The six

dimensions of government are: Voice and Accountability, Political Stability, Government

Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption. For each

measure, the index spans values of -2.5 to 2.5, with higher values reflecting more

effective governance.

The correlation between the governance measures I could use as explanatory

variables – regulatory quality, political stability, government effectiveness, and control of

corruption – is over 0.7 in each case, which makes it inadvisable to include more than one

such measure in the model, due to the likelihood of multicollinearity. The regression

would be unable to assign the appropriate coefficient and significance to each variable

because the effects of each would be indistinguishable. I choose to include regulatory quality because I believe it influences inter-country variation of consumer food prices in a variety of ways. I would expect regulatory quality to be negatively related to the prevalence of undernourishment.

I believe that regulatory quality is related to consumer food prices. Regulatory quality measures the incidence of market-unfriendly policies including excessive regulation of foreign trade and business development as well as inadequate supervision of markets. If my first model focused on food prices instead of CIF import unit value, I would be able to include regulatory quality as a direct explanatory variable for the price of imported food prices since high import tariffs (which would lower the regulatory quality measure) raise food prices. However, finding data with cross country consistency on food prices is virtually impossible and such a measure is unpractical given intra country variations in food prices based on factors such as the size and dispersion of population centers, the number of transactions and transportation costs. In effect, regulatory quality and import price differential (explained later) work together to account for variation in consumer food prices. I expect regulatory quality to be negatively related to undernourishment.

Domestic Agriculture: Hectares Arable Land per Capita and Yield

Although rural populations are believed to have a negative relationship to food security, it seems logical that a country's ability to produce food domestically may reduce food insecurity. Domestically produced food generally generates lower transportation costs than imported food and is not subject to import tariffs. Of course, crops must be successful for this relationship to hold.

I have included two WDI measures, hectares of arable land per capita and cereal yield, as explanatory variables in the model for prevalence of undernourishment. Since hectares arable land is a per capita measure, it can be compared across countries with very different populations and areas to determine relative endowments of productive land. However, a disadvantage of arable land is that is does not reflect actual crop yields. Furthermore, there is no guarantee that arable land is cultivated much less cultivated for food rather than a cash crop. Nevertheless, arable land per capita is an important component of a country's capacity to produce food. Since the variable was not normally distributed (most countries fell below 0.4 hectares of land per capita, but a few were greater, and Niger exceeded one). I took the natural log of the values to create a more uniform measure. I expect a negative relationship between arable land per capita and undernourishment.

Cereal yield in kilograms per hectare is another important component of domestic agriculture. It is dependent on natural endowments (which may vary from year to year) including soil quality, temperature and rainfall, as well as economic inputs ranging from fertilizers and genetically modified seeds to irrigation equipment and other farm machinery. Yield was approximately normally distributed and I included it in the model without modification. I expect it to have a negative relationship with undernourishment. It is important to note that although two variables, yield and log of arable land, both relate to domestic agriculture, they measure different components. As expected, the correlation between the two is very low, -0.20 and not significant, so they can both be included in the model without confounding effects.

Food Import Measures

To complete my overall view of the importance of geography in food insecurity, I use a measure of grain import prices to explain food insecurity. Cross-country variations in price are discussed in depth earlier in the thesis. I could not use rice, wheat, and maize prices all separately as explanatory variables in the same model since there is still a correlation between the prices. Instead, I created a weighted average cereal import price based on the individual grain import unit values for rice, wheat, and maize, which I gathered from FAOSTAT, as described in the spatial price differential model. I considered including millet and sorghum as well, but insubstantial amounts were traded. Although other grains and foodstuffs are important to diets, maize, rice and wheat comprise the vast majority of the grain trade, and comprehensive data on these commodities is available.

I multiplied the particular grain prices for each country by their shares of total grain imports (sum of the rice, wheat, and maize quantities imported). Adding the three resulting weighted values together yields an average import price differential for grain. The aggregate grain import price will be positively associated with food insecurity, according to my hypothesis.

When considering the impact of food import on food security, it is important to examine the relative importance of imported foods in each country. To do this, I used data from the FAO's Global Information and Early Warning System on Food and Agriculture. Twice yearly this division publishes a bulletin entitled, "Food Supply Situation and Crop Prospects in Sub-Saharan Africa." It contains detailed information

about cereal usage, domestic production, imports, and food aid for countries in the region with the goal of preventing food shortage crises through early warnings.

For each country in my data set, I multiplied the average per-person share of total calorie intake from cereals (a percentage) by the share of commercial imports, excluding food aid, in total cereal usage (also a percentage). The resulting value is the percentage of total calories from cereal imports, and the range is large. The low is 0.3 percent in Uganda, which is landlocked, with a particularly unfavorable trade route for imports, and perhaps as a consequence, one of the highest domestic cereal yields. The high is 50.3 percent in densely populated Lesotho, which is landlocked, but surrounded entirely by South Africa, with whom it enjoys a relatively hassle-free trading relationship. The median value is 9.9 percent.   I expect the relationship between percentage calories from imported cereals and undernourishment to be negative. Countries which are able to make up domestic production shortfalls by purchasing imported grain are more likely to have the resources to feed its citizens.   A high proportion of calories from cereal imports is indicative of efficient infrastructure, low tariffs, and the ability to effectively distribute food to consumers.

The correlation between percentage of calories from cereal imports and import price differential is surprisingly low. However, this can be explained by noting that countries in which people consume many of their calories from imported cereals do not necessarily import large quantities of food because they may have small populations. Thus it is impossible to ascertain a relationship between the effects of economies of scale on price and percentage of calories from cereal imports.

<u>Safewater supplies</u>

Access to safe water is an important contributor to child welfare since "unsafe water is the direct cause of many diseases in developing countries" (*Indicators*, 2003, p.64). Additionally, it serves as an indicator of the presence of other development infrastructure and health spending that contribute to child nourishment. The United Nations uses the percent of population with access to an improved water source such as piped water, public taps, boreholes or pumps, or protected spring and rainwater, as an indicator of progress towards the MDG target of halving the proportion of people without sustained access to improved water and sanitation facilities.   UNICEF and the WHO monitor access with national census and survey data. I follow Garrett and Ruel and include access to improved water as an explanatory variable for child nutrition (1999). I expect a negative relationship between the two.

<u>Caloric Consumption</u>

The quantity of kilocalories consumed per day is an integral part of food insecurity. When a person consumes fewer kilocalories than the daily energy requirement, the person is undernourished.   Thus, kilocalories per capita per day cannot be included in the model for prevalence of undernourishment since it is part of the definition.   However, it is both useful and appropriate to include kilocalories per capita per day as an explanatory variable in the model for child nutrition since the dependent variable is a weight for age measure, not a calorie measure.

This variable is available from the FAO as a three-year average, which helps prevent problems of endogeneity between kilocalorie consumption and import price, another independent variable in the model. The import price of cereal in 2003 plays a

relatively negligible role in the total calories consumed over a three-year period.

Kilocalorie consumption definitely overestimates the kilocalories consumed by children

under five who have smaller calorie requirements than adults, but it indicates overall

calorie availability in the country which should negatively relate to underweight children.

Models

I use the above variables to construct two linear models in the form of equations

13 and 14:

$$UN_c = \alpha_0 + \alpha_1 MP_c + \alpha_2 PR_c + \alpha_3 RQ_c + \alpha_4 AL_c + \alpha_5 Y_c + \alpha_6 MCP_c + \alpha_7 EXP_c + \varepsilon_c \qquad (15)$$

$$UNC_c = \beta_0 + \beta_1 MP_c + \beta_2 PR_c + \beta_3 KCAL_c + \beta_4 IW_c + \upsilon_c \qquad (16)$$

The abbreviations are the same as those used above, and ε_c and υ_c are residuals.

Data Sources

The World Bank publishes the World Development Indicators (WDI) data

annually. The WDI is a compressive set of over 600 measures of development available

by country, many of which are useful in tracking progress towards the Millennium

Development Goals. One of the measures included in the WDI is prevalence of

undernourishment measured as the percentage of the population of each country

experiencing undernourishment, ranging from 0.00 to 1.00. Expenditure data is available

from the WDI, and I divided the values by the countries' populations (also from WDI) to

generate a per capita expenditure measure, in 2003 U.S.dollars per year. Hectares of

arable land per capita and yield of cereal crops in MTs per hectare come from WDI as

well. Rural population percent information was gathered from FAOSTAT, along with

per capita kilocalorie consumption, and the unit value price information described in

depth in the previous section.

The information on access to improved water sources, and childhood malnourishment come from the UN's Statistics Division which has a database of MDG indicators. Access to an improved water sources is a percent of total population. The childhood malnourishment variable is described in depth above. Finally, regulatory quality of government, described above, comes from Kaufmann, Kraay, and Mastruzzi (2006).

I summarize the above variables in Table 2. The results from the models described in this chapter are related in Chapter Four

Table Two: Summary Statistics for Undernourishment Model

Variable	Description	Units	Number of Observations	Mean (St. Dev.)	Number of Observations	Mean (St. Dev.)
UN	Prevalence of Undernourishment	Percentage of Population	33	0.32 (0.17)	— —
UNC	Prevalence of Malnourished Children	Percentage of Population	—	— —	18	0.26 (0.09)
MP	Price of Imported Cereal	Dollars per Metric Ton	33	192.98 (48.21)	18	195.19 (56.99)
PR	Rural Population	Percentage of Population	33	0.63 (0.19)	18	0.65 (0.19)
Y	Domestic Cereal Yield	Kilograms per Hectare	33	1099.41 (356.76)	—	— —
AL	Arable Land	Natural Log of Hectares per Capita	33	-1.56 (0.43)	—	— —
RQ	Regulatory Quality	Index [-2.5 to 2.5]	33	0.70 (.059)	—	— —
MCP	Imported Cereal Consumption	Percentage	33	0.14 (0.12)	—	— —
EXP	Expenditures	Natural Log of Dollars per Capita	33	5.69 (0.73)	—	— —
KCAL	Total Consumption	Kilocalories per Capita per Day	—	— —	18	2236.11 (384.08)
IW	Improved Water Access	Percentage of Population	—	— —	18	0.64 (0.20)

CHAPTER FOUR

RESULTS

In the previous chapter, I discuss the construction of estimation models that explain the spatial price differential for imported cereals and the prevalence of food insecurity in developing sub-Saharan Africa countries. Here, I describe the results and significance for each model individually.

To estimate the coefficients for the models, I use Ordinary Least Squares (OLS) regressions. An OLS regression creates the best-fit model for the data set by minimizing the sum of the squares of the residual values. Also known as ordinary differences, residuals are the differences between the points predicted by the model and the actual values of the dependent variable.

In order to use OLS regressions to draw conclusions about the variables in the equation, certain assumptions must be met. These assumptions are outlined in the Gauss-Markov Theorem. Suppose we have a linear relationship:

$$y = X\beta + \varepsilon$$

where β are non-random but unobservable parameters, X are non random, observable explanatory variables, the errors, ε, are random, and therefore, y is also random (Griffiths, Hill, and Judge, 1993). The first assumption is that the expected value of the error term is zero. On average, the errors balance out. Second, the explanatory variables are non-random. Third, the explanatory variables are linearly independent, so that no variable can be expressed as a linear combination of other variables. Fourth, the error term is homoskedastic so that the variance of the error is the same for each observation. Finally, the error terms are not correlated with each other; there is no autocorrelation. If

these assumptions are met, the Gauss-Markov Theorem states that the estimator for β produced by the OLS regression is the best (lowest variance) linear unbiased estimator. By also assuming that the error terms are normally distributed, it can be said that the OLS estimator is the best unbiased estimator.

Although OLS regressions are not particularly flexible, the technique produces a good fit for the cross-sectional data set I describe in chapter three. Abbott justifies the use of OLS modeling for reduced-form agricultural trade in his 1979 paper, and Garrett and Ruel use it to generate their food security models (1999). I employ STATA 9.0 software to perform the regressions. After creating the models, I test for violations of the assumptions outlined in the Gauss-Markov Theorem.

Every coefficient in the sets of models has the sign predicted for the variable in chapter three. I determine the significance level (ranging from 0.01 to 0.10) of the coefficients with a one-tailed t-test. Using a one-tailed t-test instead of a two-tailed t-test results in more significant coefficients, so the approach must be justifiable theoretically to avoid artificially inflating the significance of results. For these models, previous studies and economic theory predict a particular sign for each variable. In every case, the expectation is correct, indicating that the theory influencing the models is sound. Therefore, I use a test that evaluates if the coefficients are different than zero in the anticipated direction, not simply if the coefficients are different than zero.

Spatial Price Differential Model

To evaluate whether isolated countries' food security is negatively affected by high import prices, first I had to establish the role of location in food prices. With a t-

test comparison of means, I calculate that the spatial price differential is 75 percent higher in landlocked countries than maritime countries, significant at the 10 percent level. With this initial support of my hypothesis, I construct models to explain more clearly how spatial price differentials are determined.

$$SPD_{ti} = \alpha_0 + \alpha_1 POP_{ti} + \alpha_2 OPEN_{ti} + \alpha_3 CER_{(t-1)i} + \alpha_4 LAND_{ti} + \alpha_5 SEA_{ti} + \varepsilon_{ti} \qquad (9)$$

$$SPD_{ti} = \beta_0 + \beta_1 POP_{ti} + \beta_2 OPEN_{ti} + \beta_3 CER_{(t-1)i} + \beta_4 LAND_{ti} + \beta_5 AIR_{ti} + \beta_6 EAST_{ti} + \upsilon_{ti}$$

$$(10)$$

These models and the abbreviations are described in detail in Chapter Three. I am particularly interested in the influence of the land distance variable (LAND) which indicates the overland distance from the primary disembarkation port to the major population agglomeration in the destination country. I hypothesize the following:

$$H_0^1 : \alpha_4 = 0$$
$$H_A^1 : \alpha_4 > 0$$

where α_4 is the coefficient of LAND in equation 9 (replace with β_4 for equation 10). If the model results allow me to reject the null hypothesis, I can conclude that the farther a country's main city is from the arrival port, the higher the spatial price differential on imported cereals, if all else remains equal.

I report the results of OLS regression I use to estimate equations 9 and 10 in Table 3. Each iteration is described in the next section, but a brief overview will be helpful in understanding the conclusions drawn from the individual model results.

Table Three: Determinants of Spatial Price Differential, Ordinary Least Squares estimates.

	Dependent Variable		
	Weighted Average Cereal Import Spatial Price Differential		
Independent Variable	(1)	(2)	(3)
Population	-13.29994*	-20.94739***	-14.566278*
	(-1.42)	(-2.48)	(-1.44)
Openness to Trade	-54.07285**	-50.99255*	-47.65609*
	(-1.90)	(1.62)	(-1.53)
Cereal Consumption Per Capita	-0.32886**	-0.21533	-0.37135**
	(-1.73)	(-1.16)	(-1.89)
Land Transport Distance	0.03812**	0.04303**	0.04816***
	(2.10)	(2.11)	(2.54)
Sea Transport Distance	0.00521*	—	—
	(1.58)	—	—
New Orleans to Port Distance	—	0.00244	0.00172
	—	(0.57)	(0.42)
East Africa	—	27.60136	19.21453
	—	(1.01)	(0.74)
Constant	269.5499*	398.6044***	321.2292*
	(1.55)	(2.59)	(1.69)

Regression Statistics	(1)	(2)	(3)
Number of Observations	25	34	25
R-squared	0.58	0.41	0.56
Adjusted R-squared	0.47	0.28	0.41
F Statistic	5.30	3.14	3.83
Probability > F	0.003	0.018	0.012
Root Mean Squared Error	40.642	48.044	42.815

Notes:

* = Significant at the $\alpha = 0.10$ level

** = Significant at the $\alpha = 0.05$ level

*** = Significant at the $\alpha = 0.05$ level

The variables which relate to the quantity of cereals imported are included in all three models. Openness to trade is always significant at the five or ten percent level. Population is always significant as well, although the magnitude of the coefficient changes. The significance level of cereal consumption varies across the models. In relation to transportation, the land shipping distance is significant in each model at the five or one percent level. This strong result is consistent with my expectation and allows me to reject the null hypothesis.

In the first iteration of the model, I use the sea distance variable from Faye, et al, then in the last two I use my own measure of absolute distance from New Orleans in concert with a dummy variable for East Africa (2004). The expanded data set with absolute distance has an adjusted R-squared value of 0.28, compared with 0.47 from the Faye's data set. To evaluate whether the decline in explanatory power is due to the alternate variable or the expansion of the data set, I create the third model using absolute distance and East Africa with data only from the countries in Faye's data set. It results in an adjusted R-squared variable of 0.41, indicating that the inclusion of extra countries is the reason for the decrease in explanatory power. None of the R-squared values indicate a particularly strong model, but this is unsurprising given the aggregate, cross-sectional nature of the scenario.

Model One

The first model is the initial attempt at predicting spatial price differentials. In it, *population* has a negative relationship with spatial price differential, significant at the ten percent level. Since I took the natural log of population data, the model has a semi-log functional form which affects the interpretation of the coefficient (-13.3). In effect,

increasing the population by one percent explains a $0.13 per MT decrease in the spatial price differential. I believe that my original justification for including population in the model as a measure of market potential (and thus a contributor to quantity of imported cereal) is indeed the source of its effect on spatial price differential.

Openness to trade has a strong, consistent relationship with spatial price differential in the models. Here, if the sum of imports and exports as a percent of GDP increases by one percentage point, it corresponds to a $54.07 drop in spatial price differential. However, it is unlikely that increased trade in the absence of other changes would indeed lower spatial price differentials that much. In fact, it is unlikely that the value of trade would increase significantly without corresponding changes in infrastructure investment, trade policy, wealth, etc. I include openness to trade as an explanatory variable precisely because it reflects the effects of policy and wealth on propensity to trade and integration in the world market. Openness to trade is, in effect, a predictor of the quantity of imported cereals. It is significant and contributes to the strength of the models, but the precise source of its influence is outside the scope of this thesis.

Cereal consumption is a significant variable in the first model at the five percent level. The variable reflects the importance of cereal to the diet by measuring the average amount of kilograms consumed per year. It does not differentiate between imports and domestically produced cereals. However, it is not unreasonable to assume that countries which consume more cereal may also import more cereal. As I explain in the previous chapter, the variable is lagged one year to avoid endogeneity with the dependent variable which is a component of cereal price.   The effect of the variable appears relatively

minor; a one kilogram increase in annual per capita cereal consumption reduces the spatial price differential on imports about 33 cents per MT. However, the kilogram increase in cereal consumption can be achieved by additional consumption of less than a teaspoon per day.

Land transport distance is a significant explanatory variable for the spatial price differential at the five percent level. For every 25 kilometers inland the population is from the port city, measured by road, the spatial price differential for imported grains rises one dollar per MT. For Zambia, the 1,975 kilometers from the port of Durban, South Africa, into which many of its imports arrive, is a traveled at an additional cost of $75.05 per MT. This cost incorporates additional fuel costs. However, if fuel costs were the only concern, countries would chose routes that minimized distance, which is not always the case. For instance, Zambia's imports could be shipped at shorter absolute distance through Angola. Factors such as road quality and its effect on the time of the journey and thus the wages of the transporters may induce a country to route its imports differently. The land distance variable also captures the effects of higher insurance due to the transport risk, which increases with distance, and the cost of clearing customs in the transit countries, two in the case of Zambia.

Sea distance has a much lower relative effect on spatial price differentials than land transport distance. This is unsurprising since oceanic transport is more fuel efficient and not affected by infrastructure investment or customs policies. In the first model, each additional kilometer of travel by sea increases spatial price differentials a half cent per MT. This is about thirteen percent of the effect of an additional land kilometer. However, sea distance composes the entire journey from the exporting port for countries

with coastal populations, and may have a larger aggregate affect on spatial price differential even in landlocked countries. I cannot analyze this variable extensively since Faye is vague about its composition. The sea distance measure is not available for many of the countries in my data set which shrinks the degrees of freedom in the model. Since I do not know the reasons behind the excluded countries in the Faye data, it is possible that model one's results were biased by omitted data. Indeed, this may be the case. Due to this ambiguity, I use my own distance measure in the second two models.

In the model, the adjusted R-squared of 0.47 indicates that the independent variables explain almost half the variation of the spatial price differential. The F statistic and the associated probability indicate that the independent variables can reliably predict the spatial price differential. Overall, this is a decent significance level for a cross-sectional study. The largest flaw in the model is the lack of information about the sea distance variable.

Model Two

In the second model, I use an alternate set of measures for sea distance based on absolute distance from New Orleans and a dummy variable for East Africa. This also expands the data set by nine countries.

In model two, *population* increases dramatically in significance to the one percent level and while the value of the coefficient drops. Increasing the population one percent decreases the spatial price differential $0.21 per MT, according to this model. *Openness to trade* varies only slightly from the first model, although the significance level declines to 10 percent. The effect of *cereal consumption* changes more dramatically, with a third less impact on spatial price differential, and in fact, its influence is no longer significant.

With regards to the distance measures, the effect of *land transportation* is fairly similar to the first model, with an additional kilometer in travel explaining a 4.3 cent per MT increase in spatial price differential. Since this is the variable upon which the first hypothesis is based, the consistency of the coefficient and its continued significance lend confidence to the interpretation that isolation raises import price by increasing the spatial price differential.

My substitute for sea distance, *distance from New Orleans* (a prominent grain export departure port), is not significant, and the coefficient reflects less influence on the dependent variable than Faye, et al.'s measures of sea distance. Each one hundred kilometers of distance from New Orleans explains a $2.44 per MT increase in spatial price differential.   The dummy variable for East Africa is also insignificant, although its positive sign demonstrates the expected relationship with spatial price differential. In combination, the two variables predict somewhat different results than the sea distance variable. For instance, according to model one, sea distance contributes $82.52 per MT to the spatial price differential of imported cereals in Kenya. The second model anticipates a $61.82 per MT contribution to the spatial price differential based on Kenya's location in East African and its distance from New Orleans. For western and southern countries, the difference is more dramatic. It is clear that these two measures are not completely substitutable.

The second model has lower overall explanatory power than the first, with anadjusted R-squared value of 0.28. The F statistic indicates that the independent variables account for the variation in spatial price differential at the five percent

confidence level but not at the one percent level. In order to clarify the reason for differences in the first two models, I derive a third model.

Third Model

The third model is composed from the same explanatory variables as the second model but the additional nine countries from the second model are excluded, so that the data set represents the same countries as in model one. This should help determine whether the strength of the explanatory power of the first model is due to the omissions of certain countries whose data weaken the results in the second model.

In this model, the coefficient of *population* is comparable in magnitude and significance to the first model. The value of the coefficient of *openness to trade* is slightly less than the first or second model. The coefficient *cereal consumption* is nearer to the first model in significance and value.

The value of the coefficient of *land transport distance* is slightly higher in this model than in the second model, but much closer to the second model than the first. Here it is significant at the one percent level. Meanwhile, the magnitude of the coefficient for *distance from New Orleans* decreases slightly as does the effect of the *East* dummy variable.

The third model's adjusted R-squared value, 0.41 is similar to the first model, but the F statistic is closer to the second model. All in all, I conclude that the first and third models exclude countries whose data significantly alter the coefficients of population and cereal consumption. This bias, not my alternate distance measure, changes the models' significance.   Therefore, unless the countries excluded from the first and third model are

in some way outliners, I must select the second model as my preferred model to avoid omitted data bias.

The nine countries in question are:

Angola	Democratic Republic of Congo	Gabon
The Gambia	Guinea	Guinea-Bissau
Liberia	Namibia	Sierra Leone

These countries all belong in two geographic groups: the northwest coast and the southwest coast of Africa. None of them are landlocked. These similarities can explain why they bias results when excluded from the model. I have no compelling reason to exclude these countries since I am interested in predicting import prices for the west coast of Africa. Therefore, the second model is the preferred model in spite of its weaker explanatory power.

General Results

When testing for violations of OLS assumptions, I do not diagnose any particular problem in model two. The strongest direct correlation between independent variables is a negative 0.52 correlation between population and trade (since larger countries generally meet more of their needs domestically and trade proportionally less). This does not seem to affect the model since trade is consistent across all three models, despite the differences in number of observations. Therefore, multicollinearity between independent variables is not a concern. Autocorrelation between the independent variables is not a concern because the data set is not a time series. Although I did not expect heteroskedasticity, I checked for it graphically between the residuals and the fitted values and also performed a Breusch-Pagan test for heteroskedasticity. No significant relationships were discovered. The residuals are fairly normally distributed. The results

of the tests of OLS assumptions are reported in Appendix A. I feel confident interpreting the results of the regression without correction for possible violations of OLS assumptions. The main concern with the model is the lack of explanatory power which could be addressed by using a more complex system of equations to determine quantity of cereal imports and spatial price differential simultaneously.

The second model and in fact, all three models, strongly support the idea that geography plays a role in food prices. Countries where imported cereal travels farther on land pay higher spatial price differentials, at a rate of approximately four cents per kilogram per MT. I reject H_0^1 with greater than 95 percent confidence.

This result does not carry over to sea transport distance for a variety of reasons. The variable is more problematic since it assumes that all cereal imports ship from New Orleans. The absolute minimum distance between the port of disembarkation and New Orleans may differ significantly from the routing distance, especially in the case of east Africa. Although I try to account for the difference with a dummy variable, it is a patch at best. Finally, sea distance is subject to many less price-increasing factors than land distance, so the effect of greater sea distance may be insignificant or indiscernible.

The land distance variable does not explicitly differentiate between landlocked and coastal countries. Including a landlocked dummy variable in the regression would detract from the significance of land distance due to multicollinearity problems. Landlocked countries tend to have greater land transport distance requirements, reflected in the model. Having a variable that incorporates more details of geographic isolation is a positive consequence of the land distance measure.

I can proceed to the second set of models in which I relate import prices of cereals to food insecurity having firmly established with the first set of models that spatial price differentials on imported cereals are determined in part by geographic isolation.

Undernourishment Model

After establishing the link between location and cereal import spatial price differentials (and therefore, import prices), I want to demonstrate how high import prices affect food insecurity in sub-Saharan Africa. To do so, I estimate a series of models which include import cereal price as an explanatory variable, corresponding to equations 15 and 16 in the previous chapter:

$$UN_c = \alpha_0 + \alpha_1 MP_c + \alpha_2 PR_c + \alpha_3 RQ_c + \alpha_4 AL_c + \alpha_5 Y_c + \alpha_6 MCP_c + \alpha_7 EXP_c + \varepsilon_c \qquad (15)$$

$$UNC_c = \beta_0 + \beta_1 MP_c + \beta_2 PR_c + \beta_3 KCAL_c + \beta_4 IW_c + \upsilon_c \qquad (16)$$

The abbreviations are defined in Chapter Three.

Import cereal price is simply the country-specific spatial price differential from the first set of models plus the weighted average world price for imported cereals. Although I could use spatial price differential instead of imported cereal price, I want the model to be able to explain the consequences of world price, so I use the more inclusive measure.

Mathematically, this is the hypothesis the models will test:

$$H_0^2 : \alpha_2 = 0$$
$$H_A^2 : \alpha_2 > 0$$

where α_1 (β_1 in equation 16) is the coefficient of imported cereal price. If I can reject the null hypothesis in favor of the alternate, it will mean that an increase in the price of

imported cereal increases undernourishment in sub-Saharan African countries, all else equal.

The models are estimated with OLS regressions. I run three iterations of equation 15 and one of equation 16. I report the results in Table 4 and describe each model below. In brief, the first two models weakly support the hypothesis while the third and fourth do not. The first three models, with prevalence of undernourishment as the dependent variable, have observations from the same 33 countries and have adjusted R-squared values between 0.47 and 0.50. The differences in the iterations of the models reflect attempts to reduce the multicollinearity of the explanatory variables. The last model with the underweight children variable only features 18 observations but the adjusted R-squared value is 0.71, likely due to the predictive power of the kilocalorie consumption per capita independent variable, which cannot be used in the first three models since it is part of the definition of the dependent variable.

Table Four: Determinants of Undernourishment, Ordinary Least Squares estimates.

Dependent Variable

Independent Variable	*Prevalence of Undernourishment* (1)	(2)	(3)	*Prevalence of Malnourished Children* (4)
Price of Imported Cereal	0.00077*	0.00081*	0.00059	0.00017
	(1.36)	(1.40)	(1.04)	(0.58)
Rural Population Percentage	0.00933	0.08612	0.04270	0.16682**
	(0.06)	(0.56)	(0.26)	(2.18)
Domestic Cereal Yield	-0.00023***	-0.00024***	-0.00017**	—
	(-2.72)	(-2.76)	(-2.16)	—
Arable Land Per Capita	-0.13832**	-0.16737***	-0.09493*	—
	(-2.26)	(-2.86)	(-1.68)	—
Regulatory Quality	-0.05560	-0.08180**	-0.05971	—
	(-1.15)	(-1.81)	(-1.20)	—
Imp. Cereal Consumption	-0.41433*	-0.59673***	—	—
	(-1.61)	(-2.66)	—	—
Expenditures Per Capita	-0.06486*	—	-0.10380***	—
	(-1.38)	—	(-2.50)	—
Kilocalories Per Capita	—	—	—	-0.00012***
	—	—	—	(-3.18)
Improved Water Access	—	—	—	-0.14908*
	—	—	—	(-1.61)
Constant	0.59566*	0.13755	0.767**	0.49118***
	(1.61)	(0.82)	(2.10)	(5.05)

Regression Statistics	(1)	(2)	(3)	(4)
Number of Observations	33	33	33	18
R-squared	0.61	0.58	0.57	0.78
Adjusted R-squared	0.50	0.48	0.47	0.71
F Statistic	5.61	6.02	5.76	11.27
Probability > F	0.0006	0.0005	0.0006	0.0004
Root Mean Squared Error	0.123	0.125	0.127	0.051

Notes:

* = Significant at the $\alpha = 0.10$ level

** = Significant at the $\alpha = 0.05$ level

*** = Significant at the $\alpha = 0.05$ level

Model One

In the first model, the weighted average *price of imported cereal* is a significant contributor to the prevalence of undernourishment at the ten percent level. The coefficient, 0.00077, means that, all else equal, if imported cereal prices go up $13 per MT, undernourishment will increase one percent. This result weakly supports the alternate hypothesis. The likely reason the relationship between import cereal price and food security is not stronger is due to the overall small amount of dietary energy which people get from imported cereals.

Rural population is positively related to prevalence of undernourishment, but the coefficient is very insignificant. This is surprising given the number of other studies affirming the higher incidents of food insecurity in rural areas due to their isolation and dependence on subsistence agriculture. I attribute the result to the 0.46 correlation between the expenditures per capita variable and rural population. I try to correct for the possible multicollinearity in later iterations of the model.

Domestic cereal yield is surprisingly significant in all three models in which it is included. In this first model, it is significant at the one percent level. The meaning of the -0.00023 coefficient is that a yield increase of one kilogram per hectare will decrease food insecurity .023 percent. In more understandable quantities, a yield increase of one MT per hectare will decrease the prevalence of insecurity 23 percentage points.

When interpreting the meaning of this substantial effect of yield on undernourishment, it helps to consider the causes of a yield. Natural endowments of soil fertility and water availability are primary generators of initial yield. Yield is raised with better seeds and starts, more fertilizer and other soil nutrient inputs, better irrigation

technology, and more efficient equipment. In other words, the ability to secure yield increases is tied to the availability of wealth and infrastructure investments. High yields increase returns to agricultural investments and may actually reduce the rural population. The correlations between yield, rural population, and expenditures are not particularly strong but the relationship I propose can still hold true due to the widely differing pre-improvement yields of the sub-Saharan region. I suspect that the influence of yield on food insecurity not only relates to greater availability of food, but also lower rural populations and greater wealth.

Arable land per capita, another variable related to domestic agricultural capacity, is negatively related to the prevalence of undernourishment, and the coefficient is significant at the five percent level. Due to the non-normal distribution of hectares of arable land per capita, I calculated the natural log and used these values in the model. Thus, it is hard to interpret the coefficient directly, but the result is that doubling arable land per capita would decrease the prevalence of undernourishment 9.6 percentage points. The effect of arable land per capita on undernourishment is related to the ability of a country to produce food domestically and meet food needs.

Regulatory quality is negatively related to undernourishment, but not significant in this model. Since regulatory quality is measured in an index, the coefficient itself lacks significance. Overall, market-friendly policies that raise the regulatory quality value will allow a country to have more effective distribution mechanisms that raise food security. Regulatory quality will also impact propensity to import food. Regulatory quality has a 0.47 correlation with expenditures since wealthier countries generally have better governance. There is the possibility of multicollinearity between the variables.

The percent of total kilocalorie *consumption from imported cereals* is significantly and negatively related to undernourishment. Increasing imported cereal consumption percentage one point explains a 0.41 percentage point decline in undernourishment. This effect is probably not due to an innate superiority of imported cereal at meeting nutritional needs but rather the relative wealth required for a country to import foods. Imported cereal consumption percentage has a 0.54 correlation with expenditures and multicollinearity is likely.

Expenditures per capita, the source of the multicollinearity in the model, has a weakly significant, negative relationship with prevalence of undernourishment. The equation has a semi-log functional form, and the variable included in the model is the natural log of expenditures which complicates direct interpretation of the coefficient. Its effect is that increasing expenditures one percent decreases the prevalence of undernourishment 0.06 percentage points. Doubling expenditures would cause a 9.6 percentage point decrease in undernourishment. I expect the relationship between the variables to be important since greater expenditures allow consumers to purchase more food and farmers to invest more in their crops. The only question is whether the magnitude of the coefficient is disrupted by the multicollinearity in the model. Comparisons with the second and third model should help to clarify expenditure's role.

Overall, this model has decent explanatory power for prevalence of undernourishment with an adjusted R-squared value of 0.50. The F statistic indicates that the set of independent variables can reliably predict the prevalence of undernourishment. All that remains to be determined is whether an adjusted set of the independent variables makes a model with more accurate coefficients.

Model Two

The difference between the first and the second model is the deletion of *expenditures per capita* as an explanatory variable due to its close relationship to many other independent variables I consider important. The change does affect some coefficients.

The *price of imported cereal* remains significant at the ten percent level with a coefficient only 0.00003 different from the first model. This makes sense because there is little direct relationship between expenditures and import cereal price. The coefficient for *rural population* is nine times greater, 0.086, although it is still not significant. This shows a strong confounding of coefficient determinants when expenditure is part of the model. Now a rise in rural population of one percentage point results in a .086 percent increase in undernourishment. This variable is still lower and less significant that I anticipated.

Domestic agriculture retains its importance virtually unchanged with the exclusion of expenditures. *Arable land* per capita rises from the five percent significance level to the one percent level, and the coefficient decreases to -0.167. With this new value, doubling arable land per capita would decrease undernourishment by 11.6 percentage points.

Regulatory quality becomes more negatively related to undernourishment. It is significant at the five percent level in this model. As explained above, the coefficient has little meaning on its own since the measure is an index, but the magnitude of its influence is greater in this model. Since regulatory quality is correlated with expenditures per capita, the shift is unsurprising.

Without expenditures in the model, the percent of *calories consumed from imported cereal* becomes much more significant, reaching the one percent level, and the magnitude of its effect decreases. This is due to the relationship of expenditures and cereal import consumption, both theoretically and empirically, as indicated by the correlation. Here, a one percentage point increase in the consumption of imported cereal lowers undernourishment 0.60 percent.

Overall, this model accounts for slightly less of the variation in the prevalence of undernourishment, with an R-squared value of 0.48. However, the F statistic actually increases, indicating that the reduced set of variables can better predict the prevalence of undernourishment. It does not violate the OLS assumption of no multicollinearity as much as the first model does, but it excludes an important explanatory variable.

Model Three

In this third model, I include *expenditures* in the model once again, but I drop the percent of *calories consumed from imported cereal*. This causes several substantial changes in the model.

Unfortunately for my hypothesis, the *price of imported cereal* is no longer a significant variable in the equation. The magnitude of the coefficient also decreases. This is unsurprising. Some countries' populations receive a high percentage of calories from imported cereal and others consume very little imported cereal. The effect of import cereal price should be greater in the first set of countries. Without a variable for imported cereal consumption, there is no way for the model to distinguish between the two, and the explanatory power of price decreases.

The coefficients for domestic *cereal yield* and *arable land* per capita decrease in significance and magnitude. The reason for the change is likely related to the reason for the decrease in importance of the imported cereal price. The model is unable to distinguish between countries which receive a lot or a little of their calories from domestic cereal production (1 – Imported Cereal Consumption – Other Consumption = Domestic Cereal Consumption).

Rural population percentage increases in magnitude, but it is still not significant. The change comes from the small negative correlation that exists between rural population and percentage of calories from imported cereal. Now rural population's coefficient reflects both effects. In this model, *regulatory quality* has a similar coefficient to the first model, since it is most affected by the removal of expenditures per capita. Overall, the third model has an adjusted R-squared value of 0.47 and a similar F statistic to the first model.

Model Four

The fourth model of food insecurity uses the alternate measure of hunger: the prevalence of malnourished children. This model, represented by equation 16, shares the independent variables of price of imported cereal and rural population percentage with the first three undernourishment models, but the other two independent variables, kilocalorie consumption per capita and access to improved water, are unique to this model.

The *price of imported cereal* is not significant in this model and the coefficient is much lower than in the first three models. Since the dependent variable measures underweight children under five, it is unsurprising that the price of imported cereals

generates less of an effect in this model. A large portion of this group has its nutritional needs met with breast milk. Thus the price of imported cereals would only affect children's access to adequate nutrition indirectly though the satisfaction of the mothers' energy requirement. Although the coefficient and significance of this variable is not unexpected, it does not offer any support for the hypothesis of food prices and undernourishment.

In this model, *rural population* is significantly and positively related to undernourishment so that a one percentage point increase in rural population increases prevalence of underweight children 0.17 percent. The strength of the variable compared to the first three models is likely due to the absence of the confounding variable, expenditure. Also, rural location can have non-caloric ties to the dependent variable. Access to doctors in rural areas may be limited, so disease and illness may be generating underweight children.

Increased *consumption* should decrease the prevalence of undernourished children. The variable kilocalorie consumption per capita per day is extremely significant, at the one percent level, in this equation. This is the result I anticipated. However, the magnitude of the coefficient, -0.00012, is not particularly high. A one thousand calorie increase in daily consumption will decrease the number of underweight children by only 12 percentage points. This indicates that calorie consumption alone cannot eliminate the problem of underweight children. Non-nutritional factors such as disease also contribute to childhood weight.

Finally, the percent of the population with access to improved water is a significant contributor to the model at the 10 percent level. Several effects are accounted

for in the variable, including the direct relationship between water-born diseases and being underweight. Also, the variable is a proxy for infrastructure investment and other development spending that generates a variety of weight-boosting consequences.

This model has strong explanatory power, likely due to the inclusion of the kilocalorie consumption variable. The adjusted R-squared value is 0.71, and F-statistic is 11.27 which is particularly impressive given that only 18 countries have complete sets of data. Nevertheless, the model is not particularly useful in the thesis. The low strength of the price of imported cereal does not support the second hypothesis, and there is a theoretical reason to believe that the dependent variable is a worse measure to use for determining the effect of import price on undernourishment. Therefore, the preferred model for food insecurity must be one of the first three.

General Results

The first three undernourishment models generally have good explanatory power.. Choosing a preferred model must be based on the included and excluded variables and violations of OLS assumptions. I reject the third model due to the exclusion of percent of consumption from imported cereal. The contributions of different sources of calories in the diet are an important consideration and a requisite to accurately measure the effects of price, yield, and arable land variables.

To choose between the first two models, I must determine if multicollinearity causes a significant violation of OLS assumptions in the first model. If it does not, I would prefer the first model since expenditures per capita is an important theoretical aspect of nutrition. The rule of thumb is that correlations between independent variables less than 0.8 are not problematic (Griffiths, Hill, Judge, 1993). This data meets the

criterion, but the differences in coefficients between model one and two indicate that multicollinearity does exist, perhaps as a result of several explanatory variables in linear combination, rather than a simple correlation between two. Therefore, I perform a Variance Inflation Factor (VIF) test.

The VIF test works by evaluating the power of other explanatory variables to account for variance in the problematic independent variable (Stine, 1995). First, the independent variable in question, X_i, is regressed (as the dependent variable) against all other explanatory variables, X_{i+1} through X_n,   If there is no linear relationship between X_i and the explanatory variables, the R squared value for the model will be zero. If R squared is not zero, the VIF and tolerance (the inverse of VIF) will equal:

$$VIF = \frac{1}{1 - R^2} \qquad \text{and} \qquad Tolerance = 1 - R^2$$

Unfortunately there is no hard and fast rule about objectionable VIF and tolerance levels, but I will follow the general practice of considering VIFs less than 10 as acceptable multicollinearity (Stine, 1995).

Table 5 shows the VIF results for the independent variables in model one. VIF is highest for the expenditures variable, as expected, but the value, 2.49, does not generate cause for concern.   Therefore, model one is the preferred model of undernourishment. I test of violations of the other OLS assumptions as well, but I do not discover anything significant. A Breusch-Pagan test and visual examination of the graph of the residuals does not reveal heteroskedasticity. The residuals are normally distributed, and autocorrelation is not a concern since the data set is not a time series. The results of the tests are presented in Appendix B.

Table Five: Test for Multicollinearity

Variable	VIF	Tolerance
Expenditures Per Capita	2.49	0.401
Imported Cereal Consumption	2.05	0.488
Domestic Cereal Yield	1.94	0.514
Regulatory Quality	1.71	0.586
Price of Imported Cereal	1.57	0.639
Arable Land Per Capita	1.5	0.668
Rural Population Percentage	1.46	0.685
Mean	1.82	0.549

The strength of the price coefficient in model one indicates that I can reject the null hypothesis with 90 percent confidence. This supports my original argument that the imported food is related to food security.

The final chapter joins the results of the two preferred models and describes their significance. The direction for future research and certain policy implications are also related to the results of this chapter.

CHAPTER FIVE

CONCLUSIONS

Context

In contrast to all other regions of the world, food insecurity concern over food security in sub-Saharan Africa continues to grow. Although only thirteen percent of the population lives in sub-Saharan Africa, twenty five percent of the undernourished people in the world are found there (FAO, *State of Food Insecurity*, 2006). Hunger rates have changed little over the past 35 years. Stifling poverty, poor governance, ethnic and religious conflict, and widespread disease all plague the region.

One consequence of the longstanding problem of undernourishment in sub-Saharan Africa is that development scholars have explored the root causes in detail. These explanations tend to focus on the inability of domestic agriculture to meet food needs. Variable rainfall, poor soil fertility, and the resulting low crop yields make up one widely cited cause for food insecurity. Another reason is that poverty and lack of private property protection deter investment in productivity-enhancing technologies. State-owned enterprises designed to benefit ruling elites control many aspects of agricultural input markets ,so fertilizers and new crop varieties can be prohibitively expensive. Also conflict and poor infrastructure prevent the development of efficient markets connecting producers and consumers, which would drive down food prices.

As globalization continues, some scholars have begun to analyze why trade has not improved food security in sub-Saharan Africa. They conclude that market integration has not generated positive income effects for African farmers. Currency overvaluation in many African countries in the past two decades has discriminated against agricultural

exports, while developing countries' price-distorting subsidies hurt farmers in developing countries. In this thesis, I sidestep domestic agriculture to explore a neglected aspect of sub-Saharan food security: the ability of food imports to reduce hunger. I look at the roots of import prices with an approach based on the results of recent economic-geography work by Jeffrey Sachs and his contemporaries. They show that geographic isolation is responsible for many of the economic disadvantages facing the continent. I ask how geography affects food import prices. Then I ask how fluctuations in import prices impact food security.

Overall Results

In this thesis, I test two hypotheses: that the spatial price differential on cereal imports grows with the land distance over which imports are shipped, and that increases in cereal import prices raise undernourishment in the importing county. I create two sets of models from OLS regressions to evaluate my hypotheses. Both models use variables based on the weighted average cereal import price which I created for each country based on its imports of maize, wheat, and rice in 2003.

The preferred model in the first set examines the effects of countries' demographical and geographical variables (population, openness to trade, cereal consumption, overland transport distance, distance from New Orleans, and a dummy variable for East Africa) on the cereal import spatial price differential. The result demonstrates the effect of a country's location on import price. Every kilometer in overland transport between the disembarkation port and the location of the major population in the destination country inflates the spatial price differential on imported

cereal 4.3 cents per MT. The result is significant at the five percent level, but the overall strength of the model is not particularly high.

The preferred model in the second set uses economic, political, agricultural, and demographic variables (cereal import price, rural population, domestic cereal crop yields, arable land per capita, regulatory quality, consumption of imported cereal, and expendictures per captia) to explain the prevalence of undernourishment by country. According to the model, there is a relationship between import price of cereal and food security. Each dollar increase in the price of imported cereal raises the prevalence of undernourishment 0.077 percentage points in the importing country. This model is fairly strong but the price coefficient is significant only at the 10 percent level.

Used in combination, the two preferred models indicate that a 300 kilometer increase in overland shipping distance will generate a one percentage point expansion in undernourishment. In conclusion, my hypotheses are likely to be correct. Location does affect cereal import prices, and cereal import prices do contribute to the determination of food security.

Future Research

My work suggests several avenues for future research. Although I am confident in the conclusions I draw from the models in this thesis, both models could be improved significantly. To address the first hypothesis regarding the determination of import spatial price differential, a model that permits the inclusion of quantity and price variables without endogeneity would better reflect current accepted practices of trade modeling. A system of simultaneous equations is one solution. This type of model would likely have more explanatory power than the model in this thesis, so it could give

better support for the effect of overland transport in import prices. The value of the sea distance variable could also be improved by obtaining reports of the distance over which cereal imports are shipped. The price variable is currently based on import unit value, but it would be more accurate if it were based on the observed price.

Expanding the land distance variable would be enlightening. Right now, it encompasses the costs of fuel, labor, transit countries' customs charges, time, risk, and insurance. Finding data to include the factors individually as explanatory variables would offer insight into the best ways to reduce the burden of isolation. Then, conclusions from that study could be evaluated empirically by tracking spatial price differential changes over time in countries which have undergone infrastructure development or trade barrier reduction.

In the second model, the inclusion of other explanatory variables could improve the strength of the model and might increase the significance of the import cereal price as a determinant of undernourishment. It would be especially appropriate to include a measure of domestic food prices that is uniform for all countries in the model. This would allow for a comparison of the nourishment effects of import prices versus domestic prices.

Incorporating other crops and products into the import price would also increase the validity of the models. The two preferred models in the thesis exclude relatively few countries, but as always, a more complete data set would produce more generalizable results. Also, it would be interesting to create models for other regions to compare the relative importance of geography and import prices.

Policy Prescriptions

The second model affirms a very significant relationship between domestic agriculture and nourishment, although this is not the primary focus of this thesis. In the face of population growth, arable land per capita is likely to decrease, which make yield increases all the more important at generating future food security. I will let other researchers determine the best methods to secure greater domestic agricultural productivity.

Both the models and the policy recommendations in this thesis focus on a status quo environment in which the rate of undernourishment is fairly stable. In the event of large-scale conflicts or agricultural crises in sub-Saharan countries, immediate relief action outside the scope of my recommendations is necessary. The results of this thesis do affirm the elevated nutritional vulnerability of geographically isolated countries.

The primary results from this work demonstrate that geography influences the price of imported food, which in turn affects food security in countries in sub-Saharan Africa. Barring territory takeovers to gain coastal access, which are not unprecedented, countries are endowed with an inflexible geographic position. In order to reduce the detrimental effects of geography, any group or country with the goal of promoting food security should consider pursuing policies that minimize the cost of long overland transportation. Developing rail infrastructure is an excellent way to reduce fuel costs, as is improving river navigability. Increasing highway investment also reduces transportation costs. For countries with ports, upgrading port facilities would reduce transfer costs.

Landlocked countries' imports must pass through transit countries whose policies they cannot control. Maritime countries have incentive to improve their ports, but they may have disincentives to improve roads and rails which pass into landlocked neighbors in order to preserve geo-strategic dominance. The disincentives may also hold true for improving customs procedures and reducing border charges. When the interests of landlocked countries and their maritime neighbors conflict, the opportunity exists for international organizations to mediate on behalf of the landlocked countries. Also, knowledge of landlocked countries' dependence on transit neighbors should spur foreign investment aid for infrastructure in maritime countries because of the dual benefit.

The import price measure in this paper is a CIF unit value that does not include import country tariffs (although it does include tariffs and taxes in transit countries). However, I believe that the negative relationship between import prices and food security would continue and possibly explain a greater portion of the prevalence of undernourishment if it included import tariffs. The FAO reports an average applied agricultural tariff of 17.5 percent on imported goods in sub-Saharan Africa (*State of Food and Agriculture*, 2005). If the relationship in this paper's model holds true, this tariff explains 1.4 percentage points of undernourishment in destination countries. This is strong incentive for countries to consider lowering their import tariffs. Of course, the consequences of the loss of tariff revenue and producer income must be weighed against increases in food security from lower import prices.

Knowing the relationship between prices of import food and food security in developing countries should inspire caution in the WTO as it pursues an agenda of lower agricultural subsidies in developed countries. These changes are expected to raise the

world prices of many commodities which will increase the import price for sub-Saharan countries. The FAO projects that complete policy reform which phases out all commodity supports would increase wheat prices 19 percent, rice prices 11 percent and maize prices six percent (*State of Food and Agriculture*, 2005). Depending on countries' particular import habits, these price changes would generate anywhere between a 0.5 to 1.6 percentage point increase in the undernourished population in sub-Saharan countries, all else equal. Of course, all else does not remain equal in the event of the phase out of agricultural supports. In order for developing countries to benefit from trade liberalization, they must capture increased income effects for domestic farmers, which largely depend on domestic policies and investment, both domestic and foreign.

The ties between poverty, agricultural trade, and food security are intricate. In some ways this thesis contributes to the complexity by adding a frequently neglected variable, geography, and demonstrating its influence on import prices. However, it is my hope and belief that improved understanding of food security determinants will eventually help reduce hunger in sub-Saharan Africa.

WORKS CITED

Abbott, Philip C. (1979, February). "The Role of Government Interference in International Commodity Trade Models." *American Journal of Agricultural Economics*, 61(1), 22-31.

Anderson, Kym, Will Martin, and Dominique van der Mensbruggne. (2006). "Distortions to World Trade: Impacts on Agricultural Markets and Farm Incomes." *Review of Agricultural Economics,* 28(2) 168-194.

Bloom, David E. and Jeffrey D. Sachs. (1998). "Geography, Demography, and Economic Growth in Africa." (Brookings Papers on Economic Activity, 2:1998). The Brookings Institute.

Boserup, Ester. (1965). *The Conditions of Agricultural Growth: The Economics of Agrarian Change Under Population Pressure, 2005 edition.* New Jersey: Transaction Publishers.

Brülhart, Marius. (1998). "Economic Geography, Industry Location and Trade: The Evidence." *The World Economy,* 21(6), 775-801.

Coulter, Jonathan, and Colin Poulton. (2001). "Cereal Market Liberalization in Africa." In Takamasa Akiyama, et. al. (Eds*.), Commodity Market Reforms: Lessons of Two Decades* (pp. 191-255). Washington, DC: World Bank.

de Waal, A. (1991). "Emergency food security in Western Sudan: what is it for?" In S. Maxwell (Ed), *To Cure all Hunger: Food Policy and Food Security in Sudan.* London: Intermediate Technology.

Dugger, Celia W. (2007, April 7). "Even as Africa Hungers, Policy Slows Delivery of U.S. Food Aid." *New York Times*.

Easterly, William and Ross Levine. (2003). "Tropics, germs, and crops: how endowments influence economic development." *Journal of Monetary Economics,* 50, 3-39.

Ehrlich, Paul R. (1968). *The Population Bomb*. New York: Ballantine Books.

Fafchamps, Marcel. (2004). *Market Institutions in Sub-Saharan Africa: Theory and Evidence*. Cambridge: MIT Press.

Falcon, Walter P. and Rosamond L. Naylor. (2005). "Rethinking Food Security for the Twenty-First Century." *American Journal of Agricultural Economics,* 87(5), 1113-1127.

Faye, Michael L. et. al. (2004). "The Challenges Facing Landlocked Developing Countries." *Journal of Human Development,* 5(1), 31-68.

Food and Agriculture Organization (FAO) (2003, July). "Food Supply Situation and Crop Prospects in Sub-Saharan Africa." Global Information and Early Warning System on Food and Agriculture.

Food and Agriculture Organization (FAO) (2003, December). "Food Supply Situation and Crop Prospects in Sub-Saharan Africa." Global Information and Early Warning System on Food and Agriculture.

Food and Agriculture Organization (FAO) (2006). *The State of Food and Agriculture.* Rome: FAO.

Food and Agriculture Organization (FAO) (2005). *The State of Food and Agriculture.* Rome: FAO.

Food and Agriculture Organization (FAO) (2006). *The State of Food Insecurity in the World.* Rome: FAO.

Gallup, John Luke, Jeffrey D. Sachs, and Andrew D. Mellinger. (1999, August). "Geography and Economic Development." *International Regional Science Review*, 22(2), 179-232.

Gallup, John Luke, and Jeffrey D. Sachs. (2000, August). "Agriculture, Climate, and Technology: Why Are the Tropics Falling Behind?" *American Journal of Agricultural Economics,* 82, 731-737.

Garrett, James L and Marie T. Ruel. (1999, April). "Are Determinants of Rural and Urban Food Security and Nutritional Status Different? Some Insights From Mozambique." (FCND Discussion Paper No. 65) Washington: International Food Policy Research Institute.

Gollin, Douglas, Stephen Parente, and Richard Rogerson. (2002, May). "The role of agriculture in development," *The American Economic Review*, 92(2), 160-164.

Griffiths, William E., R. Carter Hill, and George G. Judge. (1993). *Learning and Practicing Econometrics*. New York: John Wiley.

Hotez, Peter J. et al. (2006, May). "Incorporating a Rapid-Impact Package for Neglected Tropical Diseases with Programs for HIV/AIDS, Tuberculosis, and Malaria." *PLoS Medicine*, 3(5), 1-9.

"Indicators for Monitoring the Millennium Development Goals." (2003). New York: United Nations.

Johnson, D. Gale. (1998). "Food Security and World Trade." *American Journal of Agricultural Economics*, 80(5), 941-947.

Kaufmann, Daniel, Aart Kraay, and Massimo Mastruzzi. (2005, June). "Governance Matters IV: Governance Indicators for 1994-2004." (World Bank Policy Research Working Paper 3630). World Bank.

Kaufmann, Daniel, Aart Kraay, and Massimo Mastruzzi. (2006). "Aggregate Governance Indicators, 1996-2005" Dataset available from <http://info.worldbank.org/governance/kkz2005/pdf/2005kkdata.xls>. Accessed February 10, 2007.

Laier, Julie Koch, et al. (1996, June). "Gender, Household Food Security and Coping Strategies." (Development Bibliography 14). Sussex: Institute of Development Studies.

Maxwell, Simon. (1996). "Food security: a post-modern perspective." *Food Policy,* 21(2), 155-170.

Meadows, Donella H., et al. (1974). *The Limits to Growth: a report for the Club of Rome's Project on the Predicament of Mankind*. New York: Universe Books.

Miller, S.M. and M.P. Upadhyay. (2000, December). "The effects of openness, trade orientation, and human capital on total factor productivity." *Journal of Development Economics*, 63(2), 399-423.

"Ministerial Declaration." (2001, November 14). From *Doha WTO Ministerial Declaration 2001*. <http://www.wto.org/English/thewto_e/minist_e/min01_e/mindecl_e.htm> Accessed March 2, 2007.

Oshaug, A. (1985). "The composite concept of food security." In W.B. Eide, et al. (Eds), *Introducing Nutritional Considerations into Rural Development Programmes with Focus on Agriculture: A Theoretical Contribution,* (Development of Methodology for the Evaluation of Nutritional Impact of Development Programmes, Report No. 1). Institute of Nutrition Research, University of Oslo.

Paarlberg, Robert L. (1999, Autumn-Winter). "Politics and Food Insecurity in Africa." *Review of Agricultural Economics,* 21(2), 499-511.

Pinstrup-Andersen, Per, Rajul Pandya-Lorch, and Mark W. Rosegrant. (1999). "World Food Prospects (Critical Issues for the Early Twenty-first Century)." Washington DC: International Food Policy Research Institute.

"Purchasing Power Parity" *Statistical Manual*. World Bank. <http://web.worldbank.org> Accessed March 1, 2007.

Radelet, Steven and Jeffrey Sachs. (1998, January 1). "Shipping Costs, Manufactured Exports, and Economic Growth." Presented at 1998 AEA meetings in Chicago, published in *Proceedings* volume.

Radimer, K.L., C.M. Olson, J.C. Green, C.C. Campbell, and J.P. Habicht. (1992). "Understanding hunger and developing indicators to assess it in women and children." *Journal of Nutrition Education,* 24(1).

Rose, Andrew K. (2002, November). "Do WTO Members Have a More Liberal Trade Policy?" (NBER Working Paper 9347). Cambridge: National Bureau of Economic Research.

Rosegrant, Mark W. and Sarah A. Cline. (2003, December 12). "Global Food Security: Challenges and Policies." *Science*. 302(5652), 1917-1919.

Rosegrant, Mark W. et al. (2005, February). "International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT-WATER): Model Description." Washington DC: International Food Policy Research Institute.

Rosegrant, Mark W., et al. (2005, August). "Looking Ahead: Long-Term Prospects for Africa's Agricultural Development and Food Security." (2020 Discussion Paper 41). Washington DC: International Food Policy Research Institute.

Sen, A.K. (1981). *Poverty and Famines: An Essay on Entitlement and Deprivation.* Oxford: Clarendon Press.

Stine, Robert A. (1995, February). "Graphical Interpretation of Variance Inflation Factors." *The American Statistician*, 49(1), 53-56.

World Bank. (1994). *Adjustment in Africa: Reforms, Results, and the Road Ahead*. New York: Oxford University Press.

Yanikkaya, Halit. (2003, October). "Trade openness and economic growth; a cross-country empirical investigation." *Journal of Development Economics*, 72(1), 57-89.
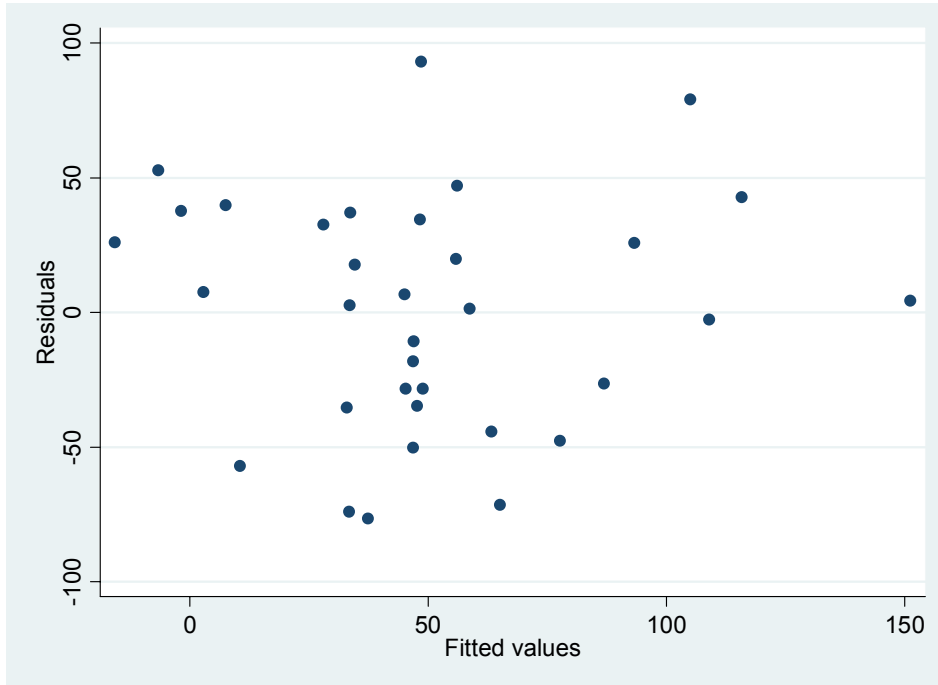
Tests for violations of OLS assumptions, spatial price differential model two:

$$SPD_{ti} = \beta_0 + \beta_1 POP_{ti} + \beta_2 OPEN_{ti} + \beta_3 CER_{(t-1)i} + \beta_4 LAND_{ti} + \beta_5 AIR_{ti} + \beta_6 EAST_{ti} + \upsilon_{ti}$$

Heteroskedasticity: no significant violations

Plot of model two residuals against values fitted by the model:

Breusch-Pagan / Cook-Weisberg Test for Heteroskedasticity:

Ho:	Constant variance (homoskedasticity)	
Variables:	Fitted values of SPD	
chi2(1)	=	0.00

The certainty level for failing to reject the null hypothesis is 96 percent.

Autocorrelation: not applicable

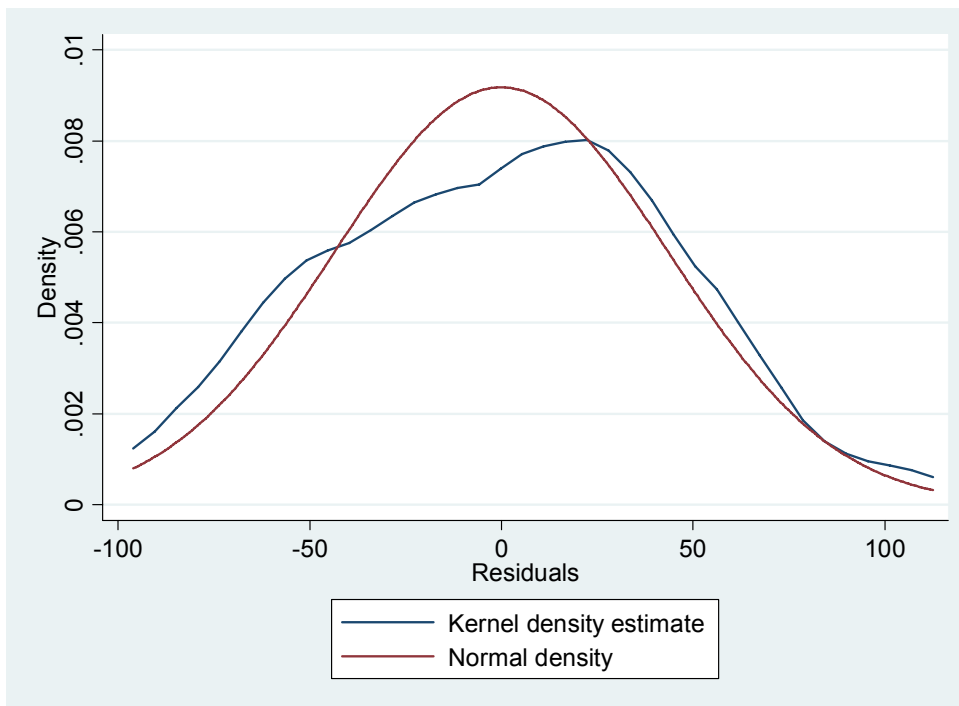**Multicollinearity:**　　no significant violations

Correlation Chart:

```
             |     SPD       POP      OPEN       CER      LAND       AIR      EAST
-------------+---------------------------------------------------------------------
         SPD |  1.0000
         POP | -0.1184   1.0000
        OPEN | -0.2041  -0.5158   1.0000
         CER | -0.1493  -0.1207   0.0459   1.0000
        LAND |  0.4308   0.1826  -0.1955   0.1571   1.0000
         AIR |  0.3517   0.0415   0.1674  -0.2120   0.4505   1.0000
        EAST |  0.2785   0.3289  -0.2810  -0.2010   0.1430   0.4341   1.0000
```

Variance Inflation Factor Chart:

```
    Variable |      VIF    Tolerance
-------------+----------------------
         AIR |     2.11     0.474012
        OPEN |     1.72     0.580546
        LAND |     1.63     0.612193
        EAST |     1.59     0.629515
         POP |     1.46     0.686927
         CER |     1.20     0.835233
-------------+----------------------
    Mean VIF |     1.62
```

Normality:　　no significant violations
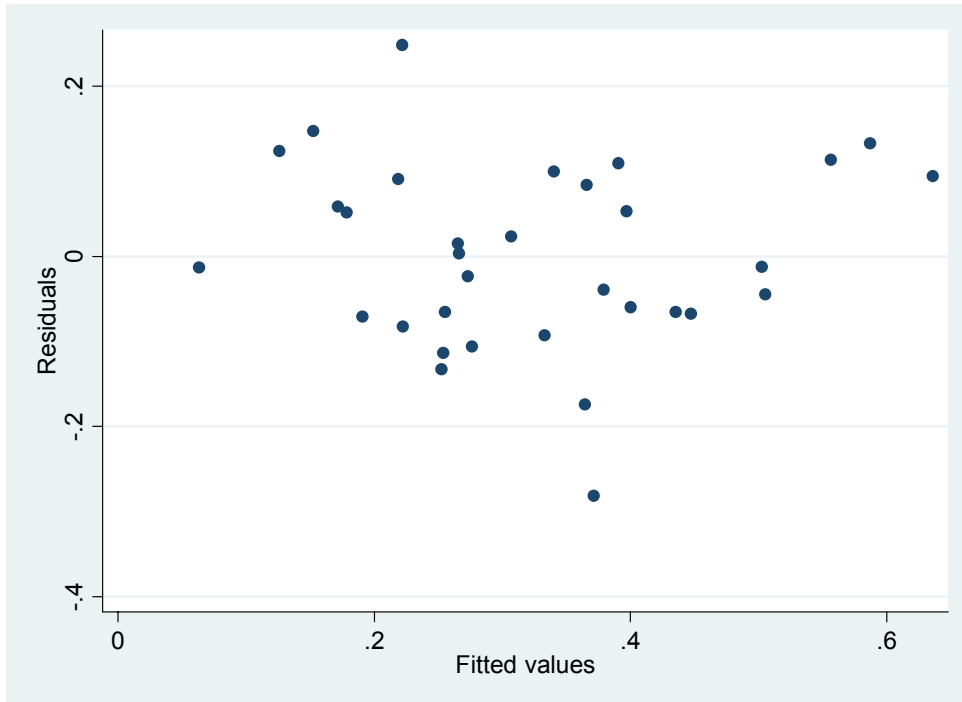
Density distribution of residuals:

APPENDIX B

Tests for violations of OLS assumptions, undernourishment model one:

$$UN_c = \alpha_0 + \alpha_1 MP_c + \alpha_2 PR_c + \alpha_3 RQ_c + \alpha_4 AL_c + \alpha_5 Y_c + \alpha_6 MCP_c + \alpha_7 EXP_c + \varepsilon_c$$

Heteroskedasticity: no significant violations

Plot of model one residuals against values fitted by the model:

Breusch-Pagan / Cook-Weisberg Test for Heteroskedasticity:

Ho: Constant variance (homoskedasticity)
Variables: Fitted values of UN
chi2(1)   =   0.00

The certainty level for failing to reject the null hypothesis is 95 percent.

Autocorrelation: not applicable

Multicollinearity: no significant violations

Correlation Chart:

```
             |     PR        RQ        AL        MP        MPC       XPD        Y
-------------+---------------------------------------------------------------------
         PR  |   1.0000
         RQ  |  -0.0248    1.0000
         AL  |  -0.1135    0.2949    1.0000
         MP  |   0.1978    0.3343    0.1538    1.0000
        MPC  |  -0.2610    0.1157   -0.1148   -0.0822    1.0000
        XPD  |  -0.4336    0.4703    0.3304    0.0475    0.5267    1.0000
          Y  |  -0.0413    0.3293   -0.0480    0.4782   -0.3363   -0.0145    1.0000
```

Variance Inflation Factor Chart:

```
    Variable |      VIF    Tolerance
-------------+----------------------
        XPD  |     2.49     0.401410
        MPC  |     2.05     0.488038
          Y  |     1.94     0.514448
         RQ  |     1.71     0.585868
         MP  |     1.57     0.638867
         AL  |     1.50     0.668409
         PR  |     1.46     0.685126
-------------+----------------------
    Mean VIF |     1.82
```

Normality: no significant violations

Density distribution of residuals: