THREE ESSAYS ON TRADE POLICY, FOOD SECURITY AND PUBLIC STOCKHOLDING IN DEVELOPING COUNTRIES

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by

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Abstract

Public stockholding for food security purposes refers to state acquisition of foodstocks in support of food security objectives. Public stockholding for food security purposes in developing countries returned to WTO agenda in the wake of the 2007/2008 and 2010/2011 food crises. During the WTO Ministerial Meeting at Bali in 2014, a group of developing countries (known as the G-33) proposed that disciplines on stockholding be relaxed to allow them to acquire large foodstocks in anticipation of future crises. They contended that stockholding was necessary because exporting countries often restrict food exports in times of crisis, which consequently affect importing countries' food security. Food exporting countries, on the other hand, opposed the policy arguing that it could lead to increased subsidies to producers of importing countries and, consequently distort trade. Due to the absence of consensus, a *Pease Clause* was introduced to temporarily restrain member countries from challenging stockholding activities until a permanent solution is reached. This thesis assessed three issues relating to WTO trade policy, food security and public stockholding in developing countries.

The first paper, presented in Chapter 2, assesses the need for public stockholding in developing countries. In this paper, the research estimates the speed at which markets respond to restore consumption distortions in developing countries. This speed is referred to as market response to consumption shocks. Low responses implies that food security cannot be guaranteed by relying on the international market. Hence, stockholding to support consumption can be legitimate food security policy in these countries. The research is applied to wheat, corn and rice due to their importance in the food security of developing countries. The results shows that markets generally fail to restore close to 60 percent of the consumption distortions, following a shock, in developing countries. This poses a risk to food security without public stockholding. Hence, the study concludes that stockholding will be a legitimate policy to consider in these countries.

The second paper, presented in Chapter 3, also assesses the need for public stockholding for food security purposes in developing countries. However, the research investigates whether or not the current *de minimis* WTO rules on public stockholding constitute a restriction to food security in developing countries. The research posits that the proposal to relax stockholding policy will be justified if current regulations constitute a restriction to achieving food security. The research is applied to wheat, corn and rice. To analyse this question, optimal public stocks required to

achieving food security are compared with WTO allowable public stocks. The policy is restrictive if optimal public stocks is more than stock levels permitted under the WTO. The results found the *de minimis* policy to be substantially restrictive across some developing countries especially those which demonstrate a high food security risk. Hence, expanding stockholding policy for these category of countries should be considered.

The third paper, presented in Chapter 4, examines the potential impact of stockholding on trade. Stockholding has two important activities that can affect trade: stock acquisition and stock disposal. While stock acquisition can increase trade, the disposal of accumulated stocks from stockholding programs in importing countries could lead to significant trade losses for exporting countries. Food exporting countries are particularly against stockholding programs policy due to these potential negative impacts on their markets. In this paper, a potential public storage policy aimed at meeting 6-months of domestic consumption is applied to rice, corn and wheat in order to gain insights into the impact of the proposed stockholding policies on trade. The research seeks to estimate the maximum impact on trade that can arise as a result of stock disposal and stock acquisition. The results suggest that stock disposal could significantly decrease trade by more than 35 percent. Where stock acquisition does lead to increased trade, the overall negative impact of the policies will be relatively low. Moreover, the impacts on trade are relatively small when the policy is considered for small consumption countries. Thus, stockholding policy can be considered for small countries faced with considerable food security risk without generating significant trade impacts.

In conclusion, the study suggests that stockholding policies can be legitimate for small countries faced with considerable food security risk. Large consumption countries seeking to implement stockholding policies must establish appropriate compensation schemes to minimise their policies impact on affected countries.

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Dedication

Dedicated to my late grandparents - Jatoe Ilinkpok Cheera and Mrs Nwajo Jatoe Iinkpok Cheera.

Table of Contents

List of Tables

List of Figures

CHAPTER 1

Introduction

1.1 Background to the issues

Food security, as a concept, varies considerably in academic discourse and public policy practice. As of 1992, Smith *et al.* (1992) noted over 200 food security definitions with each suggesting different strengths, weaknesses and methods of measurement. The definitions include self-sufficiency, self-reliance, and the entitlement approaches to food security, among others. Nonetheless, the World Food Summit's (1996) view that "food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" is the most widely accepted. This definition points to four core dimensions of food security: food availability; accessibility; stability of food supplies; and utilization. Based on these core dimensions Stevens *et al.* (2001) noted that food security, in essence, is the availability and access to sufficient food for a healthy living, and the guarantee of such at all times.

Public food stockholding and international trade are two important food security policy instruments for developing countries. Public stockholding refers to state acquisition, storage and subsequent release of food stocks. Foodstocks typically covered under public stockholding programs are cereals (especially rice, corn and wheat) as they can be stored for extended periods and, also, because of their overall importance to food security. In developing countries, public foodstocks are primarily used for food security purposes to provide emergency food aid, stabilise food prices, serve as a market for poor resource farmers in order to minimise their production risk, and/or provide food to poor households (World Bank, 2012; Gilbert, 2011; Wiggins and Keats, 2009). As such, public stockholding programs largely identify with the stability of food supplies, income and consumption components of food security.

Public stockholding programs were, however, constrained as a result of the Uruguay Round of multilateral trade negotiations as part of reformed disciplines on agricultural subsidies. This is because they, arguably, possess trade distortionary attributes by virtue of their operations. In particular, stocks are acquired at government administered prices that are normally higher than prevailing market prices. The higher prices serve as a subsidy to farmers and induce a supply response beyond levels conveyed by markets. For large importers, subsidy-induced domestic production can reduce imports, depress international prices and distort trade. Similarly, stockholding-induced domestic production can increase exports, depress international prices and, hence, distort trade as well. In some instances, stocks acquired under public stockholding programs can be sold in international markets at subsidized prices, which also has the potential to be the cause of trade losses for competing countries.

Consequently, the World Trade Organisation (WTO) members agreed at the conclusion of the Uruguay Round in 1994 to the following restrictions on public stockholding activities. For public stockholding to operate in member states: (1) the stock levels must be predetermined and acquired only for the purposes of enhancing food security; and (2) the sale and acquisition of public stocks shall be made at prices not noticeably different from the prevailing market price. More importantly, government subsidies for stockholding programs referred to as Aggregate Measure of Support (AMS) shall not exceed 5 percent and 10 percent of the total value of domestic production in developed and developing countries respectively. Any evidence of violation may lead to a countervailing duty action against products of the affected nation. These provisions are found in the Uruguay Round Agreement on Agriculture (AoA).

Recently, the need to revisit public stocks as a food security policy has moved on to the trade policy agenda. This time around, the debate focused on relaxing AMS rules to enable developing countries to acquire public stocks for food security purposes without threat of sanctions from other WTO members. The quest for regulatory reforms emerged at the 9th Ministerial Meeting of the WTO in Bali in 2014 (ICTSD, 2014a). The proposal by a group of food insecure countries (known as the G-33[1]), and led by India, argued that the 10 percent allowable subsidy for stockholding is restrictive on their ability to acquire adequate food stocks to mitigate supply shocks. Hence, the G-33 advocates the removal of the restrictions or having the constraints relaxed to accommodate larger stockholdings. However, whether or not the current *de minimis* regulation is restrictive on public stockholding for food security purposes in developing countries in general (or in India, to

[1] The G-33 list include "Antigua and Barbuda, Barbados, Belize, Benin, Botswana, China, Cote d'Ivoire, Congo, Cuba, Dominican Republic, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, India, Indonesia, Jamaica, Kenya, Korea, Madagascar, Mauritius, Mongolia, Mozambique, Nicaragua, Nigeria, Pakistan, Panama, The Philippines, Peru, Saint Kitts, Saint Lucia, Saint Vincent and the Grenadines, Senegal, Sri Lanka, Suriname, Tanzania, Trinidad and Tobago, Turkey, Uganda, Venezuela, Zambia and Zimbabwe" (WTO, 2016).

be specific) is an empirical question that has not been adequately explored. This is because countries have not been transparent with stock levels acquired for food security purposes.

Nonetheless, the G-33 argues that public stockholding is imperative for developing countries for a number of reasons. First, there is growing evidence that exporting countries often restrict food exports in times of food crises. During the 2007/2008 food crisis, for instance, Argentina - the world's second largest exporter of corn - restricted corn, wheat and soybean exports. Similar policies were employed by, for example, India, Ukraine, China and Russia (Sharma, 2011). Giordani *et al.* (2012) noted that export restrictions contributed significantly in exacerbating the 2008-09 food price spikes, affecting about 22% of global food trade while the World Bank (2009) indicates that the rise in food prices pushed over 75 million additional people into extreme hunger, especially in countries without stocks to support consumption. Rude and An (2015) demonstrated that export restrictions applied between the period of 2006 and 2011 translated to a significant increase in rice and wheat price volatilities. Where a significant proportion of people's income is spent on food, increasing price volatilities raises uncertainty about future food prices, and does not guarantee stable food consumption in food security risk countries. Thus, the impacts of such export restrictions on trade and food security is a concern for food security risk countries.

Secondly, the current WTO regulations on export restrictions do not provide any assurance that importing countries can reliably continue to depend on trade flows in their management of food security. Export taxes are permitted under the WTO without limits. Consequently, countries often apply them to restrict food exports in favour of domestic consumption in times of food market disruption thereby further limiting importers access to food. Recent studies also conclude that export restrictions will be challenging to discipline under the current WTO dispute settlement mechanism, in part because of the time required to adjudicate a dispute (Cardwell and Kerr, 2014). Despite these regulatory lapses, agreements to discipline the use of export restrictions have not been reached (ICTSD, 2014b), and the likelihood of reaching agreement remains slight (Anania, 2013). The absence of such disciplines have, therefore, exposed international markets to arbitrary government interventions with dire consequence for food security in importing countries (Gilbert, 2011).

Consequently, calls for relaxation of public stockholding rules to enable developing countries to build food reserves for food security purposes, increased. The United Nations Special Rapporteur on the Right to Food, Olivier De Schutter, for instance, called for developing countries to use food reserves in support of their food security without threat of sanctions from the WTO (UN News Center, 2013). De Schutter (2011) claimed that the WTO rules limit developing countries ability to achieve food security because they have been designed to help developed country's farmers. This led the G-33 to table a proposal calling for new rules on public stockholding (ICTSD, 2014a).

The G-33 proposal, however, proved contentious for some members of the WTO (ICTSD, 2014c). Some WTO members argued that the current WTO regulations provide sufficient policy options to enable developing countries to address their food security problems without expanding public stockholding. Many opposing countries also fear that agreeing to the proposal will impede future trade due to the high levels of subsidies associated with stockholding. India, on the other hand, threatened to block the WTO deal on *trade facilitation*[2] unless reforms on public stockholding were tabled for consideration. As an interim solution, a *Peace Clause* was introduced at the WTO to temporarily restrain countries from challenging stockholding programs of other member countries until lasting solutions are negotiated (Kerr, 2015).

1.2 Research problem

Studies exploring the need for public stockholding in developing countries are limited. First, the G-33 developing countries argued for restrictions on public stockholding policies to be lifted. However, a fundamental question lingers as to whether or not the current WTO regulations even constitute a restriction on achieving food security in these countries. Secondly, opponents of the G-33 proposal argued that developing countries accession to the WTO open them to alternative sources of imports. As such, disruptions in their domestic supply can be restored by imports. This reduce the need for stockholding programs in developing countries. However, the swiftness with which international markets can react in order to restore consumption in the event of a shock is unknown. Swiftness is a concern because a low response can lead to acute food shortage in times of crisis. Further, food exporting countries are particularly concerned that stockholding programs in importing countries can result in costly trade impacts for their exports. Nevertheless, no

[2] A WTO agreement aimed at harmonising customs practices across member countries in order to minimize the delays of goods at national borders.

empirical studies have quantified the extent to which the proposed stockholding policy will affect trade. The following research questions are, hence, raised.

1. Is there a justifiable need for public stockholding in developing countries?
2. What are the impacts of the proposed stockholding policy on international trade?

1.3 Research objectives

This research has two main objectives.

1. To assess the need for public stockholding in developing countries. Two specific objectives are used to assess the need for public stockholding in developing countries.
   a. To analyse the speed at which disruptions in consumption can be restored by relying on international markets in developing countries.
   b. To analyse the restrictiveness of the current *de minimis* AMS policy on stockholding for food security purposes in developing countries.
2. To examine the impact of the proposed stockholding policy on trade.

1.4 Thesis structure

The objectives of the thesis are addressed in three essays relating to food security, trade and public stockholding. The essay format is preferred because it allows each objective to be extensively addressed, focusing on the literature, methodology, analysis, results and discussions and references for each paper.

The first essay, presented in Chapter 2, empirically assesses the need for stockholding by focusing on market response to cereal consumption shocks in developing countries. Market response to shocks measures the speed at which distortions in food consumption can be restored by relying on international markets. If market responses are swift, disruptions in consumption can be swiftly restored by imports. Such speedy responses reduce the need for government interventions. However, a slow response to consumption shocks provides a justification for government interventions including the use public stockholding. In line with the Food and Agriculture Organization (FAO) of the United Nations recommended stock durations and the current thinking on stockholding levels in importing countries, the study argues that a market response of less than 50 percent is low. In other words, the market fails to restore more than half of a country's food needs. Such a low response can be critical for food security. Consequently, a panel error correction model is developed to estimate the speed of market responses in net food importing developing countries focusing on the major tradable staples of wheat, rice and corn.

The second essay, presented in Chapter 3, also contributes to assessing the need for public stockholding policies in developing countries. However, the assessment focus on whether or not the current AMS policy constitute a restriction on public stockholding for food security purposes in developing countries. The paper argues that it will be justifiable for public stockholding policies to be expanded in developing countries if the current AMS regulations constitute a constraint on public stock levels needed to achieve food security. To determine the restrictiveness of the policy, optimal public stocks required by countries are compared with public stocks permitted under the WTO stockholding policy. The paper focuses on wheat, corn and rice stocks in G-33 developing countries.

The third essay, presented in Chapter 4, analyses the impact of the proposed stockholding policies on trade. The paper explores the concerns raised by food exporting countries about the potential impact of stockholding policies on trade. To do this, a spatial temporal equilibrium trade model is developed and used to analyse the impact of a hypothetical storage policy aimed at meeting 50 percent of domestic consumption. The model is applied to rice, wheat and corn trade in selected countries including members of the G-33. Finally, Chapter 5 provides conclusions and recommendations for future research.

1.5 Research contribution

This thesis contributes principally to expanding understanding of the interactions between food security and public stockholding for negotiations currently ongoing at the WTO. First of all, the assessment of the need for public stockholding in developing countries provides empirical evidence that can be used to support/refute the assertions of the G-33 proposal for stockholding. The study further analyses whether or not individual countries require differential treatment to enhance their respective food security. This is important because a universal application of stockholding policy (as currently practiced under the WTO) without considering food security risk can be detrimental to countries at a higher risk. Secondly, the impact of the proposed stockholding policy on trade assessment can form a strong basis for negotiating compensation schemes if the policy produces costly trade impacts. The study also contributes by advancing the methodologies for assessing the need for public stockholding and food security policies in developing countries. In particular, the cereal consumption response and AMS restrictiveness analyses are novel approaches, introduced in this thesis, to determine the need for public stockholding policies in developing countries. This is the first study to explore such an approach.

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CHAPTER 2

Cereal consumption and market response to shocks in developing countries: Implications for food security and stockholding

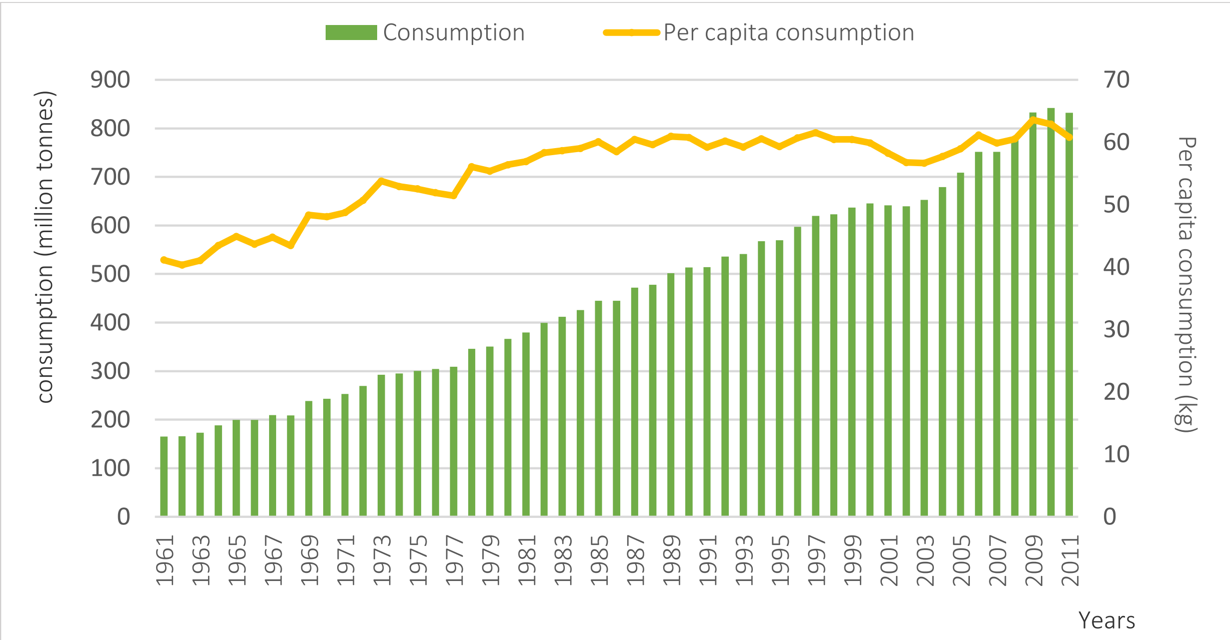
Abstract

This chapter explores the need for public stockholding in developing countries by analysing the speed of market response to consumption shocks. Market response to consumption shock measures the speed at which distortions in consumption may be restored by relying on international markets. Focusing on wheat, rice and corn, a panel error correction model is developed and used to estimate the speed of market response to consumption shocks in net food importing developing countries. The estimated responses shows that trade may restore up to 46 percent, 41 percent and 31 percent of wheat, rice and corn consumption distortions respectively in developing countries. The responses are low because more than 50 percent of food consumption distortions cannot be restored by relying on international markets in the event of a shock. Hence, establishing public stockholding programs to support consumption in times of crisis can be a legitimate policy in these countries.

2.1 Introduction

Food security is a challenge in many developing countries. The Food and Agriculture Organization (FAO) of the United Nations suggest that approximately 805 million people worldwide are at risk due to poor food security (FAO, 2014). Of these, approximately 98 percent live in developing countries where cereals are an integral part of food consumption and food security policies. Cereals constitute a large proportion of household food consumption in developing, where it provides over 60 percent of daily caloric intake (Awika, 2011). Aggregate cereal consumption increased by more than 300 percent in developing countries, from 180 million tonnes (in 1961) to over 800 million tonnes in 2011 (Fig 2.1), while per capita cereal consumption, likewise, grew by 50 percent, increasing from 40 kilograms (in 1961) to 60 kilograms per person in 2011. The increased consumption has largely been attributed to expanding population and income growth. In terms of composition, rice, corn and wheat constitute more than 70 percent of aggregate cereals consumed (Fig 2.2). The growth in cereal consumption (rice, wheat and corn) largely signifies its importance in the food security of developing countries. Consequently, corn, rice and wheat predominate in the food security policies of developing countries. Rice, wheat and corn are also preferred in stockholding programs for food security purposes because they can store for an extended period relative to other food stuffs.

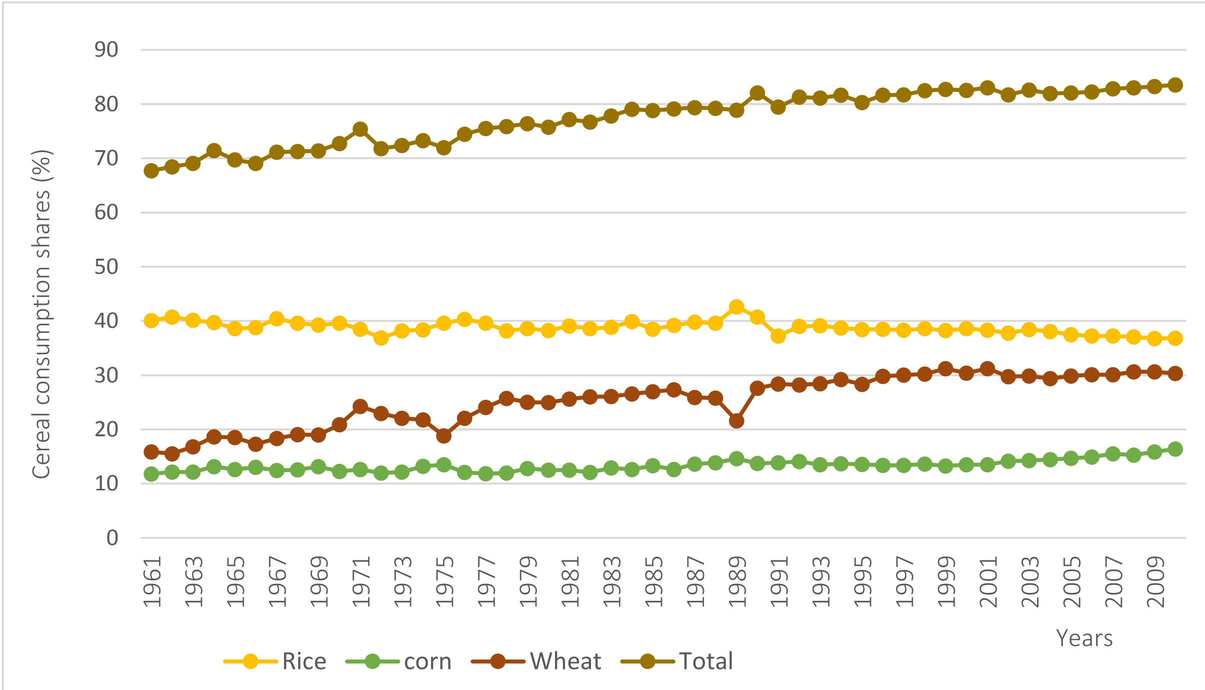
Fig 2. 1 Cereal consumption in developing countries[3]



Source: Author's computation using FAO data.

[3] Developing countries included are Afghanistan, Angola, Bangladesh, Benin, Botswana, Burkina Faso, Central African Republic, Chad, China, Cote d'Ivoire, Djibouti, Dominican Republic, Egypt, El Salvador, Ethiopia, Gabon, Gambia, Guinea, Guinea-Bissau, Honduras, India, Jordan, Kenya, Laos, Liberia, Malawi, Mali, Mauritania, Mauritius, Mongolia, Morocco, Mozambique, Namibia, Niger, Nigeria, Nepal, Pakistan, Panama, Peru, Senegal, Sri Lanka, Tanzania, Yemen, Zambia, Zimbabwe.

Fig 2. 2 Cereal consumption shares in developing countries (%)



Source: Author's computation using FAO data.

The importance of cereals in the food basket of developing countries raises concerns about the likely impact of a future consumption shock. A consumption shock in this study refers to a sudden increase in demand or decrease in quantity available for consumption leading to a major market disruption[4]. Consumption shocks often arise from crop failures due to weather and/or disease infestations. However, consumption shocks in food importing countries also extend to trade policy restrictions on exports by the food exporting countries. These restrictions include the use of export taxes and embargos to limit importers' access to food. Moreover, while countries are unlikely to simultaneously restrict exports, the effect of a shock in one market can be transmitted to others through international commodity prices.

[4] A major market disruption can be either a food shortage at prevailing prices, a spike in food prices or a combination of the two. Price spikes lead to deterioration in food security for the poor as they do not have sufficient income to acquire adequate food for an active and healthy life at higher prices.

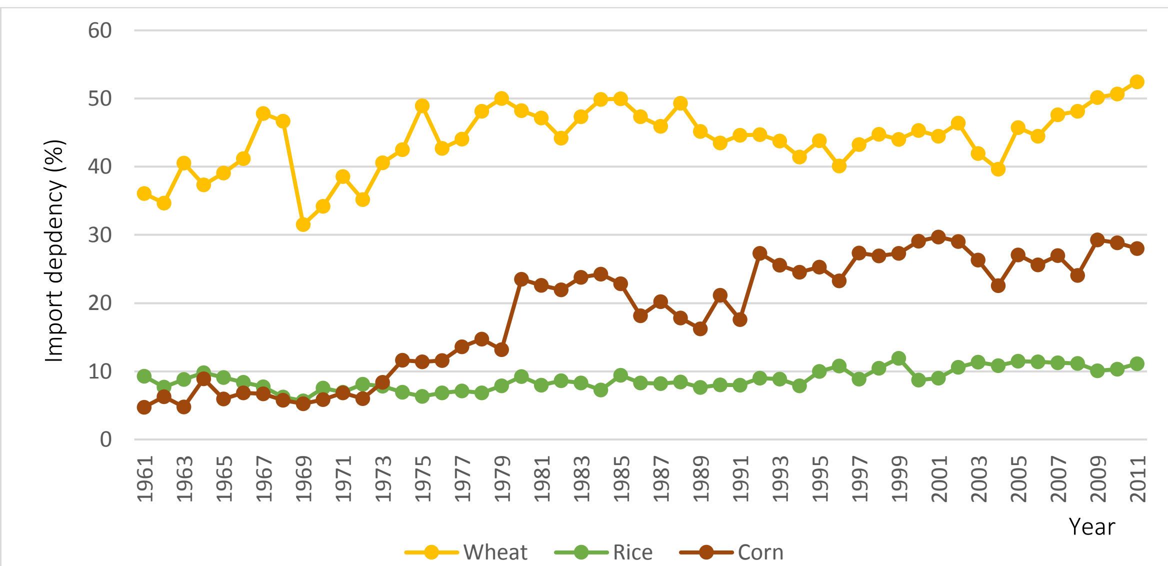
Notwithstanding the diverse sources of consumption shocks that countries face, the duration of a shock and the extent of its impact on food security can be minimized where countries are more integrated into the international trade system, which allows a rapid import response. In an integrated trade system, a consumption shock may translate into increased prices in affected countries and induce imports to mitigate the impact of the shock. Hence, a country strongly integrated into the global trade system has the opportunity to access imports to respond to consumption shocks. A rapid response will reduce the shock duration and enhance food security in importing countries while a slow response can deepen food security crisis. Hence, ensuring a more responsive market are imperative institutional reforms that can enhance trade and food security in developing countries.

Josling (2014) noted that the WTO's objective to create a transparent global trade system had food security in mind. The multilateral trade system is expected to contribute to food security by providing countries with alternative sources of imports. This is important for developing countries where food production often lags demand, and commercial food imports can be essential to meeting consumption needs in times of production shocks (Anderson, 2001; Matthews, 2014a, 2014b; Rakotoarisoa *et al.*, 2011). Trade will, thus, distribute food from surplus to deficit regions and also reduce the need for stockholding because imports can arise from surplus regions in the event of shock. This is feasible if markets are efficient and sufficiently responsive to quickly restore consumption in the event of a food crisis. Where market responses are slow, a shock to domestic consumption can lead to an acute food shortage.

Despite the liberalisation agenda of the WTO, developing countries still exhibit high transaction costs, limited trade openness and export restrictions that have the tendency to undermine the ability of trade to address food security in these countries. High transaction costs have the potential to delay swift responses to assure food security in times of shock. Transactions costs are often higher in developing countries because the institutions needed to support a rapid response from markets are not developed. As a result, the reliance on trade to induce food inflows may be problematic due to the slowness of the responses. Further, the conclusions from Zant (2010) indicate that high transaction costs can reduce economic incentives that could induce timely imports responses in developing countries. Thus, the speed at which consumption shocks can be mitigated for food import dependent countries, in effect, depends on the swiftness of access to imports. The responsiveness to shocks also provides indications as to the type of alternative policies that governments can employ to enhance food security. For instance, short-term food security can be improved for countries with low response rates if they are permitted to hold stocks. In times of food crises, such stocks could be relied upon to stabilise markets or provide food directly to the vulnerable population. This is important for many developing countries because they are highly dependent on imports, and, hence, vulnerable to exporters' trade policy restrictions.

Developing countries are generally vulnerable to exporters' trade policy restrictions because of high dependence on imports. The share of imported rice in their domestic consumption (referred to as cereal import dependency) has been approximately 10 percent. However, corn and wheat import dependency has risen considerably. Corn import dependency increased from 5 percent in 1961 to approximately 30 percent in 2011; while wheat dependency grew from 35 percent in 1960s to over 50 percent in 2011 (Fig 2.3). The increasing import dependency implies that a trade restriction on exports can create acute food shortage in these countries and consequently affect their short-term food security.

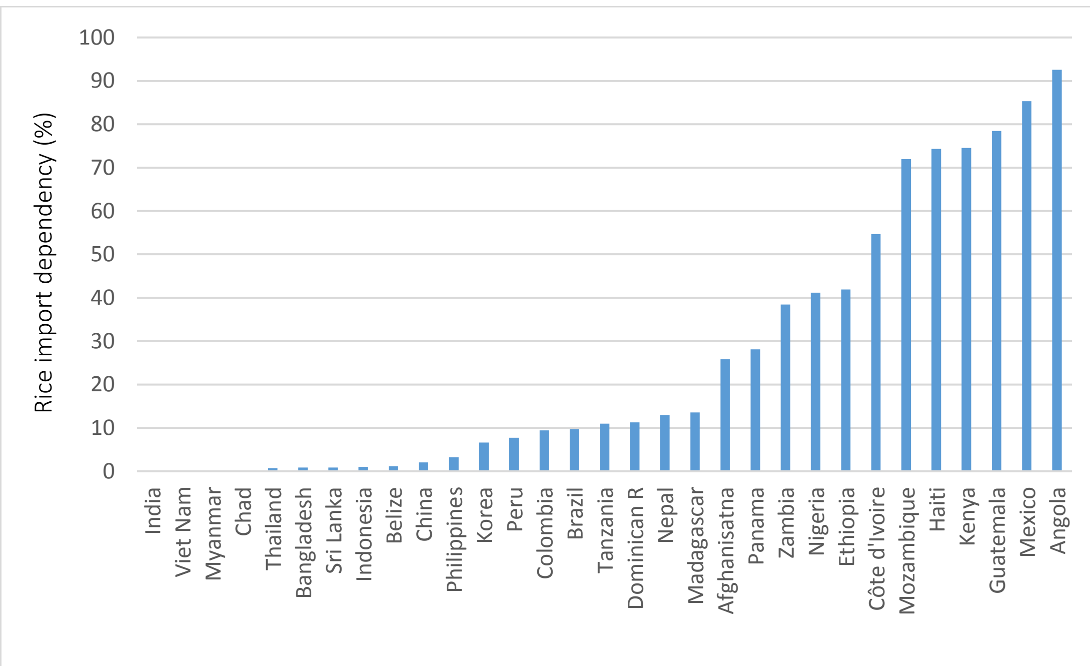
Fig 2. 3 Cereal import dependency in developing countries (%)



Source: Author's computation using FAO data.

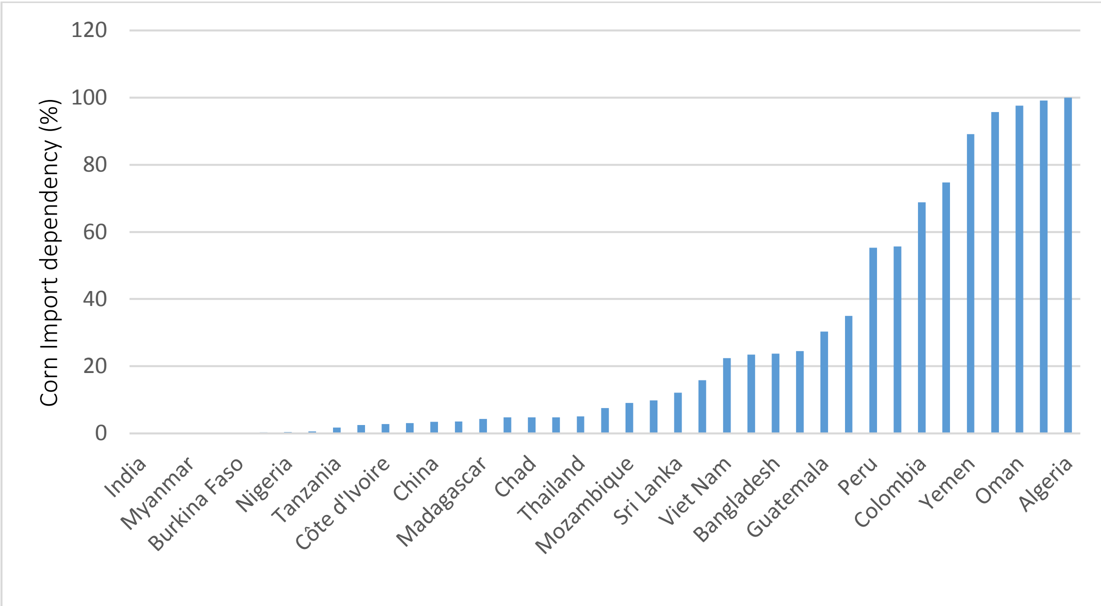
The degree of vulnerability is more evident when individual countries are examined. In 2011, for example, the share of imported rice, corn or wheat constituted less than 5 percent of consumption in India and China (Fig 2.4, Fig 2.5 and Fig 2.6) making these countries less dependent on imports, and hence, less vulnerable to trade policy restrictions. However, shares of imported rice, corn and wheat in domestic consumption constitute approximately 100 percent in Angola (Fig 2.4), Algeria (Fig 2.5) and Burkina Faso (Fig 2.6) respectively, thus making them more vulnerable to trade policy restrictions. Thus, a restriction on imports could create an acute food shortage in countries such as Burkina Faso if it has no domestic stocks to rely upon in times of a consumption shock. Moreover, given the high degree of dependency, a slow response could produce devastating effects on consumption and, hence, food security in these countries. Nevertheless, the speed of consumption response to shocks among these countries are largely unknown.

Fig 2. 4 Rice import dependency in developing countries (%)



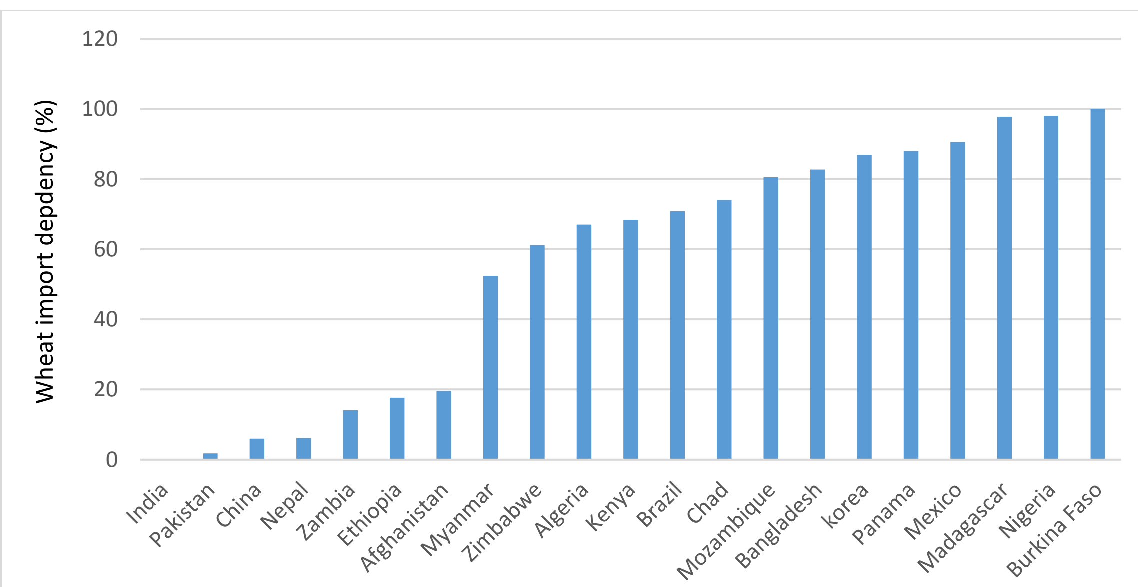
Source: Author's computation using FAO data.

Fig 2. 5 Corn import dependency in developing countries (%)



Source: Author's computation using FAO data.

Fig 2. 6 Wheat import dependency in developing countries (%)



Source: Author's computation using FAO data.

Further, the potential for trade policy restriction on exports is high. Potential for policy restriction is high because the present WTO regulation on food security allows exporting countries to restrict exports in favour of domestic consumers. Moreover, recent studies suggest that export restrictions would be difficult to discipline under the current WTO dispute settlement mechanism, in part, because of the lengthy dispute resolution process (Cardwell and Kerr, 2014). Nonetheless, the developing countries' proposal to build public foodstocks in support of food security has been opposed by some members of the WTO. Some countries argue that the current multilateral framework provides sufficient policy freedom for developing countries to achieve food security without the need for expanding public stocks.

The chapter assesses the need for public food stockholding for food security purposes in developing countries by exploring the speed of market response to consumption shocks. The research argues that the length of time (speed) involve in accessing imports from international markets should any shock to domestic food system occur (in order to restore consumption) is an important issue that will determine whether or not countries need to hold foodstocks. If accessing imports is not timely then the trade response may not be sufficiently swift to assure food security in times of food crisis. This can be a justification for stockholding. The study focuses on tradable staples that can be accessed on international markets to restore consumption in importing countries. Other factors such as market orientation, cultural practices, transaction costs and/or proximity to imports that may affect speed of consumption restoration are controlled for by including country specific fixed effects and trade openness. Similarly, the cost of food which can influnece how much food can be acquired to restore consumption are controlled for by including income and international prices in the model. The relationship between these and consumption response are fully specified in the empirical model.

The specific objective is, therefore, to estimate the speed of market response to consumption shocks in developing countries. A significant market response indicates that distortions in consumption can be restored to their long-run equilibrium (i.e. the acceptable consumption level) by relying on the international market. The magnitude of market response indicates the speed at which those distortions are mitigated. In this study, a response is said to be low when it does not restore up to 50 percent of the food needs following a distortion, and vice versa. The study is conducted using a panel of 58 net food importing developing countries (NFIDCs) spanning the period of 1961 to

2011 on rice, corn and wheat. Further, statistical test did not indicate any structural changes in the consumption patterns over the years that could lead to potential differences in responses. Hence, the estimates use the full sample from 1961 to 2011 for the estimations. As a robustness check, consumption responses are also estimated for net food exporting developing countries (NFEDCs), net food importing developed countries (NFIDEVCs) and net food exporting developed countries (NFEDEVCs). The NFIDCs, NFEDCs, NFIDEVCs and NFEDEVCs used in the study are listed in the appendix.

The study is justified for a number of reasons. First, the study focuses on NFIDCs because they are largely depended on international markets and are the most vulnerable to trade policies of exporting countries. Secondly, the speed of consumption response will inform policy as to whether or not developing countries have a case for wanting to include public stockholding in WTO subsidy exemptions. The study focuses on corn, wheat, and rice because of their high importance in trade, consumption and stockholding programs of developing countries. Hence, analysing these cereals together will provide a comprehensive assessment of consumption response to food security disruptions in NFIDCs.

The chapter is organised in seven sections. Following the introduction, section 2 reviews the relevant literature on food security modelling, consumption and trade; section 3 focuses on recent studies on stockholding and food security; section 4 provides the theoretical framework that is developed; section 5 considers the empirical model; section 6 focuses on results and discussion; and section 7 presents the conclusions.

2.2 Recent studies in trade, stockholding and food security

The 2007-2008 food crisis - in which over 75 million additional people were pushed into extreme hunger and malnutrition (FAO, 2008; World Bank, 2009) - reignited research as to how countries could best enhance food security. The causes of the food crisis have been attributed to food export restrictions and panic buying following periods of low stocks and rising food prices (Childs and Kiawu, 2009; Hansen, 2013). Following the food crisis, the World Bank (2012) provided a historical review of developing countries' stockholding programs related to food security. The study concluded that public stockholding has generally not been effective when targeted at stabilising domestic prices (as a food security measure) due to unsustainable budgetary cost. Public stocks have, however, been effective when used to provide targeted food aid.

Dorosh (2009) notes that large stock accumulations can divert state resources meant for poverty reduction, agricultural investment, and general economic growth into stockholding. Demeke *et al* (2009), Jones and Kwiecinski (2010) and Maetz *et al.* (2011) noted a general shift in policy among developing countries aimed at reducing reliance on food imports following the 2007-2008 crisis. In the same regard, Konandreas (2012) advised countries to hold modest stocks in anticipation of food crisis while initiating measures to enhance intra-regional trade. These studies generally indicate that public stockholding and trade should be used together to enhance food security. Consequently, a series of papers sought to model various public storage and trade policy combinations that countries can use to stabilise consumption and prices in developing countries.

Gouel and Jean (2015) modelled the trade–public storage policy mix that stabilises food price in small open economies by expanding upon the rational expectation framework. They conclude that the optimal trade-stockholding policy mix crowds out private sector storage. This is because lack of private sector storage discourages competition and efficient use of resources. Extending the framework to assess the impact on the global economy, their results further suggest that aggressive price stabilisation in developing countries could lead to higher global prices. Larson *et al.* (2014) used an extended form of the rational expectation storage-trade model to assess the objective of holding strategic regional wheat reserves in the Middle East and North Africa (MENA) region. Their results show that moderate stocks could be used to mitigate price spikes in the MENA region. However, because the MENA is a major importer of wheat, large reserves tend to destabilise global wheat prices and consumption. The next subsection discusses other studies related to food security, consumption, stockholding and trade that deploy non-rational expectation approaches.

2.3 Food security and consumption modelling

Food security modelling and its linkage with trade and public stockholding has taken a variety of approaches. Rocha (2007) argued that the classical economic approach to food security is one of a *market failure* problem which warrants government intervention like other forms of market failures. Market failures lead to insufficient food consumption in vulnerable societies. However, insufficient food consumption creates a social cost to the state in the form of increased social vices, disease outbreaks, among others. This implies that the private benefits of food consumption are less than the benefits to society. Consequently, the state intervenes to improve consumption. Under the market failure approach, trade liberalisation and stockholding are government policies used to enhance consumption. For food importing countries, trade liberalisation entails lowering trade barriers to improve timely food supply.

Food security has also been modelled using various trade theories. David Ricardo (1817) demonstrated that specialisation based on comparative advantage increase the production of each good for the global economy. Extending from this insight implies that specialisation, when combined with open trade, will increase production, availability and consumption of food in each country including those specialising in non-food production. Also, the efficiency gains associated with specialisation can increase income and economic growth in the general economy, enhance purchasing power and reduce vulnerability to food price shocks (Clapp, 2014). A number of studies have, therefore, explored the impact of trade on food security based on these trade theories. Measuring food security by food availability, Benuzeh and Yiheyis (2014) analysed the impact of trade liberalization on food security among 37 developing countries. Food availability was measured by dietary energy supply while trade liberalization is measured through a dummy. A country assumes a value of 1 for the year it joined the WTO, and a zero for all other years. The coefficient of liberalisation therefore measures the difference in food availability before and after accession to the WTO. Thus, a significant coefficient indicates that the period after acceding to the WTO increased food availability and hence, enhanced food security. However, their study finds no conclusive evidence that trade liberalization enhances food security.

McCorriston *et al.* (2013) summarised the evidence from studies looking at trade impacts on food security over the period of 1990 to 2012. In all, 1176 papers were identified and then screened down to 34 based on the relevance to policy and quality of research evidence. Thirteen (13) of the 34 papers concluded that agricultural trade liberalisation enhances food security. Ten (10) out of the 34 papers suggest trade liberalisation worsens food security while 11 were inconclusive, as the variable(s) measuring trade liberalisation were not significant. The general assessment is that there is no conclusive evidence that trade liberalisation unambiguously enhances food security. These studies, in themselves, do not provide any indication as to whether countries need to hold public stocks. These studies are largely static in nature in that the food security attributes are assumed to be held constant. As such, they can explain food security at a point in time but are unable to capture the dynamics of changes in food security over time. Consequently, various techniques to capture the dynamism in food security have since been explored.

The dynamic approach to food security modelling argues that countries, households and individuals' food security situation is unstable. Households move into or out of food insecurity depending on their income, socio-economic conditions at any point in time as well as macroeconomic factors such as economic recession, trade openness and international prices. Hence, adopting a static approach to food security will fail to capture these dynamics. Christiaensen and Boisvert (2000) proposed the basic economic model of vulnerability to food insecurity. Their model predicts the probability that a given household will consume an insufficient levels of food at a given point in time. These probabilities change depending on income and other factors that influence household access to food. Capaldo *et al.* (2010) applied vulnerability models to analyse food insecurity in Nicaragua. Their results suggest that a subset of households frequently fall into and out of food insecurity brackets thereby making it challenging to be able to design stable/targeted food security policies.

Econometric models can also be adapted to capture dynamism in food security from the long-run and short-run perspective. These models include, but are not limited to, Vector Error Correction (VEC) models using time series and panel data. While time series provide useful insights over time, panel analysis captures the dynamism emanating from time and cross-sections. The added advantage of a panel data approach to modelling is that there are efficiency gains in parameter estimates when data is pooled across time and cross sections into a single sample (Baltagi, 2008). Kornher and Karlkhul (2013) used a fixed effect dynamic panel data model to estimate determinants of food price volatilities (measuring food security) in developing countries. Their study shows that trade restrictions and stocks influence price volatilities. Although these studies have been helpful in providing insights into food security, trade and stockholding, analysis from the perspective of consumptions response is limited.

This chapter makes a contribution to the stockholding literature by estimating market response to cereal consumption shocks in developing countries. Responsiveness also provides information about the underlying transaction cost that countries face in accessing imports. Where transaction costs are prohibitive, trade may not be responsive to food security shocks in developing countries. By using the dynamic panel model we are able to capture the influences that change over time and control for non-time varying effects that impact cereal consumption and food security.

2.4 Theoretical framework

The theoretical models of cereal consumption demand are conceptualised within the context of utility maximization. A net food importing developing country (NFIDC) is modelled as a representative consumer seeking to maximize utility in the international market subject to an income constraint. Assuming wheat (C_w), rice (C_r) or corn (C_c) are the cereals consumed, a representative NFIDC's utility (U) can be defined over consumption as U (C_w, C_r, C_c). Further, the research assumes that international prices largely determine cereal consumption since these are net food importing countries. Letting P_w, P_r and P_c represent international prices of wheat, rice and corn respectively, an income constraint implies that the value of wheat, corn and rice purchased cannot exceed a country's income. A representative NFIDC's economic problem of maximizing utility subject to income (INC) constraint is stated as:

$$Max\ U(C_w, C_r, C_c)\ \ s.t\ \ (P_w C_w + P_r C_r + P_C C_c\ \leq\ INC) \qquad (2.1)$$

From equation (2.1), consumption demand for wheat (C_w), rice (C_r) and corn (C_c) are implicitly derived as functions of income, own price and prices of related cereals as:

$$C_w = f(P_w, P_r, P_c, INC) \qquad (2.2)$$

$$C_r = f(P_w, P_r, P_c, INC) \qquad (2.3)$$

$$C_c = f(P_w, P_r, P_c, INC) \qquad (2.4)$$

Cereal consumption demand augmented with trade openness (TO) and error term (ε) becomes:

$$C_w = f(P_w, P_r, P_c, TO, INC, \varepsilon) \qquad (2.5)$$

$$C_r = f(P_w, P_r, P_c, TO, INC, \varepsilon) \qquad (2.6)$$

$$C_c = f(P_w, P_r, P_c, TO, INC, \varepsilon) \quad (2.7)$$

In conclusion, cereal consumption demand is a function of own price, price of related cereals, trade openness and income. Based on this structure we make the following propositions:

(1) *Income (INC)*: An increase in income will raise a country's purchasing power and increase its cereals consumption. Hence, income has a positive effect on cereal consumption.

(2) *International price of cereal (own price):* An increase in the price of cereal will lead to a decline in imports and consumption. Hence, own price has a negative effect on cereal consumption in NFIDCs.

(3) *International price of related cereals (price of substitute):* A rising international price of one cereal will increase the consumption of another because wheat, corn and rice are substitutable. Price of substitutes have positive effect on consumption. Hence, the inclusion of prices of related cereals indicates that these commodities are substitutable[5].

(4) *Trade openness (TO):* Trade openness measures a country's degree of integration into the world trade. Higher integration is an indication of low trade barriers which induce imports and enhance consumption. Moreover, high trade openness also induces a swift consumption response in times of shocks. Hence, trade openness has a positive effect on cereal consumption in NFIDCs.

(5) *The error term (ε):* The error term captures all other unobservable factors capable of influencing consumption.

Estimating the consumption functions above measures the effects of own price, price of related cereals, trade openness and income on consumption in the long-run. The estimated coefficients are long-run parameters. This does not explain market responses to consumption shocks. To specify the model to capture consumption response to shocks, the data must have panel unit roots and a cointegration process. In this paper, the panel error correction approach is chosen as it allows the study to estimate the speed of consumption response which forms the principal objective in this Chapter. The requirements for panel error correction model specifications discussed in the next subsections.

[5] Prices of related cereals are however dropped due to multi-collinearity issues in the data.

2.5 Methodology

This section discusses panel unit roots (i.e. stationarity) and cointegration tests, model specification and the estimation techniques used in the paper.

2.5.1 Panel unit root test

Data is said to have unit roots if it is non-stationary in levels but becomes stationary after first differencing. Testing for stationarity is essential in order to avoid estimating spurious relationships (Kao, 1999). Unlike time series where unit root process is homogeneous, panel unit roots may be heterogeneous. Stationarity in panel data is also affected by contemporaneous correlation between panels known as cross-sectional dependence. The presence of cross-sectional dependence causes estimates to be inconsistent and, thus, affect hypothesis testing (Baltagi, 2008). As such, varying techniques have been proposed to accommodate heterogeneity and cross-sectional dependence. Levin *et al.* (2002); Breitung (2000) and Hadri (2000) proposed test methods that account for cross-sectional independence and homogeneity in the panel unit root process. The test leads to efficient estimates if the underlying unit root process is homogenous, otherwise the estimates are inconsistent.

Further, the 'Im, Pesaran and Shin Test' (Im et *al.*, 2003) and 'Fisher-ADF and Fisher-PP test' (Maddala and Wu, 1999; Choi, 2001) were developed to accommodate heterogeneity in the unit root process. The 'Im, Pesaran and Shin Test' has two short-comings. First, it does not account for contemporaneous correlation among cross-sections in the panel. Secondly, the 'Im, Pesaran and Shin Test' is developed for cases of balanced panels. Given that most panels are unbalanced, the test becomes very restrictive.

In this chapter, the 'Fisher Test' is deployed as it accommodates a heterogeneous unit root process. Although originally developed under the assumption of cross-sectional independence, recent advances in panel data estimation using STATA allows for the implementation of a Fisher test that accounts for cross-sectional dependence. Also, Fisher tests are applicable where the data is an unbalanced panel.

The Fisher Test developed in this chapter draws extensively from Baltagi (2008, Chapter 12).

Fisher test combines probability values of each cross-section's unit root test to determine overall panel statistics. For a variable C (where C represents all variables to be tested for panel unit roots), the specified model of unit root test under Fisher assumes the following linear relationship:

$$C_{it} = \beta_i + \rho_i C_{i,t-1} + \varepsilon_{ijt} \qquad (2.8)$$

Where β_i is panel specific constant terms, i = 1, 2, ….., N unique cross-sections; t=1, 2, ….., T time frame and ε_{ijt} is an error term while J is the number of lags included, determined from lag selection criterion. The symbol ρ_i is the heterogeneous unit root process which varies across panels. The hypotheses used to test for unit root process in panel data are stated as:

Ho: $|\rho_i|$ =1, all panels contain unit root

Ha: $|\rho_i|$ <1, at least one panel is stationary

Four test statistics are used to test the hypothesis. These include:

(a) Inverse chi-square statistic (P): The P statistic approximates a chi-square distribution, $P = -2\sum_{i=1}^{n} lnP_i \rightarrow \chi^2(2N)$, with a degree of freedom equal to twice the sample size (N).
(b) Inverse normal statistic (Z): The Z statistic approximates a normal distribution, $z = \frac{1}{\sqrt{n}}\sum_{i=1}^{N} \Phi^{-1}(p_i)$, with 0 and 1 as its mean and variance respectively.
(c) The inverse logit statistic (L): The L statistic approximates a logistic distribution, $L = \sum_{i=1}^{N} \ln(\frac{p_i}{1-p_i})$, with 0 and $\pi^2/3$ as its mean and variance respectively.
(d) The modified inverse chi-square statistic (Pm) is a standard normal distribution which assumes a mean of 0 and a variance of 1. Where, $P_m = \frac{1}{2\sqrt{N}}\sum_{i=1}^{N}(-2lnp_i - 2)$

In each case, p_i is the probability value of the *i*th panel unit root test. The null hypothesis is rejected if p-calculated exceeds p-critical values (Baltagi, 2008, Chapter 12). .

2.5.2 Panel cointegration

Testing for long-run relationships between consumption, income, trade openness and international price of cereals is a test for cointegration. The condition for a cointegration requires that the variables are non-stationary in levels and integrated of order one. Kao (1999) developed a residual-based fixed effect cointegration test, assuming cross-sectional independence and homogenous unit root process. Thus, Kao's test restricts the cointegration vector to be the same across panels. Pedroni (1999, 2004) expands on Kao's work and proposed a test assuming cross-sectional independence and heterogeneity in the cointegration vector.

Westerlund (2007) and Persyn and Westerlund (2008) proposed a panel cointegration test based on an error correction specification, known as "Westerlund Cointegration Test". This chapter uses the Westerlund Cointegration test as it allows for cross-sectional dependence and heterogeneity in cointegration. Westerlund developed four statistics (Gt, Ga, Pt or Pa) for testing cointegration. The group-mean statistics (Ga and Gt) assumes that cointegration relationship is different across panels. Hence, the null hypothesis of no cointegration is tested against the alternative that cointegration exists in at least one panel. The Panel Statistics (Pa and Pt) assumes a homogenous cointegration relationship; and test the null hypothesis of no cointegration against the alternative of cointegration. Where Group test (Gt, Ga) and Panel Test (Pt and Pa) leads to opposing conclusion, preference will be given to Panel Test since it focuses on the whole panel. Westerlund statistics are normally distributed under the null.

2.5.3 Model specification

Where unit roots and cointegration conditions are met, cereal consumption demand can be stated as a function of past and present own prices (OP) , prices of related cereals (PR), income (INC), trade openness (TO); and previous consumption(C) as:

$$C_{it} = \sum_{j=1}^{p-1} \tau_{ij}\, C_{i,t-j} + \sum_{j=0}^{p} \beta_{ij}\, OP_{i,t-j} + \sum_{j=0}^{p} \theta_{ij}\, PR_{i,t-j} + \sum_{j=0}^{p} \partial_{ij}\, TO_{i,t-j} + \sum_{j=0}^{p} \delta_{ij}\, INC_{i,t-j} + \mu_i + t + \varepsilon_{it} \qquad (2.9)$$

Where 'i' identifies countries and t is time; μ_i is country fixed effects; ε_{it} is error term; and 'p' is maximum lag included in the model. The equation (2.9) can be specified to capture a consumption response using a panel error correction approach. Panel error correction has three components:

(1) The long-run component: Long-run corresponds to the stable equilibrium consumption level of a country. Long-run consumption is assumed to be consistent with food security.

(2) The short-run component: Short-run consumption denotes deviations from acceptable equilibrium consumption levels arising from shocks.

(3) The speed of adjustment or error correction term-measures the speed at which deviations from equilibrium consumption are restored. The 'speed of adjustment' is operationalized in this paper as 'market response to consumption shock'.

Thus, equation (2.9) is specified in an error correction form as:

$$\Delta C_{it} = \delta_i(C_{i,t-j} - \beta_i OP_{j,t-1} - \theta_i PR_{j,t-1} - \gamma_i INC_{i,t-1} - \partial_i TO_{i,t-1}) + \sum_{j=1}^{p-1} \emptyset_{ij} \Delta C_{i,t-j} + \sum_{j=0}^{p} \beta_{ij}\, \Delta OP_{i,t-j} + \sum_{j=0}^{p} \Delta\theta_{ij}\, PR_{i,t-j} + \sum_{j=0}^{p} \partial_{ij}\, \Delta TO_{i,t-j} + \sum_{j=0}^{p} \delta_{ij}\, \Delta INC_{i,t-j} + \mu_i + t + \varepsilon_{it} \quad (2.10)$$

Where, $\delta_i = -(1 - \sum_{j=1}^{p-1} \tau_{ij})$, is the speed of adjustment term measuring market response to consumption shocks. Market response to consumption shocks measures the extent to which countries can rely on the market to restore consumption. Zero response implies consumption cannot be restored by relying on the market. This is a justification for stockholding.

Similarly, the corresponding long-run and short-run consumption relationships in the model are:

$(C_{i,t-1} - \beta_i OP_{j,t-1} - \theta_i PR_{j,t-1} - \gamma_i INC_{i,t-1} - \partial_i TO_{i,t-1})$ and $(\sum_{j=0}^{P} \theta_i\, \Delta C_{i,t-j} + \sum_{j=0}^{P} \emptyset_i\, \Delta OP_{j,t-j} + \sum_{j=0}^{P} \vartheta_i\, \Delta PR_{i,t-j} + \sum_{j=0}^{P} \varphi_i\, INC_{i,t-j} + \sum_{j=0}^{P} \alpha_i\, TO_{i,t-j})$ respectively. The estimated coefficients of prices, income and trade openness in the long-run and short-run components of the error correction model measures their (prices, income and trade openness) impact on cereal consumption in the long and short-runs respectively.

2.5.4 Model estimation

Pesaran *et al.* (1999) developed models for estimating non-stationary panel data with heterogeneous parameters. These include the Mean Group (MG) and Pooled Mean Group (PMG) estimators. The MG model assumes that the long-run consumption relationship, speed of adjustment (i.e. response to shocks), short-run dynamics (i.e. short-run consumption) and intercept terms are different across panels.

The PMG estimator, on the other hand, assumes that the long-run consumption patterns is the same across panels but short-run parameters, intercepts and response to shocks are allowed to vary. We have reasons to impose these assumptions. Given that NFIDCs are low income countries there is tendency to agree that they have the same consumption pattern in the long-run. However, we have no reason to believe that each country's response to shocks is equal, particularly, when income, trade openness and other transaction cost are likely to vary among countries. The PMG model, by restricting long-run parameters to be equal across countries, leads to efficient and consistent estimates if the restriction is valid (Blackburne III and Frank, 2007). The PMG is, however, inconsistent if the restriction is false. The MG estimator produces consistent estimates but are inefficient when the restrictions are true. Hence, a Hausman Test is conducted to select the best model.

The MG and PMG degenerate into a dynamic fixed effects model (DFE) when assumption of parameter homogeneity is imposed across long-run, short-run and speed of adjustment with the exception of country fixed effects. The counterpart of DFE in stationary data is the standard fixed/random models which assumes that all parameters are homogenous with the exception of individual fixed effects. The characteristics of MG, PMG and DFE are presented in Table 2.1.

Table 2. 1 Comparing MG, PMG and DFE models

	Mean Group (MG)	**Pooled Mean Group (PMG)**	**Dynamic fixed effect (DFE)**
Long-run	Different for each country	Same for each country	Same for each country
Short-run	Different for each country	Different for each country	Same for each country
Speed of adjustment (response to shocks)	Different for each country	Different for each country	Same for each country
Country fixed effects	Different for each country	Different for each country	Different for each country
Best model selected using Hausman test			

Source: Author presentation summarised from literature.

2.5.5 Model selection

The Hausman Test compares parameters from PMG and MG models. The hypothesis are:

Ho: Difference in coefficients not systematic (PMG is preferred)
Ha: Difference is parameters is systematic (MG is preferred).

The Hausman Test approximates a chi-square distribution with N-degrees of freedom, where N is the number of long-run parameters. The hypothesis can also be tested by comparing DFE and MG or PMG using the same technique. The DFE is efficient compared to MG/PMG because of the extent of parameter pooling. The panel error correction are fitted to wheat, corn and rice data separately using maximum likelihood estimation. The models were estimated and tested using STATA. The hypotheses for each cereal are:

2.5.6 Rice model[6]

Ho: International price of rice has no effect on rice consumption
Ha: International price has a negative effect on rice consumption

Ho: Income has no effect on rice consumption
Ha: Income has a positive effect on rice consumption

Ho: Trade openness has no effect on rice consumption
Ha: Trade openness has a positive effect of rice consumption

2.5.7 Corn model

Ho: International price of corn has no effect on corn consumption
Ha: International price has a negative effect on corn consumption

[6] Prices of related cereals are excluded due to multi-collinearity problems. The empirical reasons are shown at the results and discussions section.

Ho: Income has no effect on corn consumption

Ha: Income has a positive effect on corn consumption

Ho: Trade openness has no effect on corn consumption

Ha: Trade openness has a positive effect of corn consumption

2.5.8 Wheat model

Ho: International price of wheat has no effect on wheat consumption

Ha: International price has a negative effect on wheat consumption

Ho: Income has no effect on wheat consumption

Ha: Income has a positive effect on wheat consumption

Ho: Trade openness has no effect on wheat consumption

Ha: Trade openness has a positive effect of wheat consumption

2.5.9 Variable measurement and data

The panel consist of data on fifty-eight (58) net food importing developing countries (NFIDCs) spanning the period from 1961 to 2011. The NFIDCs are members of countries listed under the WTO Marrakesh *Decision*[7] which were considered to be at food security risk following the Uruguay Round reforms; and/or the FAO's low-income food-deficit countries. The list of countries included in the study are presented in Table 2A.1[8] in the appendix. The data sources include:

Cereal consumption (wheat, rice, corn): Consumption of each cereal is measured as the sum of domestic production, imports, and change in stock minus exports. Data on production, imports, exports and stock variations are available at FAOSTATS from 1960-2014.

[7] Marrakesh *Decision* pertains to developing countries which could face short-term food security risk as a result of trade liberalization reforms after the Uruguay Round.

[8] Table and/or Figure numbers containing letters are listed in the appendix.

International price of corn, wheat and rice: Cereal prices are available at the World Bank Commodity Statistics from 1960-2013. The World Bank collects data on cereal prices in international markets important to developing countries, extending from 1961 to 2013. In this regard, it identifies US as the leading corn market and accordingly collects data on free on board number 2 yellow corn prices at the Gulf port. The US corn export price is therefore used as the international price of corn. For wheat, Canada and United States are identified as the most important wheat markets for developing countries. However, data on Canada were discontinued in 2013 without any stated explanation. As a result, United States number 1 hard red winter wheat is used as the international wheat price. In the case of rice, Thailand and Vietnam are noted as the most important markets but data on Vietnam are not consistently available. Hence, the Thai market price is used as the international market price. All prices are measured in United States dollars per tonne.

Gross Domestic Product (GDP) and trade openness: GDP (in current US dollars) is used as a measure of income. Trade openness is measured as ratio of total trade to GDP expressed in percent. Trade openness and GDP data are available from the World Bank from 1960-2014. The dates and times at which the data was downloaded are presented in Table 2.2.

Table 2. 2 Data sources and download dates

Variable	**Date**	**Time***	**Source**
GDP	November 20, 2014	3:00pm	World Bank
Trade openness	November 20, 2014	3:00pm	World Bank
Price of rice	November 20, 2014	3:00pm	World Bank Commodity Group
Price of corn	November 20, 2014	3:30pm	World Bank Commodity Group
Price of wheat	November 20, 2014	3:30pm	World Bank Commodity Group
Rice consumption	November 20, 2014	3:30pm	FAO
Corn consumption	November 20, 2014	3:30pm	FAO
Wheat consumption	November 20, 2014	3:30 pm	FAO

*Saskatoon local time.

2.6 Results and discussion

The results are presented in three parts: the descriptive statistics; panel unit roots and cointegration tests; and the estimated panel error correction models.

2.6.1 Descriptive statistics

The descriptive statistics of the data are summarized, by model, in Table 2.3. All variables are in logarithms. The panel consist of data on fifty-eight (58) NFIDCs extending from 1961 to 2011.

Table 2. 3 Descriptive statistics

Model	Variable	Mean	Between variation	Within Variation	Overall variation	Sample Size
Rice	Consumption	12.19	2.34	0.73	2.43	2540
	International price of rice	5.54	0.07	0.42	0.42	2540
	Trade openness	4.00	0.44	0.33	0.55	2540
	Income (GDP)	22.32	1.57	0.96	1.87	2540
Corn	Consumption	12.49	2.27	0.86	2.32	2543
	International price of corn	4.62	0.09	0.39	0.40	2543
	Trade openness	3.98	0.44	0.36	0.55	2543
	Income (GDP)	22.32	1.57	0.96	1.87	2543
Wheat	Consumption	12.22	2.10	0.43	2.22	2560
	International price of wheat	4.88	0.11	0.43	0.44	2560
	Trade openness	3.99	0.44	0.34	0.55	2560
	Income (GDP)	22.30	1.57	0.96	1.87	2560

Source: Author's computation

Countries, however, differ in their choices of commodity consumption, thereby, resulting in different sample sizes for wheat, corn and rice. The difference in sample size is also attributed to missing data associated with some countries for some years. Total wheat consumption observations sum up to 2560. The overall variation about the mean for wheat consumption (12.22) is estimated at 2.22. The data reveals that wheat consumption varies more between countries (2.10) than it is within countries (0.43). Corn consumption spans over fifty-eight (58) countries with a total sample size of 2543 observations. The average of log-corn consumption is estimated at 12.49 with an overall deviation of 2.32 about the mean. The data indicates a wider variation in corn consumption between countries (2.27) than it does within (0.86) countries. Further, rice consumption also spans over fifty-eight (58) countries summing up to 2540 observations. The average log-rice consumption of 12.19 varies at 2.43 about the mean. The data shows that variation in rice consumption is larger from one country to another than it is within countries. The average log-income deviates about 1.87 about the mean (22.30). The data reveals that income varies more between countries than within countries. Trade openness varies considerably between and within countries. While overall variation in trade openness is estimated at 0.55, openness varies more from one country to another (0.44) than it does within countries (approximately 0.33) over the study period. This implies that some countries are structurally more open to trade than others.

2.6.2 Panel unit roots and cointegration tests

The panel unit root tests for: corn consumption; rice consumption; wheat consumption; trade openness; per capita income; and prices of wheat, corn and rice are presented in Table 2A.2 (in appendix). The probabilities of P, Z, L* and Pm are not significant in levels when a 'trend term' is included but becomes significant when variables are in first difference. Hence, we conclude that the data contains panel unit roots. Similarly, the Pa and Pt statistics are significant for wheat, corn and rice models. Thus, the null hypothesis of no cointegration is rejected in favour of the alternative that cointegration exist in the panel (Table 2A.3 in appendix). Thus, the requirements for estimating a panel error correction model are satisfied.

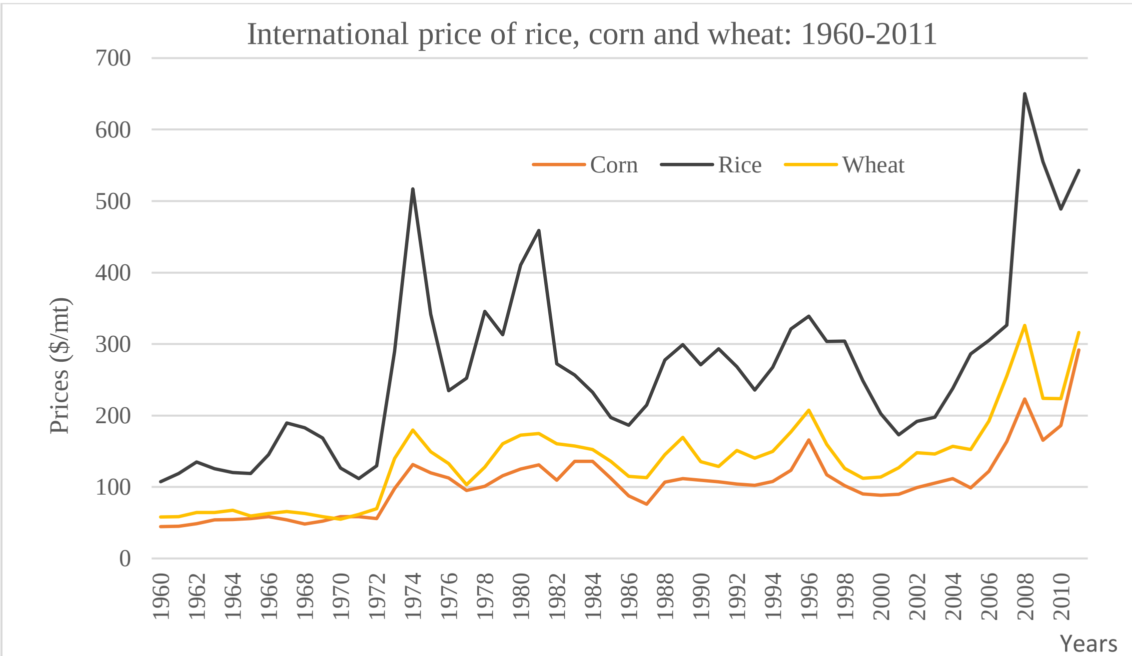
2.6.3 Estimated market responses to consumption shocks

Econometric issues in model estimation: Correlation between: rice and corn is approximately +0.87; rice and wheat is +0.89; and rice and corn is approximately +0.96 (Fig 2.7). The high correlation led to multicollinearity issues in the models. As a result, only own prices were incorporated in the estimations. The estimated panel error correction models for rice, corn and wheat are presented and discussed by commodity in the next sub-section.

Fig 2. 7 Correlation between rice, corn and wheat prices

Correlation

Rice and corn	= +0.87
Rice and wheat	= +0.89
Corn and wheat	= +0.96



Source: Author's computation using World Bank data.

2.6.3.1 Consumption response to shocks: rice

The Table 2.4 shows the estimated error correction models of rice consumption in NFIDCs. The test for overall significance for MG, PMG and DFE are all significant at 1 percent. This implies that trade openness, income and price jointly explain rice consumption in developing countries. Hence, the models are valid. Prices of wheat and corn — which measures effects of related cereals — were excluded due to multicollinearity issues. The results are discussed by impacts of international prices, trade openness and income; and estimated market responses.

Table 2. 4 Rice model results

Dependent variable: Rice consumption				
	Variable	**MG**	**PMG**	**DFE**
Long-run	International price of rice (-1)	-0.1192 (0.1020)	-0.2626*** (0.0401)	-0.1601 (0.1335)
	Trade openness(-1)	0.2119 (0.1549)	0.7684*** (0.0611)	0.1116 (0.1368)
	GDP(-1)	0.5213*** (0.0887)	0.5808*** (0.0194)	0.6009*** (0.0584)
Short-run	Δ International price of rice	0.0526** (0.0221)	0.0081 (0.0208)	-0.0064 (0.0218)
	Δ Trade openness	-0.1381* (0.0787)	-0.0688 (0.0533)	0.07572** (0.0341)
	Δ GDP	-0.1824* (0.0718)	-0.0213 (0.0396)	0.0188 (0.0358)
Response	$-(\mathbf{1}-\boldsymbol{\tau_{ij}})$	**-0.4102*** (0.0481)**	**-0. 1718*** (0.0445)**	**-0.1203*** (0.1112)**
Overall model significance (Chi-square(7))		248.96***	2639.97***	302.81***
Hausman stat. (chi-square (3))		13.66**		0.03
Sample size		2540	2540	2540

****, ** and * are 1 percent, 5 percept and 10 percent significance level*.
Model performance: DFE>MG>PMG. Hence, DFE is the statistically selected model.
Note: values in parentheses are standard errors

2.6.3.1.1 Impact of prices, trade openness and income on rice consumption

International price of rice, trade openness and income have the expected effects on long-term rice consumption under the MG, PMG and DFE models.

International price negatively affect rice consumption as expected in the long-run. This implies that rising prices reduces purchasing power and, hence, negatively affect consumption. However, its impact is found to be significant (1 percent) only under the PMG model. The results shows that a 1 percent increase in rice price leads to decrease in long-run consumption of rice by 0.26 percent in developing countries. In the short-run international price does not have significant impact on rice consumption for all cases though it does have the expected negative effect under the DFE. This implies that a price increase generally leads to a more devastating impact on long-term consumption and food security than in the short-term. This is because the attempt to substitute one cereal for another as a result a price increase lead to rising prices for all cereals in the long-term. The increased substitution drives up prices of all cereals in the long-term leading to a greater impact on consumption. The results, thus, agree with the FAO’s (2008) assertion that global food crises will increase food security risk for developing countries in the long-term.

Further, trade openness and income positively affect long-term rice consumption in developing countries as expected. This implies that long-term cereal consumption can be enhanced in developing countries with improved trade openness. Trade openness impacts are, however, only significant (1 percent) under the PMG estimation. The results shows that a 1 percent improvement in openness will lead to an increase in long-run rice consumption by 0.77 percent in developing countries. In the short-term, trade openness has a significant positive effect on rice consumption under the DFE estimation although its economic importance is relatively small compared to the long-run case. In the short-run, a 1 percent enhancement in trade openness leads to an increase in consumption by 0.08 percent under DFE. Under the PMG case, trade openness is not significant in the short-term and, also, does not meet the expected sign under MG. This results suggest that the benefits to rice consumption and food security as a result of trade openness improvements are more noticeable in the long-term. Their impacts on food security may not necessarily be immediate. A possible explanation is that the benefits of trade openness arise from efficiency gains which leads to resource use adjustments in the long-run. Without resource adjustment (as happens in the short-run), such benefits cannot be captured.

Income has a significant positive effect on long-term rice consumption as expected under all models. The results shows that a 1 percent increase in income leads to an increase in rice consumption by 0.52 percent, 0.58 percent and 0.60 percent under the MG, PMG and DFE respectively in the long-run. Income also has the expected positive effect on short-run rice consumption but not significant (under DFE). This suggest that an increased national income translates to increased purchasing power which enhances consumption and food security. However, its impacts are greater in the long-term.

2.6.3.1.2 Estimated market response to consumption shocks

Market response to consumption shocks are low in developing countries. The estimated responses are multiplied by 100 and interpreted in percentages. Market response to shocks under the DFE model is estimated at 12.03 percent (and significant at 1 percent). This means that when countries are assumed to have same consumption patterns in the short- and long-runs, the market corrects about 12.03 percent of distortions per year. This constitute a slow response because more than 50 percent of the consumption shock cannot be restored by relying on international markets. The slow response suggest that trade does not restore consumption swiftly to assure food security in developing countries, and, hence, should not be relied upon. This is because approximately 88 percent of the cereal consumption shock cannot be restored following a disruption. In the event of a large shock, the slow response will drive up food prices and likely consign a considerable proportion of food security risk people into extreme hunger. For instance, if a country's average food consumption stands at 100 million tonnes and the shock leads to a fall in supply by a million tonne, this will not affect consumption considerably. However, where the shock leads to a fall in stock available for consumption by 40 million tonnes, the slow response will create considerable impact on food security. The latter is likely to be the case because consumption shocks are relatively large in many developing countries. Consumption shocks relative to means deviates about 30 percent on average across developing countries (Table 2.3) but the impacts are fairly large (more than 50%) for some individual countries including Haiti, Malawi, and Chad among others[9].

The second case of market response to consumption shock is estimated under the PMG model, where countries are assumed to have the same consumption patterns in the long-run. Under this assumption, the estimated consumption response to shock improves to 17.18 percent, and is significant at 1 percent. Thus, the market restores approximately 17.18 percent of distortion per year following a disruption. Although, response to shocks improved compared to the DFE case, more than 80 percent of consumption shock will still not be restored without public stockholding. The response to shock is slow and, hence, not sufficiently swift to assure food security in

[9] International markets allocates global production to consumption in an open economy. The amount produced in the country is determined by international prices relative to domestic prices. Hence, the response to shocks are attributed to trade even though part of it might be coming from domestic production.

developing countries. As a result, holding public stocks to support consumption may be legitimate in these countries.

The third case of market response to consumption shock is estimated under the MG model, where countries are assumed to have different consumption patterns and response to shocks. Under this assumption the estimated consumption response to a shock improves to 41.02 percent (and significant at 1 percent). The market restores approximately 41 percent of distortion per year following a disruption. The response to shocks is an improvement compared PMG and DFE case. However, it is still slow because more than 50 percent of the shock cannot be corrected following a disruption. As a result, holding public stocks to support consumption may be legitimate in these countries.

The Hausman test for model selection between PMG and MG is significant at 1 percent. This implies that the MG model under which countries have different consumption patterns and responses to shocks is preferred to the PMG. However, the comparison between PMG and DFE is not significant which implies that the DFE is superior. Consequently, it is possible to generalise that the market mechanism (i.e. trade) corrects approximately 12 percent of rice consumption distortions in NFIDCs developing countries. However, the choice of model has no consequence on the main conclusions reached because responses are slow under each model. The DFE, MG and PMG all suggest that food stockholding can be a legitimate policy in developing countries because responses are slow. Hence, the conclusion remains the same irrespective of which model is used. As a result, this study generalises that market response to rice consumption shocks ranges from a minimum of 12 percent to maximum of 41 percent in developing countries. This is risky for food security because more than 50 percent of distortions to consumption following a shock cannot be restored. This is a concern because consumption distortions are relatively large in developing countries. Hence, allowing public stockholding in support of food security is a legitimate policy consideration in these countries.

2.6.3.2 Consumption response to shocks: corn

The estimated error correction models for corn are presented in Table 2.5. Price of wheat and rice were excluded due to multicollinearity issues. The chi-square test for overall model significance for MG, PMG and DFE models are each significant at 1 percent. This implies that international price of corn, trade openness and income jointly explain corn consumption in developing countries. Thus, the estimated models are valid. The results are discussed by impacts of international prices, trade openness and income; and the estimated market responses.

Table 2. 5 Corn model results

Dependent variable: Corn consumption				
	Variable	**MG**	**PMG**	**DFE**
Long-run	International price of corn (-1)	-0.2347 (0.2425)	-0.0884 (0.0575)	-0.3615* (0.2052)
	Trade openness (-1)	0.3725 (1.1411)	0.0082 (0.0553)	0.1678 (0.1551)
	GDP (-1)	0.6736*** (0.2033)	0.5612*** (0.0189)	0.7016*** (0.0800)
Short-run	Δ International price of corn	0.1401 (0.0835)	0.0658 (0.0437)	0.0436 (0.0386)
	Δ Trade openness	-0.0230 (0.1040)	-0.0790 (0.1887)	0.0627 (0.0454)
	Δ GDP	-0.0460 (0.0572)	0.1078 (0.0911)	0.0603 (0.0470)
Response	$-(\mathbf{1}-\boldsymbol{\tau_{ij}})$	**-0.3125***** **(0.0302)**	**-0.1564***** **(0.0235)**	**-0.1384***** **(0.0100)**
Overall model significance (chi-square(7))		141.66***	1919.68***	381.92***
Hausman stat. (chi-square(3))		0.33	6.26	
Sample size		2543	2543	2543

****, ** and * are 1 percent, 5 percept and 10 percent significance level*.
Model performance: DFE>PMG>MG. Hence, DFE is the statistically selected model.
Note: values in parentheses are standard errors

2.6.3.2.1 Impact of prices, trade openness and income on corn consumption

The international price of corn, trade openness and income have the expected signs on long-term corn consumption in developing countries.

The international price of corn negatively affect long-run consumption as expected. This implies that rising prices reduces purchasing power and, hence, negatively affect food consumption. International prices are, however, found to be only significant (10 percent) under the DFE. In the long-run, a 1 percent increase in price leads to a decrease in corn consumption by 0.36 percent in developing countries. In the short-term, price increase have no significant effects on corn consumption. This suggest that price increases have more devastating effects on cereal consumption and food security in the long-run. The effects are larger in the long-term because the substitutability between cereals/food stuffs end up increasing food prices in the long-term, leading to greater impact on consumption.

National income has the expected positive effect on long-run corn consumption in developing countries, and is significant at 1 percent. As such, a rise in the national income leads to an increase in consumption. This is because an increase in income enhances purchasing power *ceteris paribus*. The results shows that a 1 percent increase in GDP leads to an increase in corn consumption of 0.67 percent, 0.56 percent and 0.70 percent under the MG, PMG and DFE respectively in the long-run. In the short-term, national income has no significant impact on rice consumption. Thus, the results implies that growth in incomes will enhance these countries corn consumption and food security in the long-term. In the short-term, such impacts are not significant in the case of corn.

Trade openness has no significant impact on corn consumption in developing countries. This is not surprising because most corn trade is targeted at poultry and animal feed and the production of biofuels, which are largely based in developed countries. Corn consumption in developing countries often arise from domestic production.

2.6.3.2.2 Estimated market response to consumption shocks

Consumption responses to shocks are considerably low in NFIDCs. For the case of DFE, where countries are assumed to have the same consumption patterns in the long and short-runs, the market restores about 13.84 percent of consumption distortions per year. As such, over 85 percent of food consumption distortion cannot be restored. This does not assure food security in that large shocks could create significant food deficit, drive up food prices and consign a significant population into extreme hunger in developing countries. Thus, the availability of public food stocks in these countries could enable governments to alleviate these potential impacts. Where countries are assumed to have same consumption patterns (PMG) in the long-run, the estimated response to a shock is 15.64 percent, and, is significant at 1 percent. The market therefore corrects only approximately 15.64 percent of consumption distortions per year. As a result, restoring consumption will therefore require countries to have some stocks in anticipation.

Under the MG, where countries are assumed to have different consumption patterns and response to shocks, the estimated response is 31.25 percent (and is significant at 1 percent). The response to shocks is an improvement over PMG and DFE but it is still low because more than 50 percent of consumption cannot be restored by relying on the market in the event of a shock. This poses a risk to food security especially when the shock is considerably high. As a result, holding public stocks to support consumption may be legitimate in these countries.

The DFE is the selected model based on Hausman test. Consequently, it is possible to generalise that the market mechanism (i.e. trade) corrects approximately 13.84 percent of corn consumption distortions in NFIDCs developing countries. However, the choice of model has no consequence on the conclusions reached from this study. This is because responses are slow under each model. The DFE, MG and PMG all suggest that food stockholding can be a legitimate policy in developing countries. Hence, the conclusion remains the same irrespective of which model is used. As a result, it is generalised that market response to corn consumption shock ranges from minimum of 13 percent to maximum of 31 percent in developing countries. This may be risky for food security because more than 50 percent of consumption distortion are unlikely to be restored in the event of a shock. Hence, allowing public stockholding in support of food security can be a legitimate policy consideration in these countries.

2.6.3.3 Consumption response to shocks: wheat

The error correction models for wheat are presented in the Table 2.6. The price of rice and corn were excluded due to multicollinearity problems. The estimated MG, PMG and DFE models are each significant at 1 percent. Thus, trade openness, income and international price of wheat jointly explain wheat consumption in developing countries, and the estimated models are valid. The results are discussed by impacts of international prices, trade openness and income; and the estimated market responses.

Table 2. 6 Wheat model results

Dependent variable: Wheat consumption				
	Variable	**MG**	**PMG**	**DFE**
Long-run	International price of wheat (-1)	-0.4283***	-0.2902***	-0.2831***
		(0.0761)	(0.0305)	(0.0989)
	Trade openness (-1)	0.4423***	0.2101***	0.2596***
		(0.1030)	(0.0349)	(0.0788)
	GDP(-1)	0.7094***	0.5688***	0.6119***
		(0.0608)	(0.0123)	(0.0431)
Short-run	Δ International price of wheat	0.0721**	-0.0213	-0.0449
		(0.0285)	(0.0251)	(0.0304)
	Δ Trade openness	-0.0197	0.0204	0.0335
		(0.0551)	(0.0551)	(0.0365)
	Δ GDP	-0.03457	0.0558	0.0496
		(0.0490)	(0.0470)	(0.0380)
Response	$-(\mathbf{1}-\boldsymbol{\tau_{ij}})$	**-0.4615*** **	**-0.2464*** **	**-0.2241*** **
		(0.0407)	**(0.0334)**	**(0.0119)**
Overall model significance (Chi-square(7))		155.39***	4835.02***	884.50***
Hausman stat.(Chi-square(3))		5.06	0.97	
Sample size		2560	2560	2560

****, ** and * are 1 percent, 5 percept and 10 percent significance level.*

Model performance: DFE>PMG>MG. Hence, DFE is the statistically selected model.

Note: values in parenthesis are standard errors.

2.6.3.3.1 Impact of prices, trade openness and income on rice consumption

The international price of wheat, trade openness and income have the expected effects on long-term wheat consumption under the MG, PMG and DFE models.

The international price of wheat has the expected negative effects on wheat consumption, and is significant at 1 percent for all cases. Thus, a rise in wheat price will reduce consumption in developing countries. The results show that a 1 percent increase in international price of wheat leads to 0.43 percent, 0.32 percent and 0.29 percent decrease in consumption under the MG, PMG and DFE respectively in the long-run. Wheat price has the expected negative effects on consumption under DFE and PMG in the short-run but is not significant. This implies that price increases have more negative consequences on long-run consumption than it does in the short-term. The effects are larger in the long-term because the substitutability between cereals/food drive up long-term food prices leading to greater impact on consumption.

Further, trade openness and income have significant (1 percent) positive effects on long-run wheat consumption in developing countries. For instance, the results shows that a 1 percent increase in trade openness increase wheat consumption by 0.44 percent, 0.21 percent and 0.25 percent under MG, PMG and DFE respectively in the long-run. Trade openness has no significant effects on short-term wheat consumption. A possible explanation for why openness to trade largely has an impact on the long-run is that the benefits of trade openness arise from efficiency gains which leads to changes in resource use in the long-run. Without resource adjustment (as happens in the short-run), such benefits cannot be captured. In the case of income, the results shows that a 1 percent increase in national income will lead to an increase in wheat consumption of 0.71 percent, 0.57 percent and 0.61 percent under MG, PMG and DFE respectively in the long-run. Income has no significant impact on short-run consumption.

2.6.3.3.2 Estimated market response to consumption shocks

Wheat consumption responses are low in developing countries. The estimated response to shocks under the DFE is 22.41 percent and significant at 1 percent. This implies that the market restores about 22.41 percent of consumption distortions when countries are assumed to have the same consumption patterns. Consequently, over 75 percent of the distortions to cereal consumption may not be corrected in the event of a shock. This poses a risk to food security in developing countries since shock to consumption are considerably large in these countries. Thus, holding public stocks can be justified in these countries. Under the PMG where countries are assumed to have same long-run consumption patterns, the market corrects about 24.64 percent of consumption distortion annually. In the case of MG, where countries are assumed to have different consumption patterns and response to shocks, the market corrects approximately 46.15 percent of a consumption distortion annually.

The DFE is the selected model based on Hausman test. Consequently, it is possible to generalise that the market mechanism (i.e. trade) corrects approximately 22.41 percent of wheat consumption distortions in NFIDCs developing countries. However, the choice of model has no consequence on the conclusions reached in this study. This because responses are slow under each model. The DFE, MG and PMG all suggest that food stockholding can be a legitimate policy in developing countries. Hence, the conclusion remains the same irrespective of which model is used. As a result, the study generalises that market response to a wheat consumption shock ranges from a minimum of 22 percent to a maximum of 46 percent in developing countries. This is risky for food security in developing countries because more than 50 percent of distortions may not be corrected in the event of a food shock in developing countries. Since these countries face a considerably large shocks, allowing public stockholding in support of food security can be a legitimate policy consideration.

2.7 Summary results and implications for stockholding

This chapter investigated the speed of market response to consumption shocks and its implication for food security and public stockholding in developing countries. Response to shocks measured the extent to which a disruption in consumption can be mitigated by relying on the market. It is posited that where responses are low, then relying on the market to restore consumption is a risk to food security. This analysis was explored using a panel error correction model applied to wheat, rice and corn. The results established key findings that are relevant to public stockholding and food security policy in developing countries. More importantly, the results provide useful insights for the ongoing WTO policy debate regarding food security and public stockholding in developing countries. These results are summarized below (Table 2.5).

Table 2. 7 Estimated market responses

	Mean Group (MG)	**Pooled mean Group (PMG)**	**Dynamic Fixed Effect (DFE)**
Rice	41.02	17.18	12.03*
Corn	31.25	15.64	13.84*
Wheat	46.15	24.64	22.41*

Asterisk (*) mask the statistically selected model.

The results suggest that distortions in cereal consumption cannot be swiftly restored to assure food security in times of shock. For instance, the estimated consumption response indicates that the market mitigates at most: 41 percent of a rice consumption distortion; 31 percent of a corn consumption distortion; and 46 percent of a wheat consumption distortion in times of shock. Conversely, the market fails to restore approximately 59 percent of rice consumption shocks; 69 percent of corn consumption shocks; and 54 percent of wheat consumption shocks in times of food crisis. Thus, over 50 percent of the distortions to consumption cannot be restored by relying on the market. In developing countries, where cereals are an integral part of food consumption, a considerably short-fall in consumption availability can significantly increase prices and consign several vulnerable population into extreme hunger given the low responses. It therefore follows that consumption responses are not sufficiently swift to assure food security in developing countries. Hence, government intervention, including the use of public stocks, could be justified. Further, while the econometric test suggest that the DFE model is best in each case, this has no consequence on the conclusions reached. This is because responses are slow under each model. The DFE, MG and PMG all suggest that food stockholding can be a legitimate policy in developing countries. Hence, the conclusion remains the same irrespective of which model is used.

As a robustness check to these results, a similar estimate from net food exporting developing countries (NFEDCs) faced with comparable levels of food security risk, however, reveals a stronger response. Food security is also a concern for NFEDCs. However, NFEDCs' markets can restore more than 50 percent of rice, corn and wheat consumption distortions per year. A possible explanation for the higher response (compared to NFIDCs) can be attributed to their ability to limit food exports in times of shocks. The NFEDCs governments are able to limit food exports in response to public outcry when food prices rise in order to enable a swifter restoration of domestic consumption, unlike NFIDCs. Even though this has negative influence on importers food security, limiting exports in favour of domestic consumption is permitted under the WTO.

Further, estimates for net food exporting developed (NFEDEVCs) and net food importing developed (NFIDEVCs) countries shows that the markets mitigates close to 60 percent of rice, corn and wheat consumption distortions. The higher response is attributable to low transaction costs and higher market integration which enhances quicker responses compared to developing countries. First of all, food security is not a substantial issue in developed economies. Hence, the use of trade policies to limit exports in favour of domestic consumption is not common. Secondly, many developed countries are involved in regional trade agreements which reduced tariffs to zero. These, together with significant transport infrastructure supports speedy responses. Thus, these countries can afford to rely on trade to restore a significant proportion of their food needs without stockholding, unlike developing countries.

In terms of the relevance of the conclusions to WTO policy debates on public stockholding, the results suggest that food security can be negatively affected in countries without stocks to support consumption in the event of a shock. This is because market responses are too slow to assure food security. Trade cannot be relied upon to swiftly restore consumption or address food security in the event of a food crisis. The slow responses have been found to be peculiar to only NFIDCs. Thus, there is the need for government interventions in these countries. Hence, public stockholding in NFIDCs can be a legitimate policy. Public stocks are also important in NFIDCs because current WTO regulations on export restrictions have not been resolved. This renders food importing countries without public stockholding programs to be vulnerable to export restrictions.

The research results also show that trade openness and income enhances food security to a greater degree in the longer term. Such impacts are not substantial, for the most part, in the short-run. Further, while international prices have larger negative consequences on long-run cereal consumption and food security in NFIDCs[10], their short-term impacts are not significant. The trade

[10] The results discussed were estimated without prices of related cereals due to multi-collinearity. As a robustness check, price of wheat, corn and rice where summed and divided by 3. This served as an average cereal price index which is an embodiment of all cereal prices. Similarly, rice, corn and wheat were aggregated and divided by 3 to

openness results generally agree with the recommendations of Konandreas (2012) and Dorosh (2008) suggesting that countries facilitate trade in order to enhance food security in developing countries. The results also finds evidence that income enhances consumption in NFIDCs as established in Konandreas (2012).

obtain average cereals consumption for each country. This was then regressed against trade openness, average cereal prices and income. The estimated market response was still low (less than 34 percent).

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Appendix

Table 2A. 1 List of countries used in the study

NFIDCs		NFEDCs	NFIDEVCs	NFEDEVCs
Afghanistan	Madagascar	Argentina	United States	Italy
Algeria	Malawi	Brazil	Canada	Japan
Bangladesh	Mali	Ukraine	Australia	Portugal
Belize	Mauritania	Thailand	New Zealand	Sweden
Benin	Mongolia	South Africa	Netherlands	Switzerland
Burkina Faso	Morocco	Russia	Spain	United Kingdom
Central African Republic	Mozambique			
Cambodia	Namibia			
Cameroon	Nepal			
Chad	Nicaragua			
China, mainland	Niger			
Cote d'Ivoire	Nigeria			
Cuba	Pakistan			
Dominican Republic	Panama			
Egypt	Peru			
El Salvador	The Philippines			
Gabon	Senegal			
Gambia	Sierra Leone			
Ghana	Tanzania			
Guatemala	Togo			
Guinea	Trinidad and Tobago			
Guinea-Bissau	Tunisia			
Guyana	Uganda			
Haiti	Venezuela			
Honduras	Vietnam			
India	Zambia			
Indonesia	Zimbabwe			
Jamaica				
Kenya				
Lao				
Liberia				

Key
NFIDCs – Net food importing developing countries
NFEDCs - Net food exporting developing countries
NFIDEVCs – Net food importing developed countries
NFEDEVCs – Net food exporting developed countries

Table 2A. 2 Fisher-Panel unit root test

		Levels		Difference	
Variable	Test	Constant	Trend	Constant	Trend
	P	105.0055*	12.1174	488.7723*	401.5658*
Wheat consumption	Z	-3.1076*	7.7034	-18.3000*	-15.4245*
	L*	-3.2894*	8.2430	-24.2585*	-19.7997*
	Pm	3.8620*	-4.4796	38.3253*	30.4939*
	P	236.1912*	60.1577	822.8082*	628.3863*
Corn consumption	Z	-5.4759*	5.1654	-22.9749*	-17.4256*
	L*	-6.2762*	5.6503	-31.7060*	-23.6669*
	Pm	9.3953*	-2.9295	50.4667*	36.8544*
	P	201.1818*	38.6396	774.3030*	611.7578*
Rice consumption	Z	-4.5517*	8.0547	-22.4260*	-17.8126*
	L*	-4.5605*	8.4678	-30.0954*	-23.2528*
	Pm	7.1546*	-4.6924	47.6804*	36.1867*
	P	152.8271***	76.7204	512.1582***	180.2825***
GDP	Z	-3.9983***	1.8859	-16.9592***	-4.6461***
	L*	-3.7923***	1.8145	-19.6298***	-4.8958***
	Pm	3.5586***	-1.7699	28.7168***	5.6909***
	P	101.4789*	102.2952	520.5261*	280.5729*
Rice export price	Z	-5.6006*	-0.3796	-17.7219*	-9.0970*
	L*	-11.017*	-0.3942	21.1231*	-10.3119*
	Pm	15.4430*	0.7590	31.5914*	13.9020*
	P	-11.1306*	-0.3796	-17.7219*	-9.0970*
	Z	-11.8017*	-0.3942	21.1231*	-10.3119*
Wheat export price	L*	15.4430*	0.7590	31.5914*	13.9020*
	Pm	-9.8493*	3.0742	-18.2504*	-7.7392*
	P	0.0000	0.0000	-17.7219*	-9.0970*
Corn export price	Z	-	-	21.1231*	-10.3119*
	L*	-	-	31.5914*	13.9020*
	Pm	-	-7.1414	-18.2504*	-7.7392*
	P	390.4014***	129.8669**	777.4799***	639.0078***
Trae openness	Z	-13.3687***	-1.0932	-22.5530***	-19.5328***
	L*	-14.7521***	-1.5893	-30.0144***	-24.5774****
	Pm	-20.1921***	1.9511**	47.2931***	37.5981***

Note: *; **; *** indicate significance at 1%; 5% and 10% levels, at 2 lags.

Table 2A. 3 Westerlund panel cointegration test

Ho: No cointegration in each panel

Ha: At least cointegration exist in one panel

Panel cointegration test: Rice model (with constant and trend)

Statistic	Value	Z-value	P-value
Gt	-3.659	-5.027	0.000***
Ga	-20.405	-2.783	0.003***
Pt	-14.209	-3.104	0.001***
Pa	-16.885	-2.839	0.002***

Note: *; **; *** indicate significance at 1%; 5% and 10% levels.

Panel cointegration test: Corn model (with constant and trend)

Statistic	Value	Z-value	P-value
Gt	-2.641	0.323	0.627
Ga	-15.226	0.167	0.566
Pt	-13.766	-2.922	0.002***
Pa	-18.167	-3.523	0.000***

Note: *; **; *** indicate significance at 1%; 5% and 10% levels.

Panel cointegration test: Wheat model (with constant and trend)

Statistic	Value	Z-value	P-value
Gt	-3.089	-2.028	0.021**
Ga	-16.593	-0.608	0.272
Pt	-12.957	-1.773	0.038**
Pa	-14.289	-1.282	0.100*

Note: *; **; *** indicate significance at 1%; 5% and 10% levels.

CHAPTER 3

Restrictiveness of aggregate measure of support on public stockholding for food security purposes

Abstract

This chapter analyses the restrictiveness of the de minimis aggregate measure of support (AMS) restriction on public stockholding for food security purposes in developing countries. The chapter focuses on rice, corn and wheat in the G-33 countries. Using a two-period intertemporal storage model, optimal public stocks required to ensure food security are estimated and compared with stock levels permitted under the WTO. The policy is restrictive if optimal public stocks required to achieve food security are constrained by WTO permitted stock levels. The results shows that the current de minimis AMS policy is restrictive on stockholding for food security in selected countries. Hence, expanding the regulation to enhance stockholding can be justified in the case of these countries. The policy is, however, not restrictive on stockholding in India and China.

3.1 Introduction

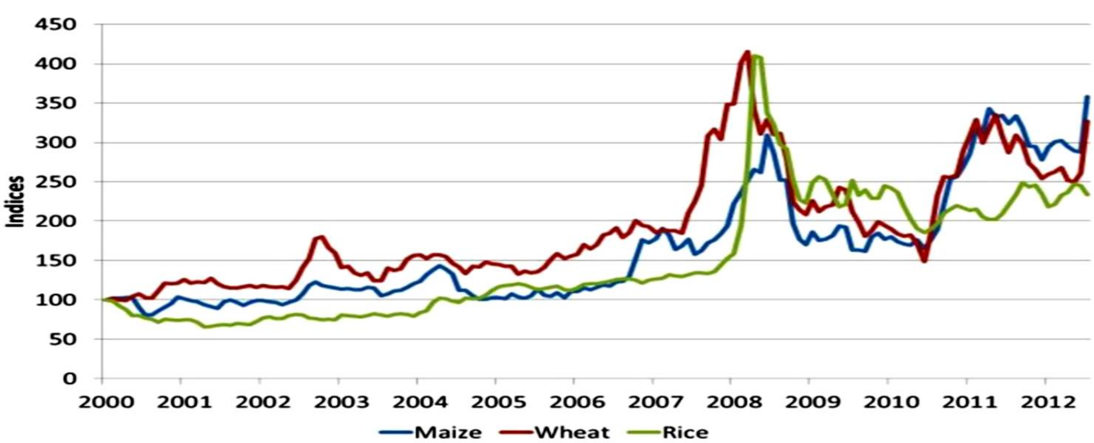
Public stockholding is an important facet of food security policy because food scarcity can lead to catastrophic social and economic costs (Gardner, 1979). The Great Chinese Famine (1959-1961), arguably the most devastating famine of the 20th century, is estimated to have caused between 16 million to 45 million deaths due to food scarcity (Meng *et al*, 2015). A number of studies also attribute the recent political unrest in the Middle East and North Africa, at least in part, to the 2007/2008 and 2010/2011 food crises (Lagi *et al*, 2011; Malik and Awadallah, 2013; Sternberg, 2012). According to Zurayk (2011) as reported by *The Observer* newspaper, in Egypt for instance:

> "When grain prices spiked in 2007-2008, Egypt's bread prices rose 37%. With unemployment rising as well, more people depended on subsidized bread – but the government did not make any more available. Egypt's annual food price inflation continued and had hit 18.9% before the fall of President Mubarak".

In an integrated global economy, public stockholdings for food security purposes is usually pursued in countries where market supplies are inadequate to achieve food security. Consequently, countries exposed to higher degrees of food security risk, in particular, tend to hold public stockpiles to mitigate its potential impact. This is important for developing countries because a considerable percentage of their people face high food security risk.

The renewed interest in public stockholding, in recent years, follows the challenges faced by food importing countries during the 2007/2008 food crisis. The spike in global food prices (Fig 3.1) threatened food security in exporting and importing developing countries (DFID, 2013). Consequently, food exports were restricted from some major agricultural countries including Ukraine, Russia, China and Argentina in order to protect their domestic food security (Sharma, 2011). The absence of food stocks in low-income food deficit countries pushed over 75 million additional people into extreme hunger (FAO, 2008; World Bank, 2009). Rapsomanikis (2009) notes that the rapid increase in food prices also translated into unanticipated and large import bills for food and foreign exchange problems for most countries which were already facing a range of food security challenges.

Fig 3. 1 Rice, maize and wheat price indices



Source: IMF, cited in DFID (2013).

While these events suggest a role for stockholding in developing countries, the amount of stocks a country can hold is restricted under WTO agreement. The WTO limits are focused on the trade distortionary aspects of public stockholding programs because stock acquisition provides a direct subsidy to producers (Matthews, 2012, 2014a, 2014b)[11]. Public stocks can be an important social intervention for countries faced with food insecurity. However, because stocks are acquired at an intervention price usually above the competitive market prices, the price difference becomes a subsidy which induces additional production beyond the competitive market level. For large importers, subsidy-induced domestic production can reduce imports and depress international prices. Similarly for large exporters, stockholding can increase exports, depress international prices and discourage long-term agricultural production and reduce food security in other economies. Thus, domestic subsidies, including those used to acquire public stocks, are part of country's Aggregate Measure of Support (AMS). The aggregate domestic support levels were negotiated down and bound during the Uruguay Round of WTO negotiations as a result of their perceived trade distortions. Consequently, countries remain critical about the levels of support provided to industries because the violation of these limits can attract disciplinary measures from other WTO members.

Support to public stockholding is one of the major ways through which countries are likely to violate their bound subsidy levels. In the case of public stockholding, the total subsidy/support provided to stock acquisition is determined based on the price difference between the intervention and an external reference price. Mathematically, the total AMS provided in public stock acquisition is stated as,

$$AMS = \frac{[Intervention\ price - Fixed\ external\ reference\ price]}{Total\ value\ of\ domestic\ production} * Eligible\ Production * 100 \qquad (3.1)$$

The intervention price, also known as government administered price, refers to the price at which public stocks were acquired from domestic producers (Montemayor, 2014). The fixed external reference price is the base price upon which the government administered price is compared to. The fixed external reference price is the 1986-1988 average of the cost insurance freight (c.i.f.)

[11] It is largely understood that all forms of subsidies are trade distortionary including public stock acquisition but the WTO restrictions, however, exempt subsidies for research and development, environmental protection and other regional development programs (the "green box" subsidies) because they are perceived to have minimal trade impacts. Whether the latter is a correct presumption is, of course, an empirical question.

prices of product notified to the WTO (Montemayor, 2014). The WTO text does not explicitly state what constitute eligible production. As a result, eligible production has been operationalized either as total production or total stock acquired.

The potential for stockholding to distort trade has therefore brought limits on the extent to which countries can subsidies stockholding. The maximum agreed limit of AMS allowed under the WTO is known as the *de minimis* limit. For developing countries, *de minimis* AMS on actionable subsidies to farmers, including the acquisition of public stockholding, cannot exceed 10 percent of the total value of production. The *de minimis* limit for developed countries is 5 percent of the value of domestic production. Any evidence of *de minimis* violation may attract countervailing duty action against products of the affected country.

To illustrate how the *de minimis* AMS feeds into bound AMS, assume the total value of a cereal (e.g. corn) produced in a given year is $100 million. Further assume the subsidy provided by government in stock acquisition is $9 million. In this instance, the AMS for stockholding constitutes 9 percent of the value of domestic production. Since this is below the *de minimis* requirement (i.e. 10 percent), the entire $9 million will not count towards the bound AMS. In another instance, if subsidy provided in stock acquisition was $30 million, this will amount to 30 percent of the value of domestic production. Since this is above the *de minimis* requirement, the entire $30 million will count towards the bound AMS level. Bound subsidy levels were relatively low (or even zero) for most developing countries because agricultural subsidies, in general, were low. Consequently, any violation of the *de minimis* AMS requirement immediately pushes countries towards their bound subsidy limits or causes them to violate their bound limits.

The *de minimis* limit, in effect, determines the maximum annual levels of public stocks a country can acquire without violating its WTO commitment irrespective of a country's food security risk level. This is a non-issue if the *de minimis* permitted stocks are optimal to achieve food security. *De minimis* is also not a concern if private sector storage is sufficient to achieve food security without the need for government intervention. However, for many developing countries whose private sector is faced with diverse forms of transaction costs and market failures, a stringent requirement for governments to limit stockholdings may be injurious to food security if private market storage is inadequate. The impact of such a restriction can be more severe for countries exposed to a higher degree of food security risk. For this group of countries, relaxing the AMS policy to enable them expand their stockholding can be legitimate. The number of G-33 countries that have, however, reached their *de minimis* limit are unknown because countries have not been transparent with their stockholding data. Notwithstanding, there has been challenges on stockholding activities of developing countries (including India, China, Indonesia) which seem to suggest that these countries might be exceeding their limits. Though countries typically do not reveal their stock levels, inferences about their de minimis subsidy are based on notified external references prices to the WTO, current prices in their domestic economies and actual production levels even though affected countries disagree with the use of actual production[12].

The *de minimis* limit on stockholding was largely a non-issue prior to the 2007/2008 food crisis because stockholding acquisitions in developing countries were low (Konandreas and Mermigkas, 2014). With growing uncertainty about future food security, the incentive to support agriculture and acquire public stocks for food security purposes intensified. For instance, the New Food Security Act of India hopes to distribute foods from public stocks to an estimated 75 percent of its population. This represents a dramatic expansion in stockholding expenditure for India (Dreze, 2013; Fritz, 2014). In Brazil - a country with the largest public stocks, government expenditure on stockholding is expected to increase considerably as it prepares to double the number of beneficiaries under its zero hunger project (Fritz, 2014). With these intended expansions in stockholding activities across developing countries, the *de minimis* restriction is set to become a significant barrier to government's ability to support stockholding for food security purposes.

Consequently, a group of developing countries, referred to as the G-33, petitioned the WTO for regulatory changes to the limits on public stockholding (WTO, 2013). The G-33 argued that the manner in which AMS is calculated puts vulnerable developing countries at risk of breeching their *de minimis* limit. This is because, first, the fixed external reference price upon which AMS values were based (the 1986-88 average c.i.f.) does not account for inflation. Secondly, global prices were depressed over 1986-88 period thereby widening the gap between the intervention and reference

[12] Countries use actual production level because the WTO text does not explicitly specify what constitute "eligible production" in the AMS determination (equation 3.1). As such stockholding countries argue it should be the actual stock levels acquired (which they do not reveal) while countries challenging stockholding argue it is total production (which is observed). Consequently, countries challenging the de minimis AMS often use actual production even though affected countries disagree.

price (ICTSD, 2014a, 2014b, 2014c; Matthews, 2014a; Montemayor, 2014). The two effects combine to inflate the AMS figure and increase the likelihood of violating the *de minimis* limit. Consequently, the G-33 wants public stockholding for food security purposes to be allowed without limits.

Even under the current policy, contention remains among countries on how the AMS should be determined. This is because the WTO's legal text does not explicitly define what constitutes "eligible production" in the determination of AMS. Whereas some interpret "eligible production" to mean total production, others suggest it should be actual stock levels acquired (DTB, 2011, 2014). Notwithstanding the fact that "total production" increases the chance of violating *de minimis*, data on actual stocks procured for public stockholding programs for most countries are not readily available (ICTSD, 2015). The failure to reach agreement on appropriate subsidy levels led to the introduction of the *Peace Clause* which temporarily protect stockholding programs from being challenged by other WTO member countries while a lasting solution is sought in the coming years (Haberli, 2014). Finding a lasting solution to stockholding is one of the contemporary issues being considered under the WTO.

As a result, a number of proposals have been made regarding public stockholding restrictions following the petition. These include: (1) expanding the *de minimis* limits for developing countries; and (2) adjusting AMS for the rate of inflation associated with the fixed external reference price (Diaz-Bonilla, 2013; Matthews, 2014a). Using total production, Montemayor (2014) undertakes simulations which indicate that strict application of AMS increases the likelihood of *de minimis* violation. Further, applying AMS to foodstocks notified to the WTO revealed that India's rice program did not violate AMS when reference prices are adjusted for inflation (Konandreas and Mermigkas, 2014) consequently giving credence to calls to account for inflation in the AMS determination. Although these studies provide useful insights into AMS restrictions, public stocks needed to achieve food security or adjustment to AMS such that food security can be achieved in developing countries have not been examined. Moreover, no empirical studies have examined as to whether or not the current AMS regulation even constitute a restriction on food security in developing countries.

The chapter contributes to assessing the need for public stockholding policies in developing countries. However, the assessment focuses on whether or not the current *de minimis* AMS policy constitutes a restriction on public stockholding for food security purposes. The research argues that it will be legitimate for public stockholding policies to be expanded in developing countries if the current *de minimis* AMS regulations constitute a constraint on stock levels needed to achieve food security. The specific objective of this chapter is, therefore, *to evaluate the restrictiveness of de minimis AMS policy on optimal public stockholding for food security purposes in developing countries, focusing on G-33*. Further, while the *de minimis* limits does not consider the level of risk faced by countries, there are, however, considerably reasons to believe that a stringent regulation that limits government's ability to provide public stock will be more severe on countries faced with higher food security risk. Consequently, the restrictiveness analysis is conducted by categorising countries as having high, moderate and low food security risk levels.

A key assumption is made in order to undertake this analysis. The research primarily assumes that public stocks are required only when the market fails to provide sufficient stocks to achieve food security. Based on this assumption, the following steps are taken to evaluate the *de minimis* AMS policy's restrictiveness on public stockholding for food security purposes.

1. Optimal stock levels needed to achieve food security in each country are determined. This is referred to as 'food security consistent stocks'.
2. Optimal public stocks required in each country is determined. Optimal public stocks is the difference between 'food security consistent stocks' and the 'observed market storage'.
3. Public stock levels permitted under the WTO (i.e. *de minimis* permitted stocks) are estimated.
4. Finally, the restrictiveness is evaluated by comparing 'optimal public stock levels required to achieve food security' with 'permitted public stocks levels under the WTO'. Optimal public stocks in excess of permitted public stocks indicates that the *de minimis* AMS policy is restrictive.

The restrictiveness of the *de minimis* AMS policy often arises during a major food crisis where countries desire to hold stocks but are not permitted to do so as a result of the policy. While some countries can still be constrained in normal years, the availability of alternative market opportunities (through which countries can imports) reduces such concerns. Under normal years, markets are not typically interrupted. Consequently, a shock to a country's consumption can be resolved by importing from other countries. The AMS restrictiveness analysis therefore requires specific years where a food crisis occurred. This study uses the most recent food crisis of 2010/2011. While a number of food crisis occurred prior to 2010/2011, the recent 2010/2011 food crisis is preferred because it will provide the most current information about the extent of restriction posed by the *de minimis* policy. The restrictiveness analysis focus on stocks to be carried from 2010/2011 to 2011/2012. The research is conducted using wheat, corn and rice because these cereals form the core of food security stock programs in developing countries.

The study is important because the evaluation of AMS restrictiveness on public stockholding for food security purposes will be helpful to parties negotiating stockholding policy at the WTO. Specifically, knowledge of AMS restrictiveness is important in determining whether or not the current AMS should be expanded for developing countries. The remainder of the chapter is organized as follows: section 3.2 is an overview of food security and cereal stocks in the G-33 developing countries; section 3.3 reviews the relevant literature on AMS and public stockholding; section 3.4 develops the methodology used in the paper; section 3.5 provides the results and discussion; and section 3.6 offers conclusions and recommendations.

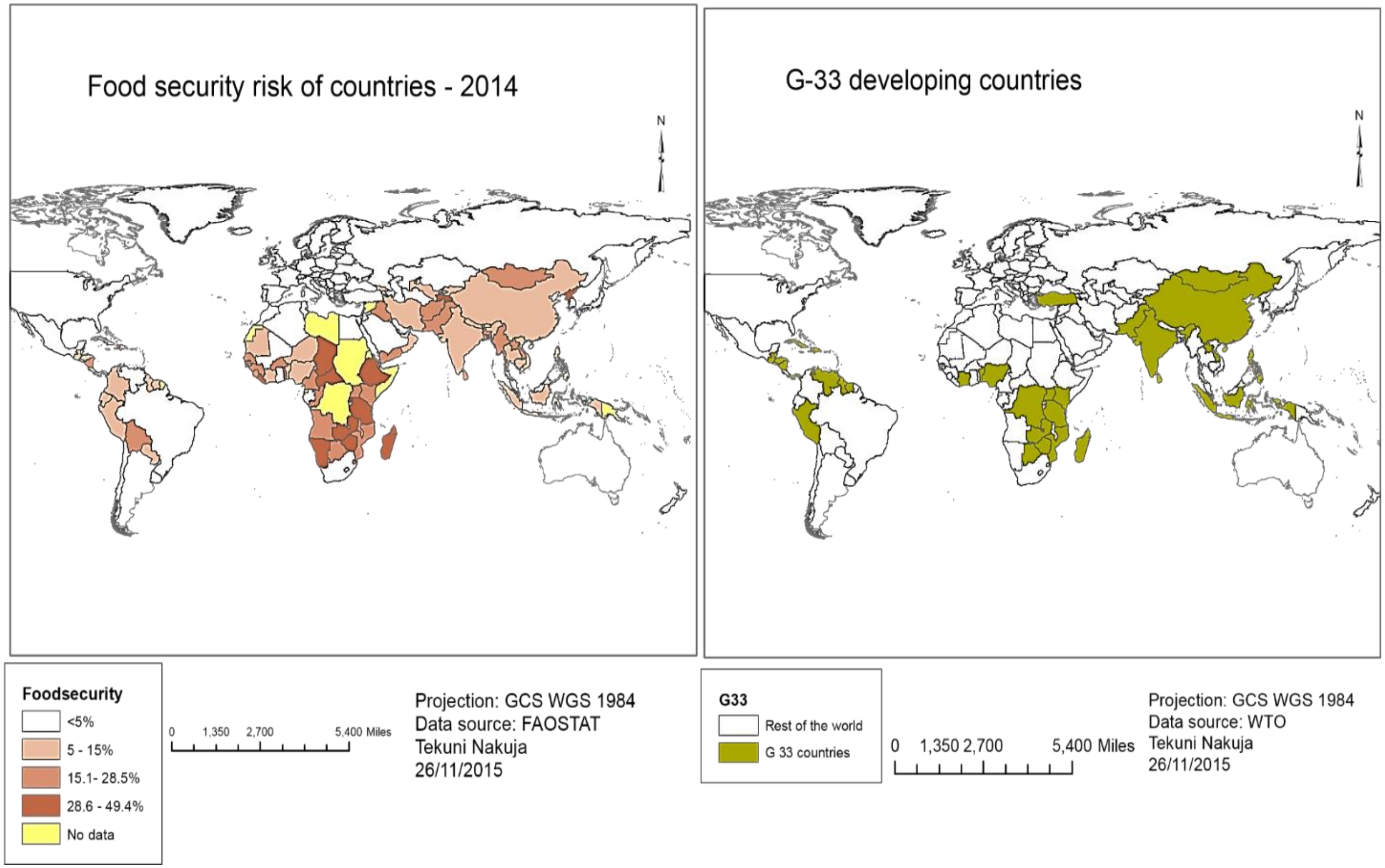
3.2 The current state of food security in G-33

The FAO employs a number of metrics for measuring food security. These metrics cover food availability, accessibility, stability of supply and utilization. The most widely used measure for comparing food security across countries is 'Prevalence of Undernourishment' (PoU). In the FAO's (2014) report titled *The State of Food Insecurity In the World*, PoU forms the primary indicator for comparing food security across countries. The PoU measures the probability that a randomly selected individual of a country is undernourished (Naiken, 2003). A country is considered 'hunger free' and 'food secured' when probability of undernourishment falls below 5 percent. The PoU is calculated as a 3-year moving average for each country. Hence the most current data (i.e. 2012-2014 average) is used to describe the current state of food security risk of G-33 members in this chapter.

Food security risk for 2012-2014 is shown in Fig 3.2. Food security risk is less than 5 percent in Europe, North America, Australia and, parts of Africa and South America. These are the food secure regions. Food security risk is high (i.e. greater than 5 percent) in sub-Saharan Africa, parts of Central and South America, and Asia. These are considered food security risk countries. Food security risk also varies among countries. For instance, the risk is less in Nigeria (5-15 percent) compared to Madagascar where the chance of undernourishment is about 30 percent.

Juxtaposed on the food security risk are the G-33 countries. Comparing the two maps, it is revealed that G-33 members are largely food security risk countries. The *State of Food Insecurity in the World* shows that, for 2014, about 65 percent of the world's food insecure population (805 million) live in G-33 countries (FAO, 2014). Food security issues are politically topical in G-33 because of their high dependency on food imports, which makes them vulnerable to trade policies of exporting countries (Konandreas, 2012). As a result, food security policies in many countries have shifted towards building public foodstocks (especially cereals) in anticipation of shocks from domestic and international sources.

Fig 3. 2 Food security risk and the G-33 group of developing countries



3.2.1 Cereal stocks in G-33 developing countries

Cereal stocks comprise of public and private stocks. However, the proportions of public and private stocks are unknown because governments are usually unwilling to reveal the levels of stocks acquired. As a result, stocks reported in most countries are aggregated comprising of both private and public stockholdings. Cereal stocks discussed in this section are the aggregate stocks (private and public) reported for each country by the USDA.

The G-33 account for a considerable proportion of global cereal stocks (Table 3.1). Average cereal stocks in the world over the period of 1960 to 2011 is approximately 313 million tonnes. Of these, 168 million tonnes representing 53.8 percent of global stocks have been held in G-33 developing countries. The G-33 also held about 88 percent, 48.1 percent and 40.3 percent of the average global rice, corn and wheat stocks respectively from 1960 to 2011.

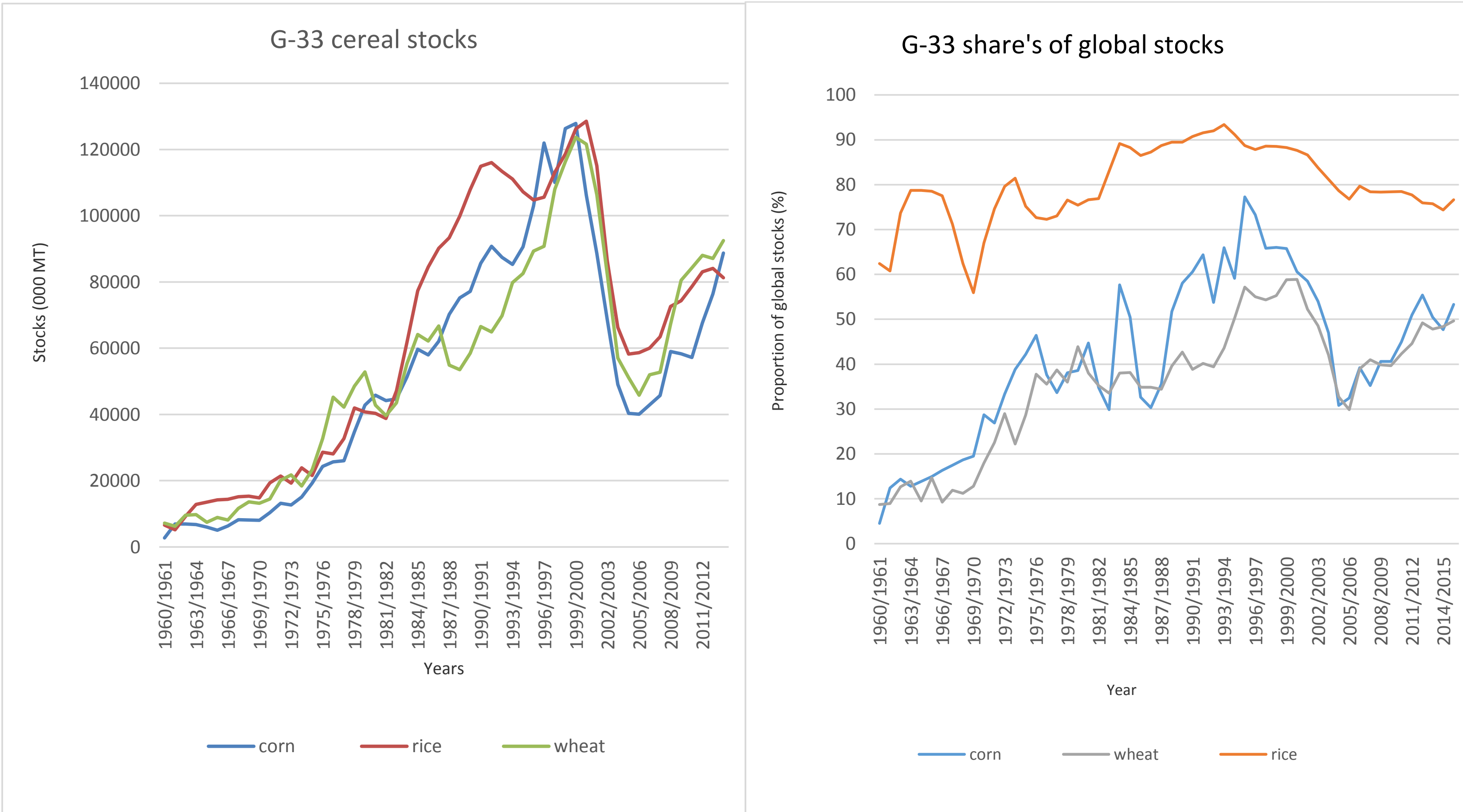
Table 3. 1 Cereal stocks in G-33: 1960 - 2011 averages

Cereal	World (000 tonnes)	G-33 (000 tonnes)	% of world
Rice	71,216.0	62,626.6	88.0
Corn	107,595.0	51,775.7	48.1
Wheat	134,210.0	54,027.2	40.3
Total stocks	313,021.0	168,429.4	53.8

Source: Author's computation using USDA data.

In terms of trend, cereal stocks in the G-33 countries experienced three major changes over the period of 1960 to 2011 (Fig 3.3). First, aggregate stocks increased considerably from 1960 to 2000. Rice, corn and wheat stocks each increased from approximately 7 million tonnes in 1960 to 130 million tonnes by 2000, representing over 1700 percent growth. This dramatic accumulation of stocks translated into an increased proportion of global stocks held in the G-33 countries.

Fig 3. 3 Cereal stocks in G-33: 1960 - 2011



Source: Author’s computation from USDA FAS data.

For instance, the G-33's share of global rice stock increased from 60 to 88 percent while corn and wheat shares rose from 5 to 66 percent, and 8 to 60 percent, respectively. The growth in stocks emanated primarily from East Asia (Fig 3.4) where devastating famines in China (the Great Chinese Famine[13]) and India (the Bengal Famine in 1943) are said to have influenced policies towards public stockholding. Consequently, stocks between 1960 and 2000 are arguably public stocks held to mitigate future supply shocks. The growth in stocks increased food security due to improvements in countries' ability to support consumption in times of a food crisis.

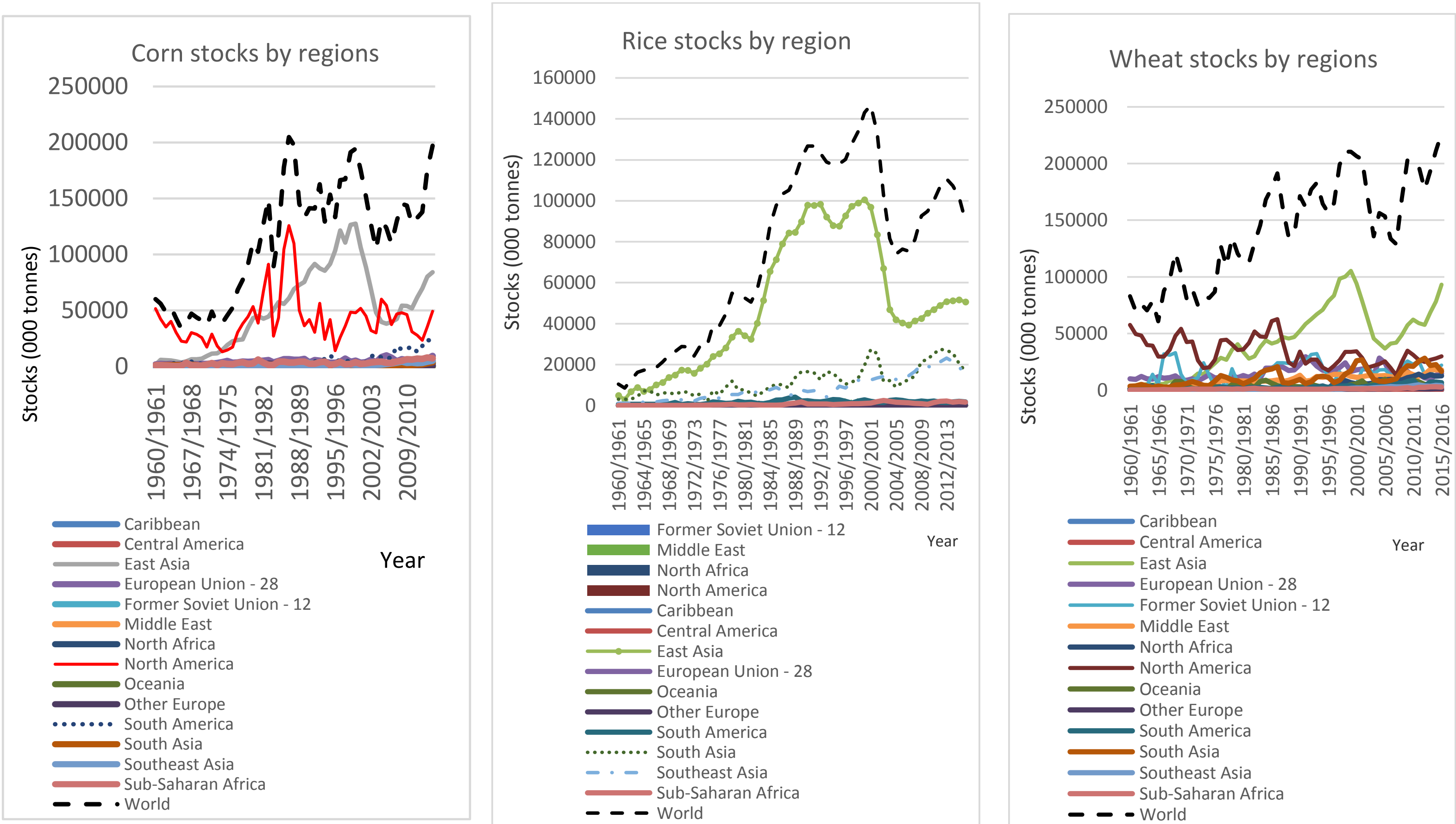
The second phase of change in cereal stocks occurred from 2000 to 2006 where wheat, rice and corn stocks declined considerably. Rice stocks declined from 130 million (in 2000) to 60 million tonnes (in 2006), signifying an over 50 percent reduction. Consequently, the G-33's share of global rice stock declined from 88 percent to 76 percent. Corn and wheat stocks declined from 120 and 122 million tonnes (in 2000) to 40 million and 45 million respectively by 2006, leading to decline in global shares from 60 percent to 30 percent in 2006. The decline in stocks can be attributed to two sources. First, China's (the global leading stockholder) accession to WTO (in 2001) brought disciplines on government stockholding. Consequently, China and East Asian stocks declined considerably. This reaction, together, with a series of crop failures in major production regions including Ukraine, US and Argentina, and the increasing use of cereals for biofuel lead to a decline in stocks (Hansen, 2013). The decline in stocks eroded countries ability to mitigate food security risk and support consumption in times of a shock. Stocks reached their lowest level in 2007/2008 and coincided with the 2007/2008 food crisis.

The third phase of change to cereal stocks follows 2007 food crisis. Wheat, rice and corn stocks have been increasing since 2007. Corn, wheat and rice each increased from 40 million, 45 million and 58 million (in 2007) to 87 million, 92 million and 81 million tonnes (in 2014) respectively. The increase in stocks following 2007 is attributable to the food crisis of 2007, which reignited interest in building stocks for food security purposes in developing countries. Consequently, global corn, wheat and rice stocks began rising following 2007. This is in accordance with plans and policies to reduce food security risk in times of shocks. Notwithstanding the change in stocks, the

[13] The Bengal Famine led to over 3 million deaths (Sen, 1981).

amount of stocks directly under government control (i.e. public stocks) are largely unknown due to the unwillingness of countries to disclose their stock levels.

Fig 3. 4 Rice, corn and wheat stocks by region: 1960 - 2011



Source: Author's computation from USDA FAS data.

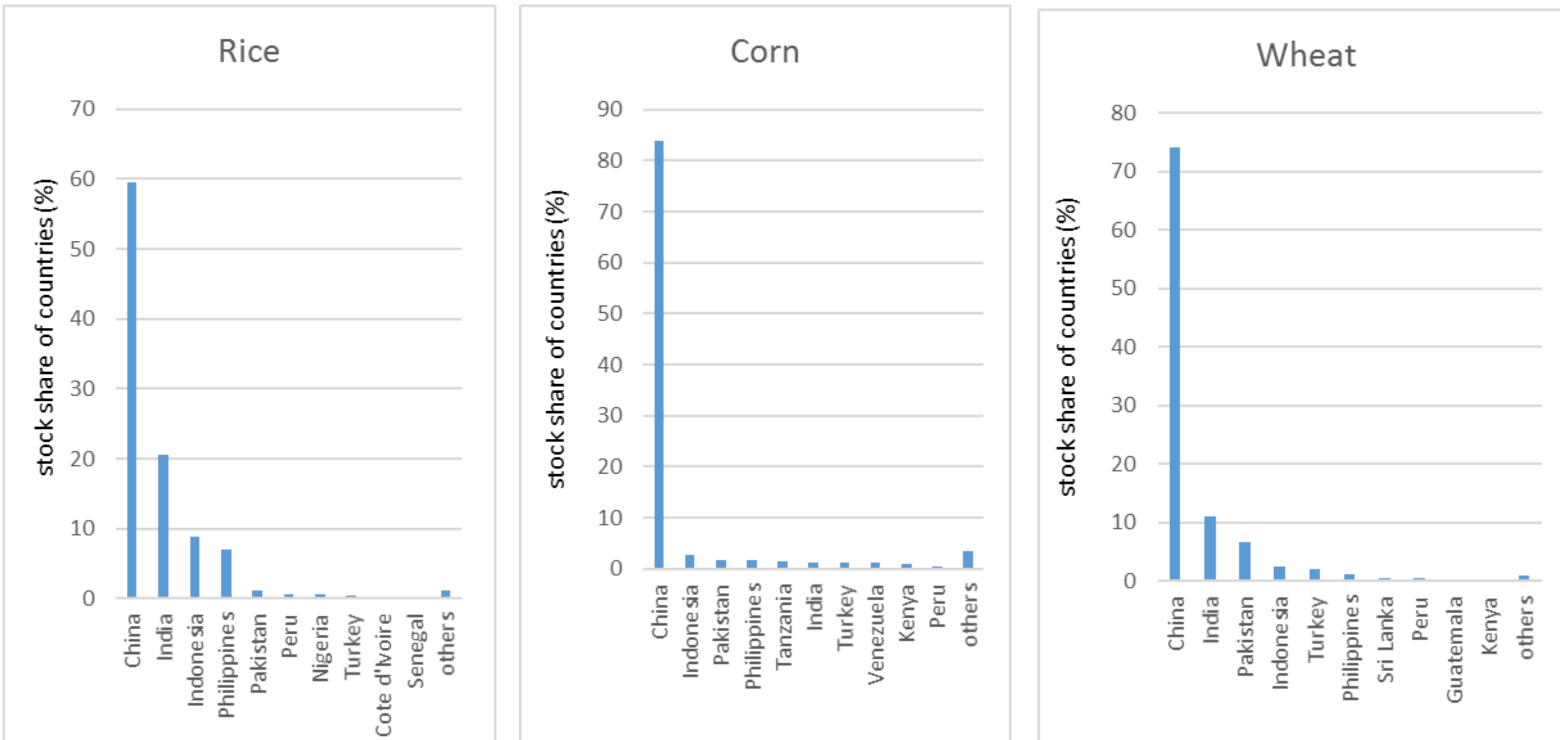
3.2.2 Stock shares among G-33 developing countries

Despite the significant accumulation of stocks in the G-33, most stocks are actually concentrated in China. In 2010/2011, for example, China held approximately 60 percent, 74 percent and 83 percent of total rice, wheat and corn stocks in G-33 countries (Fig 3.5). Other countries with considerable rice stocks include India, Indonesia and the Philippines, with approximately 20 percent, 9 and 7 percent of rice stocks respectively. Thus, nearly 96 percent of rice stocks in G-33 are controlled by China, India, Indonesia and Philippines. A considerable proportion of wheat stocks is also held by India, Pakistan, Indonesia and Turkey, each holding 11 percent, 7 percent, 2 percent and 2 percent respectively. Hence, approximately 96 percent of total wheat stocks in G-33 have been held by China, India, Pakistan, Indonesia and Turkey[14].

The importance of these stocks to the food security of their respective countries cannot be overemphasized. At risk countries desire to store against supply shocks. However, examining the volume of stocks alone provides no information about the comparative food security risk/strength across countries. This is because large countries will likely possess large stocks due to their high consumption relative to smaller countries. Thus, using aggregate stocks as a measure of food security risk/strength (without considering stocks on per capita basis) can be misleading, and can also be biased against smaller countries. Consequently, per capita stocks are examined, in the next section, in order to provide a comparative picture of the food security risk/strength provided by the stocks of each country.

[14] Even though China, India, Pakistan, Indonesia and Turkey have most stocks, whether or not these countries will require public stockholding programs is unknown. Further, it is also unknown which G-33 countries will require public stockholding. Hence, the study explores the entire G-33 countries to determine which ones could potentially benefit from stockholding programs.

Fig 3. 5 Stock shares among G-33 countries: 2010/2011



Source: Author's computation from USDA FAS data.

3.2.3 Per capita stocks as a food security risk measure

The high aggregate stocks in China, India, Pakistan, Indonesia and Turkey may provide misleading indications about food security (without considering stocks on per capita basis) relative to other countries. This is because they are high population countries which store more tocks relative to other countries. Per capita stocks measures the stocks available to support individual consumption in times of shocks across countries. Hence, countries with high per capita stocks are more food secure and vice versa. The indicator also eliminates bias against smaller countries and provides a comparative measure of the strength of protection provided by food stocks in each country.

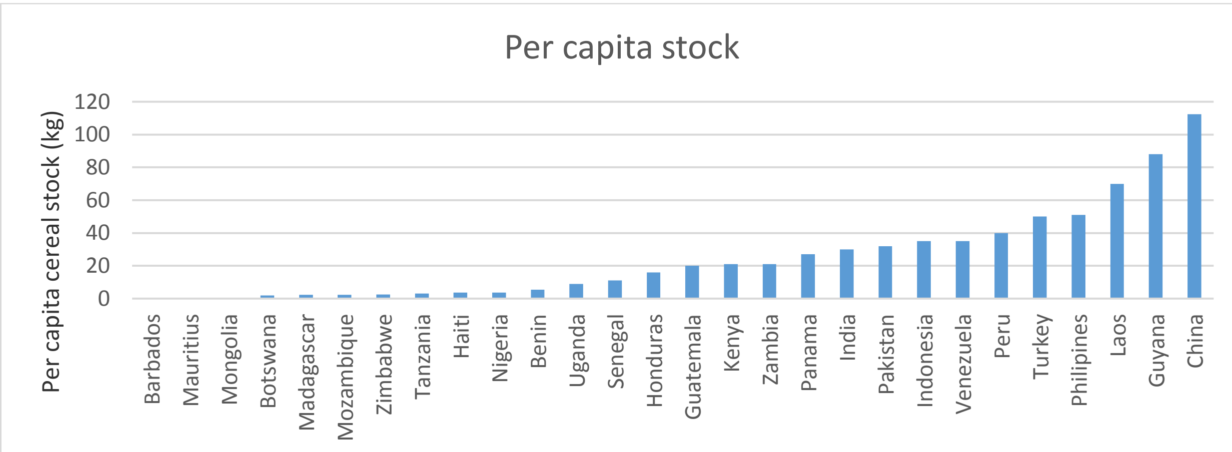
To analyse the overall food security risk based on per capita stocks, wheat, corn and rice are converted to cereal equivalent. The cereal equivalent conversion, developed by FAO, assumes that rice, wheat and corn have the same amounts of calories per volume. Hence, 100kg of rice is equivalent to 100 kg of corn or wheat (see Rask and Rask, 2014). Consequently, wheat, corn and rice were converted to aggregate cereal equivalent (kg) and their per capita stocks determined (Fig 3.6). The conversion is also important because countries usually stock less of commodities which constitute less in their consumption. This introduces bias when food security risk is analysed on per capita basis. Therefore, by converting cereals to aggregate equivalent, the bias against commodities less important in the consumption baskets are eliminated. Based on per capita stock, the study classified countries into three food security risk groups: *high food security risk countries; moderate food security risk countries; and low food security risk countries.*

High food security risk countries have per capita stock of less than 30 kilogram per person. Some of the high food security risk countries face extreme risk because per capita stocks are zero. High food security risk countries include Barbados, Mauritius, Mongolia, Botswana, Madagascar, Mozambique, Zimbabwe, Tanzania, Haiti, Nigeria, Benin, Uganda, Senegal, Honduras, Guatemala, Kenya, Zambia and Panama.

Moderate security risk countries are classified as countries with per capita stock levels greater than 30 kg and up to 60 kg. Moderately food security risk countries include India, Pakistan, Indonesia, Venezuela, Peru, Turkey and Philippines.

Low food security risk countries are classified as countries with per capita stocks greater than 60kg. Low food security risk countries in this study include Laos, Guyana and China.

Fig 3. 6 Aggregate per capita stocks in G-33 countries (kg)



Source: Author's computation using USDA FAS data.

The 'per capita stock' classification is for the convenience of organising countries into food security risk groups and, hence, limited to this study. The main challenge with most indicators seeking to classify countries is identifying appropriate cut-off points at which a country may be classified as high, low or intermediate risk (Perez-Escamilla and Segal-Correa, 2008). The 'per capita stock' indicator, used here, faces a similar challenge. However, the classification to a large extent is chosen to be consistent with the recent *State of Food Insecurity in the World* (FAO, 2014) especially the extreme cases (Fig 3.2). For example, *low food risk countries* are mostly countries where the probability of undernourishment (measuring food security risk) is between 5 - 15 percent; while *high food security risk countries* are largely consistent with countries where probability of undernourishment is greater than 28 percent.

3.3 Literature on Public stockholding, AMS and the WTO

The AMS restriction on subsidies and public stockholding has remained contentious among WTO trading nations. In 1999, the US alleged that South Korea's price support to the beef industry violated its AMS limit. The WTO Dispute Settlement Body, in 2000, sustained the US argument and ruled that South Korea's domestic support for 1997 and 1998 had actually surpassed its *de minimis* commitment (WTO, 2000). A number of studies suggest that AMS will become more contentions in coming years. Brink (2009), for instance, predicted developing countries' demands for higher AMS will intensify because their ability to support agriculture and food security policies is rising due to economic growth.

A study by DTB Associates (2011) on subsidization in selected developing countries (Brazil, India, Thailand and Turkey) showed substantial violation of total AMS commitments. A revised study in 2014 focusing narrowly on wheat, rice and corn in Brazil, India, Turkey, Thailand and China also reveals substantive violation of product specific AMS limit[15] (DTB Associates, 2014). Nonetheless, implicated countries have consistently rejected the findings, arguing that the calculations were inaccurately determined. For instance, while DTB Associates (2011, 2014) used total production (citing the case for Korea-beef as justification for their choice), affected countries argue AMS should be based on actual procured stock levels. Notwithstanding these objections, the study reveals that support prices for public stockholding in India, Brazil, Turkey, Thailand and China had substantially risen in 2010/2011. For instance, the wheat support price in Brazil, India, Turkey and China stood at $243, $288, $324 and $285 respectively, compared to $152 per tonne support price in U.S. for 2010/2011 production year (DTB, 2011). Montemayor (2014) undertook a range of simulations showing that the strict application of the AMS formula, as currently defined under the WTO, increases the likelihood that developing countries will violate their *de minimis* limit.

A number of studies also cast doubts on the efficacy of public stockholding programs in addressing food security and, thus, do not see AMS relaxation as a panacea to food security problems. For instance, Haberli (2014) argues that decisions on public stockholding may only increase governmnet support but not necessarily enhancing food security in developing countries. Similarly, the World Bank (2012) argues that public food stocks usually come with a large fiscal cost that outweighs the associated benefits of consumption and price stabilization. Deuss (2014),

[15] Product specific AMS are limits on specific products such as wheat, corn or rice. This is different from total (or non-specific) AMS which refers to total support to agriculture which is also limited by 10 percent.

however, argues that public stockholding has advantages and disadvantages for food security. According to Deuss (2014), effective targeting of food stocks can improve the food security of vulnerable individuals on one hand, but large stockholding can result in higher international food prices. Sadler and Magnan (2011) proposed a private and public storage policy mix as a strategy to resolve food security issues in the Middle East and North Africa.

Matthews (2014b) proposes two measures to help resolve food security and AMS restriction among developed and developing countries of the WTO: (1) harmonise food security and trade rules; and (2) expand AMS for developing countries. While these studies examined aspects of AMS stockholding, they do not particularly relate to the issues being addressed in this thesis regarding whether or not *de minimis* limits will lead to restrictions on optimal public stockholding for food security purposes.

3.4 Storage, public stocks and food security determination

Public stocks were first conceived as a means to make up for the difference between projected consumption and supply. Where supply is projected to fall below consumption, the government's responsibility was to estimate the difference and provide it as public stocks (Eaton, 1980). This approach, however, lacks theoretical underpinnings. The approach also fails to take into account that stocking for the future involves a cost on current consumption, which needs to be taken into consideration. Consequently, storage based on projected consumption differences led to huge stock accumulation and enormous social cost.

The fundamental economic theory of storage, both private and public stockholding, focuses on optimal allocation of available stocks between current and future consumption. Private storage occurs under competitive market conditions with the objective of maximising the intertemporal profit involved in carryover stocks from one period to another (Williams and Wright, 1991; Makki *et al*, 2001; Karali, 2007). Given current price (P_t), cost of storage (h), cost of capital (r) and expected future price (P_{t+1}), a profit-seeking storage agent maximizes the intertemporal profit of storing a unit s_i from period t to t+1. Grain will be stored from t to t+1 whenever the discounted future price is large enough to cover the current stock price and cost of storage (equation (3.2)). Conversely, no storage occurs (i.e. zero storage) if the discounted future price does not to cover the current price and cost of storage (equation (3.3)). Williams and Wright (1982, 1991) summarised the decision-making process of competitive storage as:

$$P_t + h - E_t\,[P_{t+1}]/(1 + r) = 0, S_t > 0\text{: } storage\ occurs \quad (3.2)$$

$$P_t + h - E_t\,[P_{t+1}]/(1 + r) \geq 0, S_t = 0\text{: } no\ storage \quad (3.3)$$

Where, S_t is aggregate market storage obtained by summing individual stocks (s_i) of all agents.

Competitive storage has been adapted in studies to accommodate public food security by setting a ceiling and floor price and then managing reserves to achieve them. Larson *et al* (2014) assumed that government was focused on price hikes in the Middle East and North Africa (MENA) regions. Hence, hypothetical ceiling prices were set and the corresponding reserves needed to achieve those consumer prices in the MENA region were determined. The reserves formed optimal public stocks. Their results shows that higher reserves are needed to keep domestic prices substantially lower. Despite manipulating private storage conditions to achieve public stocks there remains a striking difference between public stockholding and private stockholding motives.

The objective of public storage deviates from private storage. While private storage seeks to maximize intertemporal profit, public storage seeks to maximize society's welfare including food security. Estimating stocks levels that maximizes society's welfare was pioneered by Roberts L. Gustafson (1958). Gustafson developed a dynamic optimization framework for estimating optimal grain reserves by viewing the decision maker as a social planner. The social planner is a government or that "all-knowing person" capable of incorporating consumption needs of every person in the society. The planner then chooses consumption and carryover levels that maximizes social welfare. The estimated stocks are optimal stocks in that the food consumption needs of every member of the society are met. These technically constitute levels of carryovers needed so that food security is achieved in a society. Johnson and Sumner (1976) applied Gustafson's framework to determine optimal grain reserves in developing countries for 1975.

Gustafson's framework produces the same storage outcome as competitive storage in the absence of market failures (Gardner, 1979; Williams and Wright, 1991; Karali, 2007). Hence, public storage is only justified where the market does not provide sufficient stocks as a result of a market failure. This framework aligns with some economists who argue that food security is a market failure problem. For example, Rocha (2007) argued that the classical economic approach to food security is one of a market failure problem which warrants government intervention like other incidents of market failures. To her, although food in itself is a private good, food security is public good because food insufficiency can impose significant economic and social costs, a cost born by all. Outbreaks of disease emanating from deficient food consumption can affect the wider society irrespective of one's social and economic status. Further, with regards to market failure, Kotagama *et al* (2008/2009) estimated the level of government intervention required to induce sufficient food production to address food security in the Oman district of Sri Lanka.

In effect, studies wanting to estimate public stocks using Gustafson's framework will normally base the analysis on the size of distortion introduced by the market failure. The approach is, first of all, to estimate stocks levels in the absence of market failure. Secondly, estimate stocks levels with market failure. Third, the difference in stocks should therefore constitute public stocks. Subsequently, Gardner (1979) assumed that inefficiency in financial markets can create a significant difference in cost of capital borrowed from private markets. This will result in public and private grain storers being charged different interest rates. A high interest rate increases the opportunity costs of holding grain relative to returns on commercial savings and, therefore, leads to sub-optimal storage. With a difference in cost of capital, the associated levels of public stocks can be estimated. To illustrate this, Gardner assumed discount rates of 9 and 3 percent for private and public stockholders respectively and estimated associated stocks.

Williams and Wright (1982) modeled the interaction between private and public storage in managing oil import disruptions. To create an opportunity for public storage, they assumed that government is concerned about price hikes and will respond with a price ceiling. A price ceiling is market distortionary. Their model, therefore, incorporated private behavior and consequently estimated optimal public stocks. Gouel and Jean (2015) and Gouel (2013) introduced risk aversion on the part of consumers and incomplete contracts as market failure reasons for public storage in small open developing economies. The aforementioned means that optimal public stocks needed to achieve food security should equal the difference between total demand and the quantity of stocks provided by private storage. Thus, when a policy curtails public stocks to some fixed level (as the case of AMS) it could lead to sub-optimal public stocks. This has serious implications for food security, especially if the government is restricted in its fiscal outlays at the same time as the market is unable to provide sufficient stocks to meet food consumption demands.

This study follows suit by arguing that public storage is only necessary where private storage is insufficient. Consequently, Gustafson's framework is employed to determine optimal stock levels needed in each country. The research also argues that the estimated stocks are consistent with levels needed to achieve food security because every member of the society's consumption is incorporated. Hence, estimated stocks are total stocks (private plus public) needed for food security in each country.

The study recognize that market failures cause stocks supplied in the market to be less than optimal for food security. However, this study does not introduce market distortion as in the case of Gardner (1979); Williams and Wright (1982) or Gouel and Jean (2015). The research argues that sources of market failures facing developing economies are numerous. As such, considering only one source of market failure may lead to underestimating the effects of market failures. However, the effect of the market failures can be revealed by examining the difference between optimal stocks needed to achieve food security and actual stocks observed in an economy. Optimal stocks needed to achieve food security should therefore be the same as actual stock levels observed in an economy in the absence of market failures. However, market stocks will deviate from optimal stocks needed to achieve food security in the presence of market failures. The difference in stocks is what constitute optimal public stocks for food security. Hence, the study determines optimal public stocks by taking the difference between optimal stocks needed to achieve food security (estimated from Gustafson framework) and observed stock levels (i.e. market/private stocks) in the economy. The observed stocks (market stocks) refers to carryover stocks reported for each country by USDA.

Further, the research recognizes that optimal public stocks may differ from public stock levels permitted under the WTO. The study recognizes two different kinds of public stocks: public stocks optimal to achieve food security; and public stocks permissible under WTO such that AMS *de minimis* is not violated. For simplicity, it is assumed that maximum public stock levels permitted under WTO cannot exceed 10 percent of the value of domestic production. The AMS permissible stocks are compared with optimal public stocks to determine the restrictiveness of AMS on food security.

3.5 Theoretical framework and methodology

This section focuses on the theoretical models underpinning food security stocks, the methods used to evaluate the restrictiveness of the de minimis AMS policy and the data sources. These are discussed in steps below.

3.5.1 Theoretical framework

The theoretical model is developed chronologically as follows:

Step 1: The theoretical model for estimating food security consistent stocks

The 'food security consistent stocks' are estimated using Gustafson's framework which is based on the social planner's approach. The social planner's framework is consistent with food security because it optimises social welfare in the presence of production shocks with the objective of smoothening consumption (subject to a given storage cost). The research assumes that government, as a social planner, incorporates every individuals demand into the society's consumption function and simultaneously determines consumption and carryover levels that maximize social welfare. The estimated stocks are assumed to be consistent with levels needed to ensure food security. Cereal consumption demand at time t (C_t) is specified as inverse function of price (P_t) as:

$$P_t = f(C_t) \qquad (3.4)$$

Imposing linear functional form, the inverse consumption demand is stated explicitly as:

$$P_t = \theta + \beta C_t \qquad (3.5)$$

Where θ is a positive intercept term and β is negative coefficient measuring the inverse of unit change in price on consumption. Williams and Wright (1982) assumes that the domestic supply arises primarily from current production, Z_t, with mean production $\overline{Z}$ and additive random shock μ_t. Thus, domestic supply is stated as:

$$Z_t = \overline{Z} + \mu_t \qquad (3.6)$$

The random shock captures unexplained factors causing production fluctuations, and has mean zero (0) and standard deviation σ. The standard deviation, σ, is derived from the yield distribution of a specific cereal. Williams and Wright (1982) estimated the likelihood of a given shock μ_t as: μ_t which approximates $1/2\sqrt{3\sigma}$ within the range of $\pm\sqrt{3\sigma}$, and zero for all other places. The probaility distribution of the random term is used to form expectation about future production and prices.

Incorporating trade: The intertemporal storage used in this paper covers two years. It is assumed that countries will not allow trade deficits from each other in the final year because the world is ending. Trade must therefore balance in the second year. Given this, total consumption in each year is estimated as the sum of production, net trade and change in stocks. The change in cereal stocks is estimated as the difference between stocks brought in from the previous year (S_{t-1}) and stocks carried out from the current period t (S_t) to the next period, while net trade refers to the difference between imports (I) and exports (X) of a country. Thus, C_t is defined as:

$$C_t = Z_t + I_t - X_t + S_{t-1} - S_t \qquad (3.7)$$

Letting A_t ($= Z_t + I_t - X_t + S_{t-1}$) denote total available stocks, C_t will equals stocks available for consumption (A_t) minus carryout:

$$C_t = A_t - S_t \qquad (3.8)$$

Formulating the stockholding problem: From the standard economic analysis, welfare is obtained by integrating over the inverse demand curve (i.e. $\int_0^{A_t-S_t} P(C_t)dC$)) taking into consideration the amount of stocks consumed and stocks carried out into the future. It is assumed that every market stock taken out of the current period t to t+1 (i.e. the following year) incurs a per unit storage cost of "h". As a result the total cost of carrying S_t from t to t+1 is hS_t. The net benefit to society for consuming C_t and cost of storing St for future use equals consumer surplus ($\int_0^{A_t-S_t} P(C_t)dC$) minus cost of storage, hS_t. In summary, net welfare in period t is defined as:

$$\int_0^{A_t-S_t} P(C_t)dC - hS_t \qquad (3.9)$$

However, the carry-out stocks from period t yield a value to society when consumed in period t+1. Consequently, the welfare in period t+1 must be discounted and added to the welfare in period t to estimate total welfare for carrying out S_t from t to t+1. That is, where storage is done over several years, the expected benefits are discounted over time. The objective of the social planner is, therefore, to choose stocks (S_t) and consumption levels that maximize the discounted social welfare (W_t) over T periods. This is stated mathematically as:

$$Maximize \quad W_t = \sum_{t=1}^{T} E_t \left[\int_0^{A_t - S_t} P(c_t)dc - hS_t)\right] / (1+r)^{t-1} \qquad (3.10)$$

$$Subject\ to\ St \geq 0$$

Where, E_t is the expectation operator.

Solving the stockholding problem: As a 2-year model, the storage decision is to determine stock levels to be carried from t to t+1. No carry out from period t+1 to t+2 occurs because the world ends in period t+1. Consequently, final year storage (S_{t+1}) is set equals zero (0). Having set S_{t+1}=0, the problem is reduced to determining how much stock will be carried from t to t+1. This optimal carryover stocks from t to t+1 (i.e. S_t) is determined by differentiating equation (3.10) and setting the resultant product to zero as:

$$\frac{\partial W_t}{\partial S_t} = \left(\frac{\partial P_t}{\partial C_t}\right)\left(\frac{\partial C_t}{\partial S_t}\right) - h + (1+r)^{-1} E_t \left(\frac{\partial W_{t+1}}{\partial S_t}\right) = 0$$

$$= -P(A_t - S_t) - h + (1+r)^{-1} E_t P(Z_{t+1} + I_{t+1} - X_{t+1} + S_t)$$

$$P_t(A_t - S_t) + h = (1+r)^{-1} E_t P_{t+1}(Z_{t+1} + I_{t+1} - X_{t+1} + S_t) \qquad (3.11)$$

Substituting for inverse consumption demand and expectation:

$$\theta + \beta(A_t - S_t) + h = (1+r)^{-1}\left(1/2\sqrt{3\sigma}\right) \int_{-\sqrt{3\sigma}}^{\sqrt{3\sigma}} (\theta + \beta\left(\overline{Z} + \mu_{t+1} + I_{t+1} - X_{t+1} + S_t\right))\, du \qquad (3.12)$$

Since trade balances in the final year, imports must equal exports (i.e. $I_{t+1} = X_{t+1}$). Hence, equation (3.11) is re-written as:

$$\theta + \beta(A_t - S_t) + h = (1+r)^{-1}(1/2\sqrt{3\sigma}) \int_{-\sqrt{3\sigma}}^{\sqrt{3\sigma}} (\theta + \beta\left(\overline{Z} + \mu_{t+1} + S_t\right)\, du \qquad (3.13)$$

Consequently, optimal carryout stocks from period t is solved for as:

$$S_t^* = \frac{(1+r)A_t - \overline{Z}}{(2+r)} + \left(\frac{1+r}{2+r}\right) * \left(\frac{h}{\beta}\right) + \left(\frac{r}{2+r}\right) * \left(\frac{\theta}{\beta}\right) \qquad (3.14)$$

Thus, optimal storage is negatively explained by expected future production, storage cost and cost of capital, while current availability increases storage. Where expected production is in excess of consumption, no storage occurs from period t to t+1, and, $S_t^* = 0$. Hence, the optimal storage policy, according to Karali (2007) and Williams and Wright (1982) can be summarised as:

$$S_t^* = Maximum\left\{\frac{(1+r)A_t - \overline{Z}}{(2+r)} + \left(\frac{1+r}{2+r}\right) * \left(\frac{h}{\beta}\right) + \left(\frac{r}{2+r}\right) * \left(\frac{\theta}{\beta}\right), 0\right\} \tag{3.15}$$

Equation (3.15) is used to estimate the '*optimal food security consistent stocks'* of corn, wheat and rice for G-33 countries.

Step 2: Estimating optimal public stocks

Optimal public stocks equals optimal food-security-consistent-stocks (i.e. S_t*) minus stock levels observed in the market. The market stocks are carryover stocks observed in each country from 2010/2011 (i.e. t) to 2011/2012 (t+1).

Step 3: Estimate WTO permissible public stocks

The WTO permissible public stocks are estimated as 10 percent of the total value of domestic production. The research assumes that the maximum allowable public stocks permitted under WTO cannot exceed its *de minimis* limit. This is, however, a monetary measure. To determine the physical stocks associated with the *de minimis* level, the estimated monetary value must be divided by prices. Accordingly, the resulting WTO permissible stocks becomes equal to 10 percent of total domestic production. Consequently, the WTO permissible public stocks were estimated directly as 10 percent of total domestic production.

Step 4: AMS restrictiveness evaluation

The *de minimis* AMS restrictiveness is evaluated by computing the ratio of 'optimal public stocks' to 'WTO permissible public stocks'. This is stated mathematically as:

$$AMS\ Restrictiveness = \frac{Optimal\ public\ stocks}{AMS\ permissible\ public\ stocks} \tag{3.16}$$

The ratio is a measure of public stocks needed to achieve food security (i.e. optimal public stocks) compared to public stocks allowed under WTO (i.e. AMS permissible public stocks). Therefore:

1. If public stock allowed under WTO equals public stock levels needed to achieve food security, the restrictiveness ratio will be equal 1. In that case, AMS is not restricting on optimal stockholding.
2. If stock levels allowed under WTO are more than public stock levels needed to achieve food security, the restrictiveness ratio will be less than 1. In that case AMS is still not restricting on optimal stockholding
3. However, where public stocks permitted under AMS is less than public stocks needed to achieve food security, the ratio will be greater than 1; which implies that the AMS policy is constraining on optimal public stockholding for food security.

Step 5: Determining optimal AMS needed to achieve food security

The AMS required to achieve food security is calculated for countries constrained by AMS. Since 10 percent AMS produces the permitted stock levels, then the AMS required to produces optimal public stocks can be determined as:

$$Optimal\ AMS = \frac{Optimal\ public\ stocks * 10\%}{AMS\ permitted\ stock\ level} \qquad (3.17)$$

3.5.2 Implications of two-period analysis for longer-duration models

This study employs a two-period storage model to analyse the restrictiveness of the *de minimis* AMS policy on public stockholding for food security purposes. However, the implications of this method for longer duration models can easily be ascertained. To illustrate this, let us assume that a country has a stock of food, F, to consume over some period of time. Let us also assume that the country consumes equal amounts of food in a period.

Case 1: If the country lives for two years then 0.5F will be consumed in the 1st year while 0.5F is carried over and consumed in the 2nd year. Optimal stocks carried from 1st to 2nd period 0.5F. Hence, optimal storage for this country is 0.5F.

Case 2: What if the country lives for 3 years? In a 3-year case, 0.33F will be consumed in the 1st period. However, the optimal stocks to be carried from 1st to 2nd period is 0.66F. This is higher compared to the 2-period case.

The issues with storage are obviously more complicated than illustrated above but the simplified cases provide key understanding of how longer duration models work. The implication is that longer duration models have higher optimal storage levels compared to short-duration. Longer duration models decrease consumption per period while increasing storage; while shorter duration models increase consumption per period while reducing storage between periods. Longer duration models (such as an infinite horizon model) have higher optimal carryover stocks compared to shorter duration models (e.g. two-period storage model) because the value of future stocks are less important in shorter duration models. The shorter duration models, thus, underestimate optimal carryover stocks compared to longer duration models. Consequently, optimal public stocks required to achieve food security are relatively higher with longer-duration models. Hence, any evidence of restrictiveness under the two-period model suggest that the restrictiveness will be higher for longer duration models because of their relatively high optimal public stocks. The restrictiveness analysis from shorter duration models can also provide insights into the extent of restriction that will arise if a much severe food crises were to occur. A more severe food crisis will have a relatively low market stocks. Consequently, public stocks required to ensure food security are higher with severe food crisis. Consequently, the chance of a restriction is higher with severe food crisis (e.g the 2007/2008 food crisis).

3.5.3 Data

Production, consumption and trade data were obtained from the USDA Foreign Agricultural Services Division. Similarly, cost of storage is assumed to be $25 per tonne per year based on a World Bank study on storage cost in developing countries. Further, the World Bank Development Indicators show that interest rates varied across developing countries in 2010/2011, ranging from a minimum of 5 percent to a maximum of 35 percent in most countries. An average rate of 20 percent per annum was, however, calculated and used in the estimation. The expected future production, $\overline{Z,}$ is assumed to approximate a three-year moving average of production.

Consequently, production values of 2008/2009, 2009/2010 and 2010/2011 were used to estimate the expected production of 2011/2012 for wheat, corn and rice for each country.

The commodity elasticities were derived from varied sources in the literature. The averages of these were used to estimate coefficients of inverse demand functions of rice, corn and wheat. Intercept terms of the inverse demand functions represent the maximum price per tonne at which consumption will not occur. The research assumes that the maximum price each country is willing to pay for food, in the event of a food crisis, is the same. Consequently, intercept terms – representing maximum prices – are equal across countries for a given commodity. Further, the coefficients – representing the responsiveness of price to consumption – are allowed to vary across countries because countries have different consumption elasticities. For example, a 0.01 coefficient (for rice in China) means that a dollar increase in rice price will lead to a decrease in consumption by 100 thousand tonnes (i.e. 1/0.01) in China. The full list of parameters used in the estimation are presented in Table 3A.1 in the appendix.

3.6 Results and Discussion

The estimated results for rice, corn and wheat models are presented in Table 3.2, Table 3.3 and Table 3.4 respectively. The estimations were done in Excel Spreadsheets. The estimates cover G-33 countries and commodities for which production, consumption, trade and stock data are available for 2010/2011 year. As a result, countries, where reliable elasticities could not be obtained, were excluded.

The results are discussed in two parts. The first part (section 3.6.1) presents optimal food security consistent stocks, optimal public stocks, and WTO allowable public stocks (i.e. AMS public stocks). The components of these Tables are discussed in detail in the following sub-sections. The second part (section 3.6.2) focus extensively on the restrictiveness of AMS policy and the risk posed to food security.

Table 3. 2 Estimates for rice (000 tonnes)

	Optimal food security stocks	Market stocks	Optimal public stocks	AMS public stocks	Restrictiveness ratio
Barbados	-	-	-	-	-
Benin	110.0	0.0	110.0	8.0	13.8
Botswana	-	-	-	-	-
China	31228.0	42574.0	0.0	13700.0	0.0
Guatemala	30.0	0.0	30.0	2.1	14.3
Guyana	20.0	25.0	0.0	36.1	0.0
Haiti	207.0	20.0	187.0	7.8	24.0
Honduras	71.5	28.0	43.5	2.8	15.6
India	18414.0	23500.0	0.0	9597.0	0.0
Indonesia	7882.2	7131.0	751.2	3550.0	0.2
Kenya	200.0	57.0	143.0	5.7	25.0
Laos	182.0	78.0	104.0	140.0	0.7
Madagascar	676.0	0.0	676.0	303.2	2.2
Mauritius	35.0	0.0	35.0	0.1	350.0
Mongolia	-	-	-	-	-
Mozambique	222.4	0.0	222.4	16.8	13.2
Nigeria	1671.6	538.0	1133.6	281.8	4.0
Pakistan	0.0	300.0	0.0	500.0	0.0
Panama	59.7	22.0	37.7	17.9	2.1
Peru	457.0	424.0	33.0	193.9	0.2
Philippines	3492.0	2459.0	1033.0	1053.9	1.0
Senegal	592.0	108.0	484.0	40.8	12.0
Tanzania	212.0	0.0	212.0	132.0	1.6
Turkey	368.3	292.0	76.3	50.2	1.5
Uganda	49.1	0.0	49.1	14.2	3.5
Venezuela	242.0	251.0	0.0	35.8	0.0
Zambia	4.0	0.0	4.0	3.5	1.1
Zimbabwe	-	-	-	-	-

Source: Author's computation.

Table 3. 3 Estimates for corn (000 tonnes)

	Optimal food security stocks	Market stocks	Optimal public stocks	AMS public stocks	Restrictiveness ratio
Barbados	-	-	-	-	-
Benin	116.0	41.0	75.0	101.3	0.7
Botswana	87.4	0.0	87.4	1.1	80.0
China	46767.7	49415.0	0.0	17724.5	0.0
Guatemala	589.0	125.0	464.0	163.4	2.8
Guyana	0.0	0.0	0.0	0.5	0.0
Haiti	54.0	0.0	54.0	25.0	2.2
Honduras	322.1	89.0	233.1	54.8	4.3
India	2492.0	561.0	1931.0	2172.6	0.9
Indonesia	2322.3	697.0	1625.3	680.0	2.4
Kenya	853.1	420.0	433.1	346.5	1.2
Laos	267.0	250.0	17.0	102.1	0.2
Madagascar	57.0	42.0	15.0	41.2	0.4
Mauritius	-	-	-	-	-
Mongolia	-	-	-	-	-
Mozambique	406.0	143.0	263.0	209.0	1.3
Nigeria	1077.5	266.0	811.5	880.0	0.9
Pakistan	787.4	789.0	0.0	370.7	0.0
Panama	234.0	57.0	177.0	8.5	21.0
Peru	1388.4	287.0	1101.4	151.6	7.3
Philippines	1217.4	691.0	526.4	727.1	0.7
Senegal	0.0	14.0	0.0	18.6	0.0
Tanzania	1046.0	802.0	244.0	473.3	0.5
Turkey	682.0	367.0	315.0	360.0	0.9
Uganda	543.0	370.0	173.0	237.4	0.7
Venezuela	879.0	314.0	565.0	130.0	4.3
Zambia	870.4	900.0	0.0	280.0	0.0
Zimbabwe	389.0	25.0	364.0	100.0	3.6

Source: Author's computation.

Table 3. 4 Estimates for wheat (000 tonnes)

	Optimal food security stocks	Market stocks	Optimal public stocks	AMS public stocks	Restrictiveness ratio
Barbados	7.0	0.0	7.0	0.1	70.0
Benin	80.5	0.0	80.5	0.1	805.0
Botswana	-	-	-	-	-
China	41421.0	59091.0	0.0	11518.0	0.0
Guatemala	359.3	134.0	225.3	0.1	2253.0
Guyana	0.0	0.0	0.0	0.0	0.0
Haiti	135.2	0.0	135.2	0.1	1352.0
Honduras	118.7	0.0	118.7	0.1	1187.0
India	15992.3	15360.0	632.3	8080.4	0.1
Indonesia	4172.6	1615.0	2557.6	0.1	25576.0
Kenya	680.2	65.0	615.2	25.6	24.0
Laos	-	-	-	-	-
Madagascar	55.3	0.0	55.3	0.1	553.0
Mauritius	68.5	0.0	68.5	0.1	685.0
Mongolia	58.0	0.0	58.0	34.5	1.7
Mozambique	322.5	0.0	322.5	1.8	179.2
Nigeria	2037.5	200.0	1837.5	10.0	183.8
Pakistan	3919.2	3168.0	751.2	2390.0	0.3
Panama	68.5	0.0	68.5	0.1	685.0
Peru	1099.8	384.0	715.8	23.0	31.2
Philippines	2104.7	658.0	1446.7	0.1	14467.0
Senegal	230.5	7.0	223.5	0.1	2235.0
Tanzania	313.7	0.0	313.7	6.2	50.6
Turkey	3107.3	2885.0	222.3	1700.0	0.1
Uganda	65.0	0.0	65.0	2.0	32.5
Venezuela	864.3	84.0	780.3	0.1	7803.0
Zambia	57.5	25.0	32.5	17.2	2.0
Zimbabwe	121.5	8.0	113.5	1.8	63.1

Source: Author’s computation.

3.6.1 Estimated stock levels

3.6.1.1 Optimal food security consistent stocks

The estimated optimal food security stocks of rice, corn and wheat for G-33 developing countries are summarised in Table 3.5. The estimates are optimal carryover stocks needed to achieve consumption security in each country, referred to as *'food security consistent stocks'*.

Table 3. 5 Optimal food security consistent stocks (000 tonnes)

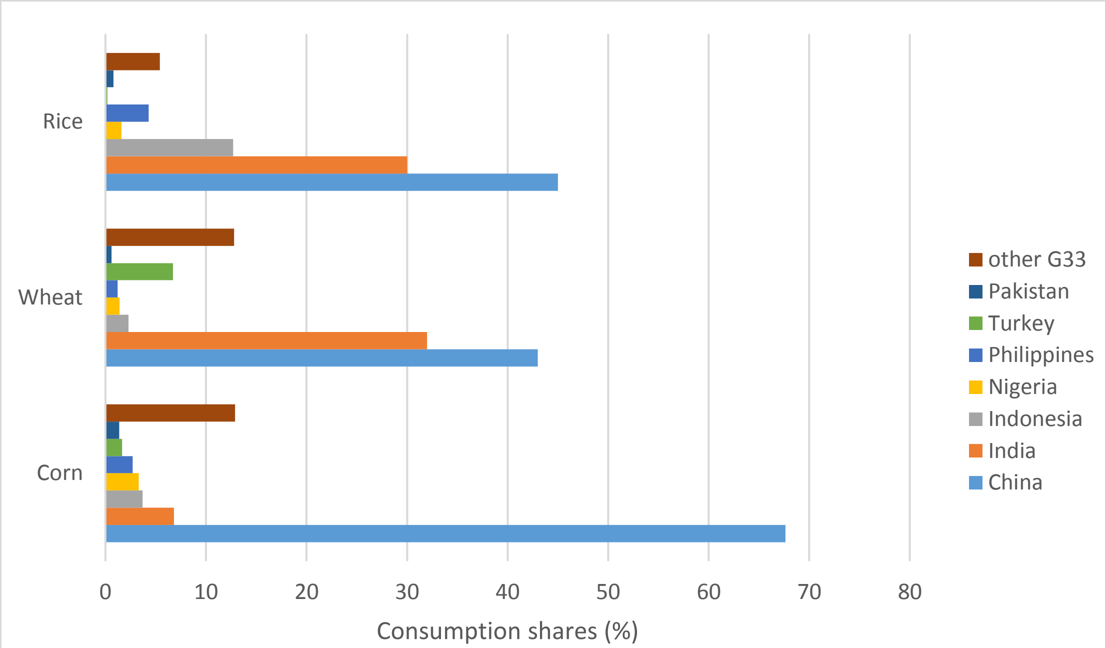
Country	Rice	Corn	Wheat
Barbados	-	-	7.0
Benin	110.0	116.0	80.5
Botswana	-	87.4	-
China	31228.0	46767.7	41421.0
Guatemala	30.5	589.0	359.3
Guyana	20.0	0.0	0.0
Haiti	207.0	54.0	135.2
Honduras	71.5	322.1	118.7
India	18414.0	2492.0	15992.3
Indonesia	7882.2	2322.3	4172.6
Kenya	200.0	853.1	680.2
Laos	182.0	267.0	-
Madagascar	676.0	57.0	55.3
Mauritius	35.0	-	68.5
Mongolia	-	-	58.0
Mozambique	222.4	406.0	322.5
Nigeria	1671.6	1077.5	2037.5
Pakistan	0.0	787.4	3919.2
Panama	59.7	234.0	68.5
Peru	457.0	1388.4	1099.8
Philippines	3492.0	1217.0	2104.7
Senegal	592.0	0.0	230.5
Tanzania	212.0	1046.0	313.7
Turkey	368.3	682.6	3107.3
Uganda	49.1	543.0	65.0
Venezuela	242.0	879.0	864.3
Zambia	4.0	870.4	57.5
Zimbabwe	-	389.0	121.5

Source: Author's computation.

Generally, optimal carryover stocks of rice, corn or wheat are less than 3 million tonnes in most countries including Barbados, Benin, Botswana, Guatemala, Haiti, Honduras, Kenya, Madagascar, Mauritius, Mongolia, Mozambique, Panama, Peru, Senegal, Tanzania, Uganda, Venezuela, Zambia and Zimbabwe. Optimal stocks are low in these countries primarily because of low consumption. The countries, together, consume less than 10 percent of aggregate wheat, corn, or rice in G-33 (Fig 3.7). As a result, stockholding in anticipation of consumption shortfalls are also low.

Optimal carryover stocks are comparatively high in China, India, Indonesia, Nigeria, Philippines and Turkey. This is because aggregate consumption relative to production is high in these countries. Hence, storage in anticipation of shocks must be high, *ceteris paribus*. For instance, China's corn, wheat and rice consumption as shares of totals consumed by G-33 are approximately 68 percent, 43 percent and 45 percent respectively (Fig 3.7). It is the highest among G-33 developing countries. Hence, comparatively high stocks must be kept in anticipation of shortfalls for each cereal. Thus, China's food security stocks of approximately 47 million, 41 million and 31 million tonnes for corn, wheat and rice respectively (Table 3.5) are the highest among G-33 countries.

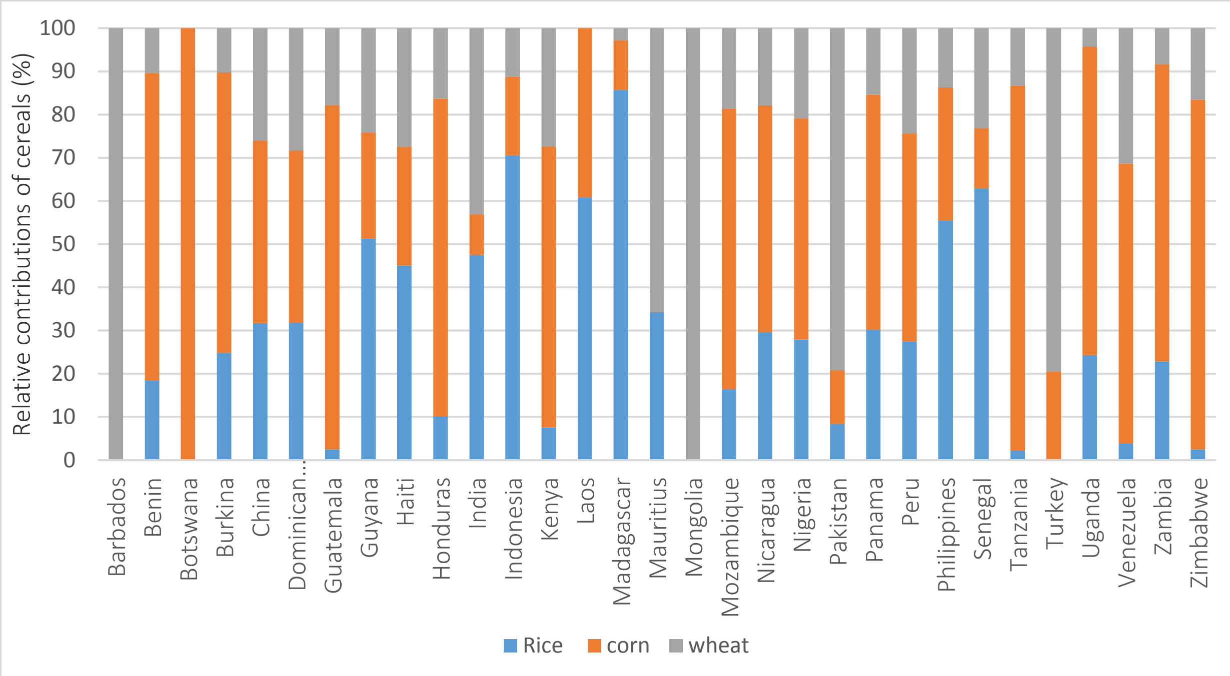
Fig 3. 7 Cereal consumption shares in G-33(%): 2010/2011



Source: Author's computation using USDA data.

Further, India as the second largest consumer of wheat and rice, also requires high stocks to maintain food security. For instance, India's corn consumption constitutes approximately 7 percent of aggregate corn consumed in G-33 while its rice and wheat shares are 30 percent and 32 percent respectively (Fig 3.7). Unlike wheat and rice, corn is neither a major cereal produced nor consumed in India. Hence, its importance in India's food security is low compared to rice and wheat. Corn contributes about 10 percent of cereal consumption compared to 47 percent and 43 percent by rice and wheat respectively in India (Fig 3.8). Consequently, food security stocks are predictably low for corn (2.5 million tonnes) but high for wheat (16 million tonnes) and rice (18 million tonnes) accordingly (Table 3.5). The high stocks of rice and wheat relative to corn also reflects in India's new food security policy under which rice and wheat are targeted cereals for its public stockholding programs (Fritz, 2014)).

Fig 3. 8 Shares of rice, corn and wheat in consumption (%): 2010/2011



Source: Author's computation.

In Turkey and Pakistan, wheat constitutes a basic input to the dietary staple bread which raises its consumption substantially relatively to rice and corn. Wheat constitutes approximately 80 percent of cereal consumption in Turkey and Pakistan. Optimal food security wheat stocks are, thus, high in Pakistan (approximately 4 million tonnes) and Turkey (3 million tonnes) compared to rice and corn (Table 3.5). Similarly, Indonesia's optimal stocks of approximately 8 million, 2.3 million and 4 million tonnes also corresponds to the 5 percent, 3 percent and 1 percent consumption shares of rice, corn and wheat respectively approximately. In Tanzania, where corn constitute over 80 percent of cereal consumption, the estimated stocks of rice, corn and wheat are less than 0.4 million tonnes for rice and wheat while corn stocks are about 1 million tonnes. Similarly, optimal stocks of corn are relatively higher compared to rice and wheat in Zimbabwe, Zambia, Venezuela, Uganda, Peru, Panama, Mozambique, Kenya, Guatemala and Benin because of its high importance relative to rice and wheat. Optimal rice stocks are relatively high in Madagascar, Senegal and Indonesia due to their importance in consumption. Optimal rice stocks are relatively high in Madagascar, Senegal and Indonesia due to their importance in consumption.

In conclusion, optimal carryover stocks vary considerably across countries and commodity. For countries with high consumption levels, appreciable stock volumes are needed to maintain consumption in those markets. This explains why stocks are high in China and India compared to other countries. Moreover, stocks vary by commodity within a country based on the importance of the cereal to its food security. Cereals which contribute more to consumption within a country are stored to a greater degree in relative terms. While this results suggest that countries tend to store cereals that constitute a greater proportion of their consumption, it should be interpreted with caution as it applies mostly to net food importers, or countries with a high consumption relative to production levels. These category of countries require high storage to mitigate uncertainty in consumption. Countries with large domestic production relative to consumption (or net exporters) have no incentive to store because expected future production are usually higher than required for consumption. Hence, the incentive to stock for future consumption is reduced. This explains why Nigeria has relatively small optimal stocks of corn compared to rice and wheat (though corn constitute over 51 percent of its consumption. Nigeria's is an exception because its corn production is substantially high relative to consumption (see, for example, USDA FAS data). This raises expected production levels relative to consumption and reduce storage compared to rice and wheat.

3.6.1.2 Optimal public stocks for food security

The estimated optimal public stocks of rice, corn and wheat are summarised in Table 3.6 for all countries. ***Optimal public stocks for food security*** is the difference between '*food security consistent stocks*' and the '*observed market storage*'. The market stocks refers to carryover levels observed from 2010/2011 to 2011/2012 marketing years.

Table 3. 6 Optimal public stocks in G-33 (000 tonnes)

Country	Rice	Corn	Wheat
Barbados	-	-	7.0
Benin	110.0	75.0	80.5
Botswana	-	87.4	-
China	0.0	0.0	0.0
Guatemala	30.0	464.0	225.3
Guyana	0.0	0.0	0.0
Haiti	187.0	54.0	135.2
Honduras	43.5	233.1	118.7
India	0.0	1931.0	632.3
Indonesia	751.2	1625.3	2557.6
Kenya	143.0	433.1	615.2
Laos	104.0	17.0	-
Madagascar	676.0	15.0	55.3
Mauritius	35.0	-	68.5
Mongolia	-	-	58.0
Mozambique	222.4	263.0	322.5
Nigeria	1133.6	811.5	1837.5
Pakistan	0.0	0.0	751.2
Panama	37.7	177.0	68.5
Peru	33.0	1101.4	715.8
Philippines	1033.0	526.4	1446.7
Senegal	484.0	0.0	223.5
Tanzania	212.0	244.0	313.7
Turkey	76.3	315.0	222.3
Uganda	49.1	173.0	65.0
Venezuela	0.0	565.0	780.3
Zambia	4.0	0.0	32.5
Zimbabwe	-	364.0	113.5

Source: Author's computation.

The results shows that public stockholding is required in most G-33 developing countries. This is because the current market storage is not sufficient to achieve food security. Countries where stockholding is required across all commodities (i.e. rice, corn and wheat) include Benin, Guatemala, Haiti, Honduras, Indonesia, Kenya, Mozambique, Nigeria, Panama, Peru, the Philippines, Turkey, Uganda, Venezuela and Zimbabwe. For instance, Kenya requires approximately 0.1 million, 0.4 million and 0.6 million tonnes of rice, corn and wheat respectively to achieve food security (Table 3.6). Further, most of these countries are faced with considerably high food security risk.

Public stock levels, nonetheless, vary by commodity and country. For instance, China and Guyana do not need public storage of rice, corn and wheat because the market provides sufficient stocks to achieve food security in these countries. Hence, China and Guyana's optimal public stocks for corn, rice and wheat are zero. These are relatively low food security risk countries. Similarly, while Venezuela does not require public stockholding of rice, it does require about 0.6 million and 0.8 million tonnes of corn and wheat respectively in public storage programs.

One of the countries leading the demand for policy freedom on public stockholding is India. The estimated optimal public stock of rice for India is zero. This implies that the current market storage of rice is sufficient to achieve food security in India. Thus, India does not require stockholding of rice. The results, however, shows that India's food security with regards to corn and wheat will be at risk without public stockholding. Consequently, the government is expected to store approximately 2 million and 0.6 million tonnes of corn and wheat respectively to ensure food security. Further, while Pakistan does not require public stockholding of rice and corn, it does requires approximately 0.7 million tonnes of wheat in public stocks to ensure food security. Considerable public stockholding of rice and wheat are also required in Indonesia, Turkey, Philippines and Nigeria. Optimal public stocks of corn required in Indonesia, Nigeria, Philippines and Turkey are estimated at 1.6 million, 0.8 million, 0.5 million and 0.4 million tonnes respectively. Similarly, optimal public stockholding of rice in Indonesia, Nigeria, Philippines and Turkey are approximately one million each while wheat stocks are estimated at 0.7 million, 1.1 million, 1.2 million and 76000 tonnes respectively.

In conclusion, public stockholding is required in most G-33 countries. This is because market storage is insufficient to achieve food security without public intervention. Further, the results reveals that the market supplies of rice are sufficient to achieve food security for China, India, Pakistan and Venezuela. Hence, public stockholding of rice in these countries are not necessary.

While this results suggest that public stockholding is required in many G-33 countries, it does not particularly provide indications as to whether or not these required public storage levels are constrained by the current *de minimis* requirement. To understand this restrictiveness, the estimated optimal public stocks levels must be compared with *de minimis* permitted stocks. Consequently, the next section focuses on the WTO permitted public storage levels.

3.6.1.3 Estimated AMS permissible public stocks

The Table 3.6 show results for optimal public stock levels of corn, wheat and rice expected in each country to ensure food security. This section presents results for optimal public stock levels allowable under WTO per *de minimis* requirement. The estimated AMS permissible public stock levels of rice, corn and wheat are summarised in Table 3.7 below. The AMS allowable stocks are estimated as 10 percent of domestic production. Applying this regulation strictly implies that countries with zero production levels will have zero permissible stocks. A division by zero AMS permissible stock will result in an undefined restrictiveness index. To avoid this, a value of 1000 tonnes was assumed for countries with zero production levels. The 1000 tonnes is also appropriate because production levels below 1000 are usually approximated to zero and not reported.

Table 3. 7 AMS allowable public stocks in G-33 (000 tonnes)

Country	Rice	Corn	Wheat
Barbados	-	-	0.1
Benin	8.0	101.3	0.1
Botswana	-	1.1	-
China	13700.0	17724.5	11518.0
Guatemala	2.1	163.4	0.1
Guyana	36.1	0.5	0.0
Haiti	7.8	25.0	0.1
Honduras	2.8	54.8	0.1
India	9597.0	2172.6	8080.4
Indonesia	3550.0	680.0	0.1
Kenya	5.7	346.5	25.6
Laos	140.0	102.1	-
Madagascar	303.2	41.2	0.1
Mauritius	0.1	-	0.1
Mongolia	-	-	34.5
Mozambique	16.8	209.0	1.8
Nigeria	281.8	880.0	10.0
Pakistan	500.0	370.7	2390.0
Panama	17.9	8.5	0.1
Peru	193.9	151.6	23.0
Philippines	1053.9	727.1	0.1
Senegal	40.8	18.6	0.1
Tanzania	132.0	473.3	6.2
Turkey	50.2	367.0	1700.0
Uganda	14.2	237.4	2.0
Venezuela	35.8	130.0	0.1
Zambia	3.5	280.0	17.2
Zimbabwe	-	100.0	1.8

Source: Author's computation.

The AMS allowable public stocks are generally below a million tonne in all countries except China, India, Pakistan, Indonesia, Turkey and the Philippines (Table 3.7). The WTO permissible public stocks of rice, corn and wheat in Nigeria are estimated at 281800 tonnes, 880000 tonnes and 10000 tonnes respectively. Similarly, Tanzania can hold public stocks up to 473300 tonnes, 132000 tonnes and 6200 tonnes of corn, rice and wheat respectively.

Countries with high permissible public stocks include China, India, Indonesia, Pakistan, Philippines and Turkey. These are countries with high production and consumption levels. China has the largest permissible public stocks among the G-33 developing countries. China's WTO permissible public stocks of corn, rice and wheat are approximately 18 million, 14 million and 12 million tonnes respectively. Hence, China has opportunity to hold more stocks in corn than with rice and wheat due to its high production of corn. For India, WTO permissible public stocks for corn, rice and wheat are about 2.2 million, 10 million and 8 million tonnes respectively. India therefore has opportunity to put more stocks of wheat and rice in its public stock programs than it does with corn. The opportunity for high wheat and rice stocks, coupled with its consumption, is in line with India's New Food Security Act aimed at providing subsidised grain to some estimated 800 million people.

Indonesia, on the other hand, has low corn and wheat stocks but relative high permissible public rice stocks. Estimated public stocks of corn and wheat are about 680000 and 100 tonnes respectively compared to about 4 million tonnes of rice. Similarly, Turkey and Pakistan have high permissible public wheat stocks relative to rice and corn. Turkey's permissible public stocks for wheat are about 2 million tonnes, rice and wheat are however below a million metric. Further, the estimated public wheat stocks in Pakistan are approximately 2.4 million tonnes compared to 300000 tonnes and 50000 tonnes for rice and corn respectively. WTO permissible wheat stocks are high in Pakistan and Turkey relative to corn and rice because of the relatively high production of wheat in these countries.

3.6.2 *De minimis* AMS restrictiveness on optimal public stockholding

The restrictiveness of AMS is determined by the ratio of 'optimal public stocks' to 'WTO permissible public stocks'. The results of AMS restrictiveness is summarised in Table 3.8 below. The ratio of 'optimal public stocks' to 'AMS permissible public stocks' is greater than 1 for most G-33 developing countries. This means that public stocks permissible under WTO are insufficient to achieve food security in these countries. Hence, expanding/relaxing the *de minimis* AMS requirement can enhance food security in these countries. To gain better insights about the restrictiveness, the results are further organised and discussed in greater detail according to food security risk below.

Table 3. 8 AMS restrictiveness on public stockholding

Country	Rice	Corn	Wheat
Barbados	-	-	70.0
Benin	13.8	0.7	805.0
Botswana	-	80.0	-
China	0.0	0.0	0.0
Guatemala	14.3	2.8	2253.0
Guyana	0.0	0.0	0.0
Haiti	24.0	2.2	1352.0
Honduras	15.6	4.3	1187.0
India	0.0	0.9	0.1
Indonesia	0.2	2.4	25576.0
Kenya	25.0	1.2	24.0
Laos	0.7	0.2	-
Madagascar	2.2	0.4	553.0
Mauritius	350.0	-	685.0
Mongolia	-	-	1.7
Mozambique	13.2	1.3	179.2
Nigeria	4.0	0.9	183.8
Pakistan	0.0	0.0	0.3
Panama	2.1	21.0	685.0
Peru	0.2	7.3	31.2
Philippines	1.0	0.7	14467.0
Senegal	12.0	0.0	2235.0
Tanzania	1.6	0.5	50.6
Turkey	1.5	0.9	0.1
Uganda	3.5	0.7	32.5
Venezuela	0.0	4.3	7803.0
Zambia	1.1	0.0	2.0
Zimbabwe	-	3.6	63.1

Source: Author's computation.

3.6.2.1 De minimis AMS restrictiveness and food security risk in G-33 countries

The restrictiveness of the *de minimis* AMS requirement on public stockholding across different food security risk countries are presented in Table 3.9 below. The results are organised and discussed according to food security risk in order to show clarity in terms of the *de minimis* AMS restrictiveness implication for different food security risk groups. Secondly, adjustments to *de minimis* AMS needed to achieve food security in countries constrained by the policy are also discussed.

Table 3. 9 AMS restrictiveness on public stocks for food security purposes[16]

Risk	Country	Rice	Corn	wheat
High food security risk countries	Barbados	-	-	70.0
	Benin	13.8	**0.7**	805.0
	Botswana	-	80.0	-
	Guatemala	14.3	2.8	2253.0
	Haiti	24.0	2.2	1352.0
	Honduras	15.6	4.3	1187.0
	Kenya	25.0	1.2	24.0
	Madagascar	2.2	**0.4**	553.0
	Mauritius	350.0	-	685.0
	Mongolia	-	-	1.7
	Mozambique	13.2	1.3	179.2
	Nigeria	4.0	**0.9**	183.8
	Panama	2.1	21.0	685.0
	Senegal	12.0	**0.0**	2235.0
	Tanzania	1.6	**0.5**	50.6
	Uganda	3.5	**0.7**	32.5
	Zambia	1.1	**0.0**	2.0
	Zimbabwe	-	3.6	63.1
Moderate food security risk countries	India	0.0	0.9	0.1
	Indonesia	0.2	2.4	25576.0
	Pakistan	0.0	0.0	0.3
	Peru	0.2	7.3	31.2
	Philippines	1.0	0.7	14467.0
	Turkey	1.5	0.9	0.1
	Venezuela	1.0	4.3	7803.0
Low food security risk countries	China	0.0	0.0	0.0
	Guyana	0.0	0.0	0.0
	Laos	0.7	0.2	-

Source: Author's computation.

3.6.2.1.1 High food security risk countries

The ratio of 'optimal public stocks' to 'AMS permissible public stocks' is greater than 1 for all *high food security risk countries*. The *de minimis* requirement is restrictive for all *high food security risk countries* for wheat and rice. This means that public stocks permissible under WTO are insufficient to achieve food security. As such, AMS policy is restrictive on stockholding across

[16] Analysis was also done by aggregating all cereals to account for substitutability in cereal consumption. However, the results did not change dramatically except for Zambia and Turkey which became less restrictive.

high food security risk countries for wheat and rice. These include Barbados, Benin, Botswana, Guatemala, Haiti, Honduras, Kenya, Madagascar, Mauritius, Mongolia, Mozambique, Nigeria, Panama, Senegal, Tanzania, Uganda, Zambia and Zimbabwe. The *de minimis* requirement is also highly restrictive in the case of corn for all high food security risk countries with the exception of Benin, Mauritius, Nigeria, Senegal, Tanzania, Uganda and Zambia. The high restriction across rice and wheat — two highly important consumption commodities in developing countries — raises a concern for food security.

The level of *de minimis* AMS restrictiveness, however, varies across *high food security risk countries*. In Benin, for instance, the levels of public rice stocks required to achieve food security is approximately 14 times higher than what is currently allowed under WTO (Table 3.9). Hence, substantive expansion in AMS is required to achieve food security. Thus, Benin requires AMS to rise from the current 10 percent to 140 percent of domestic production to achieve security in rice (Table 3.10). Moreover, public rice stocks required to achieve food security in Panama is about 2 times higher than amounts allowed under WTO. Consequently, AMS must increase from the current 10 percent to approximately 21 percent of domestic production in order to address rice food security problems. Similarly, the *de minimis* limit must be at least 40 percent and 35 percent of domestic production for Nigeria and Uganda to acquire optimal public stocks for food security in rice. Considerably higher AMS are also required in Haiti (240%), Honduras (156%), Guatemala (143%), Kenya (250%), Senegal (120%), among others, to achieve rice security (Table 3.10).

Table 3. 10 Optimal AMS for food security risk countries (%)

Risk	Country	Rice	Corn	wheat
High food security risk countries	Barbados	-	-	700.0
	Benin	138.0	✓	8050.0
	Botswana	-	800.0	-
	Guatemala	143.0	28.0	22530.0
	Haiti	240.0	22.0	13520.0
	Honduras	156.0	43.0	11870.0
	Kenya	250.0	12.0	240.0
	Madagascar	22.0	✓	5530.0
	Mauritius	3500.0	-	6850.0
	Mongolia	-	-	17.0
	Mozambique	132.0	13.0	1792.0
	Nigeria	40.0	✓	1838.0
	Panama	21.0	210.0	6850.0
	Senegal	120.0	✓	22350.0
	Tanzania	16.0	✓	506.0
	Uganda	35.0	✓	325.0
	Zambia	11.0	✓	20.0
	Zimbabwe	-	36.0	631.0
Moderate food security risk countries	India	✓	✓	✓
	Indonesia	✓	24.0	255760.0
	Pakistan	✓	✓	✓
	Peru	✓	73.0	312.0
	Philippines	✓	✓	144670.0
	Turkey	15.0	✓	✓
	Venezuela	✓	43.0	78030.0
Low food security risk countries	China	✓	✓	✓
	Guyana	✓	✓	✓
	Laos	✓	✓	-

✓ Non-AMS constraining countries

The restriction on public stockholding of corn varies across *high food security risk countries*. In Botswana, for instance, the optimal public corn stocks required to achieve food security is 80 times higher than stock levels currently allowed under the WTO. Thus, AMS is strictly constraining on public stockholding for food security in Botswana. Consequently, Botswana will require a substantive expansion of AMS to 800 percent of domestic production to achieve security. Other countries with considerably high AMS restriction on corn holding thereby requiring AMS to adjust significantly include Haiti (22%), Honduras (43%), among others. In Kenya, however, the levels of public corn stocks required to achieve food security is only 1.2 times higher than stocks permitted under WTO. Accordingly, Kenya requires, at least, a *de minimis* limit of 12 percent of domestic production to achieve food security.

Further, the AMS restrictiveness on public wheat stockholding varies considerably across *high food security risk countries*. In Mongolia, optimal public wheat stocks required to achieve food security is 1.7 times higher than current public stocks permissible under the WTO. Consequently, Mauritius requires AMS to be set at 17 percent of domestic production to achieve food security. However, AMS is more restrictive across a number of countries including Barbados, Guatemala, Senegal, among others.

3.6.2.1.2 Moderate food security risk countries

The ratio of 'optimal public stocks' to 'permissible public stocks' is less than 1 for some commodities across *moderately food security risk countries*. In the case of rice, ratio of 'optimal public stocks' to 'permissible public stocks' is less than 1 in India, Indonesia, Pakistan, Peru, the Philippines and Venezuela. This implies that public stocks permissible under WTO are sufficient to achieve food security in these countries. Hence, the AMS policy is not restrictive on rice stockholding in India, Indonesia, Peru, Pakistan, the Philippines and Venezuela.

The policy is, however, restrictive on rice stockholding in Turkey. The ratio of 'optimal public stocks' to 'permissible public stocks' is approximately 1.5 (Table 3.9). In Turkey, optimal public rice stocks required to achieve food security is 1.5 times higher than current public stocks permissible under the WTO. Consequently, Turkey, requires AMS to be set at least 15 percent of domestic production to achieve food security (Table 3.10).

In the case of corn, the ratio of 'optimal public stocks' to 'WTO permissible public stocks' is greater than 1 for all *moderately food security risk countries* with the exception of India, Pakistan, the Philippines and Turkey. The ratio for Indonesia, Peru and Venezuela are 2.4, 7.3 and 4.3 respectively (Table 3.8). This means that public corn stocks permissible under WTO are sufficient to achieve food security in all *moderate food security risk countries* with the exception of Indonesia, Peru and Venezuela. Hence, substantive expansion of AMS is required to achieve food security in these countries. In Venezuela, for instance, the levels of public stocks of corn required to achieve food security is 4.3 times higher than what is currently allowed under WTO. Thus, Venezuela requires AMS to rise from current 10 percent to 43 percent to achieve security in corn

(Table 3.10). Further, considerably higher AMS are also required in Indonesia (24%) and Peru (73%) to achieve corn consumption security.

In the case of wheat, the ratio of 'optimal public stocks' to 'WTO permissible public stocks' is greater than 1 for all *moderate food security risk countries* with the exception of India, Pakistan and Turkey. This means that public stocks permissible under WTO are sufficient to achieve wheat consumption security in India, Pakistan and Turkey. Hence, the AMS policy is not restrictive on wheat stockholding in these countries. The policy is, however, restrictive on wheat stockholding in Indonesia, Venezuela, Peru and Philippines. The AMS policy needs considerable expansion in Indonesia (255760%), Venezuela (78030%), Peru (312%) and Philippines (144670%) to achieve wheat consumption security. While these large expansions need to be interpreted with caution, they are in line with some policy intuition. The extra-large AMS figures suggest that some countries need AMS to be treated as "green box" policies to enable them to achieve food security. In order words, these countries require the removal of all restrictions on AMS in order to achieve food security.

3.6.2.1.3 Low food security risk countries

The *low food security risk countries* in this paper are Laos, Guyana and China. In the case of rice, the ratio of 'optimal public stocks' to 'WTO permissible public stocks' is less than 1 for all *low food security risk countries*. This implies that public rice stocks permissible under WTO are sufficient to achieve food security for all *low food security risk countries*. In the case of corn, the ratio of 'optimal public stocks' to 'WTO permissible public stocks' is less than 1 for all *low food security risk countries*. Thus, public stocks permissible under WTO are sufficient to achieve food security in all *low food security risk countries*. Hence, the AMS policy is not restrictive on corn stockholding for food security purposes in Laos, Guyana and China. The ratio of 'WTO permissible public stocks' to 'optimal public stocks' is also less than 1 for all *low food security risk countries* in the case of wheat. Thus, the public wheat stocks permissible under WTO are sufficient to achieve food security in Laos, Guyana and China. The results therefore suggest that low risk countries such as China, Laos and Guyana are not constrained by the *de minimis* requirement.

3.7 Conclusions and policy implications

Public stockholding is an essential aspect of food security policy in developing countries. Stockholding in member countries is governed by the AMS disciplines agreed by member countries of the WTO during the Uruguay Round of multilateral negotiations. Recently, some member countries (especially the G-33) are arguing that current AMS regulations on public stockholding are restrictive for food security purposes. This paper explored the restrictiveness of the AMS policy on optimal public stockholding for food security purposes in developing countries. Specifically, the paper categorised countries into high, moderate and low food security risk countries and assessed the levels of restrictiveness for rice, wheat and corn. It should also be noted that this paper assumes all of the allowed AMS is allocated to acquiring public stockholdings. Thus, the current AMS restrictions of 10 percent leaves no flexibility for countries to provide other forms of actionable subsidies to their farmers.

The results shows that AMS policy on public stockholding is restrictive for almost all *high food security risk* countries. These include but not limited to, Barbados, Benin, Botswana, Mauritius and Mongolia. In most cases, the levels of public stocks required to achieve food security is over 10 times the stock levels currently permissible under the WTO regulations. The *high food security risk* countries therefore require considerable freedom on AMS stockholding policy to ensure food security. This restrictions operate across, corn, wheat and rice. In other cases, the results shows that some countries are not constrained by current stockholding policies. The AMS is only restrictive on selected countries and commodities of *moderate food security risk* and *low food security risk* countries. The non-AMS restricted countries include India, Guyana, Laos, Pakistan and China.

In conclusion, the results suggest that AMS is restrictive on most G-33 countries. The result also suggests that countries require different levels of AMS in order to achieve their food security. Hence, strict application of AMS without regards to *food security risk* can be restrictive on optimal public stockholding food security purposes in developing countries. This strongly supports the request by G-33 for an expansion in AMS. However, not all G-33 countries require the policy. For example, the current WTO policy on public stockholding does not pose risk to food security to India and China. Such countries can be exempted from considerations.

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Appendix

Table 3A. 1 Intercepts and coefficients of inverse consumption demand functions for G-33

	Rice		Corn		Wheat	
	Intercept	Coefficient	Intercept	Coefficient	Intercept	Coefficient
Barbados	-	-	-	-	210	-42.40
Benin	300	-41.0	200	-38.0	210	-39.13
Botswana	-	-	200	-5.75	-	-
China	300	-0.01	200	-0.02	210	-0.09
Guatemala	300	-21.4	200	-4.00	210	-1.48
Guyana	300.0	-0.81	200	-1.2	210	-0.58
Haiti	300	-8.60	200	-11.0	210	-41.38
Honduras	300	-7.60	200	-11.0	210	-6.28
India	300	-0.02	200	-0.04	210	-0.05
Indonesia	300	-0.64	200	-2.00	210	-0.28
Kenya	300	-0.17	200	-7.00	210	-32.14
Laos	300	-7.0	200	-18.0	-	-
Madagascar	300	-0.13	200	-5.60	210	-39.60
Mauritius	300	-40.0	-	-	210	-1.84
Mongolia	-	-	-	-	210	-0.91
Mozambique	300	-9.80	200	-6.00	210	-12.54
Nigeria	300	-0.54	200	-1.30	210	-0.11
Pakistan	300	-0.08	200	-3.50	210	-0.07
Panama	300	-41.0	200	-5.30	210	-39.1
Peru	300	-12.0	200	-5.60	210	-0.79
Philippines	300	-0.23	200	-12.0	210	-1.50
Senegal	300	-0.08	200	-3.60	210	-3.06
Tanzania	300	-0.63	200	-5.40	210	-7.53
Turkey	300	-1.12	200	-0.22	210	-0.02
Uganda	300	-3.40	200	-5.30	210	-9.65
Venezuela	300	-0.68	200	-5.70	210	-43.37
Zambia	300	-7.00	200	-5.20	210	-3.67
Zimbabwe	-	-	200	-7.50	210	-1.91

Source: Author's calculation from literature.

CHAPTER 4

Trade sensitivity to food stockholding policies in developing countries

Abstract

The potential for developing countries' public stockholding programs to distort international trade has raised tension among WTO countries. This concern, in part, arises because the effects of trade losses associated with stockholding can be important for food exporters. In this paper, a hypothetical public stockholding policy aimed at meeting 50 percent of domestic consumption is considered in order to understand the policy's effect on trade. Using a spatial temporal equilibrium trade model, the impact of stock acquisition and stock disposal activities of stockholding on trade are explored: stockholding by all importing countries; stockholding by G-33 importing countries; and stockholding by small G-33 importing countries. The implications of the results for future trade and food security are then dicussed. The model is applied to rice, wheat and corn across selected countries. The results suggest that stockholding impacts (either positive/negative) can be significant for food exporters. However, such impacts are minimal (i.e. less than 5%) when the policy is considered for a relatively small group of countries.

4.1 Introduction

Public stockholding for food security purposes is a contentious issue under the WTO. During the WTO Agriculture Committee meeting on 26 September 2013, "a number of countries expressed concerns that fellow-members' stockholding of food and other agricultural products could depress prices and affect their exports…." (WTO, 2013a). This was in reaction to the then pending proposal by G-33 countries for expanded subsidies on public stockholding for food security purposes in developing countries. Canada, Pakistan and the United States raised concerns about stockholding activities in India and China and whether these constitute a violation of their WTO commitment (WTO, 2013b). Pakistan expressed concerns about stock levels to be released from India's public stockholding programs ahead of each harvesting season and the extent to which this could influence international prices and trade (WTO, 2013b). The effects of public stockholding was again a topic of interest during the WTO Agriculture Ministerial Meeting in Nairobi in 2015. As put by the EU to India (WTO, 2015, p. 11):

> "…., the European Union remains concerned about the potential adverse spill-over effects of the stockholding operations aimed at maintaining stocks of food grains and asks India to explain how it intends to address them in line with its WTO commitments."

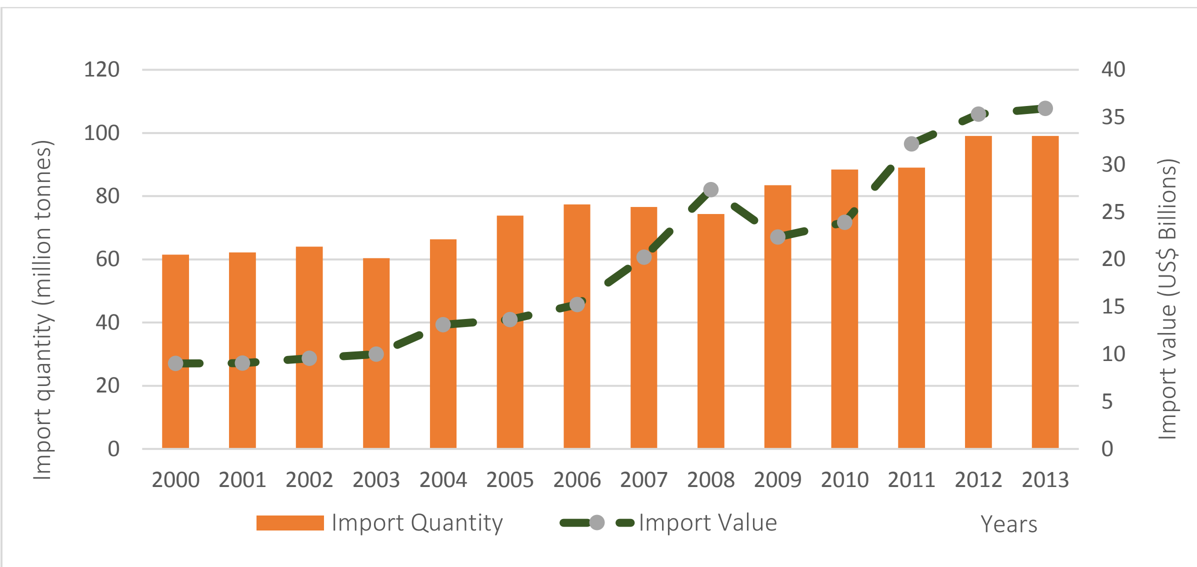
Public stockholding for food security purposes is contentious because its acceptance is perceived to come at the expense of trade benefits. Food exporting countries (the main opponents of the G-33 proposal) argue that stockholding activities in importing countries will negatively affect trade in a number of ways. First, public stockholding programs for food security purposes are designed to purchase and sell stocks in order to keep prices within acceptable limits. However, the artificially high prices at which stocks are usually acquired often induce a supply response which tend to distort trade. Specifically, the difference between the prevailing market price and the price at which public stocks are acquired serves as a subsidy to induce a supply response beyond levels conveyed by the market. This is not a concern when the implementing country has little influence on international prices. For large countries, however, the additional subsidy-induced production may affect trade in the following:

Case 1: If all the subsidy-induced production are channelled into stockholdings programs such that no excess stocks are sold in the market, the policy will have no impact on trade in the short-term. The short-term cost is borne by the implementing country as the opportunity cost of tying up resources in grain storage. The short-term impact does not affect trade and, hence, is less important to exporting countries. However, the disposal of stocks accumulated under public stockholding programs, in future, can increase supply, decrease imports, depress international prices and negatively affect exports of food exporting countries.

Case 2: If the additional production induced by subsidies is higher than levels required for stockholding programs, the excess stocks will be channelled into the market. For large food importing countries, this will increase domestic supply, decrease imports and cause trade distortions in the short-term. Further, the disposal of accumulated stocks in public stockholding programs, in future, can increase future supply, decrease imports, depress international prices and negatively affect exports of food exporting countries. Food exporting countries are primarily against public stockholding in importing countries because of the short-term impacts of excess production and the long-term effects arising from the disposal of accumulated stocks.

Moreover, food exporting countries are concerned about stockholding in developing countries because cereals, which are the main focus of stockholding in G-33 countries, largely come from imports. For instance, aggregate cereal imports by G-33 has grown considerably from 60 million tonnes (in 2000) to approximately 100 million tonnes in 2013 (Fig 4.1). In terms of value, cereal imports amounted to US$35 billion dollars in 2013. This is a market served largely by food exporting countries. Hence, the effects of a trade reduction as a result of stockholding could be significant for grain sector incomes in food exporting countries. Nonetheless, the extent to which the intended stockholding activities in importing countries may affect trade is unknown.

Fig 4. 1 Cereal import by value and quantity: 2000-2013



Source: Author's computation using FAO data.

A number of countries have downplayed the concerns of stockholding activities having any significant impact on international prices and trade. This was revealed in a question to China regarding its cotton stock management. The United States expressed concern about how China intends to dispose of its cotton stocks without affecting trade. In a response, China suggested that its stocks will be sold in the domestic market and, hence, will have no impact on international markets. As put by China's Committee (WTO, 2013b, p. 7):

> "…….Cotton stocks are distributed in the domestic market and are not for export. The Chinese government will distribute the stocks according to domestic market variables. The stocks bear no negative effects on the world market"

China's response is premised on the assumption that stockholding activities in the domestic markets have no effects on world market. This is the case where markets are not integrated. In an integrated global market system, public stockholding activities in one market can be transmitted to others through prices. It is in line with this thinking that the United States argued that internal distribution of large stocks can have negative effects on world market (WTO, 2013b). The United States disagreed with China's explanation and expect to raise further issues and challenges in the coming years against China's stockholding programs. Consequently, whether or not stockholding activities will have any negative impact on trade therefore remains an empirical question. That is one of the issues addressed in this paper.

Further, despite the opposition by food exporting countries, there are considerable reasons to believe that stockholding activities in importing countries can enhance trade in a manner that benefits exporting countries. Agricultural production is dependent on availability of land and favourable climatic conditions. In some net food importing countries, such factors of production may be a constraining such that no amount of subsidies provided to domestic producers can yield the requisite stock levels defined by their food security objectives. For such countries, the likelihood of buying from markets to build their public stocks objectives is high which will tend to drive trade. Further, exporting countries argue that the lifting of limits on AMS will lead to stocks being accumulated solely from domestic producers. While this is possible, there are no reason to believe it will reduce trade between countries. In an integrated international trade system, public stocks acquired from domestic producers tend to reduce quantities available for domestic consumption. Particularly for net food importing countries where production lags demand, the pursuant of large stockholding policies could divert large stocks into storage. This has the tendency of raising domestic prices and inducing imports to the benefits of exporting countries. Nonetheless, the extent of such positive impacts on trade are also unknown, and therefore remain an empirical question. This is a key issue of interest addressed in this paper.

While the extent of impact arising from stockholding activities on trade have not been ascertained, there are credible indications that some developing countries intend to increase stockholding activities considerably beyond WTO agreed levels. For example, Brazil, one of the major stockholding countries, intends to expand its public stockholding programs to support its large population under the zero hunger project (Fritz, 2014). Similarly, India plans to provide food from stocks to over 800 million people under its new food security law (Dreze, 2013; Fritz, 2014). Plans for significant public stockholding in the Economic Community of West African States, the Association of Southeast Asian Nations, the Middle East and North Africa countries beyond six months of domestic consumption are well advanced (World Bank, 2012).

This interest arose in response to the experiences that countries faced during the 2007/2008 and 2010/2011 food crises. The food crises threatened food security for exporting and importing developing countries (DFID, 2013). In response, exports were restricted from some major agricultural producers including Ukraine, Russia, China and Argentina in order to protect their domestic food security (Sharma, 2011). The absence of food stocks in low-income food deficit countries pushed over 75 million additional people into extreme poverty and hunger and increased demand for emergency food aid (FAO, 2008; World Bank, 2009). Rapsomanikis (2009) notes that the rapid increase in food prices translated into unanticipated and large import bills for food and, hence, foreign exchange problems for most countries which were already facing a range of food security challenges.

With these considerable expansions in stockholding, the potential negative impacts on exporting countries is a subject for further investigation. This concern sparked opposition against the G-33 proposal to allow the building of stockholding to be released from WTO disciplines. The opposition to stockholding reforms reached a climax during the WTO Ministerial Meeting in 2014 at Bali, Indonesia. India, the leader of the G-33 group of developing countries, threatened to block the WTO *Trade Facilitation Agreement* [17]unless food security was tabled for consideration. Due to lack of consensus on stockholding, a *Peace Clause* was introduced at the WTO as an interim solution. The *Peace Clause* temporarily restrains countries from challenging stockholding

[17] A WTO agreement aimed at harmonising customs practices across member countries in order to minimize the delays of goods at national borders

programs of other member countries until a permanent solution is negotiated (Kerr, 2015). The resistance against the policy also arises from the seemingly lack of transparency in public stockholding activities. Transparency is an issue because it is quite difficult to observe total stocks held in public and private hands in developing countries. The lack of accurate data makes it impossible to precisely estimate how an increase in public stock holding will impact international trade.

Moreover, policy makers remain divided over the likely impact of unconstrained public stockholdings on trade and food security. The World Bank (2012) has argued that public stocks are not an efficient food security policy because they usually come with a large fiscal cost which outweighs the associated benefits of stabilization. Rather, international trade is considered to be more efficient in dealing with food security problems related to production shocks because countries are exposed to alternative sources of imports. However, evidence about the swiftness of the market response in Chapter 2 of this thesis shows that the trade response to consumption shocks in developing countries is slow. This puts countries at risk if they rely on international trade to restore consumption in times of shocks. The low response is attributed to high transaction costs and limited trade openness, which reduces the swiftness of response needed to be able to assure food security in developing countries. Thus, short-term food security may need to be enhanced through stockholding in these countries. Lamy (2011) argued that accepting the proposed regulations will also largely affect developing countries because approximately 60 percent of developing countries' agricultural and food exports occur among themselves. The extent of the impact of public stockholding policies on trade, however, remains uncertain.

Consequently, a number of studies set out to explore the relationships between trade and public stockholding to gain insights into the effects of stockholding on trade. Banga and Sekhar (2015) used descriptive analysis to explore the effects of past and projected grain export patterns from India's public foodstock programs on African markets. Their study concluded that India is unlikely to possess a sufficient grain surplus to meaningfully distort international markets. Das (2015) argued that India's stockholding program will not distort trade because the government does not directly export grain. Instead, public foodstocks are sold to exporters in a competitive bidding process that removes the incentive to sell below the acquisition price. While these assumptions remain debatable, they studies by Das (2015) and Banga and Sekhar (2015) treat trade as exogenous. Hence, the effect of changes in stockholding activity on international markets across countries and time cannot be acertained. This paper addresses that issue.

This study employs *a 50 percent consumption target storage policy* to gain insights into the extent to which stock acquisition and stock disposal activities of stockholding strategies can affect trade. The choice of 50 percent consumption target storage policy is in line with current thinking on storage levels in developing countries. In 1997, a study for the FAO, for example, recommended that countries hold stocks capable of lasting a minimum of four months against the risk of a supply shock (Lynton-Evans, 1997). The FAO four-month storage goal is based on the argument that countries require at least four months to access imports from international markets to restore consumption. However, with the recent spikes in food prices during the 2007/2008 and 2010/2011 food crises and the growth of export restrictions, countries are considering a storage policy lasting over six months (World Bank, 2012). The six-month consumption storage policy is converted to percent consumption by assuming that stocks lasting six months will constitute half a year's consumption. This is approximated by a *50 percent consumption target storage policy* and used to assess the impact of stockholding policies on trade.

In particular, the study seeks to estimate the extent to which stock acquisition and stock disposal activities of public stockholding in importing countries will influence trade. It is assumed that public stocks are built by purely purchasing stocks from markets without subsidising domestic producers. The assumption is relevant because, in the worst case scenario where subsidies are not extended under WTO as being requested by the G-33 proposal, countries may just pursue their stockholding objectives by purchasing from the market. This has implications for trade between exporters and importing countries. Secondly, for limited and unfavourable conditions, a considerable number of food security risk countries are likely to pursue their stockholding objectives by buying from international markets. This is because no amount of subsidies extended to their producers may be sufficient to induce the required stocks defined by their food security objectives. Hence, for such countries stockholding objectives can largely be pursued by buying from the market. The assumption is also important because the ongoing negotiations have not revealed the likely subsidy levels to be agreed upon by WTO members. Hence, any assumptions on subsidy induced-production may lead to results that have no importance for policy. Consequently, ***Case 1*** and ***Case 2*** above, which are contingent upon subsidy-induced production cannot be assessed. For example, ***Case 1*** requires subsidy-induced production to be substantially higher than stock levels needed under public stockholding programs in order to have an effect on trade. Nonetheless, the levels of subsidy to be extended in countries are unknown. Moreover, what even constitutes a substantially higher subsidy is also debatable. Subsidy-induced production effects of stockholding policies on trade can best be assessed once the negotiations have reached an agreement.

The specific objectives of the paper include: (1) to simulate the extent to which the proposed stockholding policies could influence trade by focusing on stock acquisition and stock disposal; and (2) discuss the implications of the results for trade policy, public stockholding and food security in developing countries. The simulation is done for three cases: (1) policy implemented by all importing countries; (2) policy implemented by G-33 importing countries; (3) policy implemented by a small countries exposed to higher food security risk.

The study focus on only importing countries because exporting countries are not demanding stockholding policies. Exporters have export taxes and embargos which are used to limit food exporters and manage their food security risk in times of food crisis, unlike importing countries. Further, quantifying the extent of impact of the proposed stockholding policy can be important in negotiating appropriate compensation schemes if the policy does lead to costly trade impacts.

The paper focus on rice, wheat and corn trade because these are the major cereals included in the food security and stockholding programs of developing countries. The remainder of the paper is organized as follows: section 4.2 is the conceptual framework; section 4.3 is an overview of stockholding policies in developing countries; section 4.4 reviews the relevant literature on stocks and trade interaction; section 4.5 develops the theoretical model; section 4.6 discusses the results; and section 4.7 provides conclusions and recommendations.

4.2 Conceptual framework

The conceptual framework underlying the impact of stockholding activities (i.e. stock acquisition and stock disposal) on trade are presented in this section. It is assumed that public stockholding programs are built by purely acquiring stocks from the market without subsiding domestic producers. Stockholding activities can be specified into three phases.

Phase 1: Stock acquisition stage

The first phase of public stockholding programs (i.e. Phase 1) refers to years of stock acquisition. Countries first commit resources to acquire stock levels defined by their food security objective. A hypothetical stockholding policy is one aimed at acquiring 100,000 tonnes of stocks for food security purposes. Stock acquisition phase will lead to an increase in imports by food importing countries because the policy increase domestic demand for stocks relative to supply. Stockholding policy implemented by food exporting countries, however, leads to a decline in exports during the stock acquisition phase. This is because the diversion of food into storage programs reduce stocks available for exports. Stock acquisition by importing countries is therefore synonymous with *trade creation* because it increases imports while stock acquisition by exporting countries is synonymous with *trade loss*.

Phase 2: Stock replacement/management stage[18]

After government has built the stock size defined by its food security objective, the next stage is stock management/replacement (i.e. Phase 2). Stock management/replacement is necessary because agricultural products cannot be stored forever without loss of quality. Hence, old stocks must be sold out ahead of each harvesting season in order to acquire new ones as replacement. The stock replacement phase is therefore assumed to have a zero net impact on trade. This is irrespective of whether the stocks are being acquired by importing or exporting countries.

[18] Stock management phase is operationalized as a time frame when actual stock level is held constant. Stock management phase comes to an end when government decides to deplete stocks. Hence, the policy does not actually exist indefinitely. The policy has very minimal impact on trade during the stock management stage.

Phase 3: Stock disposal stage

Stock disposal phase refers to the stage where accumulated stocks are released into the market without replacement. A typical case is a change in government policy leading to a discontinuation of the stockholding policy. For food importing countries, stock disposed will increase domestic supply relative to demand. This can result in a decline in imports and negatively affect exports of the exporting countries. *This is one of the major concerns of food exporting countries for opposing the G-33 proposal for stockholding in developing countries.* Stock disposal by importing countries is therefore synonymous to *trade loss* because it decreases imports while stock disposal by exporting countries is synonymous to trade creation.

The three phases of stockholding described above underlie the methodology developed to assess the impact of the proposed stockholding policy on trade. For simplicity, it is assumed that years of stock accumulation can be expressed in a single year, represented by t_1. Also, since years of stock replacement do not affect trade, they can be excluded from any analysis without loss of generality. Further, years of stock disposal is another important aspect of stockholding programs. This is represented by t_2. Thus, the stockholding impact on trade can effectively be reduced to a two-period model where stocks are acquired in period t_1 and disposed of in t_2. Hence, the time frame for the model used here, t, is a set of t_1 and t_2 defined as:

$$t = (t_1, t_2) \qquad (4.1)$$

The above simplification has some insights for infinite horizon models. An infinite horizon model does not have stock disposal phase because stock replacement occurs forever. The policy will remain in place without closure, hence, the stock replacement decision happens over all time periods in the future. An infinite horizon stockholding, therefore, has only stock acquisition and stock management phases. Further, since stock replacement component does not noticeably affect trade, by assumption, the impact of stockholding on trade becomes a one-time effect which occurs during the stock acquisition.

The above simplifications also has insights into the extent of impact that can arise from stockholding activities. In a real world situation, stock acquisition may be done over an extended period of time. Hence, the one time period stock acquisition (assumed here) estimates the maximum impact that can arise as a result of stock acquisition. Where stock acquisition is done over an extended periods, the impacts will be relatively low. Similarly, stock disposal in a one-term period (used here) represents the maximum impact on trade that can arise when accumulated stocks are disposed in a single year. The impacts will be lower if stock disposal is done over an extended period.

In conclusion, the study seeks to provide insights into the maximum impacts on trade as a result of stock acquisition and stock disposal.

4.3 Modelling trade and public stockholding in developing countries

International trade and public stockholding have historically been important food security polices in developing countries. Trade is useful in distributing stocks from food surplus regions to deficit regions. Stockholding is perceived to dealing with contingencies, especially when the reliance on market to arbitrage between surplus and deficit areas is not swift or constrained by policy interventions.

Attempts to quantify the interaction between public foodstocks and trade, however, has followed a variety of approaches. Gustafson (1958) developed a dynamic optimisation framework for determining intertemporal optimal stocks obtained through maximizing a discounted social welfare measure. A primary condition for storage in Gustafson's framework is that the price difference between two periods must exceed/equal storage cost, or else storage does not occur. Williams and Wright (1982, 1991) expanded Gustafson's framework to estimate optimal public stocks. Their studies argue that public stocks are only justified where market failures occur. Gustafson's framework has been adapted for estimating optimal public foodstocks in open economies by Makki *et al* (2001), Gouel (2013), Gouel and Jean (2015) and Larson *et al* (2014). This approach generally considers trade as exogenous, predetermined or non-existent (see, for example, Johnson and Sumner, 1976, pp. 265). Thus, because trade is treated as exogenous, a change in public stockholding policy does not produce a noticeable change in trade. As such, Gustafson's framework has often been used in analysing the storage decisions of a country over time, but not the effects on other countries.

Models for analysing economic equilibriums where markets are separated by space and time are relevant in analysing the effects of stockholding decisions on trade. These models, referred to as "spatial-temporal equilibrium models" were first advanced by Takayama and Judge (1971). Arndt and Schiler (1998) applied a spatial-temporal equilibrium trade model to the maize market in Mozambique. Their model specifies a twelve-month period and ten regions, each comprised of rural and urban centers. Further, Mango and Yanagida (2000) used a spatial-temporal model to examine the effects of trade liberalisation on Japonica rice trade using a two-period model involving 12 countries. Trade impact was modelled using a tariff variable which assumes a value prior to liberalisation and then is reduced to ascertain the impact on trade, prices, consumption and welfare. To minimize the data required, excess demand and excess supply functions were used, while transport costs were predicted using the distance in nautical miles between countries using Cramer's *et al* (1991) estimates.

The spatial-temporal model has two equilibrium conditions that make it appropriate for modelling the impact of stockholding on trade: *the spatial equilibrium condition* and *the intertemporal condition*. The spatial equilibrium condition require that trade occurs between regions if only their price difference is large enough to cover transportation cost; while storage occurs provided the intertemporal price difference is sufficient to cover storage cost. These two conditions characterise spatial-temporal models. The equilibrium solutions are obtained by maximizing the net social surplus. The spatial and temporal equilibrium conditions of the "spatial-temporal equilibrium model" are compatible with stock management decisions in the real world.

Stock management is an intertemporal decision making process, where the policy maker determines optimal carryout stocks from the current period (t_1) to the next period (t_2). Since the model maximizes the discounted surplus, the resulting storage and equilibrium trade outcomes are optimal. Hence, the model does not allow for sub-optimal decisions where a country can understore or overstore from the previous period to t_2. Storage from period t_1 to t_2 is optimal. To illustrate how the spatial-temporal model works in managing stocks, however, let us assume the decision maker can understock or overstore in order to mirror real world outcomes. When a country gets to period t_2 and realizes that stocks carried from the previous year were inadequate, two policy decisions are available to manage stocks. The policy maker can limit amount of stocks to be taken out from period t_2 to t_3. Alternatively, since the country arrived at period t_2 and realised that the stocks from t_1 were low, this raises prices in that country relative to other countries. As a result, economic agents will realize the opportunity to import. Similarly, a country can increase carryout and/or exports if it overstocked from the previous year. The availability of carryout (i.e. stocks stored from current period to the next) and trade options simultaneously in the spatial-temporal model produces solutions that are consistent with real world stock management decisions.

For policy simulation, the spatial temporal model is first solved for benchmark solutions. Secondly, the model is re-solved to obtain new solutions which are compared with the benchmark case when parameter(s) of interest are changed. The change in equilibrium values are then attributed to the effects of the policy (Kryzan, 2015; Paris *et al*, 2011). In the study, the effect of public stockholding on trade are simulated for four cases:

- Scenario 1: No stockholding policy (i.e. benchmark case)
- Scenario 2: Policy implemented by all importing countries
- Scenario 3: Policy implemented by G-33 food importing countries
- Scenario 4: Policy implemented by small G-33 food importing countries

In each case, the effects of the policy is determined by comparing trade levels with benchmark values. The spatial-temporal equilibrium used for the simulation is developed in the next subsection.

4.4 The spatial – temporal equilibrium trade model

The spatial-temporal model developed in this paper draws extensively on the work of Mango and Yanagida (2000). The model is presented in steps which principally define the exporters market, the importers market, the spatial equilibrium condition, the storage equilibrium condition, and the public storage condition. The model is balanced by assuming that aggregate exports equal aggregate imports at all times.

Exporting country model: Exporting countries participate in the world market through excess supply, implicitly derived from the difference between domestic demand (DC) and domestic supply (DS). A country becomes an exporter when domestic supply exceeds demand at the world price. For an exporting country (E), a rise in export price leads to a fall in domestic consumption, an increase in supply and consequently increases excess supply which is available for export. Hence excess supply (ES) is a positive function of export price (EP) as:

$$ES_{E,t} = \emptyset_{E,t} + \beta_{E,t} EP_{E,t} \ \text{, for all } t \quad (4.2)$$

Where the subscript E stands for exporter; $\emptyset_{Et}$ is the intercept term representing export levels of a country even if world prices were zero[19]; and β_E is a positive parameter representing the effect of a price increase on exports. The possibility for excess supply to come from exporting regions is imposed by assuming that domestic supply minus the amount in stocks (ST) must equal domestic consumption and exports (ES) (Magno and Yanagida, 2000). This is a feasibility constraint imposed in the model to ensure that exports arises only from exporting countries. This is stated mathematically as:

$$DS_{E,t} - ST_{E,t} = DC_{E,t} + ES_{E,t} \quad \text{for all } t \quad (4.3)$$

Importing country model: Importing countries participate in the world market through excess demand, implicitly derived from the difference between domestic demand (DC) and domestic supply (DS) at prevailing world price. A country is an importer when domestic consumption exceeds supply at going world price. For an importing country (I), excess demand is negatively affected by import price (IP). A rise in import price decreases domestic consumption while increasing domestic supply. The two effects combine to decrease imports. Hence, excess demand and import price are negatively related as:

$$ED_{I,t} = \theta_{I,t} - \delta_{I,t} IP_{I,t} \qquad (4.4)$$

Where the subscript I stands for importer; $\theta_{I,t}$ is a constant representing import levels of a country even at a zero world price[20], that is, some amount of trade will still prevail among countries at zero prices; and $\delta_{I,t}$ is the coefficient measuring the effects of import price on excess demand. We impose the restriction that domestic consumption, for an importer, is the sum of stocks, domestic supply and imports such that there cannot be exports from importing regions. This is a feasibility

[19] Note that this is only a notational value arising from the linear assumption imposed on the excess export supply curve.
[20] Note that this is only a notational value arising from the linear assumption imposed on excess import demand curve.

constraint imposed in the model to ensure that imports arises only from importing countries. This is stated as:

$$DC_{I,t} = ST_{I,t} + DS_{I,t} + ED_{I,t} \qquad (4.5)$$

Spatial arbitrage condition: The spatial arbitrage condition (*i.e. spatial law of one price*) requires that trade only occurs between two countries provided their price difference equals the per unit transport cost (equation (4.6)). When the reverse holds such that the price difference between the countries is less than transport costs, there will be no trade (equation (4.7)). Although policies such as export taxes and import tariffs also act to increase the price in importing countries, for simplicity, the study focus on per unit transport cost (h). Spatial arbitrage condition is incorporated in the model as:

$$P_{I,t} - h = P_{E,t},\ TRADE > 0 \qquad (4.6)$$

$$P_{I,t} - h \leq P_{E,t},\ NO\ TRADE \qquad (4.7)$$

Where P_I and P_E are prices in importing and exporting countries respectively.

Intertemporal storage condition: The intertemporal price condition (*i.e. intertemporal law of one price*) requires that storage from period t to t+1 occurs if only the price difference is large enough to cover per unit storage cost(c). In this paper, t and t+1 are represented by t1 and t2 respective. This is defined by equation (4.8), and for no storage (equation (4.9)).

$$P_{t1} - c = \delta P_{t2},\ STORAGE > 0 \qquad (4.8)$$

$$P_{t1} - c \leq \delta P_{t2},\ NO\ STORAGE \qquad (4.9)$$

Where P_t and P_{t+1} are current and future price respectively. Expected prices are discounted by a factor δ (= (1/ (1+r)), where ‘r’ is the discount rate.

Stockholding policy: The public storage policy considered in this paper is a *50 percent consumption target.* Therefore, total stocks acquired in each country is expected to last for a minimum of six months. Representing the policy target — measuring stock duration — by the letter 'z', stock held at a given time (STt) as a percentage of consumption is defined as:

$$ST_t \geq z * Consumption \quad (4.10)$$

Where z=0.5 for the six month storage policy (i.e. 50 percent consumption target).

Algebraically, setting policy target (equation 4.10) as a function of consumption leads to undefined determinant because domestic consumption (DC) is also included as a constrain in the model (i.e. equation 4.4). As a result, the model cannot be solved. To make the model solvable, average consumption values from 2010 to 2014 were first used to calculate target stock levels in equation 4.10. Since target storage now assume parameters (instead of a function), consumption and policy target are delinked and the model can be solved. Target storage levels of importing countries used in the simulation are shown in Table 4.1.

Table 4. 1 Target storage levels of importing countries (million tonnes)

	Rice	**Corn**	**Wheat**
China	68.0	88.0	56.7
Nigeria	2.5	4.5	1.8
Indonesia	19.0	5.0	3.0
Philippines	6.5	3.5	1.2
EU-28	1.6	32.8	-
Middle East	4.1	8.5	27.5

Source: Author's computation.

Market clearing condition: For the model to close, it is assumed that the sum of imports must equal exports at a given time.

$$\sum_{I,t} IMPORT - \sum_{E,t} EXPORT = 0 \quad \textit{for all } t \qquad (4.11)$$

The market clearing condition is a feasibility condition required to ensure that total exports generated from exporting countries are sufficient to meet total imports at equilibrium.

Solving the model: The model is solved by choosing prices in importing and exporting countries that maximizes the discounted social welfare as:

Maximize W= Wt_1 + Wt_2/ $(1+r)^{t-1}$ (4.12)

Where:

$$W_{t1} = \sum\nolimits_{I,t1} (\theta_{I,t1}\, PI_{I,t1} - 0.5\delta_{I,t1} PI^2_{I,t1}) - \sum\nolimits_{E,t1} (\emptyset_{E,t1}\, PE_{E,t1} + 0.5\beta_{E,t1} PE^2_{E,t1})$$

$$W_{t2} = \sum\nolimits_{I,t2} (\theta_{I,t2}\, PI_{I,t2} - 0.5\delta_{I,t2} PI^2_{I,t2}) - \sum\nolimits_{E,t2} (\emptyset_{E,t2}\, PE_{E,t2} + 0.5\beta_{E,t2} PE^2_{E,t2})$$

Subject to:

1) Spatial price equilibrium condition

$$P_{I,t} - h = P_{E,t},\ TRADE > 0 \quad \textit{for all t}$$

2) Intertemporal storage equilibrium

$$P_{t1} - c = \delta P_{t2},\ STORAGE > 0 \quad \textit{for all importers and exporters}$$

3) Excess demand condition for importing regions

$$DC_{I,t} = ST_{I,t} + DS_{I,t} + ED_{I,t} \quad \textit{for all t}$$

4) Excess supply condition for exporting regions

$$DS_{E,t} - ST_{E,t} = DC_{E,t} + ES_{E,t} \quad \textit{for all t}$$

5) Excess supply function

$$ES_{E,t} = \emptyset_{E,t} + \beta_{E,t} EP_{E,t} \quad \textit{for all t}$$

6) Excess demand function

$$ED_{I,t} = \theta_{I,t} - \delta_{I,t} EP_{I,t} \quad \textit{for all t}$$

7) Market clearing condition

$$\sum\nolimits_{I,t} IMPORT = \sum\nolimits_{E,t} EXPORT \quad \textit{for all t}$$

The model is first solved to obtain the benchmark solutions (i.e. the base case). The model is solved using the General Algebraic Modeling System (GAMS) where computer programmable codes are written to execute the model. The GAMS programming has been used extensively for spatial equilibrium and spatial-temporal trade modelling to solve a series of algebraic equations to generate optimal values for policy simulation.

To simulate the effect of the policy on trade, the stockholding policy ($ST_t \geq z * Consumption$) condition is included and re-solved. The level of storage needed to achieve 50 percent of domestic consumption is known in advance. Hence, each stock level is entered as a parameter. In the base case where storage is not allowed, stock parameters are set to zero. The model is solved by choosing price levels that maximizes total welfare subject to the constraints. The observed difference between the new equilibrium trade and benchmark solutions represent the policy effect of stockholding in *scenario 2, scenario 3* and *scenario 4*. The specific steps involve in implementing the stockholding conditions are illustrated below.

4.4.1 Steps in implementing stockholding constrains in the model

Step 1: The benchmark case

The stockholding policy is implemented through excess demand and excess supply constraints discussed above. These are restated as:

Excess demand condition: $DC_{I,t} = ST_{I,t} + DS_{I,t} + ED_{I,t}$ for all t

Excess supply condition: $DS_{E,t} - ST_{E,t} = DC_{E,t} + ES_{E,t}$ for all t

Stockholding is a policy that leads to accumulation of stocks in implementing countries. Hence, to assess the policy's impact on trade it is assumed that storage does not occur during the benchmark case. Countries are allowed to trade under the benchmark case but not permitted to hold stocks. The zero stockholding policy implies that $ST_{I,t}$ = 0 and $ST_{E,t} = 0$. Hence, the excess demand and excess supply conditions for the benchmark case becomes:

Excess demand condition: $DC_{I,t} = 0 + DS_{I,t} + ED_{I,t}$ *for all t*

Excess supply condition: $DS_{E,t} - 0 = DC_{E,t} + ES_{E,t}$ *for all t*

With these restrictions imposed, the model is solved to determine equilibrium trade values that arises under the assumption of 'no stockholding' (i.e. Scenario 1 above). These serve as benchmark values for the simulation.

Step 2: Stockholding policy implementation[21]

Once the benchmark model is solved, the effect of increasing stocks as a result stockholding policy can now be assessed by observing the change in equilibrium trade values before and after stockholding. Stockholding policy has three stages – a stock acquisition stage, a stock management stage, and a stock disposal stage. It is assumed that stock management stage does not noticeably affect trade. As a result, only the stock acquisition and stock disposal effects of stockholding are modelled. The implementation of stock acquisition and stock disposal policies in the model are discussed below.

Step 2.1: Stock acquisition stage

Stock acquisition occurs in period t_1. Given a no storage excess demand condition:

$$DC_{I,t1} = 0 + DS_{I,t1} + ED_{I,t1}$$

The diversion of stocks (ST_{t1}) into stockholding reduces the amount available for consumption. Consequently, the resulting excess demand condition becomes:

$$DC_{I,t1} = DS_{I,t1} + ED_{I,t1} - ST_{I,t1}$$

DS is domestic supply and ST is the amount of domestic supply taken out of the market for storage. Consequently, the amount effectively supplied in the market for domestic consumption has declined. The decline in effective supply is stated as:

$$[DS_{I,t1} - ST_{I,t1}] \downarrow$$

[21] While shocks often arise from global production falls, shocks can also arise from domestic crop failures and other calamities and countries may hold stocks to mitigate shocks of domestic origin. The stockholding policy modelled herein focuses on government held stocks in the domestic economy.

Hence, the excess demand condition is stated as:

$$DC_{I,t1} = [DS_{I,t1} - ST_{I,t1}] \downarrow + ED_{I,t1}$$

Given that effective supply has declined, domestic prices will increase as a result to induce imports in order to restore consumption. If imports increase by amount of stocks put into stockholding, the policy's impact on trade will exactly equal to levels of storage. However, where imports does not increase accordingly, domestic prices will rise and lead to a decline in consumption. Consequently, stock acquisition in importing countries may increase prices, increase imports or decrease consumption in importing countries. This is summarised as:

$$\downarrow DC_{I,t1} = [DS_{I,t1} - ST_{I,t1}] \downarrow + ED_{I,t1} \uparrow$$

Step 2.2: Stock disposal stage

Stock disposal occurs in period t_2. It is important to note that stocks disposed in period t_2 must be equal to stocks acquired in period t_1. Thus, $ST_{t2} = ST_{t1}$. The disposal of ST_{t1} increase effective domestic supply in period t_2. This is stated as:

$$[DS_{I,t2} + ST_{t1}] \uparrow$$

The increased effective domestic supply leads to a decline in prices, increased consumption reduces imports by the importing country. Thus, stock disposal leads to a decline in international prices which affect exports. This is a major concern for countries opposing the stockholding in importing countries. The impact of stock disposal can be summarised as:

$$\uparrow DC_{I,t2} = [DS_{I,t2} + ST_{I,t1}] \uparrow + ED_{I,t2} \downarrow$$

Stock acquisition and stock disposal can be implemented sequentially in GAMS to analyse the impact of stockholding policy on trade. The excess demand conditions in t_1 and t_2 become:

$$DC_{I,t1} = DS_{I,t1} + ED_{I,t1} - ST_{I,t1} \text{ and: } DC_{I,t2} = DS_{I,t2} + ED_{I,t2} + ST_{I,t1}$$

The model is solved by incorporating the stockholding condition in the model to obtain the new equilibrium trade values. The observed difference between the new equilibrium trade and benchmark values represent the effects of stockholding in *scenario 2*, *scenario 3* and *scenario 4*.

4.5 Data

The 2012/2013 and 2013/2014 consumption, stocks, production and trade data is used to calibrate the benchmark model for the simulation. As indicated by Paris *et al.* (2011) and Kryzan (2015), for simulation models to have relevant policy implications, the benchmark model must closely predict real world values. For good predictions, it is important to select years which represent a normal case. The 2012/2013 and 2013/2014 are selected because:

1. No major distortions to production, consumption or trade are known to have occurred in these years.
2. The 2012/2013 and 2013/2014 provides the most recent data available. Hence, analysis based on current data is important for current policy and also going forward.

Consumption, stocks, production and trade data are available online from USDA Foreign Agricultural Services. USDA data is reported in marketing years which span across calendar years. The years 2012/2013 and 2013/2014 are designated as t_1 and t_2 respectively. Storage cost and cost of capital were assumed at $25 and 20 percent per annum respectively.

The main G-33 developing countries of interest are China, India, Indonesia, Nigeria and The Philippines. These are large consumption countries whose stockholding activities can have significant impact on trade. Turkey and Pakistan which are also large consumption G-33 countries were, however, excluded because of their limited impact on trade in cereals. While the most important cereal in Turkey's food consumption is wheat, Turkey's wheat imports and export are approximately the same. Hence, its impact on global trade is approximately zero. Further, despite rice being a major export in Pakistan, it is, however, relatively insignificant compared to India and Thailand. Hence, its influence in global market can be negligible. To ensure that the estimates approximate observed trade data, relevant non-G33 trading countries were included. These are Thailand, EU-28[22], Middle East and the United States.

The United States serves as the exporter country for corn and wheat in the model due to its large influence in wheat and corn export markets. The United States has had close to 50 percent and 25

[22] List of countries in the EU-28 region by USDA classification include Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxemburg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and United Kingdom.

percent of corn and wheat export markets respectively since 2013. Thailand and India served as rice exporting countries because of their substantial exports in the international markets in 2013 and 2014. The importing countries are China, Nigeria, Indonesia, The Philippines, EU-28 (exempted for wheat) and the Middle East[23]. Corn and wheat prices in US are available from World Bank Commodity group. Further, export prices of rice in India and Thailand were determined by taking a ratio of export values to export quantities using FAO data. Similarly, import values of cereals were divided by import quantities to determine prices in importing countries.

Obtaining data on transport cost is a challenge in spatial equilibrium analysis. As a result, economists often use regression analysis to estimate per unit transport cost. Cramer *et al* (1991), for instance, used a regression (equation 4.11) to estimate cost per tonne(TC) of shipping grain between ports of trading nations using nautical mile distance (DIST) and nationality of shipping vessel (US) as explanatory variables as:

$$\text{"}TC_{ie}=0.0124\ DIST_{ie}\ -0.000000875\ DIST_{ie}^{2} + 57.3648\ US;\text{"}$$
$$(9.96) \qquad (-6.07) \qquad (17.17)$$

"R2=0.772; Std. Error =17.19, d.f. =106"

Where, US is a dummy variable for shipment occurring on US vessels. Cramer *et al* (1991)'s approach is adapted to estimate per unit trade cost as it also focuses on cereals. The approach is, however, adapted with some modifications. First, shipment on US flagged ships are very expensive relative to non-US flagged ships due to the Merchant Marine Act of 1920. As a result, commercial shipments does not occur on US flagged ships with exception of cereal sourced in the US for food aid purposes, which are required by law to be shipped on US flagged ships to recipient countries (Prof. W. A. Kerr, personal communication, June 2016). Hence, the dummy variable representing US flagged ship was given the value zero.

Secondly, while some studies prefer to use nautical distance between ports to predict trade cost, this is problematic for landlocked countries. As a result, nautical distance between national capitals were used. Brussels served as capital city for EU-28 because it is administrative capital

[23] List of countries in the Middle East by USDA classification include Bahrain, Gaza Strip, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, Turkey, United Arab Emirates, West Bank and Yemen

of European Union. However, no definite form of integration exist among the Middle East countries. As such the most popular city, Dubai, was used as a proxy for the capital city of the Middle East. These were used to estimate per unit transport cost between countries.

Further, Cramer's estimates reflect transport cost for 1991. As such, the values were adjusted for inflation using consumer price index (CPI) data available from U.S Bureau of Labor Statistics. The US CPI is preferred because Cramer's transport cost are measured in US dollars per tonne. The annual average CPI in 1991 is estimated at 136.2 while CPI for 2012, 2013 and 2014 were estimated at 230, 233 and 237 respectively. It is assumed that transport cost did not change significantly over the period of 2012 to 2014. The average of the three CPI known as 'Average CPI in current years' was calculated and used to adjust for inflation as:

$$Adjusted\ transport\ cost = \frac{Average\ CPI\ in\ current\ years}{CPI\ in\ 1991} * Unadjusted\ transport\ cost \quad (4.12)$$

The resultant per unit transport costs adjusted for inflation are presented in Table 4.3.

Table 4. 2 Transport costs ($/tonne) between countries adjusted for inflation

		Importers					
		China	Nigeria	Indonesia	Philippines	EU	Middle East
Exporters	India	37	62	47	45	32	21
	Thailand	33	71	24	23	40	46
	US	74	67	71	75	32	74

Source: Author's computation.

The elasticities of demand and supply were derived from the literature to estimate intercept and slope parameters of the excess demand and supply functions[24] for 2012/2013 and 2013/2014. The list of intercepts and coefficients used to calibrate rice, corn and wheat base case models are presented in Tables 4.4, 4.5 and 4.6 respectively.

[24] See Appendix 4.2 for the derivations excess demand and excess supply intercepts and coefficients.

Table 4. 3 Intercepts and coefficients of excess demand and excess supply functions of rice

	t_1		t_2	
	Intercept (million tonnes)	**Coefficient**	**Intercept (million tonnes)**	**Coefficient**
Importing countries				
China	40.6	-0.08	36.3	-0.07
Nigeria	12.9	-0.02	13.1	-0.02
Indonesia	14.5	-0.03	14.8	-0.03
The Philippines	10.6	-0.02	10.3	-0.02
EU-28	45.7	-0.09	39.7	-0.08
Middle East	49.0	-0.09	43.6	-0.08
Exporting countries				
India	-122.7	0.30	-124.7	0.31
Thailand	-29.4	0.08	-24.7	0.08
US	-	-		

Source: Author's computation.

Table 4. 4 Intercepts and coefficients of excess demand and excess supply functions of corn

	t_1		t_2	
	Intercept (million tonnes)	**Coefficient**	**Intercept (million tonnes)**	**Coefficient**
Importing countries				
China	86.3	-0.23	76.7	-0.21
Nigeria	7.4	-0.02	10.4	-0.03
Indonesia	13.5	-0.03	10.6	-0.02
The Philippines	14.6	-0.04	7.6	-0.02
EU-28	122.3	-0.33	112.0	-0.30
Middle East	60.6	-0.14	56.5	-0.13
Exporting countries				
India				
Thailand				
US	-254.0	0.95	-239.0	0.98

Source: Author's computation.

Table 4. 5 Intercepts and coefficients of excess demand and excess supply functions of wheat

	t_1		t_2	
	Intercept (million tonnes)	**Coefficient**	**Intercept (million tonnes)**	**Coefficient**
Importing countries				
China	114.8	-0.31	122.0	-0.33
Nigeria	15.2	-0.03	11.0	-0.02
Indonesia	14.6	-0.02	17.8	-0.03
The Philippines	14.5	-0.03	10.8	-0.02
Middle East	72.7	-0.15	62.3	-0.13
Exporting countries				
India				
Thailand				
US	-201.0	0.82	-206.3	0.88

Source: Author's computation.

4.6 Results and Discussion

4.6.1 The Benchmark model results

This section presents the benchmark equilibrium prices, trade and welfare levels for rice, corn and wheat from the spatial-temporal equilibrium models.

4.6.1.1 Benchmark equilibrium prices

Public stockholding for food security purposes is a policy aimed at increasing stock levels in developing countries. To assess the impact of this policy on trade, it is important to assume that the base case (i.e. benchmark) stocks are zero for all countries. With zero stockholding in the in base case, the effect of increasing stocks — as a result of stockholding — can be ascertained by comparing the change in equilibrium trade relative to the base case. Thus, the model is solved to produce zero initial stocks of rice, wheat and corn to serve as initial (i.e. benchmark) values.

The shadow prices associated with the base case are presented in Table 4.6. Shadow prices reflect equilibrium prices that will prevail in importing and exporting countries if countries were to trade but not permitted to hold stocks. In all cases, the equilibrium price of rice, corn and wheat in t_1 are generally higher than price levels in t_2. For instance, shadow price of rice in Nigeria are approximately US$505/tonne and US$495/tonne in period t_1 and t_2 respectively. In China, shadow prices for wheat in t_1 and t_2 are approximately US$363/tonne and US$352/tonne respectively; while shadow price for corn in US for t_1 and t_2 are approximately US$291/tonne and US$276/tonne respectively. The higher prices in t_1 relative to t_2 is consistent with the zero stockholding condition imposed on the base case. Intuitively, since future prices are expected to be lower than present prices, there is no incentive to stock grain from the present to future in both exporting and importing countries. Further, shadow prices are generally higher in importing countries than in exporting countries. This presents an economic incentive to export grain to importing countries. In the next sub-section, the equilibrium trade levels existing under the base case scenario are presented.

Table 4. 6 The benchmark equilibrium prices ($/tonne)

	Rice		Corn		Wheat	
	t_1	t_2	t_1	t_2	t_1	t_2
Importers						
China	473	459	365	350	363	352
Nigeria	505	495	358	343	356	345
Indonesia	464	450	362	347	360	349
Philippines	463	449	366	351	364	353
EU-28	495	478	348	333	-	-
Middle East	464	454	365	350	363	352
Exporters						
India	443	433	-	-	-	-
Thailand	440	426	-	-	-	-
United States	-	-	291	276	289	278

Source: Author's computation.

4.6.1.2 The benchmark equilibrium trade

The equilibrium trade results for the benchmark case are presented in Table 4.7. Total rice traded in t_1 and t_2 are approximately 16 million and 19 million tonnes respectively. Rice imports by China, Nigeria, Indonesia and the Philippines in t_1 are approximately 2.8 million, 2.8 million, 0.6 million and 1.3 million tonnes respectively; while imports in t_2 are approximately 4.2 million, 3.2 million, 1.3 million and 1.3 million tonnes respectively. Similarly, the equilibrium exports from Thailand and India are approximately 5.8 million and 10.2 million tonnes respectively in t_1; while corresponding exports in t_2 are approximately at 9.3 million and 9.5 million tonnes respectively. The values in parenthesis are percentage error[25] between actual and the base case (i.e. benchmark/initial) trade values. For the individual countries, the error of discrepancy between observed and base case equilibrium trade values are within ± 15 percent.

Aggregate corn traded in t_1 and t_2 is 22.5 million and 31.5 million tonnes respectively. The benchmark equilibrium corn import for China, Nigeria, Indonesia and the Philippines in t_1 are approximately 2.3 million, 0.2 million, 2.8 million and 0.1 million tonnes respectively; while the

[25] Percentage error = ((Predicted-Actual)/Actual)*100. Actual trade equals absolute value of net trade (i.e. |observed imports – observed exports|)

corresponding imports, in t_2, are 3.2 million, 0.1 million, 3.7 million and 0.6 million tonnes respectively. Error of discrepancy is generally less than 15 percent for all cases with the exception of EU in period t_1, where the benchmark model under predicts actual corn imports by 18.5 percent. The benchmark model also over-predict and under-predict observed US corn exports by 56 percent and 34 percent in t_1 and t_2 respectively.

Table 4. 7 The benchmark equilibrium trade (million tonnes)

	Rice		Corn		Wheat	
	t_1	t_2	t_1	t_2	t_1	t_2
Importers						
China	2.8 (0.0%)	4.2 (+11.0%)	2.3 (-11.5%)	3.2 (-3.0%)	2.3 (+15.0%)	5.7 (-1.7%)
Nigeria	2.8 (0.0%)	3.2 (+14.3%)	0.2 (0.0%)	0.1 (0.0%)	4.5 (+12.5%)	4.1 (+2.5%)
Indonesia	0.6 (-14.3%)	1.3 (+8.3%)	2.8 (+3.7%)	3.7 (+5.8%)	7.4 (+7.2%)	7.3(+2.8%)
Philippines	1.3 (-7.1%)	1.3 (+8.3%)	0.1 (0.0%)	0.6 (-14.3%)	3.6 (+3.0)	3.7 (+5.7%)
EU-28	1.3 (+8.3%)	1.5 (+15.0%)	7.5 (-18.5%)	12.1 (-13.5%)	-	-
Middle East	7.2 (-1.4%)	7.3 (+13.5%)	9.5 (-13.6%)	12.0 (-10.8%)	18.2 (-13.3%)	17.5 (-16.7%)
Total (million tonnes)	**16.0**	**18.8**	**22.5**	**31.5**	**36.0**	**38.3**
Exporters						
India	10.2 (-3.8%)	9.5 (-10.3%)	-	-	-	-
Thailand	5.8 (-5.0%)	9.3 (-13.1%)	-	-	-	-
United States	**-**	**-**	22.5 (+56.0%)	31.5 (-34.0%)	36.0 (+33.3%)	38.3(+40.0%)
Total (million tonnes)	**16.0**	**18.8**	**22.5**	**31.5**	**36.0**	**38.3**

Source: Author's computation.

Note: Values in parentheses are percentage error of discrepancy between equilibrium benchmark trade values and the observed trade.

Further, the aggregate wheat trade are estimated at 36 million and 38.3 million tonnes in t_1 and t_2 respectively. In the base case, China imports approximately 2.3 million and 5.7 million tonnes of wheat in t_1 and t_2 respectively; while Indonesia imports are estimated at about 7.3 million tonnes in both years. The Philippines, on the other hand, has aggregate wheat imports in t_1 and t_2 of approximately 3.6 million and 3.5 million tonnes respectively. The error of discrepancy between observed and predicted imports, for each country, is within ±15 percent in most cases with exception of the Middle East where the benchmark model under-predicts observed wheat imports by 16 percent . The model over-predicts aggregate US wheat exports by 33.3 percent and 40 percent in t_1 and t_2 respectively. In conclusion, apart from US where error of discrepancy is relatively large, all other trade flows are predicted to acceptable degree of accuracy. The benchmark model predicts actual trade with minimal errors and, thus, serves as a reasonable basis for evaluating the impact of stockholding policy on trade.

4.6.1.3 Benchmark welfare

The estimated values for society's welfare are presented in Table 4.8 below. The welfare estimates are social surplus to society arising from efficient allocation of grain to trade and consumption across countries. In the base case, the welfare to society for efficient allocation of rice to consumption and trade over the two periods is approximately $150 billion. Similarly, aggregate welfare estimate for corn and wheat trade in the base case are approximately $117.4 billion and $111.0 billion respectively. In the next section, the impact of the stockholding policy on trade are assessed.

Table 4. 8 The benchmark equilibrium welfare[26] (million $)

Cereal	**Total (billion $)**
Rice	150.0
Corn	117.4
Wheat	111.0

Source: Author's computation from the model.

[26] Welfare measures do not capture the reduced risk of food insecurity associated with stockholding.

4.6.2 Impact of stockholding policies on trade

The impact of public stockholding policies on cereal trade are discussed in three scenarios. Stockholding across all importing countries (Scenario 2); stockholding across G-33 importing countries (Scenario 3); and stockholding by small G-33 importing countries (Scenario 4).

4.6.2.1 Importing countries implement storage policy (Scenario 2)

The section examines the extent of impact on trade that arises due to stock acquisition and stock disposal from *a 50 percent consumption target storage* policy. In this section, t_1 and t_2 are years of stock acquisition and stock disposal respectively. The impacts on rice, wheat and corn trade are presented in Table 4.9 below. The importing countries (i.e. all importing countries) are China, Nigeria, Indonesia, the Philippines, EU and the Middle East.

Table 4. 9 Impact of stockholding policy on trade - Importers implement policy[27] (Scenario 2)

	Rice		**Corn**		**Wheat**	
	t_1	t_2	t_1	t_2	t_1	t_2
Importers						
China	+28%	-27%	+25%	-26%	+24%	-21%
Nigeria	+36%	-34%	+32%	-30%	+33%	-35%
Indonesia	+37%	-34%	+35%	-32%	+34%	-36%
Philippines	+41%	-38%	+37%	-41%	+35%	-32%
EU-28	+23%	-25%	+25%	-24%	-	-
Middle East	+25%	-26%	+22%	-18%	+18%	-25%
Total trade in million tonnes	**23.5 (+30.6%)**	**13.2 (-42.4%)**	**28.3(+25.0%)**	**24.3(-23.4%)**	**45.1(+25.3%)**	**27.4(-28.5%)**
Exporters						
India	+27.7%	-17.7%				
Thailand	+35.3%	-43%				
US			+25.0%	-23.4%	+25.3%	-28.5%
Total trade in million tonnes	**23.5 (+30.6%)**	**13.2 (-42.4%)**	**28.3(+25.0%)**	**24.3(-23.4%)**	**45.1(+25.3%)**	**27.4(-28.5%)**

Source: Author's computation from the model.

[27] The model uses point elasticities to extrapolate and analyse the impact of stockholding on trade. Hence, the changes in trade should be interpreted with caution because the confidence level regarding such estimates declines as the degree of extrapolation increases.

4.6.2.1.1 Impact of stock acquisition on trade (t_1)

The results suggest that *a 50 percent consumption target storage policy* in importing countries will increase trade considerably during stock acquisition (i.e. t_1). The model predicts equilibrium rice, corn and wheat traded at approximately 23.5 million; 28.3 million tonnes and 45.1 million tonnes respectively (Table 4.9). This represent an increase in trade of 30.6 percent; 25 percent and 25.3 percent for rice, corn and wheat respectively relative to the base case. Rice imports by China, Nigeria, Indonesia and the Philippines increase by 28 percent, 36 percent, 37 percent and 41 percent respectively relative to base case as a result of the policy. Corn imports increase by approximately 25 percent, 32 percent, 35 percent and 37 percent for China, Nigeria, Indonesia and the Philippines respectively relative to the base case. The storage policy leads to 24 percent, 33 percent, 35 percent increase in wheat import by China, Nigeria, Indonesia and the Philippines respectively.

Trade increase because the additional stocks required for storage programs are imported from international markets. The increased demand for imports for storage programs translates into increased demand for exports. Consequently, rice exports from Thailand and India increased by more than 27 percent while corn and wheat exports from United States increase by more than 25 percent as a result of stockholding policies in importing countries. Further, the increased demand for stocks also drive up cereal prices during the stock acquisition phase. Wheat prices increase by more than 15 percent in Indonesia and Philippines as a result of stock acquisition for stockholding programs (Table 4.10). The acquisition of stocks also leads to rise in corn and rice prices for the Philippines and Nigeria by approximately 10 percent due to acquisition.

The increase in trade represent the maximum positive impact that can arise if stock acquisition were carried out in a single year. The benefits to exporters will be relatively less if public stocks are to be acquired over an extended period of time.

Table 4. 10 Stockholding policy impact on prices -Importers implement policy (Scenario 2)

	Rice		Corn		wheat	
	t_1	t_2	t_1	t_2	t_1	t_2
Importers						
China	+2.1%	-2.0%	+0.7%	-0.6%	+0.5%	-0.4%
Nigeria	+10.3%	-9.8%	+0.8%	-0.9%	+15%	-15.5%
Indonesia	+1.6%	-1.5%	+9.2%	-8.4%	+15%	-16.1%
Philippines	+5.8%	-5.4%	+0.3%	-0.3%	+10.6%	-10.5%
EU-28	+0.6%	-0.7%	+1.1%	-0.9%		
Middle East	+2.3%	-2.2%	+3.3%	-4.1%	+6.1%	-8.3%
Exporters						
India	+2.0%	-2.2%				
Thailand	+5.2%	-4.3%				
United States	**-**	**-**	**+2.0%**	**-1.8%**	**+4.0%**	**-4.4%**

Source: Author's computation from the model.

This, results, which suggest that stockholding will increase trade is not what WTO members that do not want the limits on AMS lifted expect. They expect that raising the limits on AMS will lead to stock being accumulated solely from domestic producers. The results, however, do have some useful insights into how stockholding in importing countries can affect trade. The results imply that in an integrated market system, when importers pay higher prices to acquire stocks from their domestic markets, domestic prices are bound to rise. This will induce imports from international markets. Thus, it is inconsequential as to whether stocks are acquired from domestic or international producers. In this particularly instance, the results suggest that a 50 percent consumption target storage policy could increase trade by more than 20 percent during stock acquisition.

Nonetheless, exporting countries have concerns about the impact that can arise when accumulated stocks are disposed of. Thus, the next subsection discusses the extent to which a 50 percent consumption target policy could affect trade during stock disposal.

4.6.2.1.2 Impact of stock disposal on trade (t_2)

The disposal of accumulated stocks is a concern for food exporting countries. The sale of accumulated stocks increase domestic supply relative to consumption in importing countries resulting in a decline of prices. This is a major concern for exporting countries because falling international prices negatively affect their exports. In this analysis, the period t_2 presents the impact imposed on trade when accumulated stocks are disposed. As shown in Table 4.9, wheat prices decline by more than 15 percent in Nigeria and Indonesia as result of stock disposal. This consequently led to a decline in trade between countries.

The model predicts aggregate rice, corn and wheat traded at approximately 13.2 million, 24.3 million and 27.4 million tonnes respectively as a result of stock disposal (i.e. t_2). This represent a decline in rice, corn and wheat trade by 42.1 percent; 23.4 percent and 28.5 percent respectively relative to the base case (Table 4.9). The disposal of accumulated stocks of rice in importing countries lead to decline in exports from Thailand and India by 43 percent and 17.7 percent respectively relative to the base case. Similarly, stock disposal leads to a decline in corn and wheat exports from United States by 23.4 percent and 27.4 percent respectively relative to the base case. This results therefore imply that stock disposal in importing countries can have substantial negative impact on future trade.

The decline in trade represent the maximum negative impacts that can arise if accumulated stocks were disposed of in a single year. Where accumulated stocks are disposed of over an extended period of time, the impacts will be relatively small. Secondly, given that stock acquisition might increase trade gains to exporting countries, the negative impacts of the policy (accounting for gains) can also relatively lower.

4.6.2.1.3 Impact of stockholding policy on welfare

The above impact of stockholding activities suggest two conclusions. First, 50 percent consumption stockholding program can enhance trade to the benefits of exporting countries during stock acquisition. However, considerable negative impact can arise when accumulated stocks are disposed of. Despite these respective gains and losses, the policy leads to overall negative effects on social welfare. In particular, social welfare declines by 24 percent, 28 percent and 32 percent for rice, corn and wheat respectively relative to the base case (Table 4.11). Welfare declines because stock acquisition diverts large volumes into storage beyond optimal levels and creates food scarcity, while stock disposal increase supply beyond optimal levels resulting in a glut.

Table 4. 11 Policy impact on welfare

Cereal	Welfare (billion $)	% change over base case
Rice	114.0	-24%
Corn	84.5	-28%
Wheat	74.8	-32%

Source: Author's computation from the model.

4.6.2.2 G-33 importing countries implements policy (Scenario 3)

The main G-33 importing countries considered are China, Nigeria, Indonesia and the Philippines. Stockholding in G-33 importing countries produces impacts similar to the case where the policy is implemented by all importing countries (Scenario 2). Total rice, corn and wheat stocks required by G-33 for stockholding purposes as percentage of stocks required by all importing countries are 94 percent, 71percent and 70 percent respectively. Consequently, the impacts arising from G-33 stockholding activities largely approximate impacts arising from stockholding activities by all importing countries.

The policy drives up prices during stock acquisition (t_1) and reduces prices during stock disposal (t_2). Rice price rose by 1.6 percent, 8.3 percent, 1.3 percent and 4.2 percent in China, Nigeria, Indonesia and the Philippines relative to the base case during stock acquisition (Table 4.12). Corn prices increase by more than 8 percent in Indonesia. Similarly, wheat price rose by more than 8 percent in Nigeria, Indonesia and Philippines. Price increase because of increased demand for stocks in G-33 countries. Rice, corn and wheat price, on the other hand, declined by more than 13 percent in most G-33 countries as a result of stock disposal. Stock disposal also results in falling cereal prices in the EU and Middle East.

Table 4. 12 Policy impact on prices (Scenario 3)

	Rice		Corn		Wheat	
	t_1	t_2	t_1	t_2	t_1	t_2
Importers						
China	+1.6%	-1.5%	+0.4%	-0.3%	+0.3%	-0.3%
Nigeria	+8.3%	-9.1%	+0.7%	-0.8%	+12%	-13%
Indonesia	+1.3%	-1.2%	+8.3%	-8.0%	+12%	-13%
Philippines	+4.2%	-3.8%	+0.2%	-0.2%	+8.2%	-8.0%
EU-28	+0.4%	-0.2%	+0.9%	-0.7%	-	
Middle East	+2.0%	-1.6%	+3.1%	-3.8%	+5.3%	-6.0%
Exporters						
India	+1.8%	-2.0%				
Thailand	+4.1%	-3.2%				
United States	**-**	**-**	**+1.5%**	**-1.2%**	**+3.3%**	**-3.8%**

Source: Author's computation from the model.

4.6.2.2.1 Stock acquisition effects on trade

Stock acquisition by the G-33 implementing countries (i.e. China, Nigeria, Indonesia and Philippines) increase imports by more than 20 percent for rice, corn and wheat and similar to scenario 2. The policy increases imports because the additional stocks for storage leads to an increase in imports. However, the rise in prices as a result of stockholding in G-33 negatively affect imports of other countries. Rice imports by Middle East and EU decline by 34 percent and 5.8 percent respectively. In all, the policy increase aggregate rice trade by 12.5 percent relative to the base cases. Similarly, aggregate corn and wheat trade increase by 13 percent and 16 percent respectively relative to the base case as a result of stock acquisition. In terms of food security, the policy suggest that stock acquisition by some large importers could actually make other importing countries worse-off due to rising global prices.

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Table 4. 13 Impact on trade: G-33 implement policy (Scenario 3)

	Rice		Corn		wheat	
	t_1	t_2	t_1	t_2	t_1	t_2
<u>Importers</u>						
China	+35%	-29%	+28%	-27%	+28%	-20%
Nigeria	+40%	-35%	+36%	-34%	+36%	-31%
Indonesia	+41%	-36%	+37%	-34%	+37%	-20%
Philippines	+43%	-32%	+41%	-38%	+41%	-30%
EU-28	-34%	+25%	-12%	+8.3%		
Middle East	-5.8%	+8.7%	-9.5%	+7%	-12%	+18%
Total trade in million tonnes	**18 (+12.5%)**	**16.57 (-11.8%)**	**22.8 (+1.3%)**	**31.0(-1.5%)**	**35.1(+2.5%)**	**36.5(-4.6%)**
<u>Exporters</u>						
India	+8%	-6%				
Thailand	+15%	-18.6%				
US			+1.3%	-1.5%	+2.5%	-4.6%
Total trade in million tonnes	**18.0 (+12.5%)**	**16.57 (-11.8%)**	**22.8 (+1.3)**	**31.0(-1.5%)**	**35.1(+2.5%)**	**36.5(-4.6%)**

Source: Author’s computation.

4.6.2.2.2 Stock disposal effects on trade

Stock disposal leads to a decline in prices and trade. However, the declining prices tend to increase imports by other countries. Rice, corn and wheat imports by China, Nigeria, Indonesia and Philippines decline by more than 25 percent due to stock disposal. This is partially offset, however, by the rising imports for the Middle East and the EU. Rice, corn and wheat imports by the Middle East increase by more than 5 percent due to depressed global prices. In the end, stock disposal leads to a decline in aggregate rice, corn and wheat trade by 11 percent, 1.5 percent and 4.6 percent respectively (Table 4.13). In terms of food security, the results suggest that stock disposal by a section of importing countries could actually make others better off due to declining food prices.

4.6.2.2.3 Impact on welfare

The policy leads to changes in social welfare. Overall, society's welfare decline by 15%, 19.2% and 16.1% for rice, wheat and corn models respectively (Table 4.14). This is attributed to the distortions created by the policy. Stock acquisition leads to food scarcity in the society while stock disposal creates a distortion in the form of a glut. In all, overall value to society is not maximized as a result.

Table 4. 14 Policy impact on welfare

Cereal	Welfare (billion $)	% change over base case
Rice	126.8	-15.5%
Corn	94.9	-19.2%
Wheat	93.1	-16.1%

Source: Author's computation from the model.

4.5.2.3 Small countries implement policy (Scenario 4)[28]

The main small countries considered are Nigeria, Indonesia and the Philippines. The impact of storage policies by small importing countries leads to negligible impacts on trade and welfare. Total stock required by 'small importing countries' as a percentage of stock required by all importing countries for stockholding purposes are 27.5 percent, 9 percent and 6.5 percent respectively. Hence, stock required by small importing countries are comparably low. As a consequence, its impact on prices and trade are relatively lower. Stock acquisition drive up prices marginally, by less than 2 percent across rice, corn and wheat, while causing prices to decline by less than 3 percent during disposal (Table 4.15). This suggest that storage policies by small countries may not result in significant impacts on trade.

Table 4. 15 Policy impact on prices (Scenario 4)

	Rice		**Corn**		**wheat**	
	t_1	t_2	t_1	t_2	t_1	t_2
Importers						
China	+ (<0.1%)	- (<0.1%)	+ (<0.1%)	- (<0.1%)	+ (<0.1%)	- (<0.1%)
Nigeria	+1.1%	-0.9%	+0.2%	-0.2%	+1.1%	-1.2%
Indonesia	+0.3%	-0.2%	+1.2%	-1.0%	+3.0%	-3.2%
Philippines	+0.5%	-0.3%	+ (<0.1%)	- (<0.1%)	+0.6%	-0.5%
EU-28	+ (<0.1%)	- (<0.1%)	+ (<0.1%)	- (<0.1%)	-	-
Middle East	+ (<0.1%)	- (<0.1%)	+ (<0.1%)	- (<0.1%)	+ (<0.1%)	- (<0.1%)
Exporters						
India	+ (<0.1%)	- (<0.1%)				
Thailand	+ (<0.1%)	- (<0.1%)				
United States	-	-	+ (<0.1%)	- (<0.1%)	+ (<0.1%)	- (<0.1%)

Source: Author's computation.

[28] Sensitivity analysis for large importing countries using China as a focal point was also conducted. However, the results were very similar in magnitude to those of Scenario 3. As a result they are not reported.

4.6.2.3.1 Stock acquisition effects on trade

Stock acquisition increase rice, corn and wheat imports by Nigeria, Philippines and Indonesia by more than 20 percent, similar to scenario 3. The policy increases imports because the additional demand for stocks for storage increase demand relative to supply, raise prices and induce imports. However, the rise in prices negatively affect imports by other importing countries. Rice, corn and wheat imports decline by less than 4 percent in China, Middle East and EU. Consequently, the policy's impact on trade is lessened because the increase in demand for stocks by Nigeria, Indonesia and Philippines is partly offset by the fall in demand for imports by other countries.

4.6.2.3.2 Stock disposal effects on trade

Stock disposal leads to a decline in prices and trade. The disposal of accumulated stocks by small food security risk countries leads to a decline in prices but less than price declines under Scenario 2 and 3. At equilibrium, rice, corn and wheat imports decline by less than 6. The fall in prices due to stock disposal, however, increase demand by other importing countries. Imports to China, EU and Middle East rise but less than 15 percent for most cases. However, the fall in imports is not fully offset by the increase in demand (by other importing countries) which leads to an overall decline in trade. This policy implies that stock disposal activities in small importing countries may have negligible impact on global prices, trade and food security. Hence, allowing stockholding in small countries faced with considerable food security risk may not produce noticeable impacts on trade.

Table 4. 16 Policy impact on trade (Scenario 4)

	Rice		Corn		Wheat	
	t_1	t_2	t_1	t_2	t_1	t_2
Importers						
China	-15%	+2.3%	-4.5%	+3.1%	-4.5%	+7%
Nigeria	+40%	-36%	+33%	-32%	+35%	-36%
Indonesia	+38%	-37%	+35%	-33%	+36%	-35%
Philippines	+44	-36%	+38%	-40%	+33%	-33%
EU-28	-12%	+6.6%	-6.6%	+1.6%	-	-
Middle East	-6.5%	+1.3%	-6.3%	+0.01%	-28%	+23%
Total trade in million tonnes	**16.7 (+4.3%)**	**17.8 (-5.3%)**	**22.3 (+0.01%)**	**30.8(-0.02%)**	**36.3 (+0.01%)**	**37.4 (-0.02%)**
Exporters						
India	+3.9%	-6.3%				
India	+5.2%	-4.3%				
US			+0.01%	-0.02%	+0.01%	-0.02%
Total trade in million tonnes	**16.7 (+4.3%)**	**17.8 (-5.3%)**	**22.3 (+0.01%)**	**30.8(-0.02%)**	**36.3 (+0.01%)**	**37.4 (-0.02%)**

Source: Author's computation.

4.6.2.3.3 Impact on welfare

The policy leads to marginal changes in social welfare. Overall, society's welfare declines by 2%, 1.3% and 4% for rice, wheat and corn respectively (Table 4.17). This is attributed to the distortions created by the policy. Stock acquisition creates a distortion by creating food scarcity in the society while stock disposal creates a distortion in the form of glut. Overall value to society is not maximized as a result. The welfare distortions are, however, small compared to scenario 2 and 3, where large countries implement the policy.

Table 4. 17 Policy impact on welfare

Cereal	Welfare (billion $)	% change over base case
Rice	140.4	-6.4%
Corn	113.1	-3.7%
Wheat	-105.7	-4.8%

Source: Author's computation from the model.

4.6.3 Summary results and implications for WTO negotiations

The impact of the proposed stockholding policies on trade are summarised in Table 4.18 below. The results shows that stockholding policy implemented across food importing countries could yield significant positive effects (Scenario 2). Stock acquisition could increase trade in rice, corn and wheat by 30.6 percent, 25 percent and 25.3 percent respectively. Despite these significant gains, exporting countries are primarily concerned about the negative impacts that can arise due to stock disposal. The most important concern of food exporters focuses on these negative consequences.

The results shows that disposal could lead to a decline in rice, corn and wheat trade by 42.4 percent, 23.4 percent and 28.5 percent respectively when the policy is implemented across all importing countries. Scenario 3 investigates the extent of impacts that arises when stockholding are allowed only in G-33 importing countries. These countries include China, Nigeria, Indonesia and the Philippines. The negative impacts due to stock disposal of rice, corn and wheat are approximately

11 percent, 1.5 percent and 4.6 percent respectively. Thus, with the exception of rice, stockholding impacts are largely below 5 percent. Scenario 4 investigates the case where small G-33 countries are allowed to hold stocks. These countries include Nigeria, Philippines and Indonesia. The effects of stock disposal on trade are less than 1 percent for corn and wheat, and about 5 percent for rice. While the results suggest that the negative impacts of stockholding considered for a section of countries may be small, those impacts can be significantly large when the policies is implemented across large consumption countries.

The results suggest that the negative effects of stock disposal in importing countries are inevitable. However, the extent of impact varies depending on the size of the implementing countries. Particularly, stockholding activities in small countries faced with considerable food security risk could be allowed since their impacts on trade are negligible. Allowing stockholding in all importing countries or G-33 countries can lead to significant negative impacts on trade. Large consumption countries seeking to implement stockholding policies must establish appropriate compensation schemes to minimise their policies impact on affected countries.

Table 4. 18 Summary of policy impacts on trade (%)

	Rice		**Corn**		**Wheat**	
	acquisition	disposal	acquisition	disposal	acquisition	disposal
Scenario 2	+30.6	-42.4%	+25.0%	-23.4%	+25.3%	-28.5%
Scenario 3	+12.5%	-11.8%	+1.3%	-1.5%	+2.5%	-4.6%
Scenario 4	+4.3%	-5.3%	+0.01%	-0.02%	+0.01%	-0.02%

Source: Author’s computation.

The estimated values are potential maximum impacts that can arise as a result of stock acquisition or stock disposal. This is because it is assumed that stock acquisition or stock disposal happens in one year. If acquisition took place over ten years, for example, to reach the 50 percent consumption target, then the impacts will be considerably smaller. Similarly, if stocks were run down over ten years the effects would be less. Secondly, considerable positive benefits can accrue to exporting countries as a result of stock acquisition. These impacts, when taken into consideration can substantially reduce the overall negative impacts perceived by exporting countries. Thus, the concerns of exporting countries may not be particularly realistic – and the case against stockholding may be weak.

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Appendix

4A. Derivation of coefficients and intercept terms:

Excess supply elasticity (E_s) of an exporting country is calculated as:

$$E_s = e_s * \frac{Production}{Export} - e_d * \frac{Consumption}{Export} \qquad (4.13)$$

Excess demand (E_d) of an importing country is derived as:

$$E_d = e_d * \frac{Consumption}{Import} - e_s * \frac{Production}{Import} \qquad (4.14)$$

The production, consumption, exports and imports used to estimate E_s and E_d are averages of 2012/2013 and 2013/2014. The e_s and e_d are elasticities of supply and demand respectively in each country. Given Es and Ed, the intercept and coefficients of excess demand of an exporting country (e) and excess demand of an importing country (i) can be derived as follows:

A linear excess demand function is specified for an exporter e as:

$$ES_{e,t} = a_{e,t} + b_{e,t}EP_t \qquad (4.15)$$

Where, EP, a, b and ES are export price, intercept, coefficient and export quantity at time t respectively. The E_s is derived from equation 4.15 as

$$E_s = \frac{EP_t}{ES_t} * \frac{\Delta ES}{\Delta EP} \qquad (4.16)$$

$$E_s = \frac{EP_t}{ES_t} * b_{e,t} \qquad (4.17)$$

Therefore,

$$b_{e,t} = \frac{EP_t}{ES_t} * \frac{1}{E_s} \qquad (4.18)$$

The intercept term is derived as:

$$a_{e,t} = EP_{e,t} - b_{e,t}ES_t \qquad (4.19)$$

A linear excess demand function is specified for importer i as:

$$ED_{i,t} = c_{i,t} + d_{i,t}IP_t \qquad (4.20)$$

Where, IP, c, d and ED are import price, intercept, coefficient and import quantity at time t respectively. The coefficient ($d_{i,t}$) and intercept ($c_{i,t}$) can be determined as:

$$d_{i,t} = \frac{IP_t}{ED_t} * \frac{1}{E_d} \qquad (4.21)$$

$$d_{i,t} = IP_{e,t} - b_{e,t}ED_t \qquad (4.22)$$

CHAPTER 5

Conclusions and recommendations

5.1 Summary of finding and conclusions

The food crises in 2007/2008 and 2010/2011 initiated dramatic changes to food security policies of developing countries. The food crises led to significant increase in food prices and threatened food security in food exporting and importing countries alike. As a consequence, food exports were restricted from a number of major agricultural exporting countries including Argentina, India, China, Russia and Ukraine, among others. Food export restrictions is estimated to have increased food insecurity levels and pushed over 75 million people into extreme hunger in developing countries. As a result, many developing countries want to build public food stocks which can be used to mitigate food crisis in times of supply shocks. However, the levels of stockholding a country is permitted to have is disciplined by the WTO's *de minimis* restriction on subsidies agreed in the Uruguay Round Agreement on Agriculture.

As per the *de minimis* agreement, subsidy support levels cannot exceed 10 percent of the value of domestic production. A group of developing countries (known as the G-33) concerned that the de minimis restriction would constrain stockholding efforts petitioned the WTO for a relaxation of the agreed limits. The proposal has, however, been opposed at the WTO because the building of public stocks is, arguably, trade distortionary. Some member countries also argue that the current WTO regulations provide sufficient policy freedom for developing countries to address their food security issues without the need to relax stockholding policies. This thesis provides information pertaining to two key questions: (1) Whether or not there is the need for public stockholding in developing countries. (2) What the implications are for the proposed changes in stockholding commitments on trade? Wheat, rice and corn have been the focus of this analysis given their importance in food security. The conclusions regarding these two questions and the broader implications for food security and public stockholding are presented below.

5.1.1 Is public stockholding necessary in developing countries?

The first paper (presented in Chapter 2) explored the need for stockholding in developing countries. The study concludes that the market response to consumption shocks are slow in developing countries. This implies that relying on the market — specifically international trade — to restore consumption in times of shock is not a wise policy. Hence, there is a legitimate need for government intervention, including the use of stockholding, to enhance food security. The results indicates that markets can restore at most 46 percent of cereal consumption distortion in developing countries in a timely fashion. The estimated market response to shocks ranges from 12 to 41 percent for rice; 14 percent to 31 percent for corn; and 22 to 46 percent in the case of wheat. The response rates are considered to be slow because more than 50 percent of the distortions to food needs cannot be restored by relying on the market following a shock. The weak response is attributable to issues with trade openness and transaction costs which delay the ability to respond to price incentives. The conclusions, therefore, support the general call for food security stocks in developing countries.

As a robustness check, market responses were also estimated for net food importing developing countries, net food importing developed countries and net food exporting developed countries. The responses are faster in these cases compared to net food importing developing countries. This suggest that they are generally better at restoring consumption than net food importing developing countries. Given that net food exporting developing countries face similar transaction costs and trade openness as net food importing developing countries, the higher responses can be attributed to the availability of policy instruments to limit exports in times of food crisis, which enable a quicker restoration of consumption. Such policy instruments include the use of export taxes and embargos to keep food within national bothers. Further, developed countries are highly integrated in regional trade agreements. This, together, with low transaction costs and good infrastructure arguably support quicker responses in developed countries. Thus, net food importing developing countries are the most at risk. The study also finds that trade openness and income enhance long-run consumption in developing countries.

The second paper (presented in Chapter 3) also analyses the need for stockholding policy in developing countries by focusing on the restrictiveness of the current *de minimis* policy. The study considered each G-33 country to determine whether or not it was constrained by the *de minimis* policy. For a number of these countries, the results shows that the current *de minimis* policy are constraining on their ability to hold sufficient stocks to address food security. Hence, there is the need to expand the current limits for these countries. The results, in particular, indicates that the *de minimis* policy is highly restrictive across most high food security risk countries. These include Barbados, Botswana, and Mongolia, among other. In the case of corn, for example, public stocks required in Botswana are about 80 times the current stock levels permitted under the WTO. This is an extreme restriction given that Botswana's major cereal is corn. Hence, expanding the policy to allow vulnerable countries to have sufficient stocks levels is important. Such high restrictions underline the need for public stockholding policies in these countries. The current limit is highly restrictive in the case of wheat compared to other cereals. The heavy restriction implies that these countries simply require exemptions to enhance their food security with regards to wheat consumption. Further, while India and China are spearheading the public stockholding policy debate at the WTO, the results shows that the current *de minimis* policy is largely not constraining on them.

In conclusion, the research identifies the need for stockholding policy based on two issues. First, the ability of the market to restore consumption is slow and yields less than 50 percent of what is needed. Secondly, the de minimis AMS policy is restrictive on optimal public stockholding for food security purposes. However, the requirements differ across countries. Some countries such as India and China, to a large extent, do not need the current limit to be expanded.

5.1.2 What are the potential impact of the proposed policy on trade?

The third paper investigated the impact of stockholding policy on trade. The impact of the proposed stockholding were analysed using a hypothetical 50 percent consumption target policy aiming to meet consumption requirements for six months. The estimated are maximum trade impacts that can arise as a result of stock acquisition or stock disposal in developing countries.

The results shows that tock acquisition could increase exports significantly by over 20 percent. This is, however, not the concern of food exporters. Food exporting countries are concerned about the potential negative impacts that can arise as a result of stock disposal. Insights from the 50 percent consumption target policy shows that stock disposal could increase trade losses by 30 percent for exporters of rice; 27 percent for corn; and 40 percent for wheat. This can translate to significant income losses across net food exporting countries. However, when the policy is implemented by small countries, the impacts (whether negative or positive) are relatively less than 5 percent in most cases. Hence, this policy can be considered for small countries faced with food security risk countries without substantially affecting trade. Large consumption countries seeking to implement stockholding policies must establish appropriate compensation to minimise their policies' impact on affected countries.

5.2 Recommendations

The above sets out two main recommendations regarding stockholding policies in developing countries. The study recommends that stockholding policies may be expanded for small countries faced with high food security risk without considerably affecting trade. However, where large importing countries intend to pursue the policies trade can be substantially affected. Hence, there is the need to establish appropriate compensation schemes to mitigate the impacts on other countries when large countries implement stockholding policies.

5.3 Limitations and suggestions for future research

The paper on market response used trade openness to measure the extent of integration into the world trade system. Future research could consider the use of export restrictions faced by individual countries in their estimations. Further, the analysis of *de minimis* restrictiveness were examined in a two-period time frame. The restrictiveness analysis focused on a two-period model using a specific food crisis. Future research can enhance knowledge by having several simulations for a country and then creating a distribution to determine the probability that an individual country violates its restriction. The simulation can also be done using long-duration models.

In paper 3, a hypothetical 50 percent consumption target policy is used to gain insights into the implications of stockholding on trade. The subsidy induced-production impacts have largely been ignored because the policy negotiations are still ongoing. It is recommended that future research examines the impact of stockholding from a subsidy-induced production perspective once the negotiations are concluded.