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Three essays on Upstream and Downstream Disruptions along Nutritional High-value Food Supply Chains in Emerging Countries

Mark Zingbagba

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**THREE ESSAYS ON UPSTREAM AND DOWNSTREAM
DISRUPTIONS ALONG NUTRITIONAL HIGH-VALUE
FOOD SUPPLY CHAINS IN EMERGING COUNTRIES**

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I dedicate this dissertation to my loving parents ...

Declaration

I hereby declare that the present dissertation was carried out in line with the rules and regulations of the University of Lyon governing the conduct of research by doctoral candidates, and that it has not been submitted in whole or in part for the award of any other degree. It is the candidate's own work, except where specific reference is made to the work of others. Work done in collaboration with, or with the assistance of, others has been duly acknowledged. This dissertation has about 60,000 words including appendices, bibliography, footnotes, tables and equations.

Mark Zingbagba

June 2018

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Abstract

This dissertation presents three essays on disruptions along nutritional high-value food supply chains in emerging countries. It extends our understanding of threats to the attainment of food security in emerging countries. With a contribution to agricultural economics, the dissertation relies on value chain, market growth and price transmission theories and applies both panel data and time series econometric techniques to analyse the sources and magnitudes of the disruption of nutritional high-value food chains.

The first part of the dissertation examines disruptions in unprocessed and minimally processed nutritional high-value food markets. Chapter 2 examines upstream and downstream disruptions along these food chains. Chapter 3 extends the analysis in Chapter 2 by assessing how disruptions change when nutritional high-value foods are highly processed. For each of the two chapters, disruptions are studied in terms of changes in upstream and downstream quantities and prices, with the disruption of quantity considered primary while that of prices is secondary.

Using the São Paulo food market as a case study, Chapter 4 analyses the effect of diesel price shocks on different segments of the nutritional high-value food supply chain. A Vector Error Correction Model (VECM) that takes into account upstream and downstream cross-price effects is estimated to ascertain if diesel price shocks are higher downstream based on price transmission theory.

The results of Chapters 2 and 3 show that climatological disasters are the most dominant source of disruption of nutritional high-value food supply chains and the direction of impact is negative for all foods under study. The magnitude of disruption, however, varies by food. From the VECM results in Chapter 4, we see that the price of diesel has a positive and significant effect on food prices, while the effects downstream are lower than those upstream. These results have significant implications for the design and implementation of food policies in emerging countries.

As a general introduction, Chapter 1 justifies the need to study upstream and downstream differences in the magnitude of supply chain disruption, by situating the dissertation in the existing supply chain and food price transmission literature. Chapter 5 concludes the study and offers suggestions for future research.

Key words:

Food supply chain, Nutritional high-value food, Disruption, Price transmission, Applied econometrics

Résumé

Cette thèse propose trois essais sur les perturbations tout au long de la chaîne de distribution des produits alimentaires à haute valeur nutritionnelle. Elle contribue à notre compréhension des menaces liées à la réalisation des objectifs de sécurité alimentaire dans les pays émergents. Contribuant à l'analyse économique de la chaîne de distribution et des questions agricoles, la thèse est fondée sur différents éléments théoriques relatifs à la chaîne de valeur, la croissance du marché, la transmission des prix et met en œuvre des techniques d'économétrie appliquée (économétrie des données de panel, économétrie des séries temporelles) à partir de base de données originales. L'objectif est d'analyser les sources et l'ampleur des perturbations dans la chaîne de distribution des produits à haute valeur nutritionnelle.

La première partie de la thèse analyse les perturbations sur les marchés des produits alimentaires à haute valeur non-transformés et moins transformés. Le Chapitre 2 examine les perturbations en amont et en aval de la chaîne de distribution de ces produits. Le Chapitre 3 étend l'analyse du Chapitre 2 en prenant en compte les perturbations relatives aux produits ayant subi un niveau de transformation élevé. Dans les deux chapitres, les perturbations sont analysées en termes de changement de prix et de quantité, à la fois en amont et en aval. Le changement de quantité est considéré comme une perturbation préliminaire alors que celui de prix est secondaire. Utilisant le marché de São Paulo comme sujet d'étude, le Chapitre 4 analyse les effets du prix du diesel sur les différents segments de la chaîne de distribution des produits alimentaires à haute valeur nutritionnelle. Un modèle à correction d'erreur (MCE) qui prend en considération les effets des prix entre les différents produits est estimé pour vérifier si les chocs provenant du prix du diesel sont plus élevés en amont qu'en aval. Ce chapitre est analytiquement fondé sur la théorie de la transmission des prix.

Les résultats des Chapitres 2 et 3 montrent que les désastres climatiques sont des sources dominantes de perturbation de la chaîne de distribution des produits alimentaires à haute valeur nutritionnelle. Leur effet est négatif pour tous les produits analysés, bien que l'ampleur de perturbation varie d'un produit à l'autre. Les résultats du modèle à correction d'erreur (MCE) du Chapitre 4 montrent que les effets du prix du diesel sur les prix des produits alimentaires à haute valeur nutritionnelle sont positifs et significatifs, alors que les effets en aval sont plus élevés que ceux en amont. Les résultats de la thèse ont des implications importantes pour le développement et la mise en œuvre des politiques d'alimentation dans les pays émergents. Le Chapitre 1, introduction générale, justifie l'étude des différences entre l'ampleur de perturbation en amont et celle en aval, et situe la thèse dans les littératures existantes. Une conclusion générale est proposée en Chapitre 5 avec des propositions pour de futurs travaux de recherche.

Mots clés : Chaîne de distribution, Produit alimentaire à haute valeur nutritionnelle, Perturbation, Transmission des prix, Econométrie appliquée

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GENERAL INTRODUCTION

1.1 Introduction

Dynamics in household food consumption in emerging countries since the turn of the millennium show a rising share of nutritional high-value foods in household food consumption relative to staple foods. Nutritional high-value foods are domestically consumed food crops that have high nutritional content per calorie or per kilogram. Food crops that fall under this category include meat, eggs, fresh fruits, fresh vegetables, dairy and fat and oil (Skoufias et al., 2011; Tschirley et al., 2015). The above definition differentiates these foods from high-value cash crops which are grown mainly for export, although a small percentage is consumed at home (Hazell et al., 2010; Magnan et al., 2012). This means that high-value food crops are more representative in the food basket than high-value cash crops. Additionally, they have a higher share in the local market than high-value cash crops in developing countries, because they offer an avenue for small-scale farmers to diversify their production and increase revenue (Gulati et al., 2007).

Figure 1.1 shows the trend in household meat and cereals consumption from 2000 to 2012. From this figure, we see that the consumption of meat had an increasing trend throughout the thirteen years. Inversely, the consumption of cereals showed a mixed trend, with an increasing trend from 2002 to 2005 and decreasing thereafter until 2009. After a marginal increase between 2009 and 2010, the consumption of cereals continued its decreasing trend for the rest of the period.

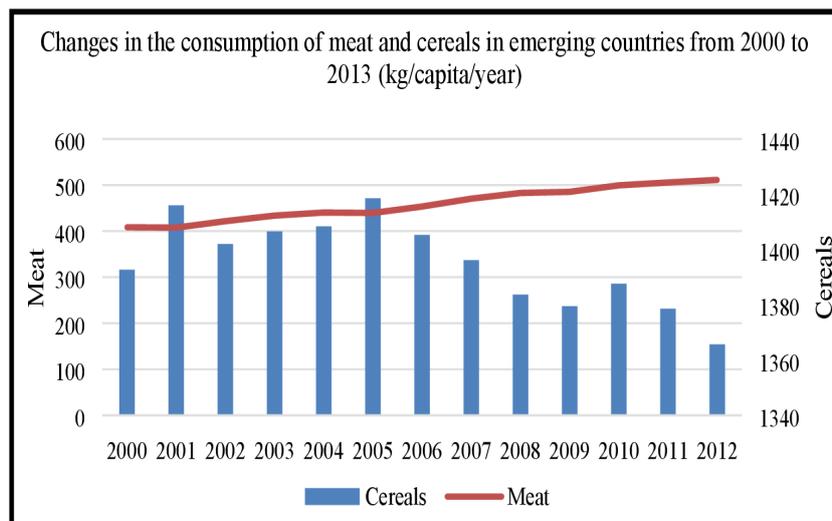


Figure 1.1: Dynamics in the consumption of cereals and meat in emerging countries
 Source: Author generated from the United States Department of Agriculture’s database

To further show the growing share of nutritional high-value foods in household food consumption, the pattern of cereal consumption is compared with that of milk as shown in Figure 1.2. From Figure 1.2, we see that milk consumption recorded an increasing trend from 2001 to 2012 and this increase was maintained throughout the period.

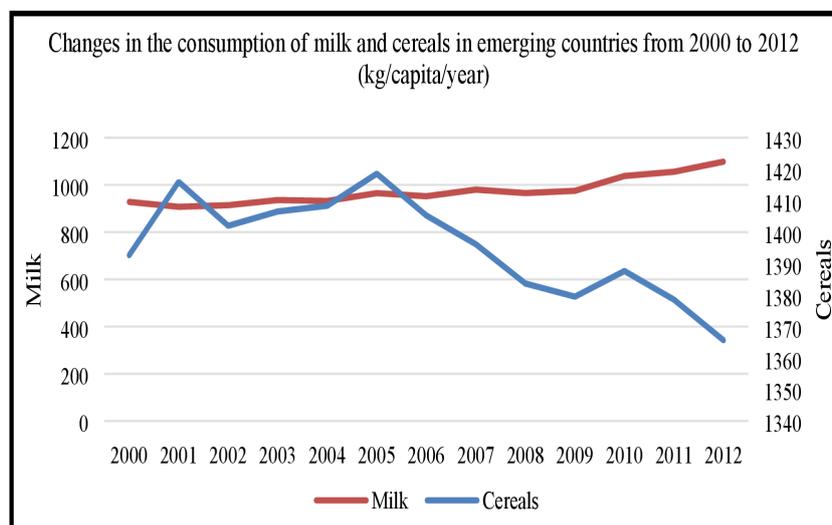


Figure 1.2: Dynamics in the consumption of milk and cereals in emerging countries
 Source: Author generated from the United States Department of Agriculture’s database

Research on food consumption dynamics in emerging and developing countries identifies a growing middle class in these countries as the most important cause of increasing demand for nutritional high-value foods (Easterly, 2001; Banerjee and Duflo, 2008; Ravalion, 2010). Country-level data on growth per capita show that since the turn of the

millennium, emerging countries have recorded sustained growth as shown in Figure 1.3.

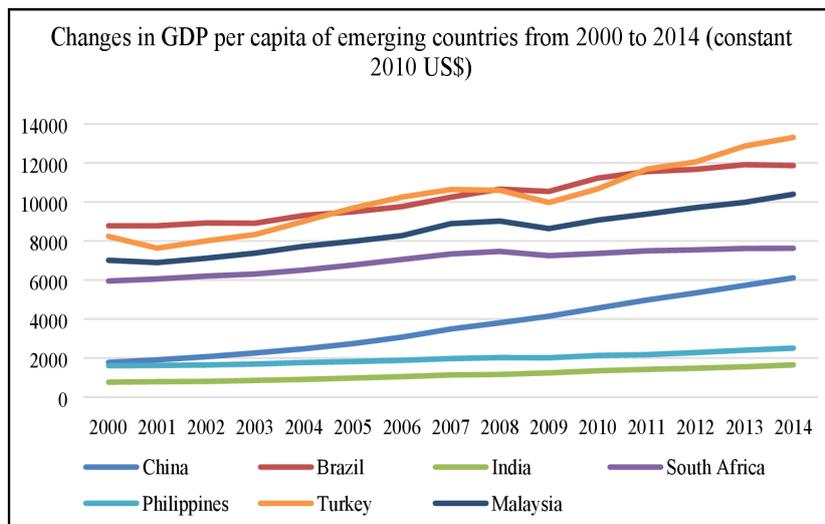


Figure 1.3: GDP per capita in emerging countries, 2004-2014

Source: Author generated from World Development Indicators, published by the World Bank

The increase in demand for these foods is seen as a catalyst for growth in the sectors involved in food processing (Reardon and Timmer, 2014), thereby creating economic opportunities for local entrepreneurs. Despite this consensus, some studies point out that the middle-class population tends to be attracted to imported foods and this can lead to unsustainable food imports (Rakotoarisoa et al., 2011; USDA, 2013). There is also an increasing focus on the food habits of the middle class population in emerging countries, with the conclusion that the high affinity for processed foods could promote obesity and other ailments (Popkin, 2014; Gomez and Ricketts, 2013). This is in spite of their increased attention to healthy food consumption.

Small-scale farmers exist as the main source of nutritional high-value foods in emerging countries (Gulati et al., 2007). A dominant issue for governments and policy-makers in these countries is how to link these farmers to the global food supply chain, in view of the dynamics in global food markets (Maertens et al., 2012; Swinnen and Maertens, 2007). Without institutional support and appropriate measures to help them to improve quality and safety, they will not be able to meet food safety and quality standards, inhibiting their ability to participate effectively along the chain. Moreover, small-scale farmers do not have control over the price that they receive from distributors due to different market powers existing between the two agents. Distributors generally tend to have higher market power both in fixing prices and in enforcing contracts (Sexton, 2012; Russo et al., 2011; Adjemian et al., 2016).

In view of their increasing share in household food consumption in emerging countries,

access to nutritional high-value foods plays a crucial role in attaining food security targets in these countries. Food insecurity remains a key global challenge, with about 795 million people lacking secure access to sufficient amounts of safe and nutritious food for normal growth and development and an active and healthy life. Many of these people are in developing countries (FAO et al., 2015). The principal causes identified for this situation include the unavailability of food, insufficient purchasing power, inappropriate distribution and inadequate use of food at the household level.

According to the Food and Agriculture Organisation, inappropriate distribution is one of the main threats to food security because it affects both access and availability of food (FAO et al., 2015). An appropriate system of food distribution depends, however, on the type of supply chain that operates in the food market. The food supply chain consists of processes that lead to the movement of food from production through sources of distribution to final consumption (Rong et al., 2011). It entails actors engaging to ensure the smooth flow of food until it reaches final consumption.

Different supply chains exist for different food products. This is because the supply chain is a function of characteristics of the food involved and the nature of the interaction between agents. With respect to nutritional high-value foods, we identify three supply chain categories that depend on the level of perishability of the food involved. The first category is the unprocessed food supply chain. This is characterised by highly perishable food products and involve the movement of food from rural producers through packaging houses to retailers as shown in Figure 1.4 below.

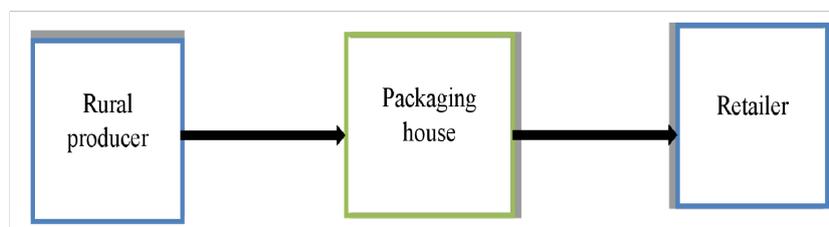


Figure 1.4: Stages and actors along the supply chain of an unprocessed food

The second category is made of semi-processed foods. Although these are perishable, they can be stored for long through refrigeration. Examples of foods that come under this category include meat and eggs. Generally, the supply chain of these foods involves movement from rural producers through slaughterhouses and processing firms to retailers. A schematic representation of this chain is as shown in Figure 1.5.

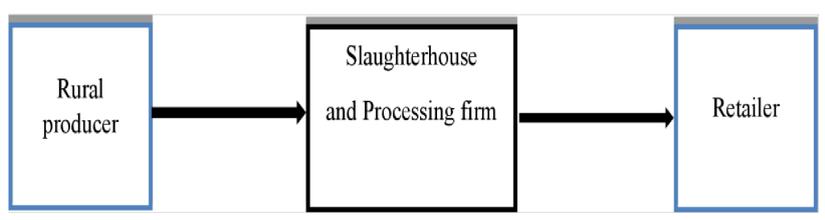


Figure 1.5: Stages and actors along the supply chain of a minimally processed food

The last category comprises processed foods such as milk, oil and fats. These foods are perishable at the rural segment of the chain (where production occurs), but are less perishable after being processed. The typical chain has the food moving from its unprocessed state upstream through processing firms then wholesale units and finally to retailers. A schematic representation of this chain is as shown in Figure 1.6.

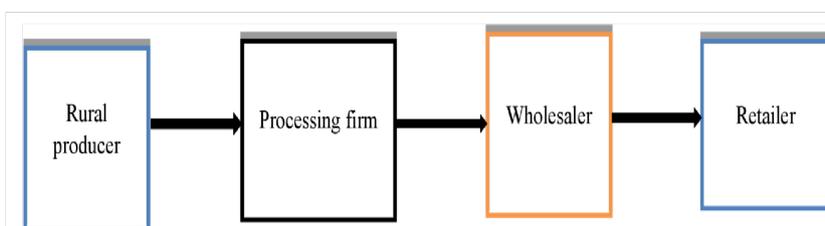


Figure 1.6: Stages and actors along the supply chain of a highly processed food

It is important to note that the characteristics of the food (unprocessed, semi-processed or processed) play a huge role in determining the supply-chain design strategies. Generally, supply chain designers aim at one of two strategies: responsiveness and efficiency (Blackburn and Scudder, 2009; Ketzenberg and Ferguson, 2008). With respect to perishable products such as nutritional high-value foods, Blackburn and Scudder (2009) assert that a combination of the two strategies is relevant, with responsiveness in the early stages and efficiency in the latter stages.

Additionally, the characteristics of the food determine the magnitude of disruption from unintended external negative shocks. Food supply chain disruptions are seen as events that impair the flow of food along the food supply chain (Ambulkar et al., 2015; Bode and Wagner, 2015; Hofmann et al., 2018; Wilson, 2005). They are unintended, anomalous-causing events occurring either within the chain or within its environment and are consequential in nature, threatening the normal functioning of the chain (Bode and Wagner, 2008). These events also impede food availability by affecting food production and reduce food use by impairing food distribution. They may also cause long lasting constraints to the movement of food depending on the degree of impact. It is, therefore, imperative to address the risks from disruptions to food supply chains in order to bolster food access, availability and use.

A cursory review of the existing studies on food supply-chain disruptions reveals that they may emanate from natural disasters (Wilson, 2005). Other studies such as Jüttner (2005) and Nagurney et al. (2005) classify disruptions under demand and environmental sources, with demand sources originating from the disruption of downstream supply chain operations that include uncertainty caused by customers' unforeseeable demand. Environmental sources include external uncertainties caused by political, natural and social uncertainties.

Although the disruption of food supply chains is considered a constant phenomenon (Craighead et al., 2007), the structural underpinnings and socioeconomic dynamics of emerging countries make it imperative to analyse disruptions along the nutritional high-value food supply chain in these countries. The increased demand for these foods offers an opportunity for increased food production by small-scale farmers in emerging countries. It is equally a conduit through which as much food as possible could be provided to households through distributors. Despite these potential gains, inherent structural and institutional bottlenecks in these countries portend that food supply chain disruptions will greatly impede their ability to attain food security. With these countries showing bright prospects in future socioeconomic dynamics, this will have important ramifications for achieving global food security goals.

Based on the list of supply chain disruptions indicated in Bode and Wagner (2008), this dissertation focuses on how conjunctural events in the form of natural disaster occurrences affect the nutritional high-value food supply chain. The study uses climatological, geophysical and hydrological disasters as sources of disruption to nutritional high-value food supply chains in emerging countries. The use of these three natural disaster types as a measure of food supply-chain disruption is justified because they have a high propensity of disrupting the flow of nutritional high-value foods along their supply chains, while their occurrence is external to the functioning of food supply chains. They, therefore, meet the unintended and anomalous-causing criterion characteristic of supply chain disruptions.

1.2 PREVIOUS RESEARCH

This dissertation finds its place in previous research on nutritional high-value foods, supply chains and food price transmission in emerging countries. To situate the study in the current studies covering these topics, the author reviewed the focus of research in these areas over the last ten years. The review traced the thematic areas of research work published in top economics and supply chain journals, based on the 2016 ranking of management and economics journals by the French national centre for scientific research (CNRS). The journals considered include Economic Development and Cultural Change, Journal of De-

1. GENERAL INTRODUCTION

velopment Economics, World Bank Economic Review, Economics of Transition, American Journal of Agricultural Economics and International Journal of Production Economics. Table 1.1 summarises the focus of research on emerging countries, nutritional high-value foods, supply chains and food price transmission and the link between these topics and the dissertation.

Journal	Main issues over the last 10 years	Links with PhD topic
EDCC	Impact evaluation in the social sector	Economic growth and poverty: Dissertation examines the implications of the changing pattern of food demand in emerging countries
	Economic growth, poverty and inequality	Access to finance: Effect of institutional weaknesses on investors in food markets
	Wages and access to finance	
JDE	Cross-cutting issues: macroeconomic policy, informal sector, and trade	Macroeconomic policy: Study assesses the effects of macroeconomic environment on the sale of food.
WBER	Trade, globalisation and governance	Effect of institutional weaknesses and food imports on investment in food markets
	Poverty, income distribution programme evaluation & post-conflict transition	Implications of the changing pattern of food demand in emerging countries
ET	Governance (institutions, rule of law) in transition countries Economic dynamics of transition countries.(effect of financial crisis, growth & financial sector reforms) External sector shocks	Governance: Study assesses link between various measures of good governance and food markets.
AJAE	Impact of the agricultural sector on welfare	Price transmission: Study examines volatility transmission from ethanol to food prices
	Methodologies in agricultural sector research	Standards: Dissertation analyses the relationship between regulatory quality and food markets
	Price transmission from energy to food markets Standards and quality of traded food	
IJPE	Supply chain performance and flexibility	Vulnerability and uncertainty: Study assesses how vulnerable food supply chains are to negative natural, environmental and structural shocks.
	Supply chain vulnerability and uncertainty	Sustainability: Disruptions can impede the formation of sustainable food supply chains. This dissertation adds to studies on this relationship.
	Sustainable food supply chains	

Table 1.1: Focus of development and agricultural economics research from 2005 to 2015

EDCC: Economic Development and Cultural Change; JDE: Journal of Development Economics; WBER: World Bank Economic Review; ET: Economics of Transition; AJAE: American Journal of Agricultural Economics; IJPE: International Journal of Production Economics

From Table 1.1, we deduce that the most topical issue researched on emerging markets over the last ten years has been the socioeconomic and macroeconomic dynamics of these countries. Studies on their socioeconomic dynamics have centred on poverty and inequality, along the lines of the performance of these countries in the attainment of the Millennium Development Goals. Overall, several studies have concluded that these countries remarkably dealt with the problem of poverty. This, notwithstanding, there are still concerns about growing inequality in these countries and this explains why some studies

have focused on the evaluation of social intervention programmes in emerging countries. These issues have featured greatly in *Economic Development and Cultural Change*, *Journal of Development Economics* and *World Bank Economic Review*.

Food research has over the years focused on food security and the regulation of standards in food markets. Research on food security has focused on changing trends in household food demand in developing countries and the impact of negative shocks from food price volatility and climate change on food availability. The effect of price volatility has particularly become dominant since the 2007/2008 global financial meltdown and the recent instability of energy markets. The general finding by several studies published in the *American Journal of Agricultural Economics* (AJAE) is that food price volatility is welfare reducing. An emerging issue is, therefore, how households adapt to these negative shocks (D'Souza and Jolliffe, 2013; Gao, 2011; Tegene, 2009).

Nutritional high-value foods have also had an important place in food research over the last ten years. The literature on these food types attribute this focus on the increasing demand for these foods and new avenues for expanded markets for farmers in developing countries. Overall, two streams of research on these foods have proven central. First is research on how household income changes are fuelling the growth of the market of these foods. Secondly, some studies have analysed the new export opportunities available to local producers of these foods and the challenges that they face as they attempt to utilise these opportunities.

Standards governing food trade are important in ensuring the consumption of safe food. Over the last ten years, research on food standards has focused on how small-scale farmers in developing countries can meet these standards both nationally and internationally. This angle of research is informed by the inability of farmers in developing countries to meet food standards in international markets, preventing them from having access to these markets.

The last ten years have also seen a growing attention to the performance of supply chains. A plethora of studies have looked at the factors that impede the smooth movement of goods and services from source points to final consumption. A review of publications in the *International Journal of Production Economics* shows that since 2008, 478 articles have used the expression “supply chain disruptions” in their titles. The number of articles has also been increasing, except for a fall in 2013 as shown in Figure 1.7. The general finding in the literature is that inefficient supply chains exacerbate the problem of economic inefficiency in business transactions.

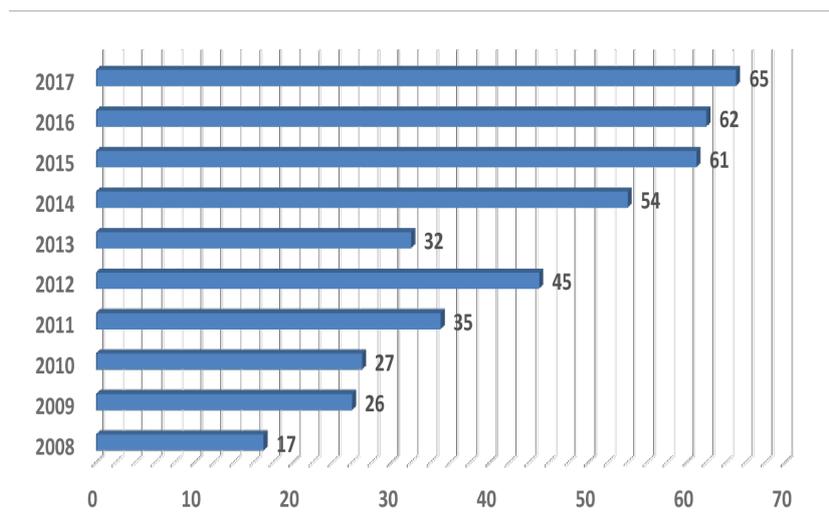


Figure 1.7: Articles published in the International Journal of Production Economics using the expression “supply chain disruptions” (2008-2017)

In the domain of food supply-chain research, the last ten years have seen growing emphasis on the issue of sustainable supply chains. Sustainable food supply chains are defined as chains that achieve the environmental, economic and social goals of their agents without negatively endangering their long-term performance and the environment in which they operate (Glover et al., 2014; Gimenez et al., 2012). The emphasis on sustainable food supply chains stems from growing concerns about increasing food consumption resulting from high population levels. A change towards efficient production, distribution and consumption that do not compromise the environment is, therefore, important. Overall, the main findings of the existing literature are as follows:

- (i) Although natural disasters affect all stages of the food supply chain, upstream partners enjoy a positive total asset turnover while downstream partners experience a negative impact (Altay and Ramirez, 2010).
- (ii) Institutional weaknesses are a disincentive to foreign direct investment in agricultural markets in emerging countries.
- (iii) Institutional arrangements determine the level of coordination along the food supply chain.
- (iv) There is no general conclusion on the relationship between energy and food prices. Some studies conclude that energy and food prices are highly correlated, showing positive and significant relationships (Cabrera and Schulz, 2016; Serra, 2011; Fernandez-Perez et al., 2016). Others, however, find that the relationship is weak and insignificant over the long run (Reboredo, 2012; Zhang et al., 2009; Fowowe, 2016).

This study is related to the previous studies because it focuses on dynamics in the food markets of emerging countries. It also analyses these food markets through their supply chains, similar to studies in supply chain journals. Additionally, many studies adopt an empirical approach that entails analysing food supply-chain data, based on strong economic theory. This dissertation uses a similar approach.

The dissertation is, however, different from most studies on food supply chains in three main respects. Firstly, it examines the disruption of different classes of nutritional high-value foods: highly processed, minimally processed and unprocessed foods. Secondly, it looks at how different conjunctural events affect different stages of the nutritional high-value food supply chain. Lastly, the study contributes to research on the relationship between food and energy markets by examining the impact of oil price shocks on different price regimes along the nutritional high-value food supply chain.

1.3 FOCUS OF THE DISSERTATION

The current research examines the differences that exist between disruptions at the upstream stage of the nutritional high-value food supply chain and disruptions downstream. The study has three key focus areas. The first assesses these differences in disruption in the minimally processed and unprocessed nutritional high-value food markets. An important characteristic of nutritional high-value foods is that without being processed and packaged, they are highly perishable (Reardon et al., 2009). The high level of perishability affects not only their prices and quantities produced, but also their flow along the supply chain. Since these foods are not highly processed, they must have swift and uninterrupted flow along the chain from production to final consumption in order to prevent loss and waste.

In view of this, disruptive events such as the occurrence of natural disasters will hugely affect their flow both upstream and downstream. The first focus of this study, therefore, is to examine the magnitude of disruptions to two minimally processed and two unprocessed nutritional high-value food supply chains in emerging countries. The minimally processed foods under study are meat and eggs while the unprocessed ones include fresh fruits and fresh vegetables. A typical supply chain for the minimally processed foods involves its movement from rural producers through slaughterhouses and processing firms to retail units as depicted in Figure 1.8 below.

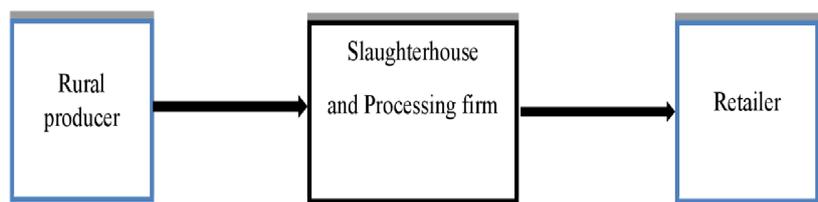


Figure 1.8: Schematic representation of the supply chains of meat and eggs

With regard to fruits and vegetables, there is no processing firm. Instead, rural producers sell their output to packaging houses who then sell to retailers. The framework of the unprocessed supply chain is as shown in Figure 1.9.

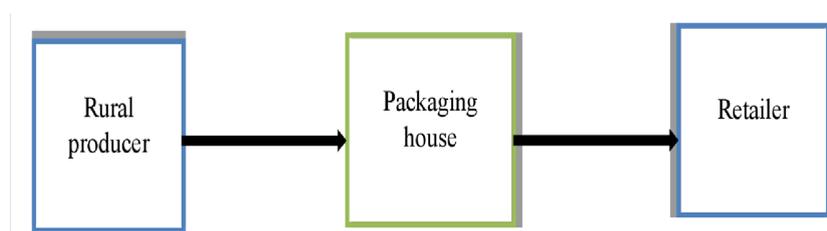


Figure 1.9: A representation of the supply chains of fruits and vegetables

As food becomes processed, it first moves in an unprocessed state from rural producers through wholesalers to retailers. Processing firms add value to the unprocessed food obtained from rural producers. They then send the final product to wholesalers in bulk, who in turn sell same to retailers in smaller quantities. The general framework of such a chain is as given in Figure 1.10.

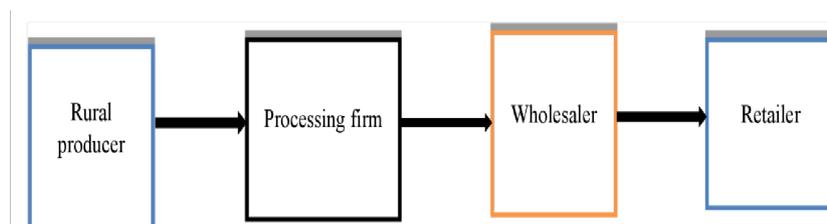


Figure 1.10: Stages along the supply chains of dairy and fat & oil

When nutritional high-value foods are highly processed and packaged, they have a longer shelf life. Food processing and packaging, however, occurs mainly at the downstream segment of the food supply chain, between their procurement from producers and sale to consumers. In their unprocessed state upstream, the flow of these foods along the supply chain may encounter disruptions that are higher than those encountered downstream where they are processed and packaged. The second focus is, therefore, to examine whether upstream disruptions are higher than downstream disruptions along the processed

nutritional high-value food supply chain.

The food supply chain is characterised by different prices. These include producer, wholesale and retail prices. Generally, farmers sell their produce to wholesalers at the producer price while wholesalers sell to retailers at the wholesale price. Finally, retailers sell food to consumers at the retail price. The level of each price determines the behaviour of agents in respect of the production, sale and consumption of food. Without a negative shock to the chain, prices are determined in such a way that a local equilibrium price is attained for all agents along the chain. A negative shock leads to a new equilibrium and affects the ability of supply chain agents to plan their investment effectively. This is particularly the case because the occurrence of the shock often lies outside the control of agents. It is important to note that, though this phenomenon may apply to both upstream and downstream stages along the supply chain, there may be differences between the two stages because of disparities in market power between agents. For this reason, disruption of food prices will differ upstream from downstream. For each food type, the study assesses the extent of price disruption resulting from an external shock (natural disaster occurrence).

Following the 2008 energy market crisis, some studies have looked at the relationship between energy market shocks and food markets and have concluded that a strong link exists between the two markets (Serra et al., 2011a; Serra, 2011; Wang et al., 2014; Tang et al., 2010). Given that food markets use energy products as inputs, shocks in the latter can be transferred to the former mainly through increased food prices (Busse et al., 2012). Some studies have looked at the link between energy markets and price volatility transmission along the nutritional high-value food supply chain. Although Zhang et al. (2009), Serra et al. (2011a) and Trujillo-Barrera et al. (2012) analyse volatility spillover effects in food markets, their focus is on staple foods (corn and soybeans). Other studies such as Abdelradi and Serra (2015) look at the link between biofuels and food markets, while Wang et al. (2014) analyse the relationship between different oil price shocks and agricultural commodities. Specifically on Brazil, Balcombe and Rapsomanikis (2008) find that an increase in energy prices leads to an increase in sugar prices through the ethanol industry.

Against the above background, the dissertation assesses the extent of shocks from diesel prices to prices along the nutritional high-value food supply chain in São Paulo, Brazil. More specifically, it examines if shocks from the price of diesel are higher upstream than downstream along the nutritional high-value food supply chain in the São Paulo food market. The study uses São Paulo as a case study not only because it has a highly developed energy market, but also because energy consumption constitutes an integral input in the transport of nutritional high-value foods. The city is also an important economic centre in Brazil. This analysis is founded on price transmission theory (McCorrison et al., 2001;

Scrimgeour, 2014). According to this theory, where there is no external price shock, the interaction between agents along the food supply chain leads to a local equilibrium of food price. In the case of an external shock, a new equilibrium regime ensues.

1.4 RESEARCH QUESTIONS

There is no denying the fact that with increasing demand for nutritional high-value foods in emerging countries, the performance of the chains that supply these foods has important implications for achieving food security in these countries. According to the FAO (FAO et al., 2015), current concerns of food loss and waste are linked with the movement of food along the food supply chain. In as much as disruptions are an important phenomenon for the entire food supply chain, the magnitude of these depends on food type. In the case of nutritional high-value foods, these foods are highly perishable in their fresh form (Gulati et al., 2007; Blackburn and Scudder, 2009; Narrod et al., 2009), making them highly exposed to the negative effects of supply chain disruptions.

To reduce these effects, appropriate supply chain strategies that mitigate the effects of disruptions are relevant. Blackburn and Scudder (2009) and Blackburn et al. (2004) find that with perishable products such as nutritional high-value foods, an appropriate strategy is one which is responsive at the early stages of the chain (upstream) and efficient at the latter stage (downstream). A responsive food supply chain is that which is able to adjust quickly to the demands of buyers while an efficient chain aims to reduce inventories between retailers and consumers (Parmigiani et al., 2011).

In spite of the increasing demand for nutritional high-value foods in emerging countries, there are concerns about the inability of farmers in these countries to increase supply to meet the high food demand, due to threats from unfavourable climatic catastrophes and negative structural dynamics that stifle the growth of the agricultural sector. The ability of food supply chains to deal with these events depends on the level of coordination between actors along the chain (Parmigiani et al., 2011; Xu and Beamon, 2006). To create value for customers, the integration of business processes, not individual functions, is imperative and these processes reach beyond the boundaries of a firm.

Some empirical studies on the resilience of supply chains to disruptions conclude that the upstream segment is better able to deal with disruptions (from conjunctural events) than the downstream stage (Altay and Ramirez, 2010; Ambulkar et al., 2015; Parmigiani et al., 2011). Indeed, Altay and Ramirez (2010) conclude that conjunctural events such as natural disasters tend to have a positive effect upstream while the downstream stage must plan for negative effects because actors upstream are more coordinated than their counterparts downstream. Contrary to this view, other studies suggest that supply-side

disruptions upstream are higher than demand-side disruptions which occur predominantly downstream (Blackburn and Scudder, 2009; Bode and Wagner, 2008). This seeks to suggest that negative effects of disruptions at the upstream stage of the food supply chain are greater.

Few other studies have suggested that threats posed by supply chain disruptions depend on firm-specific factors such as industry and location (Trkman and McCormak, 2009; Wu and Olson, 2008; Bode et al., 2011). Thus, along the high-value food supply chain, we expect upstream disruptions to be different from downstream disruptions for different nutritional high-value food chains.

Existing structural characteristics coupled with the nature of agricultural markets in emerging countries also give an indication of the different effects of the occurrence of natural disasters along the food supply chain. Food production, a major upstream activity, occurs predominantly in rural areas where roads are normally of poor quality and become unusable when natural disasters occur. Conversely, retail sale (and to a large extent, processing) of food occurs in towns and cities which often have better transport infrastructure and receive prompt reaction from public officials when natural disasters occur. Retail units, therefore, benefit from positive externalities emanating from the prevailing good infrastructure, a situation that is often not the case in the hinterlands. From the structural differences between urban and rural areas, disruption to upstream quantity and prices along the food supply chain is bound to differ from those downstream, with the former expected to be higher.

In view of the important role of coordination along the food supply chain in ensuring a smooth movement of food and the threat posed by natural disasters to effective coordination along the chain, it is imperative to understand the extent to which the flow of food at different stages of the chain is disrupted by occurrence of these disasters. With the issue of climate change remaining a significant threat to food security the world over, such an analysis is important to enable food supply-chain agents to better map up strategies to overcome the disruptive effects of natural disasters. It will also enable governments and public institutions working in agriculture to better design and implement policies targeting food insecurity.

Against the above background, this study proposes three essays to ascertain whether disruptions upstream are higher than disruptions downstream along the nutritional high-value food supply chain. More specifically, the study examines if the occurrence of natural disasters affects upstream prices and quantities much more than they affect downstream quantities and prices. Following are the questions that the dissertation seeks to answer.

General research question of study

Are disruptions from the occurrence of natural disasters higher upstream than downstream along the nutritional high-value food supply chain?

Research question 1

Are disruptions from the occurrence of natural disasters higher upstream than downstream along the unprocessed and minimally processed nutritional high-value food supply chain?

Research question 2

Are disruptions from natural disasters higher upstream than downstream along the highly processed nutritional high-value food supply chain?

Research question 3

Is there upstream and downstream asymmetry in the effect of oil price shock on food prices along the nutritional high-value food supply chain of the São Paulo food market?

1.5 METHODOLOGY AND DATA

1.5.1 Classification of countries

Different classifications of emerging countries exist. These include the International Monetary Fund (IMF), BRICS+Next Eleven, Financial Times Stock Exchange (FTSE), Morgan Stanley Capital International (MSCI), Standard and Poor's (S&P), Emerging Markets Bond Index, Dow Jones, Russell and Columbia University EMGP. Overall, these classifications look at how attractive these countries are from an investment perspective, based on their economic, social, political and international dynamics. The choice of emerging countries in the present study is based on the MSCI Market Classification Framework. The classification of countries by this Framework touches on economic development, size and liquidity requirements and market accessibility criteria. By considering both economic growth and investment attractiveness, the Classification gives a detailed description of characteristics of emerging countries. Countries under this framework and used for the current study include Brazil, China, South Africa, India, the Philippines, Turkey, Hungary, Greece, Czech and Poland.

1.5.2 Classification of foods

The study classifies nutritional high-value foods under three categories. These are unprocessed, minimally processed and highly processed foods. The unprocessed foods experience neither processing nor value addition as they move along the chain, while the minimally

processed foods have some value addition by way of packaging, but their form does not change along the chain. Lastly, highly processed foods experience both change in form and packaging as they move from producers to consumers. The study uses fruits and vegetables as unprocessed foods, while meat and eggs are minimally processed foods. With highly processed foods, dairy and fat & oil fall under this category and the study uses these as highly processed foods. The high consumption of these foods among the emerging middle class justifies their use in this study.

1.5.3 Data choices

The study uses both market-level and non-market level panel data over the period 2000-2013. The market-level data are specific to the nutritional high-value foods under study, with each data variable corresponding to a particular food item. The non-market level data are data on variables that have implications for the entire country and are not market-specific. The market-level data cover the quantity of nutritional high-value food produced, the sold (by retailers, foodservice operators and institutions), the producer and consumer prices of each food item. With the non-market level data, these include natural disaster occurrences, measures of structural constraints to economic freedom and investment in transport infrastructure (which measures transport quality). Table 1.2 itemises the sources of these data.

Variable name	Data source
Chapter 1: Answering Research Question 1	
<ul style="list-style-type: none"> i. Producer prices of meat, eggs, fresh fruits and fresh vegetables ii. Consumer prices of meat, eggs, fresh fruits and fresh vegetables iii. Quantity of meat, eggs, fresh fruits and fresh vegetables produced iv. Quantity of meat, eggs, fresh fruits and fresh vegetables sold v. Natural disaster occurrence (occurrence of climatological, geophysical and hydrological disasters) vi. Investment in transport infrastructure vii. Measures of hindrances to economic freedom (government integrity and financial freedom indices) 	<ul style="list-style-type: none"> i. Food and Agriculture Organisation (FAO) of the United Nations Organisation ii. Food price statistics published by country statistical services iii. Food and Agriculture Organisation (FAO) of the United Nations Organisation iv. Euromonitor International (Passport database) v. EM-DAT disasters database, Université Catholique de Louvain vi. The World Bank's World Development Indicators vii. The Heritage Foundation
Chapter 2: Answering Research Question 2	
<ul style="list-style-type: none"> i. Producer prices of dairy and fat & oil ii. Consumer prices of dairy and fat & oil iii. Quantity of dairy and fat & oil produced iv. Quantity of dairy and fat & oil sold v. Natural disaster occurrence (climatological, geophysical and hydrological disasters) vi. Investment in transport infrastructure vii. Measures of hindrances to economic freedom (governance integrity and financial freedom indices) 	<ul style="list-style-type: none"> i. Food and Agriculture Organisation (FAO) of the United Nations Organisation ii. Food price statistics published by country statistical services iii. Food and Agriculture Organisation (FAO) of the United Nations Organisation iv. Euromonitor International (Passport database) v. EM-DAT disasters database vi. The World Bank's World Development Indicators vii. The Heritage Foundation
Chapter 3: Answering Research Question 3	
<ul style="list-style-type: none"> i. Monthly producer, wholesale and retail prices of meat, eggs, dairy and fat & oil in Sao Paulo a. Monthly diesel prices in Sao Paulo 	<ul style="list-style-type: none"> i. Institute of Agricultural Economics of the Government of Sao Paulo, Brazil (IEA) ii. Institute of Economic Research Foundation (FIPE) a. National Agency of Petroleum, Natural Gas and Biofuels

Table 1.2: Sources of data used for the dissertation

The data sources used for the dissertation have been used in important studies on food markets and food supply chains. [Bellemare \(2015\)](#) uses disaster data published by the EM-DAT and food price indices published by the Food and Agriculture Organisation (FAO) to study the relationship between food price volatility and social unrest. The Economic Research Service division of the United States Department of Agriculture also relies on data on retail, foodservice and institutional sales collated by Euromonitor International to study annual international consumer and retail trends. Additionally, [Baylis et al. \(2009\)](#) use data from the Heritage Foundation to study factors that explain United States import refusals.

1.5.4 Data Issues

Data on producer prices, quantity of food produced and quantity of food sold are all in tonnes whereas consumer prices are in kilogramme (kg). To ensure parity, values for the consumer prices are converted to tonnes at the rate of 1 tonne = 1000 kg. Furthermore, data on consumer prices are in local currency. These prices are converted to United States dollars by dividing the each price by the annual average official exchange rate between the local currency and the U.S. dollar.

1.5.5 Methodologies

To investigate upstream and downstream disruption of unprocessed and minimally processed nutritional high-value foods in Chapter 1, a fixed-effect panel modelling technique is applied. A similar approach is used to study disruption along the processed foods chain in Chapter 2. The rationale for using the fixed-effect approach is to be able to capture differences inherent in the units under study. Capturing these differences is important because the data used for the two chapters are longitudinal, grouped along markets, countries and years. Although all the countries under study are emerging countries from an economic point of view, there exist important heterogeneities among them. Using a fixed-effect panel method enables us to account for such heterogeneities.

Time series approaches enable us to model the relationship between food and energy markets. Common approaches used include the Arellano-Bond Generalized Method of Moments ([Berck et al., 2009](#)), Vector Autoregression ([Asche et al., 2015](#)), Structural Vector Autoregression ([Wang and McPhail, 2014](#)), univariate Generalized Autoregressive Conditional Heteroscedasticity ([Agnolucci, 2012](#); [Aloui and Mabrouk, 2010](#); [Sadorsky, 2006](#)) and multivariate GARCH ([Abdelradi and Serra, 2015](#)).

This dissertation uses a Vector Error Correction (VEC) modelling technique to assess the effect of oil price shocks on food prices in the nutritional high-value food market of

São Paulo, Brazil. The rationale for using the VEC approach is that it allows us to draw theoretical and empirical hypotheses from economic theory. It is also a robust technique for capturing both long-run and short-run price dynamics, thus providing a clearer picture of how prices change over time.

1.6 OUTLINE OF THE DISSERTATION

The remainder of the dissertation is organised as follows. Disruption along the unprocessed and minimally processed nutritional high-value food supply chains, answering Research Question 1, are analysed in Chapter 2. Chapter 3 answers Research Question 2 by looking at the disruption of highly processed nutritional high-value food supply chains. Chapter 4 focuses on Research Question 3 and examines the effect of shocks from energy to food prices along the nutritional high-value food supply chain in the São Paulo region of Brazil. Finally, Chapter 5 concludes the dissertation by summarizing the findings from each chapter, presenting policy implications of these findings and suggesting a future research path.

Disruptions along Unprocessed and Minimally Processed Nutritional High-Value Food Supply Chains in Emerging Countries

2.1 INTRODUCTION

Engel's law on the relationship between food consumption and income states that as income increases, its share spent on food decreases (Murata, 2008; Foellmi and Zweimüller, 2008). This implies that rich households spend less of their incomes on food while poor households spend more on food. Although the share of income spent on food decreases, Bennett (1941) posits that people generally change the composition of their food intake as their incomes change. Central to this proposition, which has evolved to become Bennett's Law, is that as the level of income increases, people substitute nutritional high-value foods for staples. Nutritional high-value foods are food crops that are high in value per calorie, per kilogramme or per hectare and are consumed at home either in their raw form or after being processed. These foods include protein-rich foods such as meat, eggs and dairy (Skoufias et al., 2011) and horticultural crops such as fruits and vegetables (Tschirley et al., 2015).

Current dynamics of food consumption in emerging countries show that the production and consumption of fresh or unprocessed nutritional high-value foods have witnessed a remarkable growth since the turn of the millennium. Figure 2.1 shows the quantity of meat sold in eleven emerging countries from 2000 to 2014. The countries include China, Brazil, South Africa, India, Russia, the Philippines, Greece, Poland, Hungary, Czech Republic and Turkey. The figure shows a general increase in meat sales in eight countries (China, Brazil, South Africa, India, Russia, the Philippines, Poland, Czech Republic and Turkey)

2. Disruption of Unprocessed and Minimally Processed Food Chains

and a decreasing trend in Greece and Hungary. Overall, the sale of meat is highest in China followed by Brazil.

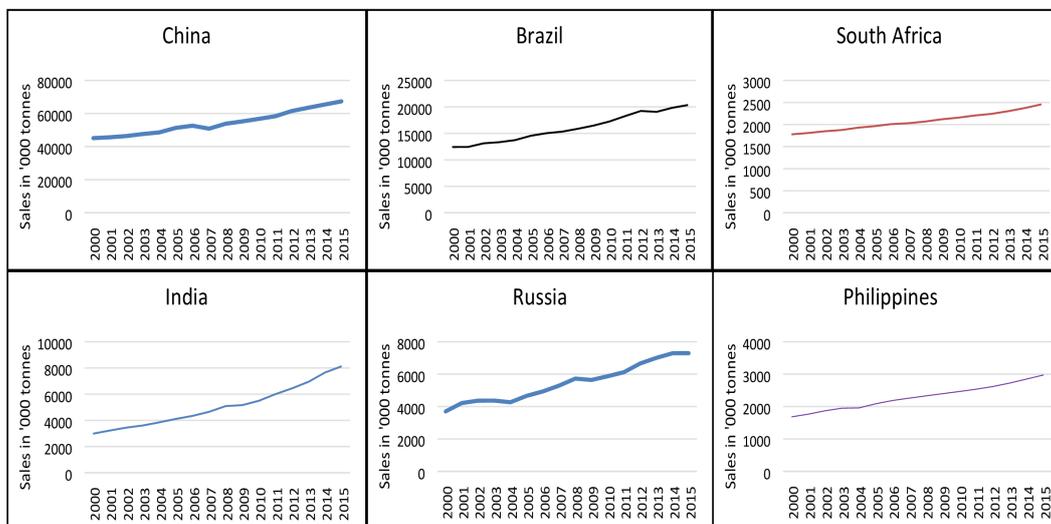


Figure 2.1: Quantity of meat sold in selected emerging countries (2000-2015)

Source: Author generated from the database of Euromonitor International

In Figure 2.2, we again see a general increasing trend in the volume of fruits sold in the Brazil, China, India, South Africa, Russia, the Philippines, Hungary, Poland, Czech Republic and Turkey. This is in spite of an initial fall between 2000 and 2002 in Brazil, India and Hungary. With respect to Brazil, it is clear that after maintaining an increasing trend from 2001 to 2010, the sale of fruits fell from 2011 to 2013. The increasing trend, however, resumed after 2013. It is important to note the fall in fruits sold between 2008 and 2010 in India and Russia. A potential cause is the food price crisis that occurred during this period. Interestingly, the sale of fruits has an overall decreasing trend in Greece. With the Greek economy going through financial doldrums, the fall in the sale of fruits explains the link between economic dynamics and dynamics in food markets. Overall, the increasing trend recorded in many of these countries lends credence to the growing importance of the fruits market in emerging countries.

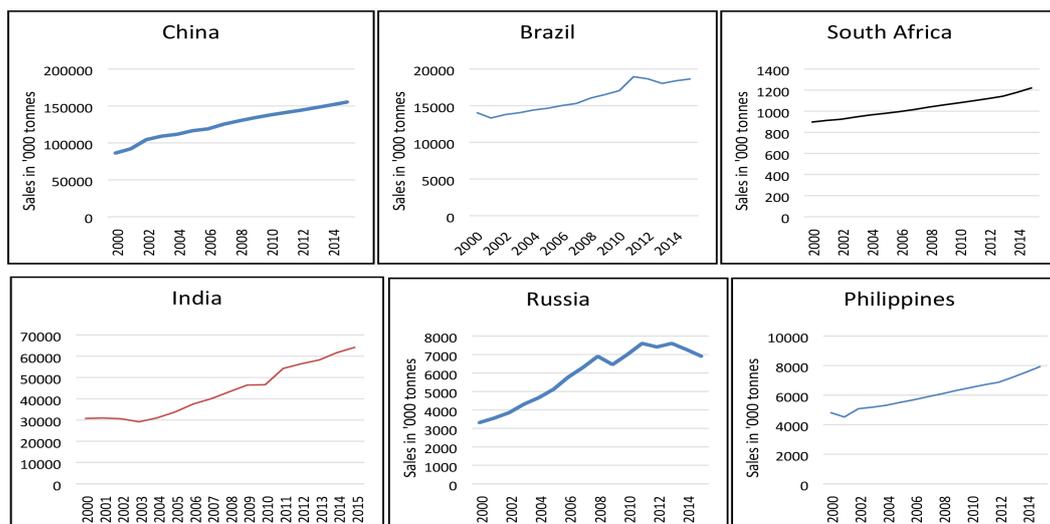


Figure 2.2: Quantity of fruits sold in selected emerging countries (2000-2015)

Source: Author generated from the database of Euromonitor International

A combination of behavioural and economic factors offers plausible reasons for the increased consumption of nutritional high-value foods in emerging countries. Economically, emerging countries have sustained growth successes since the year 2000 as shown by their high GDP growth rates. Associated with the increased growth path is an increase in the size of the middle class, a result of increased income levels in these countries. With increased income comes an increased need to diversify consumption both to reflect the new income status and, equally importantly, for an improved health status. For this reason, middle class households tend to increase their consumption of fruits, vegetables, eggs and meat relative to the consumption of staples.

It is relevant to underscore the importance of information in the increased consumption of nutritional high-value foods. Increased awareness of the health benefits associated with the inclusion of these foods in one's diet has been a strong catalyst for their increased consumption (Tiffin and Arnoult, 2010). As more people diversify their consumption towards these food types, attention to the possible effects on the consumer's health has increased, leading to higher demand for health and wellness foods. For this reason, manufacturers and distributors have placed greater emphasis on ensuring that their products meet consumers' demand for healthy food. The production and consumption of organic foods have particularly seen significant growth in recent times.

Unprocessed as well as minimally processed nutritional high-value foods are, nevertheless, highly perishable. This means that their production and eventual movement to final consumers require a high level of coordination among actors of the food supply chain. Producers need to be able to establish smooth relationships with retailers so that the latter can have easy and timely access to foods produced. Similarly, retailers ought to be able to optimise their sale of food to consumers. An efficient food supply chain reduces both

post-harvest losses and food waste, going a long way to help achieve food security.

Existing research on food supply chains indicates that the ultimate goal of these chains in emerging countries is to attain a strong and sustained coordination among farmers, distributors and consumers. This is because supply chains in these countries are more likely to be affected by natural disasters and structural weaknesses than in developed countries. Global economic dynamics and competition have also shaped the complexity of inter-firm networks, with disruptions to the flow of materials, information, and funds becoming the norm. In this wise, any firm that collaborates with other firms faces the risk of its business being undercut or even destroyed by supply chain disruptions ([Chopra and Sodhi, 2004](#)).

Although the occurrence of unintended events such as natural disasters spells important implications for the functioning of all food supply chains in emerging countries, the effect is greater along the unprocessed and minimally processed nutritional high-value food supply chain. This is because these foods are highly perishable and with structural and infrastructural weaknesses in these countries, obtaining an efficient and responsive chain becomes difficult when natural disasters occur. Given the increasing demand for these foods in emerging countries, an analysis of how natural disasters disrupt their supply chain is important in ensuring the appropriate design and implementation of policies targeting food loss and waste.

2.2 BACKGROUND LITERATURE

This study adds to the existing scholarly work on the disruption of food supply chains. This section of the study reviews studies on supply chains in general and food supply chains in particular. The thematic areas of the review include studies on semi-processed nutritional high-value foods, the roles and impacts of food supply-chain disruptions, empirical results, methodological appraisal and propositions to improve existing studies.

2.3 Roles and impact of food supply chain disruptions

The literature on supply chain disruptions distinguishes supply chain disruptions from supply chain risk. This difference is based on the type of activity that impedes the flow of goods along the supply chain. [Oke and Gopalakrishnan \(2009\)](#), for instance, categorize supply chain risk into inherent or high-frequent risk and disruption or infrequent risk. The authors identify abnormal supply and demand fluctuations that characterise the food supply chain as supply chain risks while disruptions include terrorism, political instability and natural disasters. Similarly, [Kleindorfer and Saad \(2005\)](#) itemize operational contingen-

cies resulting from the breakdown of equipment, natural hazards, terrorism and political instability as potential sources of supply chain disruptions. These events have a certain level of probability and are characterised by their severity, direct and indirect effects (Bode and Wagner, 2008).

To date, research on supply chain disruptions has covered four thematic areas. These are the causes of supply chain disruptions, supply chain vulnerability and the management of supply chain disruptions. Studies on the management of supply chain disruptions focus on how supply chain actors are able to mitigate the negative effects posed by the sources of disruption. The rationale for this focus is that the environment in which modern supply chains operate continues to experience negative socioeconomic dynamics while current threats of climate change exacerbate the potential occurrence of natural disasters. In view of this, the general conclusion in the literature is that for supply chains to better deal with disruptions, mitigating measures such as stronger coordination is required along the entire spectrum of the chain. Table 2.1 shows the sources of supply chain disruption and risk captured in the literature.

Author	Macro factors	Demand factors	Supply factors	Transportation factors	Financial factors
Wu et al. (2006)	Fire accidents; External legal issues; political/economic stability	Sudden shoot-up demand	Supplier management; supplier market strength; continuity of supply; second-tier supply	On-time delivery; accidents in transportation; maritime private attack; remote highway theft	Cost; financial and insurance issues; loss of contract; low profit margin; market growth; market size
Kull and Talluri (2008)			Delivery failure; cost failure; quality failure; flexibility failure; general confidence failure		
Manuj and Mentzer (2008)		Demand variability; forecast errors; competitor moves	Supplier opportunism; inbound product quality; transit time variability		Currency fluctuations; wage rate shifts
Tuncel and Alpan (2010)		Deficient or missing customer relation management function; high competition in the marketplace	Monopoly; contractual agreements; technological changes; low technical reliability	Stress on crew; lack of training; long working times; negligent maintenance; old technology; selected delivery modes and period	
Wagner and Neshat. (2010)		Short products' life cycles; customers' dependency; low in-house production	Small supply base; suppliers' dependency; single sourcing	Global sourcing network; supply chain complexity	

Table 2.1: Literature on the sources of supply chain disruptions and risk (Adopted from Ho et al. (2015))

Although not a complete list of all the studies covering different sources of supply chain disruptions, Table 2.1 shows that dominant themes in supply chain disruption research over the last ten years include natural disaster, war, terrorism, political instability and economic downturns.

2.4 Findings of current studies

2.4.1 Natural disasters

Overall, the literature on supply chain disruptions conclude that although natural disasters affect all stages of the supply chain, the intensity of the impact is dependent on the type of disaster. In an exploratory study on the effects of several natural disasters on more than 100,000 firms, [Altay and Ramirez \(2010\)](#) find that contrary to the all hazards approach that focuses on all disruption types irrespective of origin, damage from windstorms and floods are dramatically different from that of earthquake.

Other studies have concluded that the effects of natural disasters on firms' activities along the supply chain depend both on whether these firms are located upstream or downstream and the country in which they are located. [Cavallo et al. \(2014\)](#) analyse the effects of earthquakes in Chile and Japan in 2010 and 2011 respectively, and find that although there was a loss in product availability in both instances, goods available for sale fell by 32 percent in Chile and 17 percent in Japan. In both countries, the authors find, however, that prices were relatively stable and there was no increase for months following the earthquakes. The finding by [Cavallo et al. \(2014\)](#) corroborates that of [Oh and Oetzel \(2011\)](#) who conclude that the impact of natural disasters can be higher in emerging economies than in developed countries.

Contrary to the above findings, other studies find natural disasters to have an insignificant effect on the supply chain. An example of such studies is the research by [Bode and Wagner \(2008\)](#) on supply chains in the industry, services and trade sectors in Germany. The authors find that catastrophic events such as natural disasters are insignificant in determining supply chain performance and this is attributable to the low probability of their occurrence, making their impact on supply chain performance low.

2.5 Research on food supply chains

In spite of the food sector's relevance in promoting socioeconomic development, research on food supply chains has received little attention in the literature. This may be because the management of food supply-chain networks is complicated by specific product and

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process characteristics. Table 2.2 summarises studies conducted on disruptions to food supply chains and the methodologies these studies employed. Although this table does not present an exhaustive list of studies on food supply chains, it gives a bird's eye view of the shortfall in the analysis of disruptions to which food supply chains are exposed.

Author(s)	Study	Focus	Products	Method
Blackburn and Scudder (2009)	Supply chain inventory management strategies for perishable products: the case of fresh produce	Supply chain design strategies for a specific type of perishable product	Melons and sweet corn	Hybrid model
Cai and Zhou (2014)	Optimal policies for perishable products when transportation to export markets is disrupted	Transport breakdown where a firm produces a highly perishable good	Seafood	Optimisation
Rong et al. (2011)	An optimization approach for managing fresh food quality throughout the supply chain	Integrate food quality in decision-making on production and distribution in a food supply chain.	Bell peppers	Linear programming
Zanoni and Zavanella (2012)	Chilled or frozen? Decision strategies for sustainable food supply chains	Analyse economic aspects and energy efforts required to condition and preserve the product quality over time along the food supply chain	Potato	Optimisation
Soysal et al. (2014)	Modelling food logistics networks with emission considerations: The case of an international beef supply chain	Develop a multi- objective linear programming (MOLP) model for a generic beef logistics network problem.	Beef	Multi-objective linear programming
Bohle et al. (2010)	A robust optimization approach to wine grape harvesting scheduling	Analyse a wine grape harvesting scheduling optimization problem subject to several uncertainties. Study how effective robust optimization is solving this problem in practice.	Grape	Robust optimization
Srimanee and Routray (2012)	Fruit and vegetable marketing chains in Thailand: policy impacts and implications	Identify and study the marketing chains of fresh fruit and vegetables (FFV) in Thailand, the linkages of FFV farmers with supermarkets, and an evaluation of supermarket procurement systems	Various fruits and vegetables	Descriptive analysis (primary and secondary data)

Table 2.2: Focus of existing research on supply chains of unprocessed foods

It is clear from Table 2.2 that the most dominant focus of fresh food supply-chain research has been on inventory management, with the key objective to determine replenishment policies for inventories. Issues of the breakdown of logistics and quality changes along the food supply chain have, therefore, received particular attention in the literature. Several of such studies address the impacts of transportation disruption and analyse the strategies adopted by industries to remedy the negative shocks. The various forms of disruptions to which the production and sale of these foods are exposed have received little attention. It is, nevertheless, important to study disruptions along the fresh food supply chain since these activities serve as bottlenecks to the optimisation agenda of food chain operators.

2.6 Critical methodological issues

The past decade has seen the application of a number of quantitative and qualitative methods to the study of food supply chains. Linear programming techniques have particularly proven dominant in this arena. The approach has been widely used to study food inventory changes by [Bohle et al. \(2010\)](#), [Rong et al. \(2011\)](#), [Agustina et al. \(2014\)](#), [Ferrer et al. \(2008\)](#) and [Yu et al. \(2012\)](#). Other studies have used simulation-modelling techniques to analyse logistic constraints and their implications for food quality ([Van der Vorst et al., 2014](#)), while [Yu and Nagurney \(2013\)](#) use structural equations modelling techniques.

Although the use of linear programming techniques helps to determine the objective function of production, it is difficult to determine the natural, institutional, financial and social constraints that may impede efficient production and distribution of food. The use of these techniques in the literature on food supply chains, therefore, overlooks the different angles of food chain risk and disruptions. It is indeed important to assess not just the effect that these variables have on the food supply chain, but also how their effects differ along various stages of the chain. This is particularly imperative in the unprocessed nutritional high-value foods market where the perishable nature of these foods could increase food loss and food waste.

2.7 Research question

An important characteristic of nutritional high-value foods is that when they are not processed and packaged, they are highly perishable ([Reardon et al., 2009](#); [Rong et al., 2011](#)). This affects not only their prices and quantity produced, but also their flow along the supply chain. To reduce losses, they must have a swift and uninterrupted flow along the chain from production to final consumption. Disruptions, however, impede this smooth flow both upstream and downstream.

Studies on supply chain structure and strategy in the market of perishable goods enable us to see the different effects of disruptions upstream and downstream along the nutritional high-value food supply chain. The general conclusion in the literature is that, with perishable products (such as unprocessed nutritional high-value foods), supply chains should be responsive upstream and efficient downstream, a conclusion established by [Blackburn and Scudder \(2009\)](#), who analyse supply chain design strategies in the melon market. According to these authors, perishable products lose value rapidly and at an exponential rate upstream. A responsive chain upstream, therefore, ensures that producers reduce their stock by increasing sales to distributors. Downstream, however, the rate of deterioration declines and a chain that is cost-efficient is required. This finding is corroborated by [Bode and Wagner \(2008\)](#), who analyse the effects of supply chain risks on supply chain performance and find that, although both upstream and downstream risks negatively affect supply chain performance, the effect is higher upstream than downstream.

Besides the physical characteristics of the product, the prevailing state of transport and storage infrastructure can also compound the problem of deterioration of unprocessed and minimally processed nutritional high-value foods. Since these foods are perishable, a good transport system is required to ensure smooth movement between actors along their supply chains. The role of transport infrastructure is particularly relevant upstream where the chain needs to be responsive according to [Blackburn and Scudder \(2009\)](#). With respect to emerging countries, upstream agricultural activity occurs in areas where the quality of transport infrastructure is generally poor. Conversely, downstream actors benefit from good transport infrastructure since they usually operate in cities and towns where other economic activities generate positive externality by way of improved transport amenities.

From the above analysis, it can be deduced that the effect of disruption of unprocessed and minimally processed nutritional high-value foods would be higher upstream than downstream. Thus, although the occurrence of a natural disaster could negatively affect activities both upstream and downstream along the food chain, the loss of food upstream could be greater. In view of this conclusion and given the aforementioned gap in the existing research on nutritional high-value food supply chains, this study seeks to examine the sources of disruption along the unprocessed and minimally processed nutritional high-value food supply chain in emerging countries. It particularly assesses the extent to which upstream disruptions differ from downstream disruptions along the unprocessed and minimally processed nutritional high-value food supply chain. The study seeks to answer the following research question:

Is the magnitude of disruption from natural disasters along unprocessed and minimally processed nutritional high-value food supply chains in emerging countries higher upstream than downstream?

2.8 THEORETICAL FOUNDATION AND HYPOTHESIS

Market growth theory serves as the main theoretical foundation of this study. The theory helps to explain the role of distance as a factor in determining interactions within food markets in emerging economies, and how the disruption of proximity along the food supply chain impedes the flow of food. From this theory, hypotheses on disruptions to unprocessed and minimally processed nutritional high-value food chains are drawn and tested. Following is an analysis of how the market growth theory explains disruption to the food supply chain.

2.8.1 Market Growth theory

The study uses the market growth theory developed by [Goldman et al. \(2002\)](#) to analyse the effect of natural disasters on the production and sale of nutritional high-value foods. The theory identifies two sources of market growth. These are segment diffusion and category-dependent diffusion. Under segment diffusion, growth comes from a retailer's adoption of identifiable groups of consumers by geographical and economic segments. Geographical segment diffusion hinges on the spatial distance between consumers and retail outlets while economic segment diffusion concerns the income status of consumers.

Retail units seeking to increase growth must reduce the distance between their products and consumers (geographic segmentation) through the opening of more outlets (geographic segment diffusion). Geographic segment diffusion increases accessibility and reduces the opportunity cost of time spent on purchase, while economic segmentation creates a situation where retail markets tend towards high-income consumers. In the presence of spatial separation of economic groups, where geographic and economic segments coincide, both geographic and economic segment diffusions occur. In developing countries in particular, retailers first open in high-income areas and then in low-income areas.

The occurrence of natural disasters has significant implications for the ability of businesses to exploit gains from geographic and economic segmentation. Although a firm may expand the number of outlets to reach targeted consumers, expectations about the occurrence of natural disasters such as earthquakes, wildfires and flood may increase demand for food before the disaster occurs. This is because consumers will seek to stock items that they will not be able to procure when disasters occur. This situation creates abnormal quantity and price dynamics, affecting the profitability of firms and the subsequent availability of goods.

[Cavallo et al. \(2014\)](#) aptly capture this point in their analysis of quantity and price effect of earthquakes. According to this study, the occurrence of earthquakes creates both supply and demand disruptions that in turn affect product sales by affecting price dynamics

and product availability. Generally, there is a significant fall in product availability for days and months following such a disaster and prices of perishable products increase during the same period. This behaviour is attributable to the fact that retailers find it difficult to re-stock due to persistent supply disruptions. Re-stocking after a natural disaster is often difficult, primarily because supply sources are affected. Even when re-stocking occurs, it comes at a high cost. Thus, although prices may go up, retailers are unable to reap increased profit due to a fall in stocks. Indeed, the authors point out that the fall in stock could change the production and supply patterns of the business entities affected even after the disaster. [Nakamura and Steinsson \(2011\)](#) have studied the implications of customer markets for price-setting decisions.

Agricultural markets in emerging countries are characterised by many small-scale rural producers serving few retailers who sell their food predominantly in towns and cities ([Sexton, 2012](#)). These two entities engage with the goal to maximise profits, with producers aiming at maximising profits from the production of food while retailers aim to maximise profits from the sale of it. The occurrence of natural disasters, however, affects the price and quantity traded by increasing cost of production and harvesting. Coupled with the fact that rural producers tend to lack adequate storage facilities, natural disasters lead to post-harvest losses, reducing the quantity of food available to retailers. With a shortfall in quantity produced, producers will generally hope to sell food at increased prices. Factors such as market structure (many producers against few retailers), inadequate storage facilities and the perishable nature of farm produce, however, inhibit the attainment of this objective. These factors often give retailers an upper hand when bargaining with producers to determine price and quantity levels. Thus, producer prices may be lower when natural disasters occur.

A strong linkage exists between the quality of transport infrastructure and the effect of natural disasters on market growth. A deteriorated transport infrastructure, caused by the occurrence of natural disasters, affects both geographic and economic segment diffusion by increasing the opportunity cost of time spent in search of goods. A good transport quality facilitates the opening of more outlets by retail units and eventually improves the ease with which consumers access foods. Similarly, consumers from higher income classes tend to have higher opportunity cost of time spent on purchasing items from shops, affecting the frequency and time spent in shops.

Empirical studies on the effect of transport quality on market growth show its effect on the food supply chain. From these studies, poor transport quality is considered as a disruption in that it interrupts the flow of sales from retailers to consumers. [Wilson \(2005\)](#) reveals that irrespective of the source of the disruption, transportation disruption interrupts the material flow between two stages along a supply chain (upstream and downstream), temporarily stopping the movement of these goods. This assertion stems from

the fact that transportation disruption is often the result of other drivers. [Chopra and Sodhi \(2004\)](#) identify these drivers as labour disputes, terrorist activities and infrastructure failures, implying that transportation disruption has effects both on upstream and downstream flows of goods.

The theoretical and empirical conclusions above explain the nature of minimally processed and unprocessed food supply chains in emerging countries. The upstream stage of these foods generally consists of producers and retailers who interact to ensure that food produced moves from the former to the latter, while the downstream level has retailers selling to households. From the perspective of market growth theory, upstream activity requires bringing retailers as geographically close to producers as possible while downstream sales need retailers to reach consumers. The weak infrastructural base and inadequate storage facilities that characterise rural areas mean that natural disasters pose a greater threat to the flow of nutritional high-value foods upstream than downstream. Thus, although natural disasters may disrupt both geographical and economic segmentation along the entire spectrum of the supply chain, the effect is more likely to be higher upstream.

Weak coordination between upstream actors further compounds the effect of natural disasters upstream. Supply chain coordination is relevant to respond to demand and supply dynamics, going a long way to mitigate the negative effects of natural disaster occurrences. Agricultural value chains are time sensitive and, therefore, need a highly developed coordination. Unfortunately, coordination upstream along the food supply chain in emerging countries is weak due to information asymmetry, a problem that partly emanates from high transport costs and institutional bottlenecks in rural areas. On the contrary, coordination is better downstream because of smooth information flow from processors through suppliers to retailers. With these differences in coordination capabilities, downstream actors are better able to deal with disruptions from natural disasters.

From the above theoretical construct, it can be concluded that there is a high propensity of disruption upstream being higher than disruption downstream along the food value chain. This study seeks to ascertain if this conclusion holds in the unprocessed and minimally processed nutritional high-value food supply chains. In this regard, the hypothesis to be tested is as follows:

H1: Disruptions from the occurrence of natural disasters are higher upstream than downstream along unprocessed and minimally processed nutritional high-value food supply chains in emerging countries.

2.9 THE DATA

2.9.1 Data sources and concerns

The study uses two classes of data: market and non-market. The market-level data are data that cover specific unprocessed and minimally processed nutritional high-value foods. These include the quantity of these foods sold, the quantity produced, producer prices and consumer prices. Non-market level data are based on structural variables whose dynamics have ramifications for all markets in a country. These include the occurrence of natural disasters, transport quality measured by the occurrence of transport disasters and hindrances to economic freedom.

Data on the quantity of the high-value foods under study were obtained from Euromonitor International, a data collection, analysis and dissemination body based in the United Kingdom. It conducts detailed research on the economies of 80 developing and developed countries. Its data cover a wide range of sectors, one of which being agriculture. The institution obtains its data from national statistical institutions and field surveys. The organisation has a repository known as Passport, which contains comprehensive market data and analyses on consumer products, commercial industries and demographics covering over 80 developed and developing countries. This study used data from two sectors based on the classification of Euromonitor International. These are fresh food and packaged food. The fresh foods reported in the database and which are used for this study include red meat, eggs, fruits and vegetables.

Aside from presenting data on total sales by food item, the database also contains data on sales by source of distribution. Three distributional chains are itemised; retail, foodservice and institutional. Retail sales occur through establishments whose focus is on the sale of goods for home use, preparation and/or consumption. Establishments under this category include grocery retailers, supermarkets and hypermarkets, convenience stores and forecourt retailers. Food-service sales are sales by full-service restaurants, cafés, bars, fast food outlets and self-service cafeterias. Lastly, institutional sales comprise canteens, prisons/jails and schools.

Consumer price data for the foods under study came from data published by country statistical and agricultural departments. In the case of China, the National Bureau of Statistics of China reports annual price indices of the foods under study in its China Statistical Yearbook. These were used to estimate the prices of the foods under study. Market price data from the Instituto de Economia Agrícola of the government of São Paulo served as the basis for the calculation of price for these commodities in Brazil while prices in India were obtained from market prices published by the Directorate of Economics and Statistics of the Ministry of Agriculture, India. With regard to Turkey, the Turkish

Statistical Institute (TurkStat) publishes these prices, while the Bureau of Agricultural Statistics publishes consumer prices in the Philippines. Statistics South Africa and the Department of Agriculture, Forestry and Fisheries of South Africa provide data on food prices in South African markets. The study used these as prices of these commodities in South Africa. For the emerging EU countries in this study (Czech Republic, Greece, Hungary and Poland), I used consumer prices of red meat, eggs, fresh fruits and fresh vegetables market prices reported by EUROSTAT.

The producer price captures the price that farmers receive for sale of their produce at the farm gate. I used producer price data reported by the Food and Agriculture Organisation of the United Nations (FAO) as the price charged by farmers engaged in the production of the foods under study. The producer prices, quantity of food produced and quantity of food sold are all in tonnes while the market prices are in kilogrammes (kg). To ensure parity, the values of the consumer prices were converted to tonne at the rate of 1 tonne = 1000 kg. Additionally, consumer prices are in local currency. These were converted to United States dollars by dividing the each price by the annual average official exchange rate between the local currency and the U.S. dollar.

Data on potential natural disasters were sourced from the EM-DAT database of the Centre for Research on the Epidemiology of Disasters of Université Catholique de Louvain. The database contains data on the occurrence and effects of natural, technological and complex disasters per country from 1916 to 2016. The natural disasters presented in the database include storm, flood, drought and extreme temperature. Disaster subtypes under technological disaster classification include road, rail, water and air disasters. For each disaster type, the database reports the year it occurred, disaster group, disaster subtype, occurrence, total deaths, number of people injured, affected, homeless, total affected and total damage. For each disaster classification, I sum the number of occurrences for each year to get the total intensity of disaster.

On hindrances to economic freedom and institutional quality, I used data from the Heritage Foundation's Index of Economic Freedom. The Index covers 12 areas of economic freedom in 186 countries. The domains are property rights, government integrity, judicial effectiveness, government spending, tax burden, fiscal health, business freedom, labour freedom, monetary freedom, trade freedom, investment freedom and financial freedom. Each of these categories is graded on the scale of 0 to 100. The closer a country's score to 100, the higher its performance on a given measure.

Finally, the quality of transport infrastructure at any moment in time depends on the amount of public expenditure allocation to the transport sector. To control for this, investment in transport infrastructure, published by the World Bank in its World Development Indicators, was used as a control variable.

2.9.2 The study variables

Dependent variables

This study uses two sets of dependent variables. The first set describes the production stage of the unprocessed and minimally processed food supply chains. The variables used to describe this segment are the producer price and quantity of each food produced. The second set of dependent variables comprises the consumer price and quantity of each food item sold. These variables determine retail availability of the food. Total sales come from three main sources. These are retail, foodservice and retail sources. These constitute a key source of food procurement in emerging countries and serve as the main link between producers and consumers along the value chain.

Independent variables

The independent variables of the study are variables that disrupt the upstream and downstream movement of food along the supply chain. These factors disrupt the upstream stage of the chain by inhibiting the quantity of food produced and its flow from producers to distributors. Downstream, they impede the quantity and flow of food sold by retailers, foodservice operators and institutions.

The upstream independent variables are the occurrence of natural disasters, government integrity index, financial freedom index and investment in transport infrastructure. Natural disasters such as earthquakes, drought and flooding reduce the quantity of arable land available for food production. They also affect farmers' ability to reach retailers with cultivated food, thereby affecting the flow of food from the former to the latter. This study uses three types of natural disasters: climatological, hydrological and geophysical. Based on the EM-DAT classification (<http://emdat.be/classification>), climatological disasters comprise drought and wildfires while hydrological disasters include flood and landslides. Geophysical disasters consist of earthquakes, mass movements and volcanic.

Downstream disruptions emanate from natural disasters (climatological, hydrological, and geophysical). Although natural disasters are mainly an upstream phenomenon, they can have implications for the flow of unprocessed nutritional high-value foods downstream. A breakdown of road infrastructure due to flooding, for instance, may impede access to market centres downstream. Here again, the number of natural disasters occurring in a country for a given year is used as a measure of how severe natural disasters are in the country.

Allocation to transport infrastructure plays a cardinal in improving the quality of transport infrastructure. Quality transport infrastructure in turn affects the level of coor-

dination among actors along the food supply chain, going a long way to determine the level of post-harvest losses and food waste. To capture the effect of transport expenditure, the study uses the amount of money invested in transport infrastructure as a control variable.

An important trait of financial freedom is that it facilitates access to credit by actors in an economy, including actors in the agricultural sector. Farmers can easily access loans and expand their production. Where there is limited financial freedom, however, access to credit is limited and this could affect the intention of farmers to expand food production. Limited financial freedom can also affect the downstream segment of the nutritional high-value food supply chain negatively. Just as its effect in the upstream stage, financial freedom dictates how easy investors in the food sub-sector can access credit from financial institutions to expand their investment. When this is limited, access to loans becomes problematic, inhibiting their ability to borrow and expand sales. This study uses the financial freedom index published by Heritage Foundation as a measure of limited financial freedom in emerging countries.

Corruption hinders efficient access to agricultural inputs because it increases the cost of accessing these inputs. In developing countries, for instance, rural producers may pay higher prices to access fertilizers where public agencies charged with distributing these inputs are corrupt. Similarly, the cost of doing business will be higher when perception about corruption is high. Indeed, some studies conclude that corruption negatively affects foreign direct investment inflows (Asiedu, 2006; Uhlenbruck et al., 2006). In view of the negative effect of corruption on the food market, the study accounts for the possible effect of corruption. To do this, government integrity, which measures systemic corruption of government institutions and decision-making by such practices as bribery, extortion, nepotism, cronyism, patronage, embezzlement and graft, is used as a control variable.

Descriptive statistics

Table 2.3 displays the descriptive statistics of the dependent and independent variables used in this study. As the values show, the vegetable market recorded the highest amount of food production at 583 million tonnes, followed by the fruits market that recorded 243 million tonnes. The production of eggs has the least quantity produced at 29 million tonnes. With respect to sales, the table shows that the sale of vegetables again recorded the highest amount at 311 million tonnes, followed by fruits that recorded 148 million tonnes of sales. As with food production, the sale of eggs recorded the least amount of 21 million tonnes. The quantity of each of these foods produced exceeds the quantity sold, implying that food produced went into other uses while the remaining quantity was lost.

The statistics on market prices for the meat, eggs and fruits markets also indicate that among the three, the fruits market recorded the highest average price of US\$ 9.3

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per kilogramme while the eggs market recorded the lowest average price of US\$ 2.5 per kilogramme of eggs. We, however, see a different result in the data on producer prices. Here, the meat market has the highest producer price of US\$ 15.9 per kilogramme, a huge amount when compared with the second highest price of US\$ 2.7 recorded in the fruits market. Table 2.3 also shows that of the three natural disasters under study, hydrological disasters were the most frequent, occurring 21 times, 10 times more than second placed geophysical disasters while climatological disasters occurred a maximum 3 times. As the table again indicates, there were instances when no natural disaster occurred.

Variable	Name	Unit	N	Mean	St. Dev.	Minimum	Maximum
climatological	Occurrence of climatological disasters	No. of occurrence	140	0.343	0.697	0	3
trans_exp	Investment in transport infrastructure	US\$ million	140	12770	30956.89	96.4	142000
geophysical	Occurrence of geophysical disasters	No. of occurrence	140	0.9	1.894	0	11
hydrological	Occurrence of hydrological disasters	No. of occurrence	140	3.9	4.768	0	21
meat_prod	Quantity of meat produced	1000 tonnes	140	10,891.73	20,915.50	434	85,180
egg_prod	Quantity of eggs produced	1000 tonnes	140	3,303.09	7,591.78	93	29,129
fruit_prod	Quantity of fruits produced	1000 tonnes	140	24,496.37	34,357.26	190	154,364
veg_prod	Quantity of vegetables produced	1000 tonnes	140	62,177.68	143,315.20	161	583,328
meat_dist	Quantity of meat sold	1000 tonnes	140	8,265.94	15,575.86	500	63,555.00
egg_dist	Quantity of eggs sold	1000 tonnes	140	2,458.75	5,570.29	86.9	21,358.60
fruit_dist	Quantity of fruits sold	1000 tonnes	140	19,534.67	36,670.69	283.4	147,833.40
veg_dist	Quantity of vegetables sold	1000 tonnes	140	39,059.98	83,799.19	655.9	311,142.70
meat_mprice	Retail price of meat	US\$ per tonne	140	2,975.88	1,751.85	945.272	7,544.61
egg_mprice	Retail price of egg	US\$ per tonne	140	1,069.33	603.95	68.907	2,543.42
fruit_mprice	Retail price of fruits	US\$ per tonne	140	1,458.56	1,907.57	76.8	9,342.03
veg_mprice	Retail price of vegetables	US\$ per tonne	140	1,813.34	3,408.93	212.324	17,140.60
govt_integrity	Government integrity	Index (1-100)	140	39.529	8.083	23	55
finan_freedom	Financial freedom hindrance	Index (1-100)	140	55.929	14.339	30	90
meat_pprice	Producer price of meat	US\$ per tonne	140	4,562.96	2,978.44	1,040.20	15,882.20
egg_pprice	Producer price of egg	US\$ per tonne	140	1,200.91	584.337	136.11	2,543.40
fruit_pprice	Producer price of fruits	US\$ per tonne	140	798.113	466.804	201.6	2,739.71
veg_pprice	Producer price of vegetables	US\$ per tonne	140	615.249	373.059	163.43	1,723.92

Table 2.3: Descriptive statistics

Table 2.4 presents the relationship among the independent variables of the study. From this table, we see a negative correlation between natural disasters and the variables that describe the structural and institutional underpinnings of the countries under study. These variables are government integrity, financial freedom and transport expenditure. The negative relationship between these variables and natural disaster occurrences indicates the mitigating role of structural parameters in overcoming the negative effects of natural disasters. We often speak of natural disasters in terms of the havoc they cause to human and plant lives. Strong and transparent institutions, an effective financial system that facilitates financial transactions and considerable investment in transport infrastructure help to avert these losses.

	CLIMATE	GEOG	HYDRO	GOVT	FINAN	EXP
CLIMATE	1					
GEOG	0.391	1				
HYDRO	0.289	0.559	1			
GOVT	-0.091	-0.308	-0.616	1		
FINAN	-0.219	-0.216	-0.523	0.557	1	
EXP	-0.028	-0.134	-0.156	0.237	0.026	1

CLIMATE: climatological disasters; GEOG.: Geophysical disasters; HYDRO: Hydrological disasters; GOVT: Governance Integrity; FINAN: Financial Freedom; EXP:Investment in transport infrastructure.

Table 2.4: Correlation matrix

The presence of multicollinearity in a model can increase the variance of its coefficient estimates and make them very sensitive to minor changes in the model. With this, estimates become unstable and difficult to interpret. A way of detecting multicollinearity is to use the Variance Inflation Factor (VIF), a measure of how higher the coefficient variance is when the independent variables are correlated, compared with when they are not correlated. A high VIF (greater than 5) indicates the presence of multicollinearity. Table 2.5 presents the VIF values of the independent variables of this study. The highest value is 2.58 while the lowest is 1.13. From these VIF values, we can confidently say that the multicollinearity will not be a problem in this study.

Variable	CLIMATE	GEOG	HYDRO	GOVT	FINAN	EXP
VIF	1.5	1.84	2.58	2.19	1.7	1.13

CLIMATE: climatological disasters; GEOG.: Geophysical disasters; HYDRO: Hydrological disasters; GOVT: Governance Integrity; FINAN: Financial Freedom; EXP:Investment in transport infrastructure.

Table 2.5: Variance Inflation Factors of the covariates

2.10 ESTIMATION AND RESULTS

2.10.1 Econometric model and specification tests

This study models how the occurrence of natural disasters affects both the upstream and downstream stages of the food supply chain. It examines how climatological, geophysical and hydrological disasters affect the production (upstream) and sale (downstream) of nutritional high-value foods in emerging countries. The countries under study are China, Brazil, India, South Africa, the Philippines, Greece, Poland, Czech Republic, Hungary and Turkey.

To carry out this empirical analysis, two classes of models are conducted. The first class models the effects of natural disasters on the quantity of unprocessed and minimally processed nutritional high-value foods produced (upstream activity) and the quantity of these foods sold (downstream activity). The second class of models looks at the behaviour of producer and consumer prices when natural disasters occur. For this class of models, the study examines how natural disasters affected producer and consumer prices of each of the nutritional high-value foods under study.

For each class of models, the study controls for the effect of structural variables. This is to ascertain the severity of natural disasters on the flow of nutritional high-value foods vis-à-vis structural bottlenecks. It is important to do this because these structural variables can interfere with how severe natural disaster disrupts a supply chain. Control variables used include investment in transport infrastructure, government integrity index (a measure of the intensity of corruption) and financial freedom that captures hindrances to the ease of doing business.

To construct the above models, the empirical technique entails developing a panel model that regresses upstream and downstream quantities and prices of unprocessed and minimally processed nutritional high-value foods on potential sources of disruption along the supply chains of these foods. Equation (2.1) below shows the model for disruptions on quantities:

$$\begin{aligned} QUANT_{it} = & \alpha + \beta_1 CLIMATE_{it} + \beta_2 GEOG_{it} + \beta_3 HYDRO_{it} + \beta_4 EXP_{it} \quad (2.1) \\ & + \beta_5 GOVT_{it} + \beta_6 FINAN_{it} + \gamma Z_i + U_i + \epsilon_{it} \end{aligned}$$

where $QUANT_{it}$ is the quantity of nutritional high-value foods produced and sold in country i at time t , $CLIMATE_{it}$ is the occurrence of climatological disasters in country i at time t , $GEOG$ is the occurrence of geophysical disasters while $HYDRO$ is the occurrence of hydrological disasters. The control variables are EXP_{it} , investment in transport

infrastructure in country i at time t , $GOVT_{it}$ is governance integrity index, a measure of the pervasiveness of corruption and $FINAN_{it}$ is financial freedom index. U_i measures individual-specific effect while ϵ_{it} is the residual term. α is the intercept of the model while Z_i is a column vector of time-invariant explanatory variables excluding the constant term α , with γ being the parameters of the time-invariant regressors.

The price version, showing disruptions to upstream and downstream prices is shown in equation (2.2).

$$\begin{aligned} PRICE_{it} = & \alpha_2 + \beta_{11}CLIMATE_{it} + \beta_{22}GEOG_{it} + \beta_{33}HYDRO_{it} + \beta_{44}EXP_{it} \quad (2.2) \\ & + \beta_{55}GOVT_{it} + \beta_{66}FINAN_{it} + \gamma_2 Z_{i2} + U_{2i} + \epsilon_{2it} \end{aligned}$$

From equation (2.2), $PRICE_{it}$ measures the producer and retail prices of the unprocessed and minimally processed nutritional high-value foods under study in country i at time t . Here again, U_{2i} and ϵ_{2it} represent individual-specific effect and residual terms respectively. α_2 is the constant term while Z_{i2} represent time-invariant regressors that exclude the constant term. By subtracting the respective means of equations (1) and (2) from the said equations, we do away with the individual specific variables U_i and U_{2i} . We also eliminate the effects of the constant terms (α and α_2) and the time-invariant regressors Z_i and Z_{i2} . The resulting model in equations (2.3) and (2.4) are the fixed effect models as shown below.

$$\begin{aligned} QUANT_{it} = & \beta_1 CLIMATE_{it} + \beta_2 GEOG_{it} + \beta_3 HYDRO_{it} + \beta_4 EXP_{it} \quad (2.3) \\ & + \beta_5 GOVT_{it} + \beta_6 FINAN_{it} + \epsilon_{it} \end{aligned}$$

$$\begin{aligned} PRICE_{it} = & \beta_{11} CLIMATE_{it} + \beta_{22} GEOG_{it} + \beta_{33} HYDRO_{it} + \beta_{44} EXP_{it} \quad (2.4) \\ & + \beta_{55} GOVT_{it} + \beta_{66} FINAN_{it} + \epsilon_{2it} \end{aligned}$$

The fixed effect models ((2.3) and (2.4)) are unbiased under assumptions of linearity, independence and strict exogeneity in small samples. Additionally, assuming homoscedasticity in the error variance and normally distributed errors, these models are normally distributed in small samples. To check for the robustness of the results of models (3) and (4), we examine how structural factors affect the disruptive effect of natural disasters when they change. To do this, we drop government integrity and financial freedom indices from the models to ascertain how the initial results, that included these variables, change. The results are robust if dropping each of these does not significantly change the initial model results. Section 5.2 presents the results of the models.

2.11 RESULTS

Tables 2.6 and 2.7 present results of the models developed in section 2.10. Table 2.6 presents results of the effects of natural disasters on the quantity of food produced and sold while controlling for key structural dynamics (governance integrity, financial freedom and transport expenditure). Results of the secondary effects of disruption to quantity of food produced and sold, shown by how natural disasters occurrence affects the behaviour of producer and consumer prices, are captured in Table 2.7.

One of the ways of ensuring that the estimated results are robust is to examine how the different control variables affect the results¹. To do this, both upstream and downstream disruptions were estimated without government integrity and financial freedom indices. Results without these control variables are shown in Tables 2.8, 2.9, 2.10 and 2.11.

2.11.1 Disruption of quantity produced and sold

Disruption from natural disasters (Hypothesis 1)

The results of Table 2.6 show that climatological disasters are the most dominant source of disruption to the flow of quantities along unprocessed and minimally processed nutritional high-value food supply chains in emerging countries. From the results, we see that these disasters significantly affect three of the four markets both along the upstream and downstream stages of the supply chains. Geographical and hydrological disasters only affect downstream activities in the egg and vegetables markets. The results further show that the occurrence of climatological disasters negatively affect both food production and sales in the nutritional high-value food markets under study. The occurrence of a climatological disaster leads to an average fall of 5.2% in the quantity of meat produced and a 7.1% fall in fruits. Similarly, the quantity of meat sold falls by 3.5% on average, while the sale of fruits and vegetables fall by 5.1% and 4.3% respectively. Thus, we see that for both upstream and downstream, the effect of climatological disasters on the movement of the unprocessed and minimally processed nutritional high-value foods under study is highest in the fruits market.

Comparatively, the results of Table 8 show that disruption due to the occurrence of climatological disasters is slightly higher upstream in the meat and fruits markets, while the opposite is true in the vegetables market. Whereas the average fall in the quantity of meat produced is 5.2%, that of meat sold is 3.5%, a 1.7% fall higher in the upstream meat market. In a similar vein, the quantity of fruits produced falls by 7.1% on average while its quantity sold falls by 5.1%. This means that on average, disruption along the

¹Others include using robust standard errors to overcome the problems of heteroskedasticity and serial correlation.

fruits supply chain is 2.0% higher upstream than downstream. These findings corroborate conclusions on the characteristics of food markets in emerging countries. These markets are characterised by many rural producers who produce and sell food to few retailers (Sexton, 2012). Producers often lack adequate storage facilities and, coupled with an inability to respond quickly when natural disasters occur (due mainly to a destruction to transport infrastructure), the occurrence of climatological disasters both disrupt food production and increase post-harvest losses. Conversely, although retailers, many of whom are located in towns and cities, are also affected by climatological disasters, they possess adequate storage facilities that enable them to store food for longer periods and sell these to consumers. Actors downstream are, therefore, better able to deal with the negative effects of climatological disasters. It is also important to note that disruption in the vegetables market is higher downstream than upstream, with a difference of 0.6%.

Interestingly, the occurrence of geophysical disasters has a positive and significant effect on the sale of eggs. The occurrence of these disasters leads to an average increase of 1.4% in the tonnes of eggs sold, a result that confirms the finding by Altay and Ramirez (2010) against the all-hazards approach. The result that food sold increases when geophysical disasters occur also confirms the finding by Cavallo et al. (2014), who analyse quantity and price responses following earthquakes in Chile and Japan in 2010 and 2011 respectively. The authors conclude that consumers rush for minimally processed foods such as eggs when they anticipate earthquakes and days after the quake, so that they are not affected by food shortages occasioned by the occurrence of these disasters.

The results of Table 2.6 also show that hydrological disasters only have a significant effect in the downstream vegetables market and the effect is negative. This effect is, however, small, with the occurrence of hydrological disasters leading to a fall in the quantity of vegetables sold by 0.7% on average.

As control variables, both financial freedom and expenditure on transportation expenditure are positively correlated with upstream and downstream activities along the unprocessed and minimally processed foods under study. Transportation expenditure also has a significant effect in all food markets both upstream and downstream, while financial freedom index is significant in all markets upstream but only significant downstream in the meat market.

The hypothesis of this research posits that along the unprocessed and minimally processed nutritional high-value foods supply chains, disruption from natural disaster is higher upstream than downstream in emerging countries. The results presented above and summarised in Table 2.6 show that this depends not only on the type of natural disaster, but also on the type of food product. With respect to climatological disasters, this hypothesis is not rejected in the meat and fruits markets. It is, however, rejected in the vegetables market. The occurrence of geophysical disasters is only significant in the downstream

egg market, leading to the non-acceptance of the hypothesis that upstream disruption is greater. Similarly, hydrological disasters have a significant effect only in the downstream vegetables market, leading to the rejection of the stated hypothesis. Overall, the results of the study show that for any of the natural disaster categories under study (climatological, hydrological and geophysical), whether disruption quantity upstream is greater than downstream disruption to quantity depends on the type of market. The hypothesis that upstream disruptions are greater than downstream disruptions is, therefore, inconclusive ².

²Table A.1 in the Appendix section shows disruption to upstream and downstream quantities when the sample size is increased from 10 countries to 19 countries. We see similar results as those in Table 2.6 with climatological disasters being the main source of disruption to quantity. Here again, we see that whether disruption is greater upstream depends on the type of nutritional high-value food.

Dependent variables: Log of quantity of food produced (upstream) and log of quantity sold (downstream)								
Independent variables	Production (upstream)				Sales (downstream)			
	meat (1)	eggs (2)	fruits (3)	vegetables (4)	meat (5)	eggs (6)	fruits (7)	vegetables (8)
CLIMATE	-0.052*** (0.019)	-0.023 (0.016)	-0.071*** (0.027)	-0.037*** (0.019)	-0.035*** (0.013)	-0.021 (0.016)	-0.051*** (0.015)	-0.043*** (0.011)
GEOG	-0.003 (0.009)	0.004 (0.008)	0.009 (0.012)	0.01 (0.009)	0.009 (0.009)	0.014*** (0.008)	0.011 (0.009)	0.007 (0.006)
HYDRO	-0.002 (0.004)	-0.002 (0.004)	0.002 (0.006)	-0.004 (0.004)	-0.002 (0.004)	-0.004 (0.004)	-0.003 (0.005)	-0.007 (0.004)
GOVT	0.002 (0.003)	-0.001 (0.002)	0.008*** (0.004)	-0.003 (0.004)	0.001 (0.002)	-0.001 (0.002)	0.003 (0.003)	0.002 (0.002)
FINAN	0.005*** (0.002)	0.005*** (0.002)	0.008*** (0.003)	0.004*** (0.003)	0.002*** (0.001)	0.003 (0.002)	0.001 (0.002)	-0.001 (0.001)
ln(EXP)	0.087*** (0.012)	0.092*** (0.010)	0.060*** (0.015)	0.058*** (0.012)	0.099*** (0.011)	0.090*** (0.011)	0.092*** (0.012)	0.072*** (0.012)
Observations	140	140	140	140	140	140	140	140
R^2	0.353	0.42	0.252	0.18	0.537	0.519	0.417	0.431
Adjusted R^2	0.274	0.35	0.161	0.08	0.481	0.461	0.347	0.362
F Statistic (df = 6; 124)	11.262***	14.984***	6.953***	4.524***	23.995***	22.317***	14.788***	15.643***

CLIMATE: climatological disasters; GEOG: Geophysical disasters; HYDRO: Hydrological disasters; GOVT: Governance Integrity; FINAN: Financial Freedom; ln(EXP) is the natural log Investment in transport infrastructure. *** and ** mean significant at 1% and 5% respectively. Standard errors are in brackets and robust to heteroscedasticity and autocorrelation.

Table 2.6: Disruption of quantity of food produced and sold

2.11.2 Effects on producer and consumer prices

From the results of Table 2.7 below, we see that the occurrence of climatological disasters comprising drought and wildfires has a negative and significant effect on both producer and consumer prices in all the food markets under study. Holding all other covariates constant, an additional occurrence of climatological disasters leads to a 15.5% fall in the average producer price of meat and a 12.1% fall in the average producer price of egg. Similarly, the average producer prices of fruits and vegetables fall by 12.72% and 9.43% respectively. With respect to downstream effects, we see that the average consumer price of meat falls by 6.67% with the occurrence of climatological disasters while consumer prices of egg falls by 10.59%. Both average producer and consumer prices of fruits and vegetables fall by 9.6% when climatological disasters occur.

The results show that the upstream effect of the occurrence of climatological disasters on producer prices is highest in the meat market, followed by the fruits market and while the vegetables market records the least disruption. Downstream, however, the consumer price of eggs records the highest change while that of meat has the least change. Comparatively, changes in producer prices are higher than changes in consumer prices for all the foods under study. Although the differences in prices upstream and downstream look marginal, they could prove important with food products.

Besides climatological disasters, the other disasters variable whose occurrence has a significant effect on prices are hydrological disasters (flood, landslide and wave action). The occurrence of hydrological disasters, however, has a significant effect only in the upstream fruits market, where their occurrence leads to a 2.1% fall in the average price of the producer price of fruits. It is also interesting to note that the effect of hydrological disasters on the upstream fruits market is far less than that of climatological disasters in the same market (12.72%).

The characteristics and structure of the markets of unprocessed and minimally processed nutritional high-value foods explain the fall in both producer and consumer prices when climatological disasters occur. Already highly perishable, the occurrence of natural disasters further increases the degree of waste of these foods. With poor storage and transport systems that become highly ineffective when climatological disasters occur, rural producers are obliged to accept lower prices in order to sell their produce to retailers. At the downstream level, retailers also charge lower prices in order to meet consumer demand and prevent losses. From these results, we see that the reduction in consumer prices by the retailer is lower than the reduction in the price at which he buys the food from producers (producer price). Thus, although both producer and consumer prices fall with the occurrence of climatological disasters, we can confidently conclude that the effect of these disasters on the supply chains under study is higher on upstream prices. The upstream

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stage, therefore, experiences higher disruption than the downstream segment along meat, egg, fruits and vegetables supply chains in emerging countries, leading to the non-rejection of the stated hypothesis.

		Dependent variables: Log of producer prices (upstream) and log of consumer prices (downstream)							
Independent variables	vari-	Producer prices (upstream)				Consumer prices (downstream)			
		meat (1)	eggs (2)	fruits (3)	vegetables (4)	meat (5)	eggs (6)	fruits (7)	vegetables (8)
CLIMATE		-0.169*** (0.049)	-0.129*** (0.045)	-0.136*** (0.041)	-0.099*** (0.036)	-0.069*** (0.036)	-0.112*** (0.027)	-0.096*** (0.033)	-0.096*** (0.033)
GEOG		0.028 (0.031)	0.006 (0.025)	0.002 (0.026)	0.005 (0.021)	0.023 (0.021)	-0.003 (0.014)	0.016 (0.020)	0.02 (0.020)
HYDRO		-0.01 -0.011	-0.013 -0.011	-0.021** -0.009	-0.011 -0.011	0.003 -0.011	0.002 -0.009	0.003 -0.01	0.004 -0.01
GOVT		-0.001 (0.006)	-0.007 (0.007)	-0.005 (0.007)	-0.005 (0.006)	-0.005 (0.006)	-0.002 (0.005)	0.007 (0.005)	0.010*** (0.005)
FINAN		0.001 (0.004)	0.006 (0.004)	0.002 (0.005)	0.002 (0.004)	0.00001 (0.004)	0.001 (0.003)	0.002 (0.004)	-0.002 (0.004)
ln(EXP)		0.146*** (0.025)	0.226*** (0.035)	0.203*** (0.026)	0.261*** (0.030)	0.241*** (0.030)	0.217*** (0.022)	0.345*** (0.035)	0.181*** (0.035)
Observations		140	140	140	140	140	140	140	140
R^2		0.285	0.392	0.313	0.417	0.478	0.461	0.487	0.3
Adjusted R^2		0.199	0.319	0.23	0.346	0.415	0.396	0.425	0.216
F Statistic (df = 6; 124)		8.256***	13.332***	9.42***	14.752***	18.936***	17.686***	19.616***	8.866***

CLIMATE: climatological disasters; GEOG.: Geophysical disasters; HYDRO: Hydrological disasters; GOVT: Governance Integrity Index; FINAN: Financial Freedom Index; ln(EXP) is the natural log Investment in transport infrastructure. *** and ** mean significant at 1% and 5% respectively. For the covariates, robust standard errors are in brackets.

Table 2.7: Disruption of producer and consumer prices

Comparing changes in quantities to changes in prices both upstream and downstream reveals that, for both upstream and downstream, price changes exceed quantity changes in all the food markets under study. This result indicates that both upstream and downstream players respond more to natural disasters through prices than through quantities, a conclusion that deviates from Cavallo et al. (2014) who find that downstream players are more responsive through quantity sold than through prices charged.

2.11.3 Robustness checks

To ensure that the results presented in Tables 2.6 and 2.7 are robust, we need to control for the effect of financial freedom and government integrity. Although the results indicate a negative relationship between natural disasters and quantity of minimally processed and unprocessed nutritional high-value foods, the degree of financial freedom and government integrity may influence the decision of producers and retailers during times of disasters. Financial freedom measures the extent of banking efficiency and the independence of the financial sector from government control. In an ideal situation where financial freedom is high, credit is allocated on market terms and financial institutions are able to provide various forms of financial services to individuals and companies. Farmers are able to access credit to increase production and retailers are able to source funding from the financial sector, increasing both foreign and local investment inflows into the agricultural sector.

Corrupt practices by government institutions include bribery, extortion, nepotism, cronyism, patronage, embezzlement and graft. These acts hinder the economic well-being of actors in the agricultural sector by introducing insecurity and uncertainty in economic relations. In developing countries, public institutions play a vital role in the acquisition and distribution of farm inputs to farmers. They also play a key role in ensuring the implementation of policies geared towards attracting foreign direct investment. A high level of corruption increases the cost of accessing inputs from public institutions since distribution is done inequitably. It also increases cost of doing business in the agricultural sector, since investors have to pay more to start a business. These effects further compound losses incurred from the occurrence of natural disasters along the food supply chain.

Tables 2.8 and 2.9 show results of disruption to the supply chain without financial freedom index while Tables 2.10 and 2.11 indicate results of the model without government integrity index. The results of Table 2.8 show that climatological disasters remain the most significant source of disruption along the supply chains of the foods under study and the effect remains negative in all markets. In terms of magnitude, however, the model without financial freedom index slightly higher effects. The results also show that compared with downstream disruption to quantity, upstream disruption is higher in the meat and fruits markets while the opposite holds true in the vegetables and eggs markets. This result confirms that of Table 2.6.

Dependent variables: Log of quantity of food produced (upstream) and sold (downstream)								
Independent variables	Production (upstream)				Sales (downstream)			
	meat (1)	eggs (2)	fruits (3)	vegetables (4)	meat (5)	eggs (6)	fruits (7)	vegetables (8)
CLIMATE	-0.057*** (0.017)	-0.028*** (0.016)	-0.078*** (0.025)	-0.041*** (0.017)	-0.037*** (0.012)	-0.024 (0.017)	-0.052*** (0.015)	-0.043*** (0.011)
GEOG	-0.003 (0.010)	0.004 (0.008)	0.009 (0.013)	0.01 (0.009)	0.009 (0.009)	0.014*** (0.008)	0.011 (0.009)	0.007 (0.006)
HYDRO	-0.004 (0.004)	-0.003 (0.004)	-0.0002 (0.006)	-0.006 (0.005)	-0.003 (0.005)	-0.004 (0.004)	-0.004 (0.005)	-0.007*** (0.004)
GOVT	0.001 (0.004)	-0.002 (0.003)	0.007 (0.005)	-0.004 (0.004)	0.0005 (0.002)	-0.001 (0.002)	0.002 (0.003)	0.002 (0.002)
ln(EXP)	0.091*** (0.013)	0.096*** (0.011)	0.066*** (0.015)	0.061*** (0.012)	0.100*** (0.011)	0.093*** (0.011)	0.093*** (0.012)	0.072*** (0.012)
Observations	140	140	140	140	140	140	140	140
R^2	0.317	0.377	0.197	0.154	0.529	0.501	0.415	0.429
Adjusted R^2	0.241	0.308	0.107	0.059	0.476	0.445	0.349	0.366
F Statistic (df = 5; 125)	11.618***	15.160***	6.126***	4.556***	28.095***	25.098***	17.722***	18.818***

CLIMATE: climatological disasters; GEOG.: Geophysical disasters; HYDRO: Hydrological disasters; GOVT: Governance Integrity; ln(EXP) is the natural log Investment in transport infrastructure. *** and ** mean significant at 1% and 5% respectively. For the covariates, robust standard errors are in brackets.

Table 2.8: Quantity model without financial freedom index

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In Table 2.9 below, the effect of climatological disasters on food prices is presented without financial freedom index. From these results, we see that climatological disasters are the most dominant disasters with the potential to disruption pricing along the food supply chain. Their effect is negative and significant on both producer and consumer prices in all markets. These results mirror those of Table 2.7, with the only difference being that the magnitudes of the effects upstream are marginally higher without financial freedom index. Downstream, however, disruption in the meat market remains same while those of fruits and eggs increase marginally.

Dependent variables: Log of producer prices (upstream) and log of consumer prices (downstream)								
Independent variables	Producer prices (upstream)				Consumer prices (downstream)			
	meat (1)	eggs (2)	fruits (3)	vegetables (4)	meat (5)	eggs (6)	fruits (7)	vegetables (8)
CLIMATE	-0.170*** (0.049)	-0.135*** (0.044)	-0.138*** (0.042)	-0.100*** (0.037)	-0.069*** (0.026)	-0.113*** (0.027)	-0.098*** (0.035)	-0.094*** (0.033)
GEOG	0.028 (0.031)	0.006 (0.025)	0.002 (0.026)	0.005 (0.021)	0.023 (0.018)	-0.003 (0.014)	0.016 (0.023)	0.02 (0.020)
HYDRO	-0.01 (0.011)	-0.014 (0.011)	-0.022** (0.009)	-0.012 (0.011)	0.003 (0.009)	0.002 (0.009)	0.002 (0.015)	0.005 (0.010)
GOVT	-0.001 (0.006)	-0.007 (0.007)	-0.005 (0.007)	-0.005 (0.007)	-0.005 (0.005)	-0.002 (0.005)	0.007 (0.008)	0.010** (0.005)
ln(EXP)	0.147*** (0.026)	0.231*** (0.036)	0.204*** (0.026)	0.262*** (0.031)	0.241*** (0.023)	0.217*** (0.022)	0.347*** (0.039)	0.180*** (0.035)
Observations	140	140	140	140	140	140	140	140
R^2	0.285	0.383	0.312	0.415	0.478	0.461	0.486	0.299
Adjusted R^2	0.205	0.314	0.235	0.35	0.42	0.401	0.428	0.221
F Statistic (df = 5; 125)	9.978***	15.549***	11.330***	17.769***	22.906***	21.378***	23.640***	10.668***

CLIMATE: climatological disasters; GEOG.: Geophysical disasters; HYDRO: Hydrological disasters; GOVT: Governance Integrity; ln(EXP) is the natural log Investment in transport infrastructure. *** and ** mean significant at 1% and 5% respectively. For the covariates, robust standard errors are in brackets.

Table 2.9: Price model without financial freedom index

Tables 2.10 and 2.11 show results of disruption without government integrity index, a measure of corruption in emerging countries. Table 2.10 presents the results of disruption to quantity without government integrity while Table 2.11 shows results of disruption to price without government integrity. From Table 2.10, we see that climatological disasters have a negative correlation with the meat, fruits and vegetables markets both upstream and downstream. Compared with the results of Table 2.6 showing disruption to quantity with government integrity, we see that the effects are the same in terms of significance. It is important to note that, the expected value of the occurrence of geophysical disasters on the quantity of egg sold is the same both with and without government integrity index.

Dependent variables: Log of quantity of food produced (upstream) and sold (downstream)								
Independent variables	Production (upstream)				Sales (downstream)			
	meat (1)	eggs (2)	fruits (3)	vegetables (4)	meat (5)	eggs (6)	fruits (7)	vegetables (8)
CLIMATE	-0.051*** (0.019)	-0.024 (0.016)	-0.068*** (0.029)	-0.039*** (0.018)	-0.035*** (0.013)	-0.021 (0.016)	-0.050*** (0.015)	-0.042*** (0.011)
GEOG	-0.003 (0.009)	0.004 (0.008)	0.01 (0.013)	0.009 (0.008)	0.009 (0.009)	0.014*** (0.008)	0.011 (0.009)	0.007 (0.006)
HYDRO	-0.003 (0.004)	-0.001 (0.004)	0.0002 (0.005)	-0.004 (0.004)	-0.002 (0.004)	-0.003 (0.004)	-0.004 (0.005)	-0.007*** (0.004)
FINAN	0.005*** (0.002)	0.005*** (0.002)	0.007*** (0.003)	0.005*** (0.003)	0.002*** (0.001)	0.003 (0.002)	0.001 (0.002)	-0.001 (0.001)
ln(EXP)	0.088*** (0.013)	0.092*** (0.009)	0.066*** (0.015)	0.056*** (0.011)	0.099*** (0.011)	0.090*** (0.011)	0.094*** (0.012)	0.074*** (0.012)
Observations	140	140	140	140	140	140	140	140
R^2	0.35	0.419	0.224	0.173	0.537	0.518	0.412	0.425
Adjusted R^2	0.277	0.354	0.137	0.081	0.485	0.464	0.346	0.36
F Statistic (df = 5; 125)	13.476***	18.038***	7.212***	5.248***	28.970***	26.900***	17.510***	18.452***

CLIMATE: climatological disasters; GEOG.: Geogphysical disasters; HYDRO: Hydrological disasters; FINAN: Financial Freedom; ln(EXP) is the natural log Investment in transport infrastructure. *** and ** mean significant at 1% and 5% respectively. For the covariates, robust standard errors are in brackets.

Table 2.10: Quantity model without government integrity

In Table 2.11, the results of disruption to producer prices show negative and significant correlation between the occurrence of climatological disasters and food prices both upstream and downstream. Comparing these results with those of the full model (Table 2.7) reveals that climatological disasters have the same level of significance in both models. Here again, hydrological disasters negatively affect the production of fruits in both models, albeit at a lower rate compared with the effect of climatological disasters.

Independent variables	Dependent variables: Log of producer prices (upstream) and log of consumer prices (downstream)							
	Producer prices (upstream)				Consumer prices (downstream)			
	meat (1)	eggs (2)	fruits (3)	vegetables (4)	meat (5)	eggs (6)	fruits (7)	vegetables (8)
CLIMATE	-0.170*** (0.049)	-0.132*** (0.044)	-0.138*** (0.041)	-0.101*** (0.036)	-0.071*** (0.026)	-0.113*** (0.027)	-0.093*** (0.037)	-0.092*** (0.035)
GEOG	0.028 (0.031)	0.005 (0.025)	0.002 (0.026)	0.004 (0.021)	0.022 (0.018)	-0.003 (0.014)	0.017 (0.022)	0.021 (0.021)
HYDRO	-0.009 (0.011)	-0.011 (0.011)	-0.020** (0.008)	-0.01 (0.011)	0.004 (0.009)	0.003 (0.009)	0.001 (0.015)	0.002 (0.010)
FINAN	0.001 (0.003)	0.006 (0.004)	0.003 (0.005)	0.002 (0.004)	0.0003 (0.003)	0.001 (0.003)	0.002 (0.005)	-0.003 (0.004)
ln(EXP)	0.145*** (0.025)	0.222*** (0.035)	0.200*** (0.025)	0.257*** (0.030)	0.237*** (0.023)	0.216*** (0.022)	0.350*** (0.040)	0.188*** (0.035)
Observations	140	140	140	140	140	140	140	140
R^2	0.285	0.387	0.311	0.414	0.475	0.461	0.484	0.288
Adjusted R^2	0.205	0.318	0.234	0.348	0.416	0.4	0.426	0.208
F Statistic (df = 5; 125)	9.977***	15.777***	11.272***	17.649***	22.593***	21.364***	23.408***	10.107***

CLIMATE: climatological disasters; GEOG.: Geophysical disasters; HYDRO: Hydrological disasters; FINAN: Financial Freedom; ln(EXP) is the natural log Investment in transport infrastructure. *** and ** mean significant at 1% and 5% respectively. For the covariates, robust standard errors are in brackets.

Table 2.11: Price model without government integrity

2.12 COMMENTS AND DISCUSSION

The problem of climate change remains a very topical issue as far as global economic development is concerned. Current concerns particularly focus on how climate change can endanger the attainment of food security goals in developing countries (Falco et al., 2011; Stern, 2007). Given its role in linking producers to consumers, food supply chains play a crucial role in the fight against food insecurity. The results of this study have shown that the effect of natural disasters, expressed predominantly through climatological disasters, negatively affect both the quantity of food produced (upstream activity) and the quantity of food sold (downstream activity) along the minimally processed and unprocessed nutritional high-value food supply chains in emerging countries. Similarly, climatological disasters negatively affect both upstream and downstream food prices.

The negative effect of climatological disasters on the quantities of food produced and sold is indicative of the extent to which external shocks disrupt activities along the food supply chain. In the case of food production, climatological disasters reduce the quantity of food produced by reducing soil quality. Since these foods are highly perishable, producers and retailers, in their bid to reduce further losses, reduce their prices in order to attract consumers.

Although the negative effects of natural disasters are felt both upstream and downstream along the supply chains, the study reveals that upstream disruption to quantity is higher in the meat and fruits markets while the inverse result is seen in the vegetables and eggs markets. With respect to price disruption, however, we see that upstream disruption is higher in all food markets.

The finding that disruption of quantity is higher upstream in the meat and fruits markets indicates that there is a stronger correlation between the production of these foods and climatological disasters than their sale and these disasters. The production of meat depends heavily on the availability of plant fodder. Climatological disasters such as drought and wildfires destroy plant life, limiting access to animal feed, and going a long way to affect animal production. The production of fruits is also exposed to the negative effects of wildfires in that these fires affect both soil quality and will destroy plants if uncontrolled. Thus, although drought and wildfires may affect the quantity of these foods sold by reducing the quantity that retailers purchase and sell, the impact is greater on production due to the losses producers incur.

Although the difference between the fall in the quantity of vegetables sold and that produced is only 0.6% (an amount of 3,499,968 tonnes), this value is significant given that vegetables recorded the highest sales among the nutritional high-value foods under study. This figure indicates that not only does the quantity of vegetables produced fall when climatological disasters occur, but there is an additional reduction in the sale of

these foods, indicating that disruption upstream is transmitted downstream. In this case, fresh vegetables begin to lose value upstream and must have ready market downstream in order to avert further decay. From the higher disruption downstream, we can deduce that this segment is not very responsive, leading to further losses ([Blackburn and Scudder, 2009](#)).

The results also show that although both producer and consumer prices fall in all minimally processed and unprocessed nutritional high-value food markets when climatological disasters occur, the fall in upstream prices exceeds that of downstream prices. This finding indicates how climatological disasters affect upstream and downstream behaviour along the supply chain. As earlier intimated, these foods are highly perishable and the occurrence of climatological disasters compounds this problem. Upstream, rural producers are obliged to reduce producer prices since failure to sell their produce will lead to loss in view of the poor storage facilities that these farmers often have. The imperfect nature of agricultural markets in emerging countries also gives retailers more power in determining producer prices, enabling them to bid prices further downward. At the downstream segment of the chain, the need to free storage space for other products, coupled with the fact that these foods are unprocessed and lose some value the longer they are kept unsold, compel retail units to reduce prices in order to increase sales. This is in spite of good storage facilities at their disposal.

From the results of the study, we see that price reduction by retailers is lower than producer price reduction, implying that retailers transmit less of the reduced producer price effect to consumers. This finding is in line with the conclusion in the price transmission literature that there is an asymmetry in price transmission from upstream to downstream along the food supply chain ([Leibtag, 2009](#); [Ben-Kaabia and Gil, 2007](#)).

The results of the study also throw light on the welfare loss from the occurrence of natural disasters along the food supply chain. Both producers and sellers engage in activities along the supply chain with the goal to maximise profits from production and sales respectively. While the producer's profit maximisation is a function of the producer price that he receives, that of the retailer depends on the consumer price that he is able to charge. Generally, both agents will wish to limit quantity and increase price ([Sexton, 2012](#)). From this study, we see that the occurrence of climatological disasters, leads to the reduction of both quantities and prices. Profit levels decrease, leading to a worsening of both producer and retailer welfare. The magnitude of loss, shown by the magnitude of reduction in both price and quantity, is, however, dependent on the type of product in which an agent deals and where it is located along the chain.

2.13 CONCLUSION

This study analysed disruption from natural disasters along unprocessed and minimally processed nutritional high-value food chains in emerging countries over the period 2000-2013. The foods analysed include meat, eggs, fruits and vegetables. Given the rising share of the middle class population in these countries, the demand for these foods continue to increase and will constitute an important component of household food consumption in the near future. The sources of disruption analysed include climatological, geophysical and hydrological disasters. The study considered disruption by how these disasters affect the behaviour of quantity and price both upstream and downstream along the supply chain. These effects determine the how these foods move along the chain.

The results of the study showed that climatological disasters are the main source of disruption along the unprocessed and minimally processed nutritional high-value food supply chains. The impact of climatological disasters on food quantity was found to be negative both upstream and downstream. Similarly, the occurrence of climatological disasters led to a fall in both producer and consumer prices for all the foods under consideration. Comparing upstream and downstream disruption, the study showed that upstream disruption to quantity is higher in the meat and fruits markets, while downstream disruptions are higher in the eggs and vegetables markets. Thus, the hypothesis that disruption from the occurrence of natural disasters is higher upstream is not rejected in the meat and fruits markets, but rejected in the vegetables and eggs markets. With respect to disruption to food prices, the study showed that the occurrence of natural disasters affect producer prices more than it affects consumer prices in all the food markets under study, leading to the non-rejection of the stated hypothesis.

The results of this study have important implications for policy formulation in developing countries. The finding that both quantities and prices of unprocessed and minimally processed nutritional high-value foods decrease when climatological disasters occur despite an increasing demand for these foods may compromise their availability to households, impeding efforts made at achieving food security. This study has shown, however, that this negative is market-specific and depends on where supply-chain agents are located along the chain. In view of this and given the linkages that exist between upstream and downstream chains, policies aimed at ensuring efficiency along these supply chains must be tailored around market and supply chain differences. Industry-specific policies will ensure that most food markets are shielded against natural disasters, going a long way to improve the participation of emerging countries in the global food supply chain.

Drought is a key component of climatological disasters. The finding that this class of disasters disrupts the flow of quantities along the food supply chain calls for improved research into the development of drought-resistant nutritional high-value foods. This is

imperative given the current threats of global warming. Developing countries particularly need to give more attention to this kind of research, since it will not only ensure that farmers increase their output, but retailers would have much food in store for consumers. Additionally, governments should consider helping farmers to acquire inputs after a natural disaster has occurred in order to enable them to mitigate any loss incurred.

Disruption to producer prices is a recipe for increased food losses along the supply chain. An unintended price change resulting from the occurrence of a natural disaster can disincentive farmers' production plans. Where the change is negative and exceeds the cost incurred in harvesting food crops, they may be compelled to leave food on farms, leading to food loss. To prevent this, governments should implement price support schemes during and after times of natural disasters to cushion small-scale farmers against unintended negative shocks to producer prices.

Due to limited data, this study did not analyse natural disaster disruptions by source of distribution. Downstream disruptions may vary depending on the type of distributor. Three main distributors exist in the unprocessed and minimally processed nutritional high-value food markets in emerging countries. These are retailers, foodservice operators and institutions. To better target policies along the food supply chain, an analysis of the differences in natural disaster disruptions to these sources of distribution is necessary.

Disruption of Processed Nutritional High-value Food Supply Chains in Emerging Countries

3.1 INTRODUCTION

An overarching issue in current food research are the dynamics in the consumption of processed foods. The increased consumption of these foods is seen as a major contributor to incidences of obesity and other diseases (Nayaga Jr., 2008; Uauy et al., 2009). The increased attention to issues related to the health effects of processed food consumption is due to increased focus on healthy living by consumers. Consumers are increasingly paying attention to nutritional labels and point-of-sale regulation. Information such as the “best” before or “use by” dates have been shown to contribute significantly to consumers’ choice of processed foods (Grunow and Piramuthu, 2013; Godfray et al., 2010). There is, therefore, the need for food markets to provide more information to consumers on food products (Tsiros and C.M., 2005). Additionally, governments continue to implement policies and regulations on quality food production, imports and exports and these have contributed to the dynamics in the consumption of these foods.

In view of the increased focus on food quality and healthy eating, firms engaged in the packaging and marketing of processed foods continue to push the boundaries to ensure that they do not lose their customers. This is done through the use of new materials and packaging types that help maintain the freshness of food products at the highest possible level. These new developments may translate into cost savings for firms, which can be passed down to consumers whose main objective is to enjoy better quality at lower prices.

The above analysis has important implications for the design and operation of supply chains in the processed food market. Generally, processed foods exist in an unprocessed state at the initial stages of the food supply chain (corresponding with the upstream

segment), increasing the risk of perishability ([Blackburn and Scudder, 2009](#)). Through processing and packaging, however, value is added to these foods, making them exist in a processed form at the latter stage of the supply chain (mainly downstream). The interplay of upstream events (when the food is unprocessed) and downstream events (after they have been processed and ready to be sold) implies that the profit margin of an operating firm will depend hugely on how it is able to coordinate both streams of events. An inability to effectively coordinate the two stages will increase the probability of quantity losses both upstream and downstream.

Given that processed foods downstream are initially unprocessed upstream, a very high level of supplier-processor coordination is required in order to ensure timely movement of food from suppliers to processors. Thus, a highly responsive supply chain is required upstream. Although processed foods still have some level of waste, the rate is lower compared with their state upstream. Keeping these foods for long may, however, lead to stock build-up, increasing cost of operations. The appropriate strategy will, therefore, be a cost-efficient supply chain.

The change in the state of food as it moves downstream also determines the extent to which the supply chain of a processed food is exposed to disruptions. Events such as natural disasters impede the flow of food along the food supply chain. The magnitude of disruptions depends, however, on the type of food and level of coordination between actors along the supply chain. Generally, disruptions are high when a food item is unprocessed and coordination between agents is weak. On the other hand, disruptions are low when food is processed and coordination between actors is strong. It is important to underscore that, even where a food is unprocessed, a strong coordination between actors dealing in this food can mitigate the negative effects of disruptions, albeit lower than the case where both strong coordination and processed foods characterise the chain. As earlier intimated, foods that are sold in a processed form downstream are in a raw unprocessed form upstream. This means that for a given level of coordination, there is a high propensity that disruptions upstream could differ from disruptions downstream.

Two important reasons underpin the need to study disruptions along the processed nutritional high-value foods supply chain. Firstly, the consumption of these foods is expected to grow, particularly in emerging countries ([Unnevehr and Jagmanaite, 2008](#); [Corley, 2009](#)). This is because, although focus on food quality and the health implications of the consumption of processed foods have attracted tight public policy measures to regulate the processed food market, firms operating in this market have adopted innovative ways aimed at bolstering consumer demand for these foods. These ways include better packaging and diversified supply in which different forms of these foods are supplied to consumers. With potential stability and even increase in the demand for these foods, the disruption of the means through which they are distributed has important implications for their availability,

a significant component of food security.

Secondly, current threats from climate change and global warming portend that food supply chains will be more exposed to disruptions in the future. Countering these threats entails the implementation of adaptation strategies to both increase output and preserve quality. With processed foods, this often requires high production and sale costs since these foods have to meet stringent quality control standards (Hammoudi et al., 2009). Since these chains have differentiated agents that exhibit different market powers, knowledge of the ways in which different negative shocks disrupt the food supply chain will enable policy-makers to better target the design and implementation of standards to ensure fairness along the chain.

3.1.1 The dairy and fats and oils markets

Dairy products play an important role in the diet of households in emerging countries. For instance, milk products are considered as a staple food in many countries. Along with its relatively low price, this has made the milk sub-sector very resilient to recessionary pressures since consumers tend to substitute other non-essential items such as impulse and indulgence foods like confectionery for milk products.

Growth in dairy markets is expected to be spearheaded by an increasing number of consumers switching from home-made dairy products to branded packaged goods, based on the perception that these alternatives are more convenient, time-saving and of higher quality. Additionally, health concerns about the sources of fresh dairy products could propel the acceptance of packaged milk against that purchased directly from farms. For this reason, franchising chains, partnerships and supermarket acquisition have emerged as key pillars promoting the growth of the dairy market in emerging countries. In Brazil, for instance, Coca-Cola entered into partnership with Leã Alimentos e Bebidas and the two reached an agreement to acquire the dairy company Laticínios Verde Campo in late 2015. In addition, an increase in the demand for flavoured milk in India made Coca Cola to launch Vio in February 2016. In China, Coca-Cola has purchased Culiangwang, a plant-protein beverage company in 2015, introducing itself into the fast-growing non-dairy milk alternative category.

In Europe, new market opportunities in Eastern Europe offer very strong indications of the continued growth of the dairy market on the continent given the growth path sustained by these countries and the fact that activities of other large multinationals are still at an early stage. The growth of the market is particularly spearheaded by Lactalis, a global player in the production and distribution of dairy products. Besides entering new markets in Eastern Europe, Lactalis has also expanded its market share in countries where it already operates. In the Czech Republic, for instance, the company's

operations have intensified since the acquisition of Promil-PML in 2006 and Mlékárna Kunín in 2007, with both companies owning well-established local and regional brands such as Kunin and Laktino. Although Danone, an important multinational company and two non-Czech companies Bel Groupe and Bongrain SA also operate in the dairy market, Lactalis continues to consolidate its dominance in the dairy market through these new acquisitions. The pattern of dairy market growth in selected emerging countries is shown in Figure 3.1. From this figure, we see a continuous growth in the size of the dairy market in both the BRICS (Brazil, Russia, India, China and South Africa) and other emerging countries. The growth in market size is indicative of the increasing trend in the quantity of dairy sold in these countries as shown in Appendix A.1.

With respect to the production of unprocessed dairy products, the stylized facts indicate that rapidly rising demand for milk due to a strong population growth in less-developed countries is creating increased local production without having enough quality control systems place. In view of this, sustaining high quality milk production in these domestic markets is becoming paramount in order to reach out to established international dairy partners.

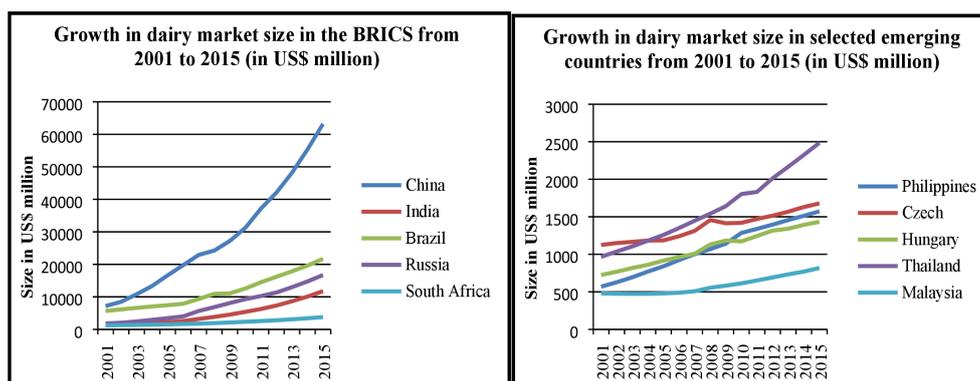


Figure 3.1: Growth in the size of the dairy market in selected emerging countries
Source: Author generated from the database of Euromonitor International

Figure 3.2 offers a bird's eye view of the growth in the size of the fats and oils markets in the BRICS and selected (Philippines, Czech Republic, Hungary, Thailand and Malaysia) countries. As the figure shows, after an increasing trend in market growth from 2001 to 2011 in China, the size of the market reduced albeit slightly between 2012 and 2015. After a mixed performance between 2001 and 2009, the fats and oils market in Brazil assumed an increasing from 2010 onwards, showing an increasing demand for these foods after 2009. With respect to the other emerging countries, we see an overall increasing trend in the size of the fats and oils markets. This lends credence to the growing importance of the processed food market in these countries.

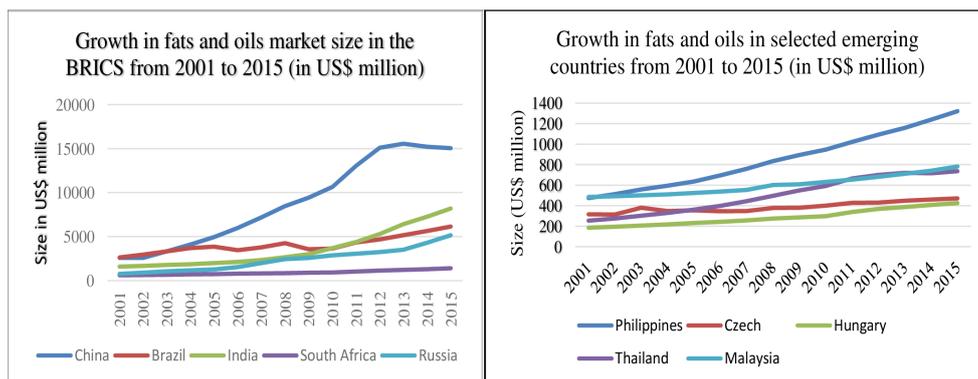


Figure 3.2: Growth in the size of the fats and oils market in selected emerging countries
 Source: Author generated from the database of Euromonitor International

Compared with the quantity of fats and sold as depicted in Appendix A.2, we see a contrasting picture between market size and the quantity of these foods sold in China and Thailand. In China, although the market size dipped after 2012, the quantity of fats and oils sustained an increasing trend thereafter. With respect to Thailand, the quantity sold fell between 2007 and 2008, but picked up again after 2008. A potential cause of this could be the global financial meltdown of 2007/2008.

3.2 BACKGROUND LITERATURE

To situate the current study in existing research on food supply chains, a thorough review of the thematic areas of published studies on the dairy and fats & oils supply chains in top agricultural economics journals was carried out. The journals studied include the American Journal of Agricultural Economics (AJAE), Econometrica, American Economic Review (AER), European Review of Agricultural Economics (ERA), Food Policy and Agricultural Economics. The period of the review spanned eighteen years, from 2000 to 2017.

The analysis of existing research work shows that dominant themes that have been treated on the milk and dairy markets cover both the production and sale sides of these products. With respect to production, the general focus is on how to improve both quantity and quality in milk production. Emerging themes include production efficiency (Burke et al., 2015; Falkowski, 2012; Glover et al., 2014; Guan and Philpott, 2011; Wang et al., 2015) and the effect of climate change on milk production (Key and Sneeringer, 2014; Qi et al., 2014).

On the sales side, the focus is generally on how to ensure that the health of consumers of dairy and fats & oils products is enhanced through safe consumption and the protection of local markets against inferior dairy imports. Dominant themes from 2007 to 2017 include

food safety (Chen et al., 2014; Zhao et al., 2013; Mu et al., 2014; Unnevehr and Jagmanaite, 2008), efficient distribution (Validi et al., 2014; Reiner et al., 2013; Corley, 2009), price pass through (Bonnet et al., 2015; Smith and Thanassoulis, 2015), market power (Cakir and Balagtas, 2012; Hovhannisyan and Gould, 2012) and trade quotas.

The existing research on dairy supply chains also reveal that supply chain sustainability, coordination, integration and resilience are dominant emerging themes. Sustainability research along the milk supply chain is premised on the assertion that, in relation to their production activities through supplier relationships, firms should address economic, environmental, labour, human rights and societal concerns (Boland et al., 2015). Using an institutional theory perspective, Glover et al. (2014) analyse the role of supermarkets in the development of legitimate sustainable practices across dairy supply chains. From the existing studies, we can deduce that studies on sustainability along the dairy supply chain have touched on the relationship between firm behaviour and sustainability (Glover et al., 2014), supply chain design (Validi et al., 2014; Wilhelm et al., 2016), supplier relationship and quality management (Dubey et al., 2015) and corporate social responsibility (Lu et al., 2012).

With regard to supply chain coordination and integration, existing research has touched on interdependent security and market participation along the milk and dairy supply chains. Research on the former has been conducted along the lines of how actors along the chain are able to deal with security challenges such as the 2001 terrorist attack. Nganje et al. (2008) study how coordination and vertical integration help reduce the risk of terrorism and derive market implications of such security measures. With respect to market participation, the literature focuses on how heterogeneity among supply chain actors impacts their participation in activities along the chain. An important study on dairy market participation is Falkowski (2012), who studies the factors that prevent households from participating in the Polish dairy market and the effect this has on revenues.

Over the last ten years, research on fats and oils markets has been dominated by the desire to combat the negative health effects posed by the consumption of low quality fatty products, particularly in developed countries. Given the important role of public policy in resolving this problem, the issue of fat tax has been widely addressed in the existing literature. Notable studies in this area include Zheng et al. (2012), who study the impact of fat tax on household nutrient purchases. Similarly, Mytton et al. (2007) and Allais et al. (2010) assess the effect of fat tax on household nutrient purchases across different income groups.

3.2.1 Findings of current studies on sources of disruptions

Natural disasters

Studies on the link between natural disasters and the dairy market focus on how negative changes in climatic conditions affect milk production. Fundamental in this literature is the relationship between a changing thermal environment and animal productivity. The issue of heat stress has been analysed by [Key and Sneeringer \(2014\)](#), [West \(2003\)](#) and [Saint-Pierre et al. \(2003\)](#). Dairy cattle experience stress when their core body temperature is out of the thermoneutral zone ([Qi et al., 2014](#)). Using both economic and climate data, [Key and Sneeringer \(2014\)](#) study how the local thermal environment affects technical efficiency of dairies across the United States. [Saint-Pierre et al. \(2003\)](#) quantify the economic costs of heat stress in the dairy market by comparing animal performance, reproduction and mortality under situations of heat stress to a hypothetical normal situation of no stress.

Existing research on the link between heat stress and the dairy market focuses on output effects. This is because heat stress, which is more likely to occur in lactating cows when summer days are very hot, affects feed intake, feed efficiency, milk yield, reproductive efficiency, cow behaviour, and disease incidence. Generally, the literature shows a negative relationship between a negative climatic change and milk output. Using a frontier production function that incorporates an annual average Temperature and Humidity Index (THI), [Mukherjee et al. \(2012\)](#) find a negative relationship between heat stress and milk output in South-Eastern United States. [Saint-Pierre et al. \(2003\)](#) and [Key and Sneeringer \(2014\)](#) also find that heat stress affects livestock in all continental states of the United States, though at slight spatial variations. Similarly, [Qi et al. \(2014\)](#) conclude that higher summer month temperatures are harmful for dairy production, while higher precipitation proves deleterious for dairy production.

From the studies presented above, it is clear that the dominant focus of analysis on the effect of natural disasters on the dairy supply chain is the upstream stage of the chain, since milk production is an upstream activity. There is, therefore, little attention to the effect of negative climatic changes on the downstream section, although this section plays an equally important role in ensuring that households have access to milk and dairy products.

Additionally, very few studies have looked at how milk and dairy prices behave when natural disasters occur. Although [Cavallo et al. \(2014\)](#) analyse price and quantity behaviour in perishable and non-perishable goods including milk following the occurrence of earthquakes, they focus only on retail quantity and price changes. It is, nevertheless, important to compare these with quantity produced and producer prices to assess the full impact of these disasters.

3.2.2 Critical methodological and empirical issues

Quantitative techniques have been widely applied in dairy and fats & oils supply-chain research as indicated in Table 3.1. Notable techniques include stochastic programming and simulation. Few other studies such as Glover et al. (2014) employ qualitative techniques. In the area of supply chain disruption, the general approach entails estimating a stochastic frontier model to establish the relationship between climate and technical efficiency. From this relationship are calculated estimates of the effect of heat stress (Key and Sneeringer, 2014; Qi et al., 2014).

Author	Study	Focus	Food	Methodology
Boland et al. (2015)	Making sustainability tangible: Land O'Lakes and the dairy supply chain	Examines sustainability of the entire dairy supply chain.	Dairy	Exploratory analysis (questionnaires)
Glover et al. (2014)	An institutional theory perspective of sustainable practices along the dairy supply chain	Focuses on dairy supply chain organizations and their consumption of energy.	Dairy	Qualitative analysis
Chen et al. (2014)	Quality control in food supply chain management: An analytical model and case study of the adulterated milk incident in China	Study the managerial and policy issues related to quality control in food supply chain management with focus on the Chinese dairy industry	Milk	Analytical industrial organisation model with China as a case study
Guan and Philpott (2011)	A multistage stochastic programming model for the New Zealand dairy industry	Models production planning by taking into account milk supply, price-demand curves and contracting	Dairy	Stochastic programming
Falkowski (2012)	Dairy supply chain modernization in Poland: what about those not keeping pace?	Investigates factors affecting a farmer's decision to cease milk sales given rapid and profound changes in the Polish dairy market. Further assesses if non-participation is optimal.	Dairy	Semi-parametric econometric modelling.
Reiner et al. (2013)	Analyzing the Efficient Execution of In-Store Logistics Processes in Grocery Retailing: The Case of Dairy Products	Examine in-store logistics processes for handling dairy products, from the incoming dock to the shelves of supermarkets and hypermarkets.	Dairy	Data Envelopment Analysis; simulation
Mu et al. (2014)	Improving the Milk Supply Chain in Developing Countries: Analysis, Insights and Recommendations	Analyse the behaviour of stations towards the reduction of adulterated milk supplied by milk producers	Dairy	Theoretical analysis (non-cooperative game)
Unnevehr and Jagmanaitė (2008)	Getting rid of trans fats in the US diet: Policies, incentives and progress	Assess the role of policy in reducing the consumption of trans fats in the United States	Animal fats	Descriptive statistics
Corley (2009)	How much palm oil do we need?	Estimates future demand for palm oil	Palm oil	Descriptive statistics

Table 3.1: Selected studies on dairy and fats & oils supply chains and their methodologies

Although by applying quantitative techniques existing studies have been able to estimate the effect of climate change on the dairy and fat & oil markets, the effect of different climatic changes over time has not been studied. The study by [Key and Sneeringer \(2014\)](#) treat only two years, 2005 and 2010. Although [Qi et al. \(2014\)](#) use a 17-year period for their study, they rely on the Climatic Effect Index (CEI), which lumps the effects of all climatic variables.

Additionally, existing studies analysing the effect of climate change on the dairy and fats & oils markets focus mainly on developed countries such as the United States ([Key and Sneeringer, 2014](#); [Qi et al., 2014](#); [Cabrera and Schulz, 2016](#); [Mukherjee et al., 2012](#)). Given the increasing importance of nutritional high-value foods (including dairy and fats & oils) in emerging countries and the implication this dynamic has for food markets around the world, it is imperative to study how the supply chains of these foods are affected by natural disasters.

3.2.3 Research question

There is no denying that increased demand for dairy and fats & oils products offers an opportunity for growth to actors in these markets ([Unnevehr and Jagmanaite, 2008](#); [Corley, 2009](#)). This is true for all actors along the chain (farmers, processors, wholesale and retail units). In emerging countries, this is an opportunity for poor households to exit the poverty trap, since food production in these countries tends to be dominated by small-scale farming.

The ability of these actors to meet increased demand depends, however, on the nature of the supply chain on which they operate. Given that a processed food exists in an unprocessed form upstream prior to being processed and sold downstream, a high level of coordination is required in order to reduce losses. This means improving proximity between actors along the chain, where farmers are, for instance, able to reach processors as easily as possible. When a supply chain is highly coordinated, efficiency improves and waste reduces.

As with many other supply chains, the processed food supply chain is exposed to various forms of disruptions, notable among these being disruptions from natural disasters. Natural disaster occurrences such as flood, drought and earthquakes have significant implications for food production and, impliedly, the quantity of food made available to wholesale and retail units. Empirical studies on threats to global food markets consider natural disasters resulting from climate change as the most important threat both now and in the future ([Beg, 2002](#); [Adger, 2008](#); [Hanjra and Qureshi, 2010](#)).

It is important to note, however, that although the entire spectrum of the processed food supply chain is exposed to disruptions, the magnitudes vary along the chain. This is

because different activities occur along different sections of the chain, leading to a change in the state of the food as it moves along the chain. Since coordination helps to mitigate the negative shocks of disruptions (Agustina et al., 2014; Kanda and Deshmukh, 2008), areas with higher magnitudes of disruption require higher levels of coordination.

Within the context of processed food supply chains in emerging countries, empirical evidence suggests that the magnitude of supply chain disruption is higher at the upstream segment of the chain than the downstream segment. This is partly because market power is unevenly distributed along the chain, with downstream actors wielding higher power (Sexton, 2012). In view of this, retailers and wholesalers are able to adjust more quickly when events that lead to disruptions occur. The fact that the nature of the food changes from an unprocessed state to a processed one exacerbates the effect of differences in market power. Generally, foods are more perishable when in an unprocessed state. For this reason, the propensity of food loss both during cultivation and after harvesting is high when natural events such as droughts, earthquake and flood occur. With respect to producer prices, farmers are obliged to accept prices at levels lower than they would have otherwise wished to receive, a disincentive to future production.

Existing studies on dairy and fats & oils supply chains have generally neglected the issue of the varying degrees of disruption as food changes state along the supply chain. This study, therefore, contributes to the existing literature by analysing the extent to which the magnitude of disruptions reduces as these foods move from an unprocessed state upstream to a processed one downstream. The associated research question is as follows:

Does the magnitude of disruption decrease as food moves from an unprocessed state to a processed state along the food supply chain?

3.3 THEORETICAL FOUNDATION AND HYPOTHESES

This chapter of the dissertation analyses the sources of disruption to upstream and downstream movement of processed nutritional high-value foods in emerging countries. Upstream movement entails the flow of these foods from producers to processors while downstream flow involves movement from wholesalers to retailers. From this set-up, we identify four activities; production, processing, wholesale and retail sales.

Given that different actors constitute the processed food supply chain and that the food changes in nature (both quantity and quality) as it moves from producers to retailers, the theoretical basis of the chapter should touch on the implications of changes in food quality for the functioning of the food supply chain. It should also explain the nature of the interaction between different actors along the chain. Finally, the theory should provide

an insight into how unintended and negative external events threaten the flow of these foods along the supply chain.

A detailed analysis of the supply chain literature reveals that value chain theory meets all the aforementioned requirements and, therefore, offers an important theoretical basis for the study. According to this theory, value addition along the food supply chain comes from primary and support activities. Primary activities are geared towards governing input materials, transforming inputs into final products and delivering the finished product. Support activities entail improving product quality, finance and legal issues, technological development and resource management. The goal of all these activities is to bring food from an unprocessed state upstream to a processed form downstream for consumption, by adding value to the product and ensuring a profit margin for supply chain agents (Ivarsson and Alvstam, 2011).

Empirical studies on processed food supply chains reveal that the ability of supply chain actors to effectively carry out both primary and support activities hinges on certain key factors. These include the number of actors participating in the value-creating activities along the chain, how the actors relate with one another (value chain governance), the capacity of actors to innovate and seize market opportunities through changes in products and processes, as well as the distribution of benefits along the value chain.

Although value chain theory encompasses several aspects of the food supply chain and offers an insight into ways to increase the value of production activities, certain conditions lead to the loss of value, leading to both food loss and waste. These conditions are both economic and non-economic variables, are linked to the above factors and may inhibit value creation activities along the chain. One of such conditions is the disparity in market power between actors. Within the framework of the value chain theory, a win-win and collaborative relationship among actors promotes efficiency. Main actors like farmers face huge threats in their quest to produce food and should receive proportional profit from the sale of farm produce. Unfortunately, however, interactions along the supply chain tends to be win-lose and sometimes non-transparent due to market competition. This is particularly the case in developing countries where farmers constitute the smallest, most numerous and ineffectively organised actors along the value chain. These farmers interact with bigger actors (mainly wholesalers and retailers) who wield higher market power because they are more coordinated and operate in concentrated markets. They are, therefore, able to dictate the parameters of contracts and subcontracts along the chain, sometimes through collusion (Gereffi et al., 2005; Sexton et al., 2007). For instance, they can define specific standards, quantities and conditions of delivery by which dominant firms can reject some agricultural products, even if edible.

Weaknesses in the structural underpinnings of the environment in which food producers operate exacerbate the effect of the disparity in market power between producers and other

agents. Farmers in developing countries generally operate in rural areas, where there is a general lack of quality transport and communication infrastructure. Additionally, an unfavourable financial climate that renders access to credit difficult impedes farmers' ability to effectively adapt to shocks, while the lack of adequate storage facilities impedes the ability of farmers to store food for long. Coupled with the fact that nutritional high-value foods are unprocessed and highly perishable upstream, farmers are obliged to sell their produce to processors and wholesalers as early as possible in order to avert losses, a situation that further enhances the market power of downstream actors.

The differences in market power also affect the rate of price transmission, a measure of the extent to which upstream prices affect downstream price levels. Economic theory establishes that upstream and downstream food prices are connected and, in the absence of an external shock, reach an equilibrium. An external shock propels adjustments towards a new equilibrium, with agents trying to maximise profits by increasing selling prices and reducing costs (McCorriston et al., 2001). This, however, depends on the market power wielded by an agent. By having a higher market power in fixing prices, wholesale and retail units are able to bid market prices in their favour leading to higher profits (Sexton, 2012). Conversely, small-scale farmers are often at the mercy of bigger agents and may be compelled to accept lower producer prices.

The explanations above have significant implications for the governance structure of food supply chains in emerging countries. The real governance structure of these chains shows the dominance of few firms, mostly wholesale and retail units. For this reason, only a limited number of value chain agents tend have competitive advantage. Indeed, given that primary producers are many and not effectively organised, these agents may consider them as interchangeable and exploitable sources of raw materials. At the other end of the chain, farmers are unable to react equally when a shock or price change occurs. Thus, they may decide not to harvest products when selling prices decrease excessively below the cost of production, a result that leads to food loss.

Empirical analysis on processed food supply chains indicate that shocks from natural disasters have a high recipe to disrupt both quantity and price supply chain activities (Cavallo et al., 2014). Dealing with such disruptions requires a responsive supply chain upstream and an efficient chain downstream (Blackburn and Scudder, 2009). A responsive supply chain implies that, given the highly perishable nature of food upstream, farmers must be able to locate processors and wholesalers quickly in order to prevent losses. Downstream, however, an efficient chain means that retailers should be able to free storage space by increasing sales to consumers. From the perspective of value chain theory, market structure and the change in the nature of food as it moves from upstream to downstream determine how disruptions vary along the two segments of the food supply chain. Since downstream actors are more coordinated and have higher market power than farmers,

they are better positioned to deal with negative shocks and move towards efficiency. Additionally, processed foods have longer shelf life downstream, enabling retailers to adjust to overcome potential negative shocks.

From the foregoing, we can conclude that the magnitude of disruption of the processed nutritional high-value food chain due to natural disaster occurrence would reduce as the food moves from its unprocessed state upstream to a processed one downstream. Against this background, the study tests the following hypothesis:

H1: Downstream effects of natural disaster disruptions along nutritional high-value food supply chains in emerging countries become weaker as the level of processing increases.

3.4 THE DATA

3.4.1 Data sources and concerns

The study uses secondary data published by national statistical service divisions and international research organisations. The rationale for using these data sources is that they are authentic from the point of view of source and are among the best available sources. Some studies published in top peer-reviewed articles have used similar data.

Overall, the study uses four different classes of data. First are data on the quantity of dairy and fats and oils produced. These data were obtained from Euromonitor International, an international research institution with expertise in the collection and analysis of market-level data in developed and emerging countries. Through its Passport repository, Euromonitor International makes available data on the quantity and value of agricultural products sold by retailers, foodservice distributors and institutions in emerging countries. The present study used sales data published by the organisation. The second class of data concerns data on the quantities of the foods under study produced. These were obtained from the Food and Agriculture Organisation of the United Nations Organisation (FAO). Through its FAOSTAT online resource (<http://www.fao.org/faostat/en>), the FAO makes data on food production collated from national agriculture departments and agencies, freely available. Data on consumer prices of dairy and fat and oil were sourced from Euromonitor International. These prices are retail prices expressed in kilogrammes. Producer prices were, however, obtained from the Food and Agriculture Organisation (FAO), through its statistics division.

The occurrence of natural disasters and transport accidents are integral variables in this study. Natural disaster occurrence, as used in this study, denotes the number of times a country records climatological, geophysical and hydrological disasters. This classification

is informed by research and data published by the Center for Research on the Epidemiology of Disasters (CRED) of the Université Catholique de Louvain (UCL). All these data were obtained online from the Emergency Events Database (EM-DAT) of CRED, UCL (<http://www.emdat.be/database>).

Hindrances to economic freedom can emanate from dynamics in property right laws, low government integrity (corruption) and restrictions to international trade and investment. One of the most commonly used data on these factors are the economic freedom indices published by Heritage Foundation. These are indices ranging from 0 to 100, with a higher value indicating low hindrance and vice versa. These variables are used in this study to examine how negative dynamics in the local economy could constrain the flow of dairy and fat and oil along the value chain.

3.4.2 The Study Variables

Dependent variables

To assess the sources and magnitude of disruptions along the dairy and fats & oils supply chains, two sets of dependent variables are used. The first has to do with the quantities of these foods produced and sold. Using the quantity of food produced enables us to capture disruption upstream, since food production is predominantly an upstream activity. On the other hand, retail sales occur downstream, enabling us to capture disruptions downstream.

The second set of dependent variables are the producer and consumer prices of dairy and fats and oils products. The rationale for considering these variables as dependent variables is to ascertain how producers and distributors react to disruptions through prices. Here again, producer prices enable us to capture disruptions upstream while retail prices help us to analyse disruptions downstream.

Independent variables

The key independent variables of the study are the potential sources of disruption along the food supply chain. Three classes of these variables are used in this study. The first is the occurrence of natural disasters, made of climatological, geophysical and hydrological disasters. By being events whose occurrence lies outside the control of man although they can sometimes be predicted, natural disasters are expected to be an important source of supply chain disruptions.

Control variables

The study uses two sets of control variables to account for the severity of disruptions from natural disasters. The first is investment in transport infrastructure. According to [Fan](#)

and Chan-Kang (2008), transport expenditure induces growth and helps to reduce poverty by linking households to markets and farming centres. Per this conclusion, investing in transport infrastructure affects both upstream and downstream segments of the food supply chain. The second control variable is a set of variables that measure economic freedom in the countries under study. We use government integrity and financial freedom as measures of economic freedom that affect agricultural markets. Government integrity measures the extent of corruption in a country. Corruption increases the cost of investment and, given that the processed food market attracts a considerable amount of foreign direct investment inflows, may hinder the preparedness of businesses to invest and expand their activities in this sector. Access to finance is a cardinal factor for rural producers to expand production and processors to procure produced food. An efficient financial market where businesses easily obtain loans from financial institutions at reasonable interest rates promote activities both upstream and downstream along the food supply chain. To capture this effect, the study uses the financial freedom index, which measures banking efficiency as well as the independence of financial markets from government control and interference, as a control variable.

Table 3.2 shows the descriptive statistics of variables used for the study. From this table, we see that mean sale is higher in the dairy market than in the fats and oils market. This is true for both overall sales and sales by source of distribution. Additionally, the average quantity of milk produced exceeds that of fats and oil crops. It is important to note the huge difference between the values of sales and production. These foods are initially in unprocessed form and, thus, have high weight after production. Processing the produced crops often leads to a reduction in size. Table 3.2 again shows that on average, sale price exceed producer price in both the dairy and fats and oils markets. This shows asymmetry in prices along the processed food supply chain, implying that the market price of a processed food is reflected in the costs that processors, wholesalers and retailers incur as food moves from an unprocessed state upstream to a processed one downstream.

Variable	Meaning	Unit	Obs.	Mean	St. Dev.	Minimum	Maximum
dairy_ret	Quantity of dairy sold by retail	1000 tonnes	247	3,180	4,472	254	28,816
dairy_fs	Quantity of dairy sold by foodservice	1000 tonnes	247	423	457	33	2,313
fatoil_ret	Quantity of fats and oils sold by retail	1000 tonnes	247	837	1,056	55	6,040
fatoil_fs	Quantity of fats and oils sold by foodservice	1000 tonnes	247	334	547	12	3,942
trans_exp	Investment in transport infrastructure	US\$ million	247	7,697	23,828	2	142,000
dairy_dist	Total quantity of dairy sold	1000 tonnes	247	3,604	4,796	305	29,700
fatoil_dist	Total quantity of fats and oils sold	tonnes	247	1,171,648	1,569,764	130,900	9,983,400
govt_integrity	Governance integrity index	Rate (0-100)	247	39.4	11.7	21	75
finan_freedom	Financial freedom index	Rate (0-100)	247	54.3	14.6	30	90
climatological	Occurrence of climatological disasters	no. of occurrence	247	0.3	0.6	0	3
geophysical	Occurrence of geophysical disasters	no. of occurrence	247	0.7	1.5	0	11
hydrological	Occurrence of hydrological disasters	no. of occurrence	247	3	3.8	0	21
dairy_prod	Quantity of dairy produced	1000 tonnes	247	15,556	25,029	11	135,600
fatoil_prod	Quantity of fats and oils produced	1000 tonnes	247	11,117	19,581	25	87,370
dairy_mprice	Average market price of dairy	US\$/tonne	247	1,620.60	756	300	4,300
fatoil_mprice	Average market price of fats and oils	US\$/tonne	247	2,370.40	1,428.60	700	8,000
milk_pprice	Average producer price of milk	US\$/tonne	247	433.6	196.8	119	1,034.90
fatoil_pprice	Average producer price of fats and oil crops	US\$/tonne	247	563.7	368.4	60.5	2,132.00

Table 3.2: Descriptive Statistics of the Data

Correlation matrix and VIF

Highly correlated independent variables are a potential cause of multicollinearity. The presence of multicollinearity makes model results unreliable. A way of detecting this problem is to examine the correlation among the independent variables of the study and their levels of significance as shown in Table 3.3. As the table shows, the independent variables are not highly correlated, with the highest value being 50.7%. This value corresponds with the correlation between geophysical disasters and government integrity index (a control variable).

	Climatological	Geoph.	Hydro.	Govt.	Finan.	Transport Exp.
Climatological	1					
Geoph.	0.241*	1				
Hydro.	0.2178*	0.507*	1			
Govt.	-0.081	-0.158*	-0.376*	1		
Finan.	-0.129*	-0.089	-0.327*	0.492*	1	
Transport Exp.	-0.003	-0.087	-0.086	0.121	0.059	1

Climatological: climatological disasters; Geoph.: Geophysical disasters; Hydro.: Hydrological disasters; Govt.: Governance Integrity; Finan.: Financial Freedom; Transport Exp.: Transport Expenditure

Table 3.3: Correlation Matrix

In Table 3.4, the Variance Inflation Factors (VIF) of the independent variables are presented. The VIF of a variable shows the contribution of each variable to the inflation of model standard errors. As the Table indicates, all VIF values are less than 2, an indication of a minimal explosion in standard errors in any econometric modelling technique applied to the data.

VARIABLE	Climatological	Geoph.	Hydro.	Govt.	Finan.	Transport exp.
VIF	1.6	1.43	1.4	1.38	1.08	1.02

Climatological: climatological disasters; Geoph.: Geophysical disasters; Hydro.: Hydrological disasters; Govt.: Governance Integrity Index; Finan.: Financial Freedom Index; Transport Exp.: Transport Expenditure

Table 3.4: Variance Inflation Factors

3.5 ESTIMATION AND RESULTS

3.5.1 Model and specification tests

A two-step model is used to model disruptions to the processed nutritional high-value food supply chain in emerging countries. In the first step, we model how natural disasters,

investment in transport infrastructure and bottlenecks to economic freedom disrupt quantity availability both upstream and downstream along the supply chain in the dairy and fat and oil markets. In the second step, we examine price dynamics occasioned by these events. That is, we assess how the occurrence of natural disasters, transport expenditure and hindrances to economic freedom affect producer prices (upstream) and consumer prices (downstream). The rationale for conducting a two-step approach as itemised above is to capture both the direct and indirect effects of disruptions.

The above models are estimated through the Fixed Effects (FE) panel modelling approach as follows. Consider a multiple panel linear model for country $i = 1, \dots, N$ observed over several years $t = 1, \dots, T$. Then the general framework of the model is shown in equation (3.1) below:

$$y_{it} = \alpha + x'_{it}\beta + z'_i\lambda + c_i + u_{it} \quad (3.1)$$

where y_{it} is the dependent variable, x'_{it} is a K -dimensional row-vector of time varying independent variables while z'_i is an M -dimensional row vector of time-invariant independent variables that exclude the constant term, α is the intercept while c_i and u_{it} are the individual-specific effects and idiosyncratic error terms respectively. The idiosyncratic error term u_{it} is assumed to be uncorrelated with the explanatory variables of all past, current and future time periods of the same country.

Within the context of the focus of the current study, the dependent variable y_{it} has two meanings. It refers to the quantity of milk and fats and oils products produced upstream in an emerging country i in year t . It also refers to the quantity of same foods sold downstream in country i in year t . The explanatory variables x_{it} include the number of occurrence of natural disasters, comprising climatological (climatological), hydrological (hydrological) and geophysical (geophysical) disasters. Other independent variables include government integrity index (Govt. integrity), which measures the level of pervasiveness of corruption financial freedom index (Finan. freedom) and investment in transport infrastructure (Transport exp.). Subtracting time averages from model (3.1) yields the fixed effects model:

$$\ddot{y} = \ddot{x}'_{it} + \ddot{u}_{it} \quad (3.2)$$

The fixed effects model in (3.2) cancels out the individual-specific effect c_i , the intercept α and the time-invariant regressors z_i . The model is unbiased under assumptions of linearity, independence and strict exogeneity in small samples. Additionally, assuming homoscedasticity in the error variance and normally distributed errors, the FE model is normally distributed. To ensure that obtained results are robust, cluster-robust standard

errors that correct the problems of heteroscedasticity and serial correlation are used in all models.

Endogeneity tests

The problem of endogeneity may be present in the specification. This is due to simultaneous causality between food production and investment in transport infrastructure. Generally, current investment in transport infrastructure that improves the quality of existing transport could lead to an increase in productivity and thus the quantity of food produced (Bezemer and Headey, 2008; Diao et al., 2010). Inversely, food production may also influence the allocation of resources to transport infrastructure. This is the case where governments give special attention to improving infrastructure in regions that play an important role in food production and sale.

Similarly, improved transport infrastructure is seen as a factor that may affect the sale of food, particularly by attracting foreign direct investment to the food market and increasing food consumption (Dercon et al., 2009). Important food centres in developing countries may also determine how expenditure allocation in the transport sector is done (Fan et al., 2000).

The issue of simultaneous causality between food production (and sale) and government expenditure has been addressed in the literature. These studies include Fan et al. (2000), who analyse the direct and indirect effects of government expenditure on poverty and productivity growth in India. To address the problem of endogeneity due to simultaneous causality between government expenditure and food productivity, the authors use the lag of government expenditure as a covariate. Similarly, Zhang and Fan (2004) examine the effect of public expenditure on road infrastructure by analysing different strategies of addressing the simultaneous causality problem. They conclude that infrastructural development and productivity affect each other in the long run, not in the short run.

Without controlling for the presence of simultaneous causality, Ordinary Least Squares (OLS) estimates are biased. Fan et al. (2000) and Zhang and Fan (2004) propose that one of the ways of controlling for the simultaneous causality between productivity and investment in transport infrastructure is to use the lag of the covariate that is suspected to be endogenous instead of its current value. Using the lagged value instead of the current allows for weak exogeneity of the endogenous variable. As Fan et al. (2000) conclude, simultaneity between current productivity growth (or poverty reduction) and past government expenditures is likely small or even non-existent. Similarly, Zhang and Fan (2004) find that the effect of investing in road construction and improvement on food production is often long-term.

In line with the above conclusions, I use the lagged value of transport expenditure as

an instrument for investment in transport infrastructure. It is important to note, however, that unlike quantity produced and sold, transport expenditure is not endogenous in the price model. Although from economic theory the setting of prices is often a function of the quality of transport (which in turn is a function of investment in transport infrastructure), food prices are not a key determinant of transport expenditure. Thus, the probability of simultaneous causality between food prices and transport expenditure is very small.

Having established a potential presence of endogeneity of transport accidents, the first step entails running statistical tests to ascertain if indeed the endogenous variable is truly endogenous. The null hypothesis of the test is that the perceived endogenous variables can indeed be treated as exogenous. This test has a Chi-square distribution with the degrees of freedom equal to the number of regressors tested. Based on the i.i.d assumptions, the test is numerically equal to a Hausman test statistic (Baum et al., 2003). Results of the test statistic are reported in along with the model results (Tables 3.5, 3.7, 3.8 and 3.10). From the results, we reject the null hypothesis at the 5% significance level.

Testing the relevance of the instrument

We speak of weak identification when there is a weak correlation between the excluded instruments and the endogenous independent variables. When instruments are weak, estimators can perform poorly and different estimators are more robust than the IV approach. We test for the under-identification and weak identification using the Sanderson and Windmeijer (2016) first-stage test. The Sanderson-Windmeijer (SW) test is a chi-squared statistic constructed by partialling-out linear projections of the remaining endogenous regressors. The test is distributed under the null hypothesis that the endogenous regressor in question is unidentified.

Assuming the errors are i.i.d, the weak identification becomes an F version of the Cragg-Donald Wald statistic. Stock and Yogo (2002) propose critical values for the Cragg-Donald F statistic. The decision criteria are that the instruments perform strongly when the Cragg-Donald F statistic exceeds the Stock-Yogo critical values at the 10% maximum IV and while they are said to perform weakly when the Cragg-Donald statistic is less than this threshold. From the results of study, we see that the Cragg-Donald F statistic is 99.647 while the 10% maximum IV value for the Stock-Yogo critical values is 16.38. We can, therefore, confidently conclude that the instrument used performs strongly.

Weak instrument robustness tests

To further confirm the significance of the endogenous regressors, the Anderson and Rubin (1949) and Stock et al. (2000) S statistics are used. Both tests have a chi-square distribution with the degrees of freedom equal to the number of excluded instruments. The null hypothesis tested by both statistics is that the coefficients of the endogenous regressors in the structural equation are jointly equal to zero and the over-identifying restrictions are

valid. Both tests are robust to the presence of weak instruments and are equivalent to estimating the reduced form of the equation (with the full set of instruments as regressors) and testing that the coefficients of the excluded instruments are jointly equal to zero. From the results of the test, we reject the null hypothesis, further confirming the presence of the endogenous regressor. All tests on the validity of the instrument are reported with results of the study where appropriate.

3.6 RESULTS

3.6.1 Disruption of quantity produced and sold

Table 3.5 shows results of the disruption of quantity along the dairy and fats & oils supply chains in emerging countries. The first section of the Table (models (1) to (4)) presents results of upstream disruption while the second section (models (5) to (8)) shows results of disruption downstream. The variables of interest for all models are the occurrence of natural disasters and these include climatological, geophysical and hydrological disasters. Government integrity index (a measure of corruption), financial freedom index and investment in transport infrastructure are all control variables. Given the potential presence of endogeneity between investment in transport infrastructure and food production and sales, both the Ordinary Least Squares and Instrumental Variable estimates are presented.

The results show that of the three disaster types, climatological disasters, comprising drought, glacial lake outburst and wildfire, are the most dominant source of disruption both upstream and downstream along the dairy and fats & oils supply chains. This is true in both magnitude and significance. In furtherance, an increase in the occurrence of climatological disasters leads to a reduction in the quantity of dairy and fats & oils produced and sold. An additional occurrence of climatological disasters leads to a 6.5 percent average fall in the quantity of milk produced, while the quantity of fats & oils reduces by an average of 9.96 percent. Downstream, the sale of dairy falls by an average of 10.74 percent when climatological disasters occur while fats & oils sales reduce by 8.76 percent. We see clearly from these figures that the highest effect of climatological disasters both upstream and downstream is on the sale of dairy products while the least effect occurs in the production of milk.

It is important to note that although these reductions seem minute, food production and sales run into million tonnes as indicated in the summary statistics (Table 3.2). The loss incurred from the occurrence of climatological disasters could, therefore, run into millions of tonnes. Given increasing demand for the foods under study as itemised in the stylised facts and empirical studies, such losses could have important implications for the attainment of food security goals in emerging countries.

The finding that climatological disasters are negatively correlated with the quantity of milk produced corroborates that of [Key and Sneeringer \(2014\)](#) who conclude that climate change-induced heat stress leads to a reduction in milk production in the United States. In a similar vein, [Mader et al. \(2009\)](#) estimate reductions in milk production of 5.1% to 6.8% by 2090 in the Great Plains region. Although these studies focus on developed countries, they offer an insight into how climate change may affect milk production in emerging countries.

Comparing upstream disruption with disruption downstream shows that the magnitude of disruption is higher downstream in the dairy market while the opposite holds in the fats and oils market. Whereas the average fall in the quantity of milk produced is 6.5 percent, the quantity sold decreases by 10.74 percent, a difference of 4.24 percentage points. Conversely, the decrease in the quantity of fats & oils products produced is 9.96 percent while the quantity sold falls by 8.76 percent, a reduction by 1.20 percentage points. The study's hypothesis is that disruptions become weaker downstream along the processed food supply chain. The finding that the magnitude of downstream disruption increases in the dairy market, therefore, leads to the rejection of the stated hypothesis. In the case of the fats and oils market, however, the hypothesis is not rejected.

The finding that the quantity of dairy lost downstream is higher than the quantity of milk produced reveals that although higher temperatures that lead to drought and wildfires may lead to heat stress and affect both the quantity and quality of milk of milk produced ([Mukherjee et al., 2012](#)), the loss in quality and quantity is significantly transferred downstream. The loss in quality upstream affects how long dairy, obtained from milk, can be stored, while the reduction in milk production means that retailers will be able to procure less milk. Thus, even though higher market power and better coordination will enable processors, wholesalers and retailers to easily access milk from farmers, their ability to benefit from these positive forces is negatively affected by the occurrence climatological disasters. Financial freedom index and investment in transport infrastructure are significant and positive both upstream and upstream. This shows that positive financial sector dynamics such as improved access to credit enhance both food production and sales. Similarly, an increase in government investment in transport infrastructure leads to improved transport infrastructure, making farms and markets more accessible.

Dependent variables: Log of quantity of food produced (upstream) and sold (downstream)									
Independent variables	Upstream				Downstream				
	Milk		Fats and oils		Dairy		Fats and oils		
	FE (1)	IV (2)	FE (3)	IV (4)	FE (5)	IV (6)	FE (7)	IV (8)	
Climatological	-0.056*** (0.026)	-0.063*** (0.016)	-0.089*** (0.028)	-0.095*** (0.029)	-0.097** (0.023)	-0.102*** (0.023)	-0.079** (0.018)	-0.084*** (0.018)	
Geophysical	0.002 (0.012)	0.006 (0.009)	0.002 (0.016)	0.005 (0.016)	0.005 (0.013)	0.011 (0.012)	0.013 (0.010)	0.018 (0.009)	
Hydrological	-0.004 (0.005)	-0.002 (0.004)	-0.013 (0.007)	-0.014 (0.008)	-0.009 (0.005)	-0.008 (0.006)	-0.004 (0.005)	-0.003 (0.005)	
Govt. Integrity	-0.004 (0.003)	-0.002 (0.003)	-0.001 (0.004)	0.001 (0.004)	-0.002 (0.003)	-0.0004 (0.004)	0.002 (0.003)	0.004 (0.003)	
Financial Freedom	0.005*** (0.002)	0.005*** (0.003)	-0.001 (0.003)	-0.002 (0.003)	0.006*** (0.002)	0.006*** (0.002)	0.002 (0.002)	0.002 (0.002)	
ln(Transport expenditure)	0.050*** (0.009)	0.075*** (0.014)	0.061*** (0.014)	0.105*** (0.025)	0.069*** (0.011)	0.124*** (0.019)	0.045** (0.009)	0.073*** (0.015)	
Observations	247	228	247	228	247	228	247	228	
R^2	0.205	0.145	0.119	0.058	0.256	0.149	0.173	0.117	
F Statistic (df= 6, 222; 6, 203)	9.564***	7.57***	5.026***	4.13***	12.70***	9.46***	7.750***	7.520***	
Anderson canon. LM statistic (P-value)		68.813(0.000)		68.813(0.000)		68.813(0.000)		68.813(0.000)	
Cragg-Donald Wald F statistic		99.647		99.647		99.647		99.647	
Endogeneity Test (P-value)		7.431(0.006)		5.586(0.018)		11.899(0.001)		8.060(0.005)	

Climatological: climatological disasters; Geophysical: Geophysical disasters; Hydrological: Hydrological disasters; Govt. Integrity: Governance Integrity; Finan Freedom.: Financial Freedom; ln(Transport Expenditure) is the natural log Investment in transport infrastructure. *** and ** mean significant at 1% and 5% respectively. For the covariates, robust standard errors are in brackets.

Table 3.5: Disruption of production and sales (quantities)

3.6.2 Disruption of producer and consumer prices

The secondary effects of natural disasters on the food supply chain are shown through changes in producer and retailer prices. Table 3.6 shows the results of how climatological, geophysical and hydrological disasters affect the movement of upstream and downstream prices. We see from this table that a negative and significant relationship exists between food prices and climatological disasters in both upstream and downstream segments of the processed nutritional high-value food supply chain. The occurrence of climatological disasters leads to an average fall of 9.3 percent and 9.08 percent in the producer prices of milk and fats & oils respectively. At the downstream stage of the supply chain, the retail price of milk falls by 7.5 percent while that in the fats and oils market reduces by 7.25. Comparatively, the producer price of milk is higher than the retail price of dairy by 1.8 percentage points, while upstream producer price in the fats and oils market is higher than retail prices by 1.83 percentage points. Given that both farmers and retailers produce to sell more at high price, these results show that natural disasters have a higher effect on the profit maximisation agenda of producers than that of retailers. In line with the stated hypothesis, the finding leads to the non-rejection of the study's hypothesis. Disruption from hydrological disasters is only significant downstream, with their occurrence leading to the reduction of both dairy and fats & oils prices. Their effect is, however, less when compared with disruption from the occurrence of climatological disasters.

3. Disruption of Processed Food Supply Chains

Independent variables	Dependent variables: Log Producer and consumer prices			
	Producer prices (Upstream)		Retail prices (Downstream)	
	Milk	Fats & oils	Dairy	Fats & oils
	FE	FE	FE	FE
	(1)	(2)	(3)	(4)
Climatological	-0.089*** (0.034)	-0.087** (0.037)	-0.072** (0.032)	-0.070*** (0.027)
Geophysical	-0.015 (0.019)	0.001 (0.018)	0.007 (0.011)	-0.002 (0.012)
Hydrological	-0.01 (0.007)	-0.015 (0.012)	-0.014** (0.006)	-0.019*** (0.005)
Govt. integrity	-0.003 (0.002)	-0.005 (0.007)	-0.005** (0.003)	-0.0004 (0.003)
Financial freedom	0.013*** (0.001)	0.013*** (0.004)	0.007*** (0.002)	0.008*** (0.002)
ln(Transport expenditure)	0.138*** (0.009)	0.131*** (0.021)	0.109*** (0.018)	0.095*** (0.015)
Observations	247	247	247	247
R^2	0.305	0.218	0.354	0.323
Adjusted R^2	0.230	0.133	0.284	0.25
F Statistic (df = 6; 222)	16.260***	10.309***	20.253***	17.684***

Climatological: climatological disasters; Geophysical: Geophysical disasters; Hydrological: Hydrological disasters; Govt. Integrity: Governance Integrity; Financial Freedom.: Financial Freedom.; ln(Transport Expenditure) is the natural log Investment in transport infrastructure. *** and ** mean significant at 1% and 5% respectively. For the covariates, robust standard errors are in brackets.

Table 3.6: Disruption of upstream and downstream prices

We again see in Tables 3.5 and 3.6 that both quantities and prices reduce when climatological disasters occur. The fall in both quantity and price at the upstream stage of the supply chain is indicative of the need for producers to reduce prices in order to sell their products, since the foods under study tend to be highly perishable upstream and easily lose quality when climatological disasters occur. With respect to downstream reduction in both quantity and price, this can be seen from the sticky price phenomenon coupled with the intervention of government policies aimed at protecting consumer welfare.

It is interesting to note that in the upstream milk market, the fall in quantity (6.5 percent) is lower than the fall in the producer price of milk (9.3 percent) when climatological disasters. This result lends credence to the existence of asymmetric market power along the dairy supply chain. The fall in quantity of fats and oils produced, however, exceeds the fall in the producer price of fats and oils. Tables 3.5 and 3.6 further show that downstream decrease in the quantity of dairy and fats & oils products sold exceeds the decrease in the retail price of these foods.

Two main sources of distribution characterise downstream activity in the dairy and fat & oil markets. They are retail and foodservice sales. Table 3.7 presents the results

3. Disruption of Processed Food Supply Chains

disruption in these markets. Here again, the IV approach is applied in order to capture endogeneity between sale activity and investment in transport infrastructure. Similar to the results showing downstream disruption of total food distribution (Table 3.5), the results in Table 3.7 show that climatological disasters are the most significant source of disruption. The occurrence of climatological disasters leads to an 8.5 percent reduction in the average quantity of dairy sold in both the retail and foodservice markets. With respect to fats and oils, the quantity sold by retailers decreases by 8.5 percent while foodservice distributors register a fall of 9.09 percent. Thus, in terms of distribution by retail and foodservice sources, there is no significant difference in disruption caused by the occurrence of natural disasters.

Dependent variables: Log of quantity of food sold in retail and foodservice markets								
Independent variables	Retail				Foodservice			
	Dairy		Fats and oils		Dairy		Fats and oils	
	FE (1)	IV (2)	FE (3)	IV (4)	FE (5)	IV (6)	FE (7)	IV (8)
Climatological	-0.074*** (0.019)	-0.082*** (0.019)	-0.074*** (0.019)	-0.082** (0.019)	-0.079*** (0.018)	-0.082*** (0.018)	-0.089*** (0.019)	-0.087*** (0.019)
Geophysical	0.01 (0.011)	0.018 (0.010)	0.01 (0.011)	0.018 (0.010)	0.006 (0.010)	0.012 (0.009)	0.014 (0.011)	0.014 (0.011)
Hydrological	-0.007 (0.005)	-0.004 (0.005)	-0.007 (0.005)	-0.004 (0.005)	-0.007 (0.005)	-0.007 (0.005)	0.001 (0.005)	0.0004 (0.005)
Govt. Integrity	-0.001 (0.003)	-0.003 (0.003)	-0.001 (0.003)	0.003 (0.003)	0.004 (0.003)	0.005 (0.003)	0.004 (0.003)	0.005 (0.003)
Financial Freedom	0.002 (0.002)	0.002 (0.002)	0.002 (0.002)	0.002 (0.002)	0.006*** (0.002)	0.005*** (0.002)	0.002 (0.002)	0.002 (0.002)
ln(Transport expenditure)	0.045*** (0.249)	0.071*** (0.016)	0.045*** (0.249)	0.071*** (0.016)	0.070*** (0.229)	0.109*** (0.016)	0.045*** (0.009)	0.079*** (0.017)
Observations	247	228	247	228	247	228	247	228
R^2	0.149	0.106	0.149	0.106	0.307	0.188	0.175	0.086
F Statistic (df= 6, 222; 6, 203)	6.51***	6.56***	6.507***	6.56***	16.419***	12.08***	7.839***	7.31***
Anderson canon. LM statistic (P-value)		68.813(0.000)		68.813(0.000)		68.813(0.000)		68.813(0.000)
Cragg-Donald Wald F statistic		99.647		99.647		99.647		99.647
Endogeneity Test (P-value)		6.921 (0.001)		6.921 (0.009)		14.812 (0.000)		10.009 (0.002)

Climatological: climatological disasters; Geophysical.: Geophysical disasters; Hydrological: Hydrological disasters; Govt. Integrity: Governance Integrity; Financial Freedom.: Financial Freedom; ln(Transport Expenditure) is the natural log Investment in transport infrastructure. *** and ** mean significant at 1% and 5% respectively. For the covariates, robust standard errors are in brackets.

Table 3.7: Disruption in retail and foodservice markets

3.6.3 Robustness checks

Model without government integrity

The magnitude of disruption along the food supply chain depends on the environment in which these chains operate. For this reason, the control variables used in the study could determine the extent to which natural disasters affect both upstream and downstream activities along the food chains of the foods under study. Generally, the results of the study are robust if dropping these control variables yields no significant change in the full models in which they are included. Table 3.8 summarises the results of disruption of quantity produced and sold without government integrity index, a measure of the pervasiveness of corruption. The results show no marked difference from those of Table 3.5, indicating that the quantity model as presented in Table 3.5 is robust to the effects of government integrity.

Dependent variables: Log of quantity of food produced (upstream) and sold (downstream)									
Independent variables	Upstream				Downstream				
	Milk		Fats and oils		Dairy		Fats and oils		
	FE (1)	IV (2)	FE (3)	IV (4)	FE (5)	IV (6)	FE (7)	IV (8)	
Climatological	-0.054*** (0.017)	-0.061** (0.016)	-0.089*** (0.028)	-0.095*** (0.029)	-0.097*** (0.022)	-0.102*** (0.023)	-0.079*** (0.018)	-0.085*** (0.018)	
Geophysical	0.001 (0.009)	0.006 (0.009)	0.002 (0.016)	0.005 (0.016)	0.005 (0.013)	0.011 (0.012)	0.013 (0.010)	0.018 (0.009)	
Hydrological	-0.003 (0.004)	-0.002 (0.004)	-0.013 (0.007)	-0.014 (0.008)	-0.009 (0.006)	-0.009 (0.006)	-0.004 (0.005)	-0.004 (0.005)	
Financial Freedom	0.005*** (0.001)	0.005*** (0.001)	-0.001 (0.003)	-0.002 (0.003)	0.006*** (0.002)	0.006** (0.002)	0.002 (0.002)	0.003 (0.002)	
ln(Transport expenditure)	0.049*** (0.008)	0.074*** (0.014)	0.060*** (0.014)	0.105*** (0.025)	0.079*** (0.011)	0.124*** (0.019)	0.045*** (0.009)	0.075*** (0.016)	
Observations	247	228	247	228	247	228	247	228	
R^2	0.196	0.145	0.12	0.058	0.255	0.15	0.172	0.101	
F Statistic (df= 6, 222; 6, 203)	10.86***	8.97***	6.055***	4.98***	15.22***	11.42***	9.27***	8.49***	
Anderson canon. LM statistic (P-value)		69.026(0.000)		69.026(0.000)		69.026(0.000)		69.026(0.000)	
Cragg-Donald Wald F statistic		100.599		100.599		100.599		100.599	
Endogeneity Test (P-value)		7.127(0.008)		5.637(0.018)		11.883(0.001)		8.507 (0.004)	

Climatological: climatological disasters; Geophysical.: Geophysical disasters; Hydrological: Hydrological disasters; Financial Freedom.: Financial Freedom; ln(Transport Expenditure) is the natural log Investment in transport infrastructure. *** and ** mean significant at 1% and 5% respectively. For the covariates, robust standard errors are in brackets.

Table 3.8: Quantity model without government integrity

3. Disruption of Processed Food Supply Chains

With respect to disruption of food prices without government integrity, Table 3.9 shows that climatological disasters are a significant source of disruption along the dairy and fats & oils supply chains. Compared with Table 3.6, we again see that price reduction is higher upstream than downstream. Additionally, hydrological disasters are the only other significant source of disruption and their effect is felt downstream. Compared with disruption from climatological disasters, the results again show that hydrological disasters lead to less disruption.

Independent variables	Producer price (upstream)		Retail price (downstream)	
	Milk	Fats and oils	Dairy	Fats and oils
	FE	FE	FE	FE
	(1)	(2)	(3)	(4)
Climatological	-0.088*** (0.031)	-0.085** (0.037)	-0.070** (0.032)	-0.070*** (0.027)
Geophysical	-0.015 (0.012)	-0.0004 (0.018)	0.006 (0.011)	-0.002 (0.012)
Hydrological	-0.01 (0.007)	-0.014 (0.012)	-0.013** (0.006)	-0.019*** (0.005)
Financial freedom	0.012*** (0.003)	0.013*** (0.004)	0.007*** (0.002)	0.008*** (0.002)
ln(Transport expenditure)	0.137*** (0.019)	0.131*** (0.021)	0.108*** (0.018)	0.095*** (0.015)
Observations	247	247	247	247
R^2	0.304	0.216	0.346	0.323
Adjusted R^2	0.233	0.135	0.279	0.254
F Statistic (df = 5; 223)	19.520***	12.273***	23.643***	21.312***

Climatological: climatological disasters; Geophysical.: Geophysical disasters; Hydrological: Hydrological disasters; Financial Freedom.: Financial Freedom; ln(Transport Expenditure) is the natural log Investment in transport infrastructure. *** and ** mean significant at 1% and 5% respectively. For the covariates, robust standard errors are in brackets.

Table 3.9: Price model without government integrity

Model without financial freedom

Financial freedom index measures the ease with which both upstream and downstream actors along the food supply chain access funds for their activities. A high index indicates a favourable financial climate in which farmers and retailers are able to borrow and invest. The ability to secure funding to invest helps cushion actors against the disruptive effects of natural disasters. For the results of the study to be robust, it is imperative to consider how they change without the effect of financial freedom. Table 3.10 shows the quantity model without financial freedom index as a covariate. Here again, we see climatological disasters as the most important source of disruption along the dairy and fats & oils supply

3. Disruption of Processed Food Supply Chains

chains. There is also no marked difference between the coefficients in the full model (Table 3.5) and that without financial freedom index. Overall, the quantity model can be said to be robust to dynamics in financial markets in emerging countries.

Dependent variables: Log of quantity of food produced (upstream) and sold (downstream)									
Independent variables	Upstream				Downstream				
	Milk		Fats and oils		Dairy		Fats and oils		
	FE (1)	IV (2)	FE (3)	IV (4)	FE (5)	IV (6)	FE (7)	IV (8)	
Climatological	-0.060*** (0.017)	-0.063*** (0.016)	-0.089*** (0.028)	-0.094*** (0.029)	-0.103*** (0.023)	-0.108*** (0.023)	-0.081*** (0.018)	-0.085*** (0.018)	
Geophysical	0.001 (0.009)	0.005 (0.009)	0.002 (0.016)	0.006 (0.016)	0.005 (0.013)	0.009 (0.013)	0.013 (0.010)	0.017 (0.009)	
Hydrological	-0.005 (0.004)	-0.003 (0.004)	-0.013 (0.007)	-0.014 (0.008)	-0.011 (0.006)	-0.009 (0.006)	-0.004 (0.005)	-0.003 (0.005)	
Govt. Integrity	-0.004 (0.003)	-0.002 (0.003)	-0.001 (0.004)	0.0004 (0.005)	-0.001 (0.003)	0.0001 (0.004)	0.002 (0.003)	0.004 (0.003)	
ln(Transport expenditure)	0.047*** (0.008)	0.068*** (0.014)	0.607*** (0.014)	0.107*** (0.025)	0.076*** (0.011)	0.117*** (0.019)	0.044** (0.009)	0.069*** (0.015)	
Observations	247	228	247	228	247	228	247	228	
R^2	0.167	0.123	0.119	0.052	0.229	0.144	0.166	0.119	
F Statistic (df= 6, 222; 6, 203)	8.930***	6.620***	6.049***	4.91***	13.28***	9.72***	8.90***	8.57***	
Anderson canon. LM statistic (P-value)		69.272(0.000)		69.272(0.000)		69.272(0.000)		69.272(0.000)	
Cragg-Donald Wald F statistic		101.135		101.135		101.135		101.135	
Endogeneity Test (P-value)		4.999 (0.025)		5.984 (0.014)		9.266 (0.002)		6.960 (0.008)	

Climatological: climatological disasters; Geophysical.: Geophysical disasters; Hydrological: Hydrological disasters; Govt. Integrity: Governance Integrity; ln(Transport Expenditure) is the natural log Investment in transport infrastructure. *** and ** mean significant at 1% and 5% respectively. For the covariates, robust standard errors are in brackets.

Table 3.10: Quantity model without financial freedom index

3. Disruption of Processed Food Supply Chains

In Table 3.11, we examine the disruption of prices without financial freedom index as a covariate. As with the full model that included financial freedom index, the results show that disruption from climatological disasters have a higher effect on producer prices than on retail prices. This is true for both the dairy and fats & oils markets. Unlike the base model, however, we see that disruption from hydrological disasters is significant both upstream and downstream. Like the base model (Table 3.6), however, the magnitude of disruption from hydrological disasters is less than that of climatological disasters, further confirming the robustness of the base model.

Dependent variables: Log of producer and consumer prices				
Independent variables	Producer price(upstream)		Retail price(downstream)	
	Milk FE	Fats & oils FE	Dairy FE	Fats & oils FE
	(1)	(2)	(3)	(4)
Climatological	-0.101*** (0.030)	-0.099*** (0.037)	-0.078** (0.033)	-0.077*** (0.027)
Geophysical	-0.016 (0.012)	-0.001 (0.018)	0.006 (0.011)	-0.003 (0.012)
Hydrological	-0.013** (0.008)	-0.019 (0.013)	-0.016** (0.007)	-0.021*** (0.006)
Govt. integrity	-0.001 (0.006)	-0.004 (0.007)	-0.005 (0.003)	0.0002 (0.003)
ln(Transport expenditure)	0.132*** (0.019)	0.125*** (0.020)	0.106*** (0.018)	0.091*** (0.015)
Observations	247	247	247	247
R^2	0.248	0.171	0.316	0.277
Adjusted R^2	0.17	0.086	0.246	0.203
F Statistic (df = 5; 223)	14.705***	9.212***	20.639***	17.111***

Climatological: climatological disasters; Geophysical.: Geophysical disasters; Hydrological: Hydrological disasters; Govt. Integrity: Governance Integrity; ln(Transport Expenditure) is the natural log Investment in transport infrastructure. *** and ** mean significant at 1% and 5% respectively. For the covariates, robust standard errors are in brackets.

Table 3.11: Price model without financial freedom index

3.7 COMMENTS AND DISCUSSION

The threats posed by natural disasters to the efficient functioning of food supply chains can be both short-term and long-term. In the short-term, they result in major shortfalls in food production and assert disruptions that affect information and services flow. Over the long-term, multiple farming and distribution cycles are affected, leading to the disruption of market relations. Their effects also span geographical boundaries, implying that their occurrence affects not only interrelationships along the food supply chain, but also the

3. Disruption of Processed Food Supply Chains

external environment. This means that the negative effects of natural disasters are not market-specific, but may have ramifications for other markets within the geographical area where they occur.

Since natural disasters may also affect the external environment, dealing with their effects is also dependent on the strength of the external environment in linking actors in less affected areas to affected ones. Developing countries often lack the requisite structural underpinnings needed to mitigate the disruptive effects of these disasters. For this reason, the issue of food insecurity exists as a very dominant concern in these countries. The increased threat of climate change and global warming portends that food insecurity could further worsen if steps are not taken to adequately respond to natural disaster shocks.

The results of this study have shown that climatological disasters comprising drought and wildfires are the most important source of quantity and price disruption along the processed food supply chain in emerging countries. Their occurrence leads to the reduction in the quantities of dairy and fats & oils products produced and sold. With respect to production, droughts limit access to feed inputs, leading to milk yield, reproductive efficiency, cow behaviour, and disease incidence (Qi et al., 2014).

Rainfall is also an important input for plant growth. Its shortage, therefore, reduces the output of oil crops. These disasters also affect food distribution by restricting availability and reducing product quality. They also increase logistic costs and the costs to develop new supply sources. Together, these factors reduce the quantity of food sold.

As is evident from the results, the magnitude of disruption varies across supply chains for the different foods under study. The quantity effect of climatological disruptions is higher upstream than downstream in the dairy market while the opposite holds in the fats and oils market. With respect to price effect, upstream disruptions are higher in both markets. The differences in quantity effect mirrors the characteristics of the foods under study. Although milk goes through some form of processing either through packaging or conversion to dairy before it is sold by retailers, quality shortfalls upstream when natural disasters occur are transmitted to retailers downstream, decreasing the shelf life of milk and dairy products sold. Thus, processing milk given a specified quality control measure generally leads to improved sales downstream due to increased shelf life in the absence of climatological disasters. The occurrence of climatological disasters, however, affects dairy quality leading to a reduction in sales. The opposite result in the fats and oils market reveals that quality losses with the occurrence of natural disasters are minimally transmitted downstream.

It is interesting to note that quantity losses are associated with price reductions both upstream and downstream. The finding that the producer prices of milk and fat & oil crops reduce when climatological disasters occur resonates with the phenomenon of imperfect competition existing in the agricultural markets of emerging countries (Chen et al., 2014;

[Sexton, 2012](#)). With a high propensity of quality loss upstream and the presence of many suppliers, farmers are obliged to accept lower producer prices in order to sell their output. The reduction in retail prices downstream further supports the finding on quantity effects. Here, retailers reduce prices in order to sell foods that may have already lost quality. They may also do so in order free space for other produce. Despite a reduction in both upstream and downstream prices, the results indicate that upstream prices falls farther than prices downstream, a finding that further confirms an increase in market power down the chain.

When we compare upstream price and quantity changes, the results indicate that the fall in the producer price of milk exceeds the fall in the quantity of milk produced. The higher price effect may indicate that farmer welfare is worse than retailer welfare. However, when we consider that the fall in the quantity of dairy sold exceeds the fall in the retail price of dairy, then we can conclude that the net welfare of the retailer worsens. With respect to the fats and oils market, we see that the fall in quantity is higher than the fall in price for both upstream and downstream stages of the supply chain.

Considering disruption by source of distribution, the finding that there is no marked difference between the fall in quantity in the retail market and that in the foodservice market shows the importance of foodservice distributors in the dairy and fats & oils markets in emerging countries. This result runs counter to the big middle phenomenon, which posits that retailers wield a bigger control in the distribution of goods.

The results of the study have important implications for the implementation of policies aimed at achieving food security. To better mitigate the negative effects of natural disasters, both ex-ante and ex-post strategies are needed. While ex-ante measures are required before the disaster occurs, ex-post measures help to mitigate the negative effects after the disaster has occurred. In the case of the dairy market, ex-ante measures include buffer stocks that ensures the long-term availability of feed for cattle, enterprise diversification with an increased focus on low-risk cropping patterns and diversified production techniques. Similar strategies and the protection of oil crop plantations are needed in the fats and oils market. Given that the food supply chain links the upstream stage to the downstream segment, happenings upstream may be transmitted to downstream actors ([Berck et al., 2009](#); [Leibtag, 2009](#)). In view of this, the aforementioned measures will improve performance along the entire spectrum of the chain.

In emerging countries, small-scale farmers may be the main architects of the aforementioned measures. This notwithstanding, public policy plays an overarching role in ensuring that they are efficient. Public policy is particularly important in the area of price determination. Since the occurrence of natural disasters leads to the disruption of food prices, there is the need for support schemes that are capable of containing the spirals associated with price dynamics when disasters occur.

3.8 CONCLUSION

This study analysed disruptions from the occurrence of natural disasters along the dairy and fats & oils supply chains in emerging countries, using a panel of 19 emerging countries over a time frame of 13 years. Given the increasing demand for these foods in and the threats of global warming and climate change, such a study proves essential for the effective development and implementation of policies targeting food insecurity.

The results of the study indicated that among the three sources of natural disasters under study (climatological, geophysical and hydrological), climatological disasters are the most dominant source of disruption along the dairy and fats & oils supply chains. These disasters lead to the reduction of both upstream and downstream quantities. Additionally, both producer and retail prices fall when they occur. Comparatively, however, there are differences in upstream and downstream disruptions depending on the type of food and class of disruption. With respect to the disruption of quantity, the results showed that upstream disruption is higher along the dairy supply chain, while the opposite holds in the fats and oils market. In the case of food price disruptions, upstream disruption is higher than downstream disruption in both markets. These results have important implications for the attainment of food security goals in emerging countries, which requires a concerted effort from governments and all stakeholders along the food supply chain.

Oil Price Shock and its Effects on Food Prices: Evidence from São Paulo

4.1 INTRODUCTION

Research on the relationship between food and energy markets can be traced as far back as 1983, with the analysis of the potential disruptive effect of fuel ethanol on global agricultural commodity prices (Zhang et al., 2010). The increasing attention to the energy-food relationship also emanates from the global energy crises of the 2000s. The general consensus among agricultural economists is that energy price shocks are a potential source of food insecurity, because they may lead to an increase in food prices since producers and retailers may consider these shocks when fixing their prices. For a given income level, household purchasing power on food decreases. In developing countries where food constitutes an integral share of household expenditure (Prakash, 2011; Rapsomanikis and Hallam, 2006), this could be a recipe for worsening living standards. Additionally, volatile energy prices may impede the ability of agents in the food market to correctly predict and plan for future market patterns, a potential source of social unrest (Bellemare, 2015).

A cursory look at the existing literature on the relationship between food and energy prices reveals that the dominant energy markets studied are biofuel, particularly ethanol (Serra et al., 2011a; Serra, 2011) and gasoline (Serra et al., 2011b; Taheripour et al., 2010; Hochman et al., 2008). Dominant food crops examined by these studies include corn, soybeans, wheat and rice. The dominance of these crops in the existing research can be explained by their role in the production of biofuels. Corn is used in the production of ethanol while soybean is used mainly in the production of biodiesel (Fernandez-Perez et al., 2016). For this reason, there exists some competition between producing these crops for livestock feed against producing them for energy.

Despite the dominance of staples and traditional cash crops in the research on the food-energy relationship, the nature of nutritional high-value foods coupled with the char-

acteristics of their supply chains underpin the need to analyse the relationship between high-value food prices and energy prices. These foods are highly perishable, implying that an efficient transport system is required to carry them through the supply chain. But transportation also relies on the energy sector for fuel input. Thus, dynamics in the energy sector may affect both upstream and downstream activities through transportation. Where the shock is negative, players may respond by adjusting prices to cover the associated losses. Given the increasing demand for nutritional high-value foods in developing and emerging countries (Gulati et al., 2007), price dynamics in these markets have relevant ramifications for household food security in these countries. In furtherance, to effectively implement policies that mitigate the negative effects of oil shocks, it is important to assess how energy price shocks affect different sections of the food market chain. This is relevant because different prices exist along the chain due to the presence of agents with different market powers along the supply chain. Despite the importance of this angle of research, the existing studies have generally not looked at this issue.

This study assesses how dynamics in diesel prices determine both the long-run and short-run behaviour of prices in four nutritional high-value food markets (meat, egg, dairy and fats & oils) in São Paulo. The rationale for using diesel price despite the growing importance of the ethanol market in Brazil is because diesel continues to be the main source of fuel for vehicles in the major cities of Brazil. For this reason, dynamics in the price of diesel may have significant implications for both producer and retailer welfare. Figure 4.1 shows the changes in the average price of diesel in the São Paulo region from 2001 to 2013.

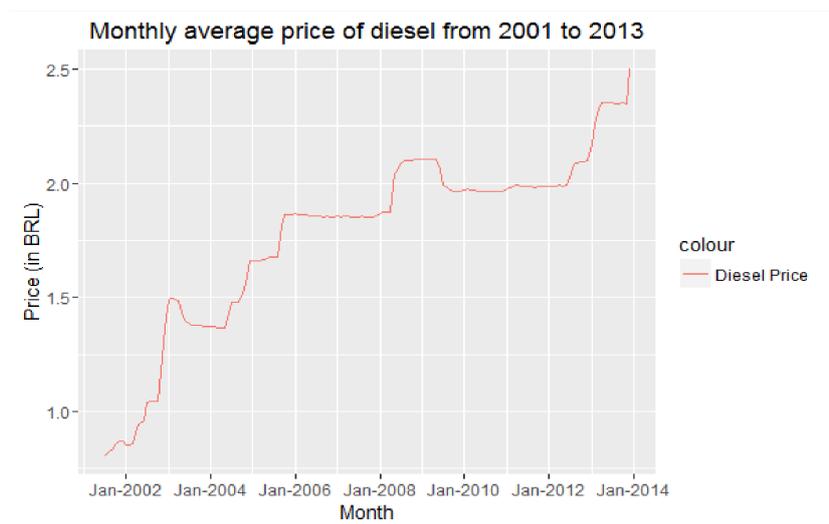


Figure 4.1: Changes in the average price of diesel from July 2001 to December 2013
Source: Author generated from the database of the National Agency of Petroleum, Brazil

Figure 4.1 shows that the movement of diesel prices between 2001 and 2013 is characterised by periods of increasing, decreasing and constant trends. Between July 2001

and December 2002, the price of diesel has an increasing trend but falls thereafter up to mid-2004. It is interesting to note that the price is constant between 2005 and 2008, a period that coincides with the global financial meltdown. A relatively constant trend is witnessed between 2009 and mid-2012. The presence of a constant trend shows how rigid diesel prices are in São Paulo.

The prices of the nutritional high-value foods under study are presented in Figure 4.2. We see an increasing trend in the producer and retail prices of meat, although the latter is higher than the former over the entire period. The difference between retail and producer prices is even bigger in the eggs market. Whereas the general trend of the producer price assumes a decreasing trend, the retail price has a mixed trend, with a generally decreasing trend between 2003 and 2007, and an increasing trend between 2010 and 2013.

In Appendix A.3, we see how retail sales change over the period under study. The retail sale index, a measure of how much retailers sell their goods, shows an increasing trend throughout the period, after a slight dip in 2003. This shows that retailers sold more goods over the period.

This study examines the relationship between changes in the price of diesel and changes in the prices of four nutritional high-value foods in São Paulo. More succinctly, the study ascertains if the impact of diesel price shocks is higher on upstream prices than downstream prices along the nutritional high-value food supply chain. Relevant policy recommendations are made to protect agents along the chain from the effects of negative shocks.

The study contributes to the existing research on the relationship between energy shocks and food prices in two respects. Firstly, it focuses on energy price shocks in nutritional high-value food markets. As earlier intimated, existing studies focus heavily on staples and traditional cash crops because they can be converted to biofuel. Although nutritional high-value foods do not have this characteristic, their high dependence on efficient transportation implies that shocks in the energy market affect these food markets. Secondly, the study contributes to research on the upstream and downstream distribution of external shocks along the food supply chain.

4. Effect of Diesel Prices on Food Prices



Figure 4.2: Changes in the average prices of selected foods
Source: Author generated from IEA and FIPE data

4.2 RELATED LITERATURE

This section of the analysis reviews the existing studies on the link between energy price shocks and food price dynamics. The thematic areas of the review include the sources of food price transmission both in the staples and nutritional high-value foods markets, as well as an overview of methodologies used to analyse the transmission of energy price shocks to food prices. From the review, gaps in the existing studies are identified and the research question to be addressed in the present study developed.

4.2.1 Studies on energy price shocks

Focus of existing research

The existing research on the fuel-food relationship is anchored on empirically ascertaining if oil prices affect food prices. While some studies focus on analysing the effect of global oil prices on local food prices (Dillon and Barrett, 2015), others examine the relationship at the local market level. Econometric studies have found evidence of causality between oil and agricultural commodity prices. Based on cointegration analysis, Cooke and Robles (2009) find the influence of oil on food prices, while Nazlioglu (2011) provides evidence of

a nonlinear relationship between oil and food prices and nonlinear causality from oil to corn and soybean prices. Other studies have examined the dynamic relationship between oil prices, agricultural prices and the US dollar, concluding that oil price increases and a weak dollar lead to an increase in food prices (Nazlioglu and Soytaş, 2012).

More recently, few studies have addressed the issue of price volatility by modelling price volatility spillovers between energy and food markets (Serra, 2011; Zhang et al., 2009; Mensi et al., 2014). Using weekly international crude oil, ethanol and sugar prices, Serra et al. (2011a) examine spillovers in the Brazilian ethanol market. They find a positive relationship between ethanol and oil prices at equilibrium, while price dynamics indicate substitution between oil and ethanol. Zhang et al. (2009) analyse volatility in the wholesale prices of corn, ethanol, soybeans, gasoline and oil in the United States. The authors develop a multivariate autoregression model and find that the demand for vehicle fuel is a key driver of the demand for ethanol and oil, while the price of gasoline determines the prices of ethanol and oil.

Cabrera and Schulz (2016) investigate dynamics in price and volatility risk associated with linkages between energy and agricultural commodity prices in Germany. The studies on price volatility transmission are based on the assertion that an increased correlation between food and energy prices is bound to result in strong volatility spillovers between these prices. Without accounting for these changes, traditional risk management tools are less reliable in mitigating risks. In this wise, a plethora of articles have sought to analyse the effects of price volatility spillovers within the context of how price dynamics in the ethanol market affect economic welfare (Babcock, 2008; de Gorter and Just, 2007; Bruce, 2007) and agricultural land allocation (Fabiosa et al., 2008). Other authors have looked at these effects on land values (Henderson and Gloy, 2009) and agricultural commodity prices both locally and at a more aggregate level (Balcombe and Rapsomanikis, 2008; de Gorter and Just, 2008; Luchansky and Monks, 2009; McNew and Griffith, 2005; McPhail and Babcock, 2008; Serra et al., 2011a; Tyner and Taheripour, 2008).

Key findings

Findings on the relationship between oil and agricultural commodity prices can be classified under three broad categories. Firstly, many studies find no evidence that oil prices drive agricultural prices. Using monthly price data for five commodities (corn, rice, soybeans, sugar and wheat) and three fuel commodities (ethanol, gasoline and oil), Zhang et al. (2010), assess the relationship between fuel prices and food prices. Their results show neither short-run nor long-run relationship between fuel prices and sets of agricultural commodity prices.

The second category of studies extract short-run and long-run relationships between

series by dividing the study sample into two periods, with the second often coinciding with the period after the global financial meltdown of 2007/2008. Overall, the studies under this category find neutrality between oil and food prices in the first period and a conclusion that oil prices drive food prices during the second period. Using wheat and corn markets as a case study, [Du et al. \(2011\)](#) investigate the role of speculation in determining volatility in crude oil prices, and how this volatility in turn affects variation in food prices. They find that in the first sub-sample period (November 1998 to October 2006), there is moderate evidence of price variation in crude and wheat markets, while the price of corn behaved differently from that of crude oil prices. A strong and progressively connected variation is, however, found in the second period (October 2006 to January 2009), confirming the hypothesis that higher crude oil prices forecast large corn impact on corn prices and eventually, corn price formation.

In a similar vein, [Reboredo \(2012\)](#) examines co-movements between world oil prices and prices of corn, soybeans and wheat, using weekly data over the period 9 January 1998 to 15 April 2011. Although his results generally showed weak dependence between oil and food prices (in support of the neutrality phenomenon), the last three years of the period witnessed significantly increased dependence between the two markets.

[Nazlioglu et al. \(2013\)](#) study volatility transmission between oil and selected food prices (wheat, corn, soybeans and sugar) over pre and post-crisis periods. The authors use daily data spanning the period 1 January 1986 to 21 March 2011, with the pre-crisis period running from 1 January 1986 to 31 December 2005 and the post-crisis period being 1 January 2006 to 21 March 2011. The study concludes that although there is no risk of transmission between oil and food markets in the pre-crisis period, there is significant price spillovers from oil to food markets in the post-crisis period, a finding that is confirmed from both variance causality tests and impulse response functions.

Lastly, other studies find that oil prices are significantly related with agricultural commodity prices along the entire period of the study. These studies often deviate from the common methodologies and as a result, differences in the estimates of the impact of oil prices on food prices depend mainly on the nature of the food basket and the underlying assumptions about the interaction between the two markets. [Nazlioglu and Soytas \(2012\)](#) examine the relationship between world oil prices, the US dollar and food prices in twenty-four (24) food markets, using Granger causality and panel cointegration methods. They find strong evidence of information transmission from world oil prices to several agricultural commodity prices.

4.2.2 Studies on energy price shocks in Brazil

Within the Brazilian context, the existing studies focus heavily on the sugar-ethanol oil nexus. This is because the Brazilian ethanol industry is characterised by its competitiveness and flexibility, with a large number of plants operating on a large scale while using a dual technology that enables producers to switch between ethanol and sugar production depending on dynamics in market prices. Additionally and depending on the pump price, consumers are able to shift from high to low ethanol-gasoline blends thanks to a strong infrastructural base for handling and distributing fuel ethanol coupled with the steady increase in flex fuel vehicle (FFV) sales. According to [de Almeida et al. \(2007\)](#), increased demand for ethanol, both internationally and in Brazil explains the expansion of ethanol production in the country.

Studies on the impact of oil prices on agricultural commodity prices in Brazil have naturally adopted an empirical methodology. [Balcombe and Rapsomanikis \(2008\)](#) assess the sugar-ethanol-oil nexus in Brazil using generalized bivariate error correction models. They find that over the long run, oil prices are a key driver of ethanol and sugar prices. Sugar prices also Granger-cause ethanol prices. Using weekly data over the period July 2000 to November 2009, [Serra \(2011\)](#) analyses volatility transmission between crude oil, ethanol and sugar prices in Brazil, and find that long-run equilibrium parity exists between ethanol and crude oil as well as ethanol and sugar price levels. This result implies that an increase in both crude oil and sugar prices signifies an increase in ethanol prices.

4.2.3 Overview of empirical methodologies

The literature on the relationship between oil prices and agricultural commodity prices is methodologically founded on standard supply and demand frameworks and partial or general equilibrium models ([Babcock, 2008](#); [Luchansky and Monks, 2009](#); [McPhail and Babcock, 2008](#)). Among these studies, linear regression models such as the Vector Autoregression (VAR), Vector Error Correction (VEC) and the corresponding cointegration and causality tests are hugely applied. Other econometric approaches include the Threshold Vector Error Correction Modelling (TVECM), Autoregressive Distributed Lag (ARDL) and BEKK-MGARCH. [Serra and Zilberman \(2013\)](#) conduct a thorough analysis of the main methodologies applied in analysing the energy-food relationship. Their findings show that the VECM approach and its variant forms have been the most dominantly used approaches to assess the effect of energy price shocks on the food market. This is in part due to the non-stationary nature of these prices and the presence of cointegration between the prices. Table 4.1 presents studies that use these approaches as reported by [Serra and Zilberman \(2013\)](#).

Study	Approach	Variables used
Balcombe and Rapsomanikis (2008)	Taylor series expansion of VECM; AVECM; TVECM	Brazilian ethanol and sugar prices, world crude oil prices
Busse et al. (2012)	MS VECM	German diesel, biodiesel, rapeseed oil and soy oil prices
Campiche et al. (2007)	VECM	Corn, sorghum, soybeans, soybean oil, palm oil, world sugar and crude oil prices
Ciaian and Kancs (2011)	VECM	World corn, wheat, rice, sugar, soybeans, cotton, banana, sorghum tea, crude oil
Mallory et al. (2012)	VECM	Nearby and 1-year to expiration futures prices of ethanol, corn and natural gas
Natalenov et al. (2011)	VECM; TVECM	Crude oil, cocoa, coffee, corn, soybeans, soybean oil, wheat, rice, sugar and gold futures prices
Nazlioglu and Soytas (2012)	Panel cointegration; VECM	World prices for 24 agricultural commodities (grains, oils, meats, beverages and other food prices), world crude oil price and USD exchange rates
Peri and Baldi (2010)	TVECM	European sunflower oil, rapeseed oil, soybean oil and diesel prices
Rajcaniova and Pokrivcak (2011)	VECM	EU oil and gasoline prices, German bioethanol, maize, wheat and sugar prices
Rapsomanikis and Hal-lam (2006)	TVECM	Brazilian ethanol and sugar prices, world crude oil prices
Zhang et al. (2010)	VECM	US prices for ethanol, gasoline, corn, soybeans and wheat; free market sugar price; Thailand rice price; international crude oil price
Serra (2011)	VECM-BEKK-MGARCH	International crude oil, Brazilian ethanol and sugar prices
Serra and Gil (2012)	VECM-BEKK-MGARCH	US corn, US ethanol prices; US corn stocks; US interest rate

Table 4.1: Dominant methodologies applied in researching the food-oil relationship

4.2.4 Studies on nutritional high-value foods

Similar to the literature on staples and traditional cash crops, studies on the relationship between oil price and nutritional high-value food prices focus mainly on the dynamic relationship between the two prices. [Esmaeili and Shokoohi \(2011\)](#) use a principal components approach to examine co-movement between food prices and macroeconomic indices (particularly oil prices). They use food prices in seven food markets, including meat, eggs, milk, oilseeds, rice, sugar and wheat. The results of their Granger causality tests show a unidirectional influence of oil prices on the food price index. [Nazlioglu and Soytas \(2012\)](#) use a dynamic panel approach to examine world oil prices and commodity prices, and account for intermarket links by including meat and fresh fruit prices. The authors find that over the long-run, there is a significant and positive transmission of shock from oil prices to prices of nutritional high-value foods. Using a random parameter model, [Balcombe and Rapsomanikis \(2008\)](#) examines price volatility in the meat, dairy and food oils markets, and find a strong evidence of volatility in these price series.

4.2.5 Gap in the literature

Besides being a relevant source of energy, biofuel feedstock also helps in food production. For this reason, changes in feedstock prices induced by biofuel price changes affect agricultural input prices, going a long way to influence retail prices. To effectively implement policies that mitigate the negative effects of biofuel shocks, it is important to assess how energy price shocks affect different sections along the food market chain. This is relevant because different prices exist along the chain due to the presence of agents with different market powers along the supply chain. Despite the importance of this angle of research, the existing studies have generally not looked at this issue.

4.3 RESEARCH QUESTION

Both upstream and downstream activities along the nutritional high-value food supply chain depend heavily on the means of transport available where these chains operate. An efficient transport system is imperative to distribute goods on time and avoid food waste and/or loss ([Cai and Zhou, 2014](#)).

Given quality of transport infrastructure, fuel prices become a key determinant of transport cost. Higher fuel prices often indicate higher transport cost since supply chain operators have to pay more to transport food. With respect to the food market in Brazil, dynamics in diesel prices are an important source of transport cost adjustment due to high consumption by freights and passengers. Similarly, the transportation of foodstuff along

the supply chain is done predominantly through trucks that use diesel fuel.

By affecting transport cost, changes in fuel price affect the extent of price transmission along the food supply chain. Upstream, producers who pay higher prices for fuel will like to charge higher producer prices to wholesalers in order to offset the effect of the increased fuel price. Similarly, wholesalers would wish to increase the price at which they sell their produce to retailers downstream, while the latter's goal would be to charge higher prices to consumers.

The ability of a supply chain agent to transmit food price when fuel price changes depends, however, on the position of the supply chain in which the said agent operates and the nature of nutritional high-value food markets in the country. In the case of São Paulo, an imperfectly competitive market in which food producers far outnumber retailers exists (Sexton, 2012). This market structure creates disparities in market power, and thus in the ability of agents to transmit the effect of fuel price shocks. Generally, retailers tend to have a higher market power and are able to bid down the producer's attempt to increase price.

From the above analysis, we can deduce that a change in diesel price will affect upstream agents by limiting how much they are able to transmit to their counterparts downstream. This leads to a reduction in producer welfare because they receive less prices for the foods they produce. The effect downstream is of two forms. Firstly, retailers still pay a certain amount of the price increased by the producer. This means that retailers are not able to completely erase the price increase proposed by producers, showing a lack of absolute market power. Secondly, the change in diesel price also means a change in transport cost to access foods produced upstream and to sell these foods to consumers. To offset the negative effect of a fuel price increase, for instance, they may charge higher prices to final consumers.

Given that retailers face price changes from both producer and fuel prices paid to procure food upstream, a change in the price of diesel would have a higher effect on downstream prices than on upstream prices along the food supply chain. From this conclusion, the study seeks to answer the following question:

Are shocks from diesel price change higher on downstream prices than upstream prices along the food supply chain?

4.4 THEORETICAL FOUNDATION AND HYPOTHESIS

Asymmetric Price Transmission (APT), the case where price transmission increases or decreases, has attracted attention from agricultural economists since the turn of the millennium (McCorriston et al., 2001; McCorriston, 2002; Meyer and von Cramon-Taubadel,

2004). The increased attention stems from the conclusion by both theoretical and empirical studies that Asymmetric Price Transmission (APT) may reveal the weaknesses of traditional economic theory, since if APT is the rule, then it will be difficult to accept an economic theory that treats it as an exception. Secondly, asymmetry in price transmission could spell significant welfare and policy implications, since the presence of asymmetry implies that a group is not benefiting from a price reduction (for buyers) or increase (for sellers).

The theoretical underpinnings of asymmetric food price transmission along the nutritional high-value food supply chain can be found in microeconomic theory, through the structure of agricultural markets and the role food prices play in ensuring the attainment of market goals. Prices determine decisions about resource allocation and output mix, thus determining the extent of vertical and/or horizontal integration of markets. From a market organisation perspective, the structure of a market determines the behaviour of firms in respect of the magnitude and speed of transmitting market prices. The structure of the market also determines the differences in market power. In the case of agricultural markets, farmers and consumers often suspect that imperfect competition in processing and retailing grants to middlemen the ability to abuse market power. This results in a positive APT, where retail prices react more quickly or fully to an increase in producer price and less quickly or fully to a decrease in producer price.

McCorriston et al. (2001) proffer a theoretical framework that explains the above conjecture by examining how differences in market power from imperfect competition leads to asymmetric price transmission in food markets. They develop a model of farm-retail spread that accounts for imperfect competition. The framework of the model is to have a single intermediate stage, where a food-processing retailer produces a homogeneous good with firms pursuing quantity-setting strategies. The extent of price transmission from the impact of an external shock (such as diesel price shock) occurring at the farm stage (upstream) on retail price depends, therefore, on the change in aggregate mark-up for firms in this intermediate and oligopolistic stage and any change in cost.

Assuming the initial structure of the food market is competitive, such that the mark-up is zero. Then only changes in costs will explain price transmission. Given a fixed proportion of technology, the level of price transmission will be explained through the competitive industry's share of agricultural raw materials in its cost function. A positive mark-up, however, shows that market power drives price transmission because the mark-up could change based on industry cost. The level of market power and the nature of the demand function also determine how much the aggregate mark-up will change. Under a constant elasticity demand function, even a change in cost will not lead to a positive change in mark-up, implying that the mark-up will not influence price transmission. In situations where the elasticity of demand is not constant, however, the change in mark-up

reduces the price transmission elasticity. This means that retail prices will change less than changes in producer prices, a clear case of negative APT.

[McCorriston \(2002\)](#) expands the above model by examining price transmission when downstream players have market power and operate under non-constant returns to scale. They develop a theoretical model in which agricultural firms produce food by using agricultural inputs together with other variable inputs (such as materials and labour). Based on models of short-run equilibrium with quasi-fixed capital, the authors assume that firms can maximise their profits only by varying the variable inputs and there is potential substitutability between inputs. The authors further assume that the food market cannot exert oligopsonistic power, despite having oligopolistic power.

Given the above assumptions and model set-up, a firm's quantity is a function of agricultural inputs, material inputs and capital inputs that are fixed in the long run. Its input supply is a function of the prices of agricultural inputs, material inputs and an exogenous shift factor that represents the source of external shock after the agricultural sector. Deriving the elasticity of transmission, therefore, involves estimating changes in the endogenous variables following an external shock.

The authors assert that, the level of this elasticity in the short-run depends on whether a firm's cost function is characterised by constant, increasing or decreasing returns to scale. In the case of constant returns to scale, the level of price transmission when the price of agricultural inputs declines is determined by the change in industry mark-up over the marginal cost required to restore equilibrium. This adjustment in turn depends not only on the level of market power, but also on the nature of the demand curve. With non-constant returns to scale, however, adjustment towards equilibrium is also a function of the cost faced by the firm. When a firm faces increasing returns to scale, the expansion of output required to restore equilibrium exceeds that of constant returns, leading to an increase in price transmission, since the fall in input price is reflected in the corresponding decrease in consumer prices. This implies that although market power may reduce the extent of price transmission when a firm is operating under increasing returns to scale, the level of price transmission is all the same higher than the case of constant returns to scale. Decreasing returns to scale leads to a lower output expansion to equilibrium that is lower than in the constant cost case. Thus, the market power effect is further reinforced, leading to a further relative reduction in consumer prices for a decline in agricultural input prices. In the long run, capital is variable implying that the scale parameter can thus, rise, leading to increasing returns.

Empirical studies on agricultural markets in developing countries reveal that agricultural markets in developing countries are characterised by imperfect competition ([Sexton, 2012](#)). This imperfection creates an imbalance in market power along the supply chain, with downstream players (such as retailers) wielding more power in determining prices.

An increasing demand for nutritional high-value foods coupled with access to agricultural inputs means that farmers produce more for a given input in order to meet demand from retailers. As per the framework of [McCorrison et al. \(2001\)](#), the increased production will require reduced price levels in order to sell produce to retailers. In the case of nutritional high-value foods, these tend to be perishable and require a reduction in producer price in order to find market. This analysis also applies to retailers who may wish to sell more food procured from producers to meet consumer demand.

We can deduce from the above that in the event of a shock from diesel price, higher retail power means that they are able to reduce price transmission from producers (who may wish to pass on the effect to retailers). Downstream, however, [Meyer and von Cramon-Taubadel \(2004\)](#) argue that retailers selling these foods may be unwilling to raise prices when producer and diesel prices increase for fear of being left with unsold food. Overall, retailers will have higher net welfare losses since they are unable to fully pass the increased cost from producer and diesel prices to consumers.

It is important to note that, the downstream demand-side effect results from the assumption that the elasticity of demand is not constant. With nutritional high-value foods, this assumption is justifiable since the consumption of these foods tends to be income-elastic, with higher incomes meaning higher consumption ([Gulati et al., 2007](#)).

From the theoretical framework presented above, it can be concluded that in the presence of increasing rate of return, a diesel price shock will have a higher impact on downstream prices than upstream prices in the market of perishable products. Following from this conclusion, the study seeks to ascertain if the impact of a diesel price shock is higher upstream along nutritional high-value food chains, using São Paulo as a case study. The hypothesis to be tested is as follows:

H1: The impact of diesel price shock along the nutritional high-value food supply chain is higher downstream than upstream

4.5 THE DATA

The empirical analysis of this study relies on two sets of data. The first set concerns monthly average prices of meat, eggs, dairy and fats & oils products sold in São Paulo. The Instituto de Economia Agrícola (Institute of Agricultural Economics) of São Paulo and the Institute of Economic Research Foundation (FIPE) are two major institutes that collate this data. The former collates and publishes different food price series covering the prices received by rural producers, as well as average wholesale and retail prices in the city of São Paulo. In surveying the retail prices, the IEA considers household food

expenditures using average family size and income levels based on the FIPE Family Budget Survey. On its part, FIPE estimates the producer and consumer price indices of various foods and services, based on a determined basket of food consumed by households. From these indices, a general food price index is calculated ¹.

The second set of data is average monthly prices of diesel. The National Agency of Petroleum, Natural Gas and Biofuels (ANP) publishes data on average monthly prices of all fuel products on its website ². The dissertation uses data on diesel prices published on the site. The data spans a period from July 2001 to December 2013. Using this time frame enables us to capture both pre-crisis and post-crisis periods, while providing sufficient sample size for the study. The prices of the foods under study are expressed per kilogramme while diesel prices are per litre. All prices are in Brazilian Real and with the data being complete, the problem of missing data is not encountered. A challenge with the data is that diesel prices in 2013 are recorded twice for each month. The average of the two prices is taken for each month to obtain the monthly average.

The use of monthly data to explore oil price shocks enables us to capture major price changes that may have occurred during the month. This point is relevant because households may plan their food expenditure for a month. Monthly data has also been used by studies in the oil-food literature. [Bastianin et al. \(2014\)](#), [Zhang et al. \(2010\)](#) and [Wang et al. \(2014\)](#) are examples of studies that use monthly data. Table 4.2 provides the summary statistics of the data, both in untransformed and log-transformed forms. Mean producer price is highest in the fats and oils market, while the producer price of eggs records the lowest mean price. With respect to retail prices, the price of meat has the highest mean while that of dairy has the lowest. The Jarque-Bera test leads to the rejection of the null of normality in all the variables except the producer price of fats and oils. Transforming the variables to log leads to the non-rejection of the null in four series.

¹A big thank you to the statistics division of the Fundação Instituto de Pesquisas Economicas (Institute of Economic Research Foundation) for making data on price indices available for the dissertation.

²<http://www.anp.gov.br/dados-estatisticos>

Summary statistics: untransformed data									
Variable	Name	Observations	Mean	Std. Dev.	Min.	Max	Jarque-Bera	Skewness	Kurtosis
meat_producer	Producer price of meat	150	3.686	1.028	2.02	5.834	10.172***	0.26	-1.187
egg_producer	Producer price of eggs	150	0.507	0.136	0.276	0.935	15.331***	0.765	0.214
dairy_producer	Producer price of dairy	150	10.798	3.056	5.824	17.01	8.863***	0.188	-1.141
fat_producer	Producer price of fats & oils	150	45.411	11.179	22.71	71.19	2.679	0.202	-0.546
meat_retailer	Retail price of meat	150	9.254	2.883	4.945	14.995	12.458***	0.3	-1.298
egg_retailer	Retail price of eggs	150	2.776	0.685	1.59	4.48	0.666***	0.511	-0.059
dairy_retailer	Retail price of dairy	150	2.29	0.604	1.41	3.603	11.060***	0.543	-0.782
fat_retailer	Retail price of fats and oils	150	5.019	0.806	2.622	6.546	36.448***	-1.035	1.152
propensity	Retail sale index	150	67.97	17.108	46.3	100.3	13.707***	0.424	-1.232
diesel_price	Average price of diesel	150	1.77	0.392	0.809	2.502	21.244***	-0.908	0.148

Summary statistics: log-transformed data									
Variable	Name	Observations	Mean	Std. Dev.	Min.	Max	Jarque-Bera	Skewness	Kurtosis
meat_producer	Producer price of meat	150	1.265	0.284	0.703	1.764	8.429***	-0.073	-1.177
egg_producer	Producer price of eggs	150	-0.713	0.26	-1.286	-0.067	1.109	0.139	-0.348
dairy_producer	Producer price of dairy	150	2.338	0.292	1.762	2.834	7.931***	-0.183	-1.089
fat_producer	Producer price of fats & oils	150	3.784	0.256	3.123	4.265	3.951	-0.372	-0.299
meat_retailer	Retail price of meat	150	2.176	0.316	1.598	2.708	10.442***	-0.008	-1.315
egg_retailer	Retail price of eggs	150	0.991	0.248	0.464	1.5	0.7	-0.119	-0.269
dairy_retailer	Retail price of dairy	150	0.795	0.259	0.344	1.282	5.967	0.164	-0.947
fat_retailer	Retail price of fats & oils	150	1.598	0.183	0.964	1.879	98.608***	-1.569	2.321
propensity	Retail sale index	150	4.188	0.248	3.835	4.608	12.916***	0.208	-1.396
diesel_price	Average price of diesel	150	0.54	0.264	-0.212	0.917	60.909***	-1.408	1.231

The subscripts *producer* and *retailer* mean producer and retail prices respectively. Thus, $meat_{producer}$ means the producer price of meat. $diesel_{price}$ means the average price of diesel while *propensity* is the propensity of retail sale.*** means significant at the 5% level.

Table 4.2: Summaries Statistics of the Series

4.6 ESTIMATION AND RESULTS

4.6.1 Model and specification tests

Based on the discussion above and the focus of the study, the empirical strategy is to model agricultural commodity prices based on the interaction between actors along the supply chain and dynamics in diesel prices. This means that the producer price of food depends of the retail price and vice versa, while both prices are determined by the price of diesel. An increase in diesel price may, therefore, result in a higher market price for agricultural commodities. The log-log form of the associated empirical model is as shown in equation (4.1) below:

$$\begin{cases} \ln PRODPRICE_t = \alpha_{0i} + \alpha_{1i} \ln RETPRICE_t + \alpha_{2i} \ln DIESELP_t + \epsilon_t \\ \ln RETPRICE_t = \alpha_{3i} + \alpha_{4i} \ln PRODPRICE_t + \alpha_{5i} \ln DIESELP_t + \alpha_t \end{cases} \quad (4.1)$$

where $\ln PRODPRICE_t$ is the natural log of the average producer price of the nutritional high-value food at month t , $\ln RETPRICE_t$ is the natural log of average retail price and $\ln DIESELP_t$ denotes the natural log of average diesel price in month t .

Having provided the general framework of the model to be estimated, the next stage entails examining the properties of the time series data. This is relevant in order to avoid spurious results. The empirical steps involve four stages. Firstly, stationarity properties of the variables are investigated by performing various unit root tests. The presence of a cointegrating relationship is then tested. Based on the results of the preceding steps, either a Vector Autoregression (VAR) or Vector Error Correction Model (VECM) is estimated.

4.6.2 Testing for Unit Roots

Conventional OLS estimation with non-stationary data yields spurious regression results. For this reason, it is imperative to determine the order of integration of the variables used in this empirical analysis. The Augmented Dickey-Fuller test, a modified version of the Dickey-Fuller test, is used to test for the presence of unit roots in the variables under study. For higher-order correlation, the ADF test makes a parametric correction of the Dickey-Fuller test by assuming that the series follows an AR(p) process. To do this, lagged differences of the dependent variable are added to the right-hand side of the regression. The form of the Augmented Dickey-Fuller test is specified in equation (4.2):

$$\delta Y_t = b_0 + \beta Y_{t-1} + \mu_1 \delta Y_{t-1} + \mu_2 \delta Y_{t-2} + \dots + \mu_p \delta Y_{t-p} + \varepsilon_t \quad (4.2)$$

where Y_t is the series to be tested, b_0 is the intercept term and β the coefficient of interest in the unit root test. The parameter of the augmented lagged first-difference of Y_t is denoted by μ_i while e_t is the error term and a white noise. The null hypothesis of the ADF unit root test is the presence of unit roots against the alternative of no unit roots. Table 4.3 presents the Augmented Dickey-Fuller unit root test for the time series variables under study. Given that the results depend on the selected lag length, different lag lengths are used to capture how the results vary when the lag length changes. In the case of untransformed data and lag length selected using the AIC criterion, a length of 5 leads to the rejection of the null hypothesis of unit roots only for the producer price of meat. A lag length of 10 with AIC does not reject the null for all the food prices, diesel price and retail sale index. With log transformation, the results show the presence of unit root in all the variables both for AIC and SIC lag selection criteria.

Price series (no transformation), maximum lag length is 5							Price series (no transformation), maximum lag length is 10						
Variable	Using AIC			Using SIC			Variable	Using AIC			Using SIC		
	Lag	Statistic	P-value	Lag	Statistic	P-value		Lag	Statistic	P-value	Lag	Statistic	P-value
meat_producer	4	-3.619	0.034	3	-3.443	0.05	meat_producer	8	-2.024	0.567	3	-3.443	0.05
meat_retailer	1	-2.774	0.254	1	-2.774	0.254	meat_retailer	7	-2.254	0.471	1	-2.774	0.254
egg_producer	2	-2.924	0.192	1	-3.026	0.149	egg_producer	8	-3.002	0.159	1	-3.026	0.149
egg_retailer	3	-2.376	0.419	1	-2.889	0.206	egg_retailer	3	-2.376	0.419	1	-2.889	0.206
dairy_producer	2	-3.39	0.059	1	-2.921	0.193	dairy_producer	2	-3.39	0.059	1	-2.291	0.193
dairy_retailer	4	-1.557	0.761	1	-0.934	0.946	dairy_retailer	6	-0.899	0.951	1	-0.934	0.946
fat_producer	2	-3.235	0.084	2	-3.235	0.084	fat_producer	2	-3.235	0.085	2	-3.235	0.085
fat_retailer	1	-2.848	0.223	1	-2.848	0.223	fat_retailer	1	-2.848	0.223	1	-2.848	0.223
propensity	1	-3.223	0.087	1	-3.223	0.087	propensity	1	-3.223	0.087	1	-3.223	0.087
diesel_price	2	-2.451	0.389	2	-2.451	0.389	diesel_price	2	-2.451	0.389	2	-2.451	0.389
Price series (log transformation), maximum lag length = 5							Price series (log transformation), maximum lag length = 10						
Variable	Using AIC			Using SIC			Variable	Using AIC			Using SIC		
	Lag	Statistic	P-value	Lag	Statistic	P-value		Lag	Statistic	P-value	Lag	Statistic	P-value
meat_producer	4	-3.343	0.052	4	-3.343	0.052	meat_producer	4	-3.434	0.052	4	-3.434	0.052
meat_retailer	1	-3.065	0.133	1	-3.065	0.133	meat_retailer	1	-3.065	0.133	1	-3.065	0.133
egg_producer	1	-3.059	0.135	1	-3.059	0.135	egg_producer	8	-2.876	0.211	1	-3.059	0.135
egg_retailer	3	-2.734	0.271	3	-2.734	0.271	egg_retailer	3	-2.734	0.271	3	-2.734	0.271
dairy_producer	1	-3.087	0.124	1	-3.087	0.124	dairy_producer	1	-3.087	0.124	1	-3.087	0.124
dairy_retailer	4	-2.642	0.309	1	-1.718	0.694	dairy_retailer	6	-2.059	0.552	1	-1.718	0.694
fat_producer	2	-2.959	0.177	2	-2.959	0.177	fat_producer	2	-2.959	0.177	2	-2.959	0.177
fat_retailer	1	-3.25	0.082	1	-3.25	0.082	fat_retailer	1	-3.25	0.082	1	-3.25	0.082
propensity	1	-3.223	0.087	1	-3.223	0.087	propensity	1	-3.223	0.087	1	-3.223	0.087
diesel_price	2	-2.988	0.165	2	-2.988	0.165	diesel_price	2	-2.988	0.165	2	-2.988	0.165

The subscripts *producer* and *retailer* mean producer and retail prices respectively. Thus, $meat_{producer}$ means the producer price of meat. $diesel_{price}$ means the average price of diesel while *propensity* is the propensity of retail sale.

Table 4.3: Unit root tests (for untransformed and log-transformed data)

Given the presence of unit roots in the data, it is important to examine the degree of integration of the variables. Table 4.4 presents the unit root tests of the first difference and the log of the first difference of the series. Differencing the series leads to the rejection of the null hypothesis of unit root in all the variables for both the first difference and its log. Since this study uses the log of the series which has been shown to be non-stationary in Table 4.3, we can confidently conclude that all the series are integrated with an order of $I(1)$.

Price series (difference transformation), maximum lag length is 5							Price series (difference transformation), maximum lag length is 10						
Variable	Using AIC			Using SIC			Variable	Using AIC			Using SIC		
	Lag	Statistic	P-value	Lag	Statistic	P-value		Lag	Statistic	P-value	Lag	Statistic	P-value
meat_prod	3	-5.928	0.01	3	-5.928	0.01	meat_prod	7	-6.471	0.01	3	-6.377	0.01
meat_retail	1	-8.607	0.01	1	-8.607	0.01	meat_retail	1	-8.856	0.01	1	-8.856	0.01
egg_prod	1	-9.903	0.01	1	-9.903	0.01	egg_prod	7	-4.688	0.01	1	-9.915	0.01
egg_retail	2	-7.516	0.01	2	-7.516	0.01	egg_retail	2	-7.337	0.01	2	-7.337	0.01
dairy_prod	1	-8.079	0.01	1	-8.079	0.01	dairy_prod	1	-7.991	0.01	1	-7.991	0.01
dairy_retail	5	-5.35	0.01	2	-5.344	0.01	dairy_retail	5	-4.974	0.01	1	-7.124	0.01
fat_prod	1	-5.876	0.01	1	-5.876	0.01	fat_prod	1	-6.345	0.01	1	-6.345	0.01
fat_retail	1	-9.782	0.01	1	-9.782	0.01	fat_retail	1	-8.922	0.01	1	-8.922	0.01
propensity	1	-8.804	0.01	1	-8.804	0.01	propensity	1	-8.804	0.01	1	-8.804	0.01
diesel_price	1	-6.125	0.01	1	-6.125	0.01	diesel_price	1	-6.502	0.01	1	-6.502	0.01

Price series (difference of log transformation), maximum lag length is 5							Price series (difference of log transformation), maximum lag length is 10						
Variable	Using AIC			Using SIC			Variable	Using AIC			Using SIC		
	Lag	Statistic	P-value	Lag	Statistic	P-value		Lag	Statistic	P-value	Lag	Statistic	P-value
meat_prod	7	-6.541	0.01	3	-6.541	0.01	meat_prod	7	-6.541	0.01	3	-6.541	0.01
meat_retail	1	-6.258	0.01	1	-6.258	0.01	meat_retail	1	-6.258	0.01	1	-6.258	0.01
egg_prod	7	-4.869	0.01	1	-4.869	0.01	egg_prod	7	-4.869	0.01	1	-4.869	0.01
egg_retail	2	-5.059	0.01	2	-5.059	0.01	egg_retail	2	-5.059	0.01	2	-5.059	0.01
dairy_prod	1	-5.889	0.01	1	-5.889	0.01	dairy_prod	1	-5.889	0.01	1	-5.889	0.01
dairy_retail	5	-4.974	0.01	1	-4.974	0.01	dairy_retail	5	-4.974	0.01	1	-4.974	0.01
fat_prod	1	-4.862	0.01	1	-4.862	0.01	fat_prod	1	-4.862	0.01	1	-4.862	0.01
fat_retail	1	-4.045	0.01	1	-4.045	0.01	fat_retail	1	-4.045	0.01	1	-4.045	0.01
propensity	1	-3.754	0.023	1	-3.754	0.023	propensity	1	-3.754	0.023	1	-3.754	0.023
diesel_price	1	-4.62	0.01	1	-4.62	0.01	diesel_price	1	-4.62	0.01	1	-4.62	0.01

The subscripts *producer* and *retailer* mean producer and retail prices respectively. Thus, $meat_{producer}$ means the producer price of meat. $diesel_{price}$ means the average price of diesel while *propensity* is the propensity of retail sale.

Table 4.4: Unit root tests (for first difference and log of first difference data)

4.6.3 Cointegration Estimation

If two prices move together in the long-run, they are said to be cointegrated. Although a short-run relationship may exist between the series, cointegration implies that there is a linear relationship that ties them together. Methodologically, the presence of cointegration determines the type of long-run econometric model applied.

To test for the presence of cointegration, the Johansen trace test is applied to all the 8 price series. Another test is the Engle-Granger test. The advantage of the Johansen test is that it is able to handle several time series variables. Table 4.5 presents results of the test statistic and critical values of the Johansen trace test. With r denoting the cointegration rank, the test sequentially assesses if r is equal to zero, equal to one, through to $r = n - 1$, where n is the number of price series under study. At the rank of 0, the null hypothesis is $r = 0$ while the alternative is $r \leq 0$. Subsequent ranks are based on a null of r less than or equal to the rank number while the alternative hypothesis examines where the rank is greater.

The overall rank of cointegration is obtained up to when we fail to reject the null hypothesis. From Table 4.5 and based on the 5% critical value, we reject the null only for $r = 0$, $r \leq 1$, $r \leq 2$ and $r \leq 3$. We, therefore, have a cointegration rank of 4.

H0	H1	Test statistic	10% critical value	5% critical value	1% critical value
$r = 0$	$r > 0$	366.77	256.72	263.42	279.07
$r \leq 1$	$r > 1$	270.79	215.17	222.21	234.41
$r \leq 2$	$r > 2$	205.17	176.67	182.82	196.08
$r \leq 3$	$r > 3$	148.24	141.01	146.76	158.49
$r \leq 4$	$r > 4$	102.7	110.42	114.9	124.75
$r \leq 5$	$r > 5$	67.01	83.2	87.31	96.58
$r \leq 6$	$r > 6$	47.16	59.14	62.99	70.05
$r \leq 7$	$r > 7$	28.01	39.06	42.44	48.45
$r \leq 8$	$r > 8$	14.96	22.76	25.32	30.45
$r \leq 9$	$r > 9$	6.45	10.49	12.25	16.26

Table 4.5: Johansen trace test results

4.6.4 Vector Error Correction Model

Having established that the series are all integrated of order $I(1)$ and cointegrated at rank 4, a Vector Error Correction Model (VECM) that specifies the short-run dynamics of each price series in such a way as to capture the dynamics in long-run equilibrium relationships is specified. The VECM is a variant of the Vector Autoregression (VAR) model that enables us to capture short-run causality through differencing and long-run causality through an Error Correction Term (ECT). Consider the general form of the

VAR(p) model in equation (4.3):

$$X_t = \mu + A_1 X_{t-1} + \dots + A_p X_{t-p} + w_t \quad (4.3)$$

where μ represents the vector-valued mean of the series, while the coefficient matrix of each lag is shown by A_i . w_t is the noise term assumed to have a mean of zero. The VECM model can be obtained by differencing equation (4.3), giving us equation (4.4) as follows:

$$\Delta X_t = \mu + A_1 X_{t-1} + \Gamma_1 \Delta X_{t-1} + \dots + \Gamma_p \Delta X_{t-p} + w_t \quad (4.4)$$

where $\Delta X_t = X_t - X_{t-1}$, A the coefficient matrix for the first lag and Γ_i the matrices for each differenced lag.

The results of the VECM model are presented in Appendix A.2. All price series are included in the VECM. The rationale for doing this is to be able to capture any cross-price relationship among the products. This is relevant because the foods under study are heavily consumed by middle class households, a great percentage of whom are found in São Paulo given the economic importance of the city (Levy-Costa et al., 2005). All these foods would, therefore, be purchased together, at least over a month (the time frame of the study). Buying these foods together may, however, signal cross-price effects among them. Since they are bought together (at least over a month), there is a high probability that a change in the price of one generates a change in the demand for and price of another, an analogy that can be extended to explain the effect of fuel prices.

It is important to note that the cross-price effects may occur along the entire spectrum of the supply chain. This is because of the interconnected nature of the interaction between agents along the chain, leading to downstream behaviour affecting activities upstream. Including the interaction between retail price of own and other nutritional high-value foods in the same VECM, therefore, enables us to capture both long-run and short-run dynamics not only for a particular food, but also other purchased foods.

4.7 RESULTS

4.7.1 Granger Causality Test

Results of the short-run causality test are reported in Table 4.6. The results show a bidirectional relationship between upstream and downstream prices only in the meat market and this relationship is significant at the 5% significance level. Upstream meat price, however, has a higher influence than downstream prices. A unidirectional relationship in

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which producer prices significantly influence retail prices is seen in the eggs and fats and oils market.

With respect to the effect of diesel price on food prices, we see that this is significant only in the dairy, eggs and fats & oils markets. In the eggs and dairy markets, the effect of diesel price is only significant downstream, while the producer price of fats & oils influences the price of diesel. In all these markets, we see a positive relationship between diesel and food prices. The results also indicate that the price of diesel significantly influences the retail sale index, a measure of the propensity to consume retail products.

Granger causality tests (short-run Chi-square tests)					
Producer and retail prices		Producer and diesel prices		Retail and diesel prices	
Meat market					
$Meat_{prod} \rightarrow Meat_{ret}$	27.731***	$Meat_{prod} \rightarrow Diesel$	0.308	$Meat_{ret} \rightarrow Diesel$	1.573
$Meat_{ret} \rightarrow Meat_{prod}$	3.974***	$Diesel \rightarrow Meat_{prod}$	1.945	$Diesel \rightarrow Meat_{ret}$	1.185
Eggs market					
$Egg_{prod} \rightarrow Egg_{ret}$	10.718***	$Egg_{prod} \rightarrow Diesel$	0.097	$Egg_{ret} \rightarrow Diesel$	0.057
$Egg_{ret} \rightarrow Egg_{prod}$	0.067	$Diesel \rightarrow Egg_{prod}$	0.967	$Diesel \rightarrow Egg_{ret}$	5.701***
Dairy market					
$Dairy_{prod} \rightarrow Dairy_{ret}$	2.651	$Dairy_{prod} \rightarrow Diesel$	0.243	$Dairy_{ret} \rightarrow Diesel$	0.539
$Dairy_{ret} \rightarrow Dairy_{prod}$	0.654	$Diesel \rightarrow Dairy_{prod}$	0.074	$Diesel \rightarrow Dairy_{ret}$	6.448***
Fats and oils market					
$Fat_{prod} \rightarrow Fat_{ret}$	11.934***	$Fat_{prod} \rightarrow Diesel$	4.837***	$Fat_{ret} \rightarrow Diesel$	3.979***
$Fat_{ret} \rightarrow Fat_{prod}$	1.904	$Diesel \rightarrow Fat_{prod}$	0.165	$Diesel \rightarrow Fat_{ret}$	2.133
Granger causality between retail sales index and diesel price					
Propensity \rightarrow Diesel	1.398	Diesel \rightarrow Propensity	7.679***		

The subscripts *prod* and *ret* mean production and retail prices respectively. Thus, $Meat_{prod}$ means the producer price of meat. *Diesel* means the average price of diesel while *Propensity* is the retail sale index. *** mean significant at the 5% significance level.

Table 4.6: Short-run Granger causality test

4.7.2 Forecast Error Variance Decomposition

Variance decomposition analysis enables us to assess the relative magnitude of the causal influence of one price on another. More precisely, decomposition provides the share of the variance associated with each price in the VECM caused by shocks to other prices. Table 4.7 presents the forecast error variance decomposition for upstream food prices, downstream food prices, retail sale index and diesel price. The results show that in the meat market, changes in the price of diesel contributes 2.7% of the variance of the producer price and 0.6% of the variance of the retail price of meat. In the eggs market, however, an

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opposite trend where the price of diesel accounts for 1.2% of the variance of the retail price of eggs and 0.1% of the change in egg producer price is seen. Similarly, the variance of the producer price of dairy changes by 2.7%, while contribution to the variance of the retail price is 3.8%. In the fatty oil market, the variances of the producer and retail prices are 7.6% and 1.7% respectively. Comparing the above results with the result that the price of diesel accounts for a 39.4% of the retail sale index shows that prices of products other than nutritional high-value foods may be more responsive to changes in diesel prices.

	Contribution of shock in log prices									
	$Meat_{prod}$	$Meat_{ret}$	Egg_{prod}	Egg_{ret}	$Dairy_{prod}$	$Dairy_{ret}$	Fat_{prod}	Fat_{ret}	Propensity	Diesel
$Meat_{prod}$	0.769	0.007	0.005	0.004	0.101	0.005	0.01	0.029	0.041	0.027
$Meat_{ret}$	0.594	0.19	0.048	0.005	0.084	0.005	0.023	0.008	0.035	0.006
Egg_{prod}	0.009	0.026	0.788	0.122	0.02	0.0001	0.0003	0.025	0.009	0.001
Egg_{ret}	0.015	0.033	0.585	0.247	0.034	0.014	0.008	0.051	0.001	0.012
$Dairy_{prod}$	0.125	0.002	0.055	0.042	0.687	0.001	0.022	0.036	0.003	0.027
$Dairy_{ret}$	0.014	0.038	0.168	0.045	0.009	0.667	0.006	0.013	0.002	0.038
Fat_{prod}	0.002	0.016	0.013	0.015	0.14	0.0002	0.679	0.02	0.037	0.076
Fat_{ret}	0.021	0.025	0.006	0.015	0.029	0.019	0.167	0.683	0.019	0.017
Propensity	0.005	0.006	0.034	0.009	0.013	0.008	0.057	0.075	0.399	0.394
Diesel	0.015	0.008	0.009	0.029	0.106	0.006	0.013	0.155	0.071	0.587

The subscripts *prod* and *ret* mean production and retail prices respectively. For example, $Meat_{prod}$ means the producer price of meat. *Diesel* means the average price of diesel while *Propensity* is the retail sale index.

Table 4.7: Forecast error decomposition of log prices after 10 periods (months)

With respect to upstream and downstream price shocks along the respective food supply chains, the producer price contributes more to variations in the retail price than vice versa in all the markets under study. In the meat market, for instance, the producer price of meat contributes a whopping 59.4% to the variance of meat retail price while the latter accounts for only 0.7% for the variation in the former. In the eggs market, the share of the producer price is 58.5% while the retail price contributes 12.2%. In terms of cross-price contribution, the results reveal that overall, producer prices have a higher cross-price variance contribution than retail prices for all the food prices under study.

4.7.3 Impulse Response Analysis

Impulse response analysis enables us to identify dynamics in a variable of interest along a given time horizon after an external shock. The analysis indicates the extent to which an unanticipated change in the impulse variable impacts the response variable over the next several periods. The response of producer and retail prices of the foods under study to diesel prices is shown in the Appendix. Appendix A.4 presents the response of producer and retail prices of meat to diesel price. In Appendix A.5 and Appendix A.6, price responses in the eggs and dairy markets are presented respectively, while Appendix A.7 indicates the response of producer and retail prices of fatty oils to the price of diesel. A

period of 24 months, long enough to account for any significant price change, is used for all the impulse response curves.

Studies on the behaviour of food prices show that they behave differently during periods of crisis (Esposti and Listorti, 2012). This conclusion is examined in the impulse response analysis by controlling for the period of financial crisis and plotting the associated impulse response curves. The period June 2006 to December 2013 is used as the crisis period, in order to capture the effects of the global financial meltdown of 2007 and the food price crises of 2010 and 2011.

The results of the impulse response functions show that the initial response of food prices to diesel price is positive and significant only with retail prices in the dairy and fats & oils markets. This response, however, dies out after five months in the case of the dairy market, and after two months in the fats and oils market. This result shows that generally, the prices of nutritional high-value foods do not respond to diesel price shocks in the short-run, a finding that corroborates the short-run Granger causality results. Considering that the price of diesel shows periods of minute changes as shown in Figure 4.1, this finding indicates that food price response follows the direction of movement of diesel prices. Thus, although the analysis took into consideration periods covering the global financial crisis, the fact that diesel prices did not change considerably between 2008 and 2013 means that the reaction of food prices was minimal.

The VECM results indicate that long-run relationship is significant among own, cross and diesel prices in all the food markets. This is true for both producer and retail prices. Convergence to equilibrium upstream is, however, seen in the meat and dairy markets. In the former, 45.9% of the disequilibrium is corrected after the first month while 13.9% of disequilibrium in the producer price of dairy is corrected for the same period. Downstream, only the retail prices of eggs and dairy converge to equilibrium, with 42% of the disequilibrium in the former corrected after the first month while 9.0% of the latter is corrected.

4.8 COMMENTS AND DISCUSSION

The extent of and asymmetry in price transmission along the food supply chain has important implications for the functioning of the chain. With respect to nutritional high-value foods, the increasing demand for these foods implies that asymmetry in price transmission will hugely affect not only producers and retailers, but also consumers. Although farmers producing these food see increasing demand as a catalyst for increased production and profit (Reardon and Timmer, 2014; Gulati et al., 2007), the inability to transmit higher input prices to wholesalers and/or retailers through higher producer prices indicates that farmers face the risk of recording low profit margins. This has two possible effects. They

may be discouraged from investing more to meet demand. Secondly, and in case they increase investment, may leave food on the field, culminating in food loss (Segrè et al., 2014). Downstream, retailers may also suffer a fall in profit margins if retailers are unable to increase price despite increased demand for fear of throwing food away.

The results of the study have shown that the magnitude and direction of food price transmission along the nutritional high-value food supply chain depends on food type and time (short-run or long-run). The short-run Granger causality results show that bidirectional relationship is only significant in the meat market and the producer price of meat has a higher effect than its retail price, an indication that producers are better able to transmit prices to retailers than the latter. The positive and significant effect of the producer price of meat on its retail price can also be seen from the high contribution of the latter to the variance of the former. Comparing this finding with the long-run elasticity results in the VECM, it is seen that the producer price of meat converges to equilibrium while the retail price diverges.

Contrary to the results in the meat market, although short-run shocks in the eggs market only move from producer price to retail price, long-run equilibrium convergence is found only in the latter. This shows that although egg producers wield some amount of market power in transmitting prices to retailers, the actions of the latter have a bigger impact in establishing long-run equilibrium. With the fats and oils market, although producer price influences retail price in the short run, there is no long-run convergence.

The results of the relationship between diesel and food prices also reveal differences by type of market price. From the Granger causality findings, it is seen that a change in diesel price significantly affects retail prices in the eggs and dairy markets, but affects only producer prices in the fats and oils market. For all these effects, the direction is positive, implying that an increase in diesel price results in an increase in food prices.

It is also important to note that, although changes in both the producer and retail prices of eggs significantly lead to an increase in retail price, the effect of the producer price is greater than that of diesel price. This finding confirms the market-power and returns-to-scale conjecture. With increasing returns to scale, retailers in the egg market get to sell more eggs. But this also reduces their ability to increase the price of egg when producer price increases.

A potential source of the diesel price effect in the high-value food market of São Paulo is the development of the ethanol market in Brazil. Rising sugar prices tend to be transitory in that they affect the prices of other agricultural commodities. These transitory effects are caused both by yield and acreage responses, due to the redistribution of land in favour of ethanol production (Zhang et al., 2010).

The results of the study have important implications for policies targeting high-value

food markets. Price support policies in developing countries have often targeted farmers, with the goal to help them receive higher producer prices ([McCorriston et al., 2001](#)). The study has shown that in the case of diesel price shock, the efficiency of such policies in enhancing the welfare of farmers is specific to the market in which these policies are implemented. In certain markets (such as eggs), the producer price effect is higher than the diesel price effect. In such a case, policy reforms during diesel price changes are necessary to reduce the effect of the differential between retail and producer prices.

CONCLUSION

The issue of food insecurity remains a serious threat to socioeconomic advancement in developing countries. With about 179 million people being undernourished (FAO et al., 2015), addressing this issue has become very relevant, a reason for which Goal 2 of the United Nations Sustainable Development Goals targets the elimination of hunger. Interestingly, despite the increasing threat to food security, general income levels have risen, leading to the increasing demand for nutritional high-value foods. Since these foods have high nutritional value per kilogramme, they offer an excellent opportunity to supply the energy needs of consumers in underdeveloped countries.

Nutritional high-value foods are, however, highly perishable, implying that an efficient and responsive supply chain is required to avert losses. Their perishable nature also varies along the supply chain, with foods in a more perishable state upstream. It also depends on the type of food, with some having a longer shelf life than others.

Given the growing demand for nutritional high-value foods and their perishable nature, disruptions to their supply chains will have significant implications for the attainment of food security. Natural disasters such a drought and flood may affect not only the quantity of these foods produced, but also the quality made available to consumers. With these foods differing from one another both in terms of where they are along the chain (upstream or downstream) and in shelf life, policies that aim an helping agents to mitigate the negative effects of disruption need to consider not only the differences in magnitude of these disruptions along sections of the chain, but also the type of food.

In light of the above, this dissertation has presented three essays on disruptions to nutritional high-value food supply chains in emerging countries. The first essay analyses disruptions to the unprocessed nutritional high-value food chain, with a focus on meat, eggs, fruits and vegetables. In the second essay, focusing on the dairy and fats & oils markets, examined disruptions in the processed food supply chain. The last essay assesses the impact of diesel price shocks on the nutritional high-value food supply chain, using São Paulo as a case study. For each of these essays, the emphasis is on identifying how different upstream disruptions are from downstream ones.

The three essays are linked in the sense that the foods under study are all unprocessed

in their initial state. Some may stay unprocessed and thus not witness any significant change throughout the supply chain. The first essay addresses this issue. Other foods are, however, processed and significantly change state as they move from upstream to downstream and the second essay captures this change. Disruptions other than natural disasters include diesel prices, because diesel price shocks are external and both categories of food use diesel as an input. The third essay examines this other source of disruption.

The results of the study have shown that not all disruptions have the same disruptive effect along the food supply chain. Among the different natural disasters under study, climatological disasters have the most dominant impact. The magnitude of the disasters upstream and downstream also depends on food commodity. This finding is also confirmed when we consider diesel price shocks, where the magnitude and direction of short-run and long-run shocks vary based on market. From a policy-making perspective, the findings show that for efficiency, food-related policies need to be market specific.

From a thorough review of the food supply chain literature, this dissertation can be said to be the first to assess the primary and secondary effects of different natural disasters along the nutritional high-value food supply chain. This contribution is relevant because of dynamics in food consumption in emerging countries with an increasing share of nutritional high-value foods. Current threat from climate change which may lead to natural disasters implies that food markets will be hardly hit and the situation of food insecurity could worsen.

A limitation of this study is that it has not included wholesale prices, particularly in the processed foods markets where the intermediary role of wholesalers may be very important in determining both upstream and downstream prices and quantities. The extent of pass-through from producers to retailers will, therefore, be dependent on the behaviour of wholesalers in respect of quantity and price. Since wholesalers eventually sell to retailers, excluding the prices and quantities of the former means that the dissertation makes the implicit assumption that their effects have been captured in prices and quantities of the latter. Although such an assumption may be justifiable given the strong interdependence along the food supply chain, a more disaggregated analysis would be appropriate in capturing wholesale effects.

Three avenues for future research can be drawn from the dissertation. Firstly, disruptions along the food supply chain affect the behaviour of agents along the chain. Agents may adapt to quantity and price changes in order to reduce losses. Although the dissertation has looked at quantity and price disruptions and thus reflect the behaviour of upstream and downstream agents, a theorizing of the behaviour of agents will better unearth the behaviour of agents. The cardinal goals of supply chain agents entail cost reduction and profit maximisation. Disruptions to the supply chain may increase cost and reduce profit. Developing a theoretical model that captures these dynamics and testing

5. CONCLUSION

the ensuing conclusions with data will be an ideal way of understanding how quantities and prices behave to mitigate the effects of disruptions.

Secondly, the sources of disruption examined are exogenous to the activities along the supply. They are also unwanted and their occurrence may be unaccepted although general trends may show that their probability of occurrence may be high. Given these traits, it is possible to develop a risk modelling framework that enables us to develop a food supply system through which the effects of the sources of disruption are propagated as probabilities. Doing this is relevant in that it enables us to obtain a risk model that can be updated with new disruption data to calculate new risk levels.

Last but not least, the analysis of fuel price effects has focused on diesel price shocks. Other fuel inputs include gasoline and ethanol. Dynamics in the price of the latter has particularly been found to lead to dynamics in the agricultural sector ([Balcombe and Rapsomanikis, 2008](#)). Given the effect of different price shocks on food prices, an analysis of differences in their short-run and long-run shocks on the different prices along the food supply chain is relevant to enable agents to better plan and adjust prices and quantities. With this angle of research generally missing from the existing literature, future research will seek to fill this gap.

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Appendices

APPENDIX

A.1 A. APPENDIX TO CHAPTER 1

Dependent variables: Log of quantity of food produced (upstream) and sold (downstream)								
Independent variables	Production (upstream)				Sales (downstream)			
	meat (1)	eggs (2)	fruits (3)	vegetables (4)	meat (5)	eggs (6)	fruits (7)	vegetables (8)
Climatological	-0.054*** (0.014)	-0.031** (0.013)	-0.044** (0.018)	-0.044*** (0.011)	-0.046*** (0.011)	-0.033*** (0.011)	-0.070*** (0.015)	-0.052*** (0.008)
Geophysical	0.001 (0.007)	0.005 (0.007)	0.013 (0.009)	-0.001 (0.006)	0.002 (0.005)	0.005 (0.005)	0.004 (0.006)	0.001 (0.004)
Hydrological	-0.005 (0.003)	-0.004 (0.004)	0.004 (0.005)	-0.002 (0.004)	-0.003 (0.003)	-0.003 (0.003)	-0.004 (0.004)	-0.005** (0.003)
Govt. Integrity	0.002 (0.003)	-0.003 (0.003)	0.005** (0.003)	-0.006** (0.003)	0.0001 (0.002)	0.001 (0.002)	0.005** (0.002)	0.003 (0.002)
Financial Freedom	0.006*** (0.002)	0.005*** (0.002)	0.003 (0.002)	0.004** (0.002)	0.004*** (0.001)	0.004*** (0.001)	0.004*** (0.001)	0.002** (0.001)
ln(Transport Expenditure)	0.067*** (0.010)	0.076*** (0.010)	0.036*** (0.010)	0.030*** (0.007)	0.060*** (0.009)	0.059*** (0.008)	0.044*** (0.009)	0.038*** (0.006)
Observations	266	266	266	266	266	266	266	266
R^2	0.329	0.321	0.129	0.117	0.393	0.424	0.303	0.3
Adjusted R^2	0.262	0.253	0.042	0.029	0.333	0.367	0.233	0.231
F Statistic (df = 6; 241)	19.679***	18.980***	5.957***	5.337***	26.044***	29.562***	17.435***	17.240***

Climatological: climatological disasters; Geophysical: Geophysical disasters; Hydrological: Hydrological disasters; Govt. Integrity: Governance Integrity; Financial Freedom: Financial Freedom; ln(Transport Expenditure) is the natural log Investment in transport infrastructure. *** and ** mean significant at 1% and 5% respectively. Standard errors are in brackets and robust to heteroscedasticity and autocorrelation.

Table A.1: Disruption of quantity with an increased sample size

A.1 B. APPENDIX TO CHAPTER 2

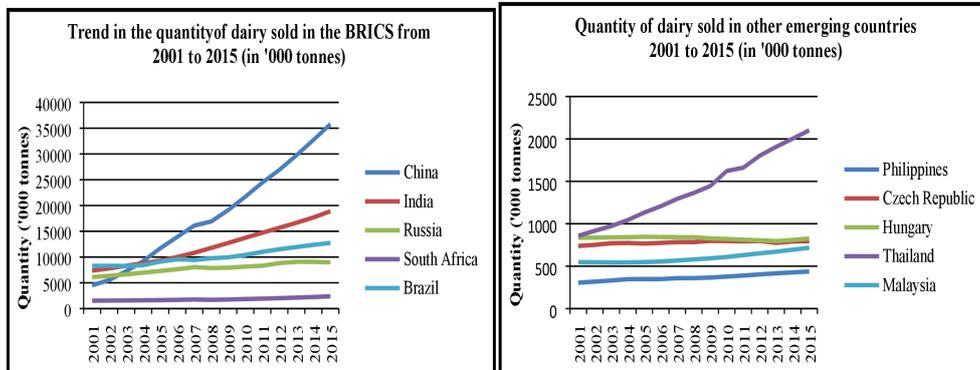


Figure A.1: Quantity of milk sold in the BRICS and other emerging countries
Source: Author generated from Euromonitor International's database

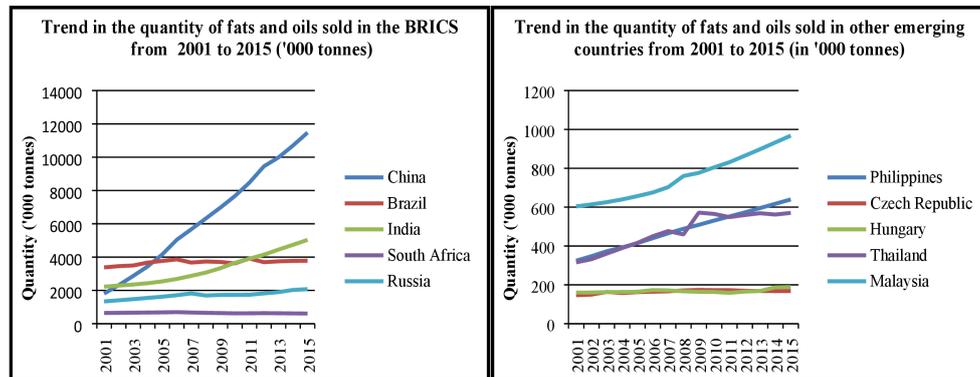


Figure A.2: Quantity of fats and oils sold in the BRICS and other emerging countries
Source: Author generated from Euromonitor International's database

A.1 C. APPENDIX TO CHAPTER 3

A.2 VECM Results

	$\Delta \ln \text{Meatprod}, t$	$\Delta \ln \text{Eggprod}, t$	$\Delta \ln \text{Dairyprod}, t$	$\Delta \ln \text{Fatprod}, t$	$\Delta \ln \text{Meatret}, t$	$\Delta \ln \text{Eggret}, t$	$\Delta \ln \text{Dairyret}, t$	$\Delta \ln \text{Fatret}, t$	$\Delta \ln \text{Propensity}, t$	$\Delta \ln \text{Dieselt}$
Error correction terms										
α_1	-0.459(0.113)***	-0.186(0.179)	-0.017(0.065)	0.066(0.091)	0.304(0.053)***	0.078(0.083)	-0.036(0.036)	0.044(0.059)	0.016(0.020)	-0.015(0.052)
α_2	-0.072(0.094)	0.435(0.148)***	-0.139(0.054)**	0.018(0.075)	0.100(0.049)**	-0.421(0.068)***	-0.090(0.030)**	-0.026(0.048)	-0.002(0.017)	-0.019(0.043)
α_3	0.372(0.121)**	-0.083(0.192)	-0.183(0.069)**	0.383(0.098)***	-0.0001(0.057)	-0.136(0.088)	-0.106(0.039)**	0.034(0.063)	0.039(0.021)	0.036(0.055)
α_4	0.088(0.034)	-0.031(0.053)	-0.009(0.019)	-0.044(0.027)	0.048(0.015)***	0.075(0.025)**	0.010(0.011)	0.069(0.018)***	-0.019(0.006)**	-0.008(0.015)
Meat producer lags										
$\Delta \ln \text{Meatprod}, t-1$	0.107(0.119)	0.493(0.188)**	0.140(0.068)**	-0.013(0.096)	0.007(0.056)	-0.188(0.087)**	0.052(0.038)	-0.040(0.062)	0.001(0.021)	0.016(0.054)
$\Delta \ln \text{Meatprod}, t-2$	0.542(0.099)***	0.167(0.157)	0.114(0.057)**	-0.019(0.079)	0.046(0.047)	-0.117(0.072)	0.012(0.032)	-0.049(0.051)	0.006(0.017)	-0.004(0.045)
Meat retail lags										
$\Delta \ln \text{Meatret}, t-1$	-0.027(0.176)	0.225(0.278)	-0.154(0.101)	-0.012(0.142)	-0.169(0.083)**	0.132(0.128)	-0.036(0.057)	0.094(0.091)	-0.002(0.031)	0.034(0.080)
$\Delta \ln \text{Meatret}, t-2$	-0.357(0.157)**	-0.315(0.248)	-0.195(0.090)**	-0.106(0.127)	-0.277(0.074)***	0.203(0.115)	-0.022(0.050)	-0.098(0.081)	-0.024(0.028)	0.046(0.071)
Egg producer lags										
$\Delta \ln \text{Eggprod}, t-1$	0.101(0.103)	-0.489(0.163)**	0.056(0.059)	-0.157(0.083)	-0.047(0.048)	0.145(0.075)	0.014(0.033)	0.022(0.053)	0.004(0.018)	0.005(0.047)
$\Delta \ln \text{Eggprod}, t-2$	0.119(0.080)	-0.352(0.127)**	0.088(0.046)	-0.125(0.065)	-0.018(0.038)	0.135(0.058)**	0.032(0.026)	0.043(0.042)	0.009(0.014)	-0.009(0.036)
Egg retail lags										
$\Delta \ln \text{Eggret}, t-1$	0.167(0.151)	-0.367(0.238)	0.054(0.087)	-0.092(0.122)	-0.029(0.071)	0.258(0.109)**	-0.041(0.048)	0.107(0.078)	0.023(0.027)	-0.014(0.069)
$\Delta \ln \text{Eggret}, t-2$	0.096(0.119)	-0.337(0.189)	0.158(0.069)**	0.207(0.096)**	-0.034(0.056)	-0.055(0.087)	0.041(0.038)	-0.028(0.062)	0.040(0.021)	0.005(0.054)
Dairy producer lags										
$\Delta \ln \text{Dairyprod}, t-1$	-0.344(0.172)*	0.069(0.272)	0.019(0.099)	-0.271(0.139)	0.080(0.081)	-0.025(0.126)	0.003(0.055)	0.035(0.089)	-0.061(0.030)**	-0.047(0.078)
$\Delta \ln \text{Dairyprod}, t-2$	-0.027(0.171)	0.731(0.271)**	0.152(0.098)	-0.040(0.138)	0.087(0.081)	-0.057(0.125)	0.129(0.055)**	0.007(0.089)	-0.0004(0.030)	-0.009(0.078)
Dairy retail lags										
$\Delta \ln \text{Dairyret}, t-1$	-0.306(0.295)	0.334(0.466)	0.034(0.169)	-0.086(0.238)	0.036(0.139)	-0.102(0.215)	-0.059(0.095)	-0.322(0.153)**	0.065(0.052)	0.012(0.134)
$\Delta \ln \text{Dairyret}, t-2$	-0.188(0.273)	0.063(0.432)	-0.039(0.157)	0.302(0.221)	-0.075(0.129)	-0.161(0.199)	0.104(0.088)	-0.099(0.142)	0.013(0.048)	-0.084(0.124)
Fats and oils producer lags										
$\Delta \ln \text{Fatprod}, t-1$	-0.219(0.113)	0.091(0.179)	0.079(0.065)	0.259(0.091)**	0.0003(0.053)	-0.032(0.083)	-0.025(0.036)	0.101(0.059)	-0.003(0.019)	0.052(0.051)
$\Delta \ln \text{Fatprod}, t-2$	0.045(0.113)	0.046(0.178)	-0.009(0.065)	-0.034(0.091)	0.069(0.053)	-0.068(0.082)	0.030(0.036)	0.038(0.059)	-0.008(0.019)	0.042(0.051)
Fats and oils retail lags										
$\Delta \ln \text{Fatret}, t-1$	0.087(0.177)	-0.335(0.281)	0.159(0.102)	0.438(0.143)**	0.021(0.084)	0.038(0.129)	-0.036(0.057)	-0.215(0.092)**	-0.022(0.031)	0.071(0.081)
$\Delta \ln \text{Fatret}, t-2$	0.163(0.172)	0.090(0.272)	-0.037(0.099)	0.212(0.139)	0.004(0.081)	-0.247(0.126)	-0.060(0.055)	-0.137(0.089)	0.007(0.030)	0.108(0.078)
Consumption propensity lags										
$\Delta \ln \text{Propensity}, t-1$	0.768(0.485)	0.117(0.767)	-0.164(0.279)	1.318(0.391)**	-0.292(0.229)	-0.386(0.354)	-0.092(0.156)	-0.794(0.251)**	-0.039(0.086)	-0.316(0.221)
$\Delta \ln \text{Propensity}, t-2$	1.009(0.507)**	-0.909(0.802)	-0.0004(0.292)	-0.259(0.409)	-0.333(0.239)	0.068(0.369)	-0.359(0.162)**	-0.768(0.263)**	-0.039(0.089)	-0.061(0.231)
Diesel lags										
$\Delta \ln \text{Dieselt}, t-1$	0.163(0.217)	0.032(0.346)	-0.162(0.126)	-0.081(0.176)	-0.036(0.139)	0.201(0.159)	0.146(0.070)**	0.093(0.113)	-0.025(0.039)	0.318(0.099)**
$\Delta \ln \text{Dieselt}, t-2$	-0.392(0.225)	-0.453(0.356)	-0.077(0.129)	0.073(0.181)	-0.212(0.101)**	-0.052(0.164)	-0.102(0.072)	-0.768(0.263)	-0.063(0.039)	0.005(0.102)
R^2	0.486	0.257	0.277	0.467	0.558	0.545	0.436	0.398	0.41	0.34
Adjusted R^2	0.38	0.105	0.129	0.358	0.468	0.452	0.32	0.275	0.289	0.205
No. of observations	150	150	150	150	150	150	150	150	150	150
F-statistic	4.605***	1.688***	1.868***	4.281***	6.163***	5.843***	3.768***	3.233***	3.397***	2.517***
Diagnostic tests										
Portmanteau test for serial correlation :										
-Chi-squared (P-value): 1344(0.251)										
Arch-LM test:										
-Chi-squared (P-value): 7920(0.998)										
White's test for heteroskedasticity:										
-Test statistic (P-value): 3500(0.136)										

Meatprod, Eggprod, Dairyprod and Fatprod are the producer prices of meat, eggs, dairy and fat and oil respectively. Meatret, Eggret, Dairyret and Fatret are the retail prices of meat, eggs, dairy and fat & oil respectively. t is time, with t-1 and t-2 being lags of one month and two months respectively. *** and ** mean significant at 1% and 5% respectively. Standard errors are in brackets and are robust to heteroscedasticity and autocorrelation.

Table A.2: Vector Error Correction Model Results

A.3 Retail Sale Index



Figure A.3: Changes in the retail sale index (July 2001 to December 2013)

A.4 Impulse Response Function

A.4.1 Meat Market

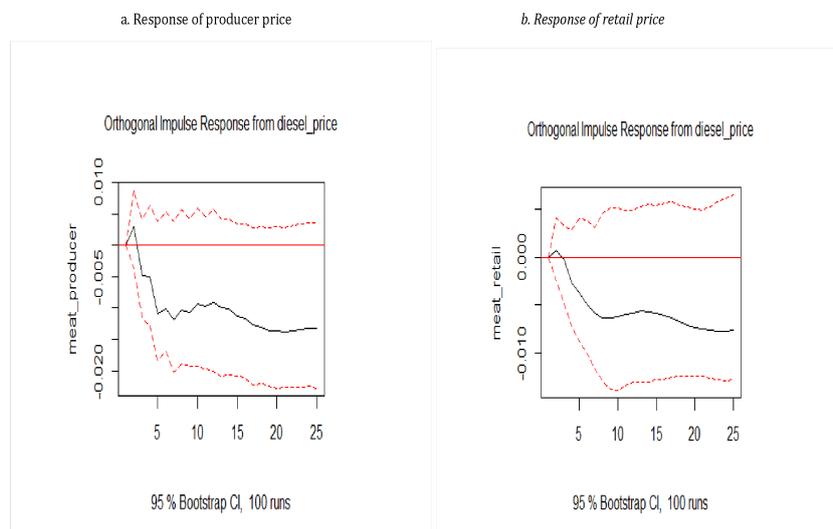


Figure A.4: Response of meat prices to diesel price

A.4.2 Egg Market

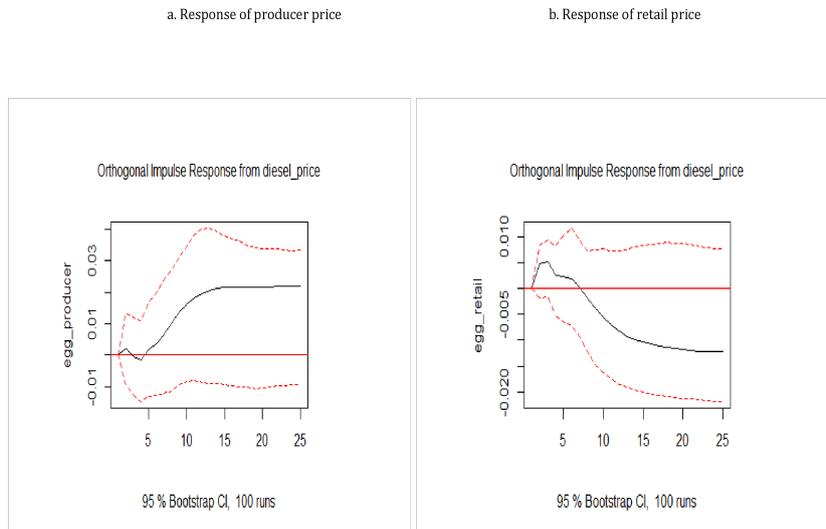


Figure A.5: Response of egg prices to diesel price

A.4.3 Dairy Market

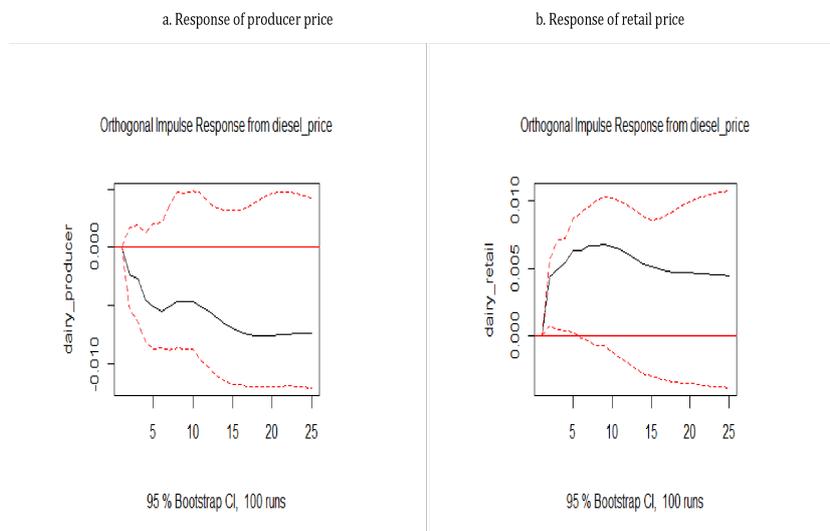


Figure A.6: Response of dairy prices to diesel price

A.4.4 Fats and oils Market

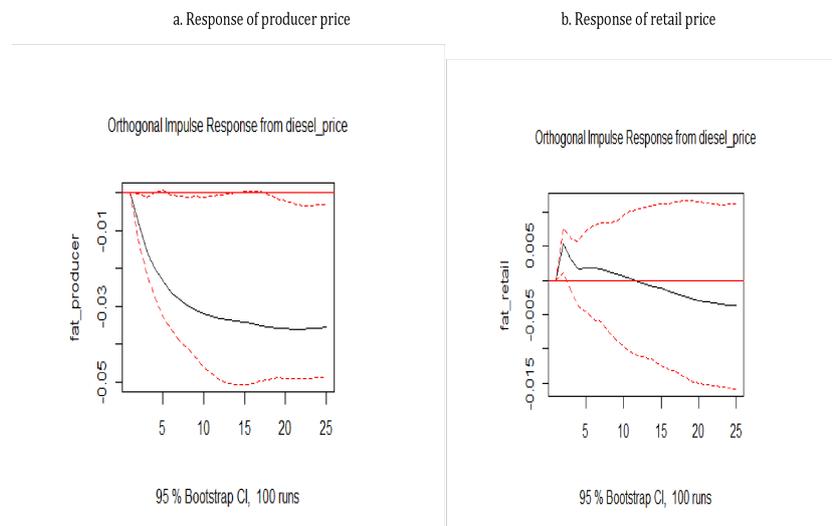


Figure A.7: Response of oil prices to diesel price