FAMINE EARLY WARNING SYSTEMS NETWORK TECHNOLOGY SUPPORT CONTRACT (FEWS NET TSC)

SPATIAL ANALYSIS OF MARKET INTERACTIONS FOR EARLY WARNING PURPOSES

June 2014

This publication was produced for review by the U.S. Agency for International Development. It was prepared by Kimetrica LLC under contract number AID-OAA-C-11-00171

DISCLAIMER

The authors' views expressed in this publication do not necessarily reflect the views of the United States Agency for International Development or the United States Government

CONTENTS

1 PROBLEM STATEMENT 4

1.1 IMPLICATIONS OF PRICE CHANGES FOR FOOD ACCESS/FAMINE 4
1.2 OVERVIEW OF THE CURRENT USE OF PRICE AND MARKET ANALYSIS IN EARLY WARNING 2
1.3 RELEVANCE OF A SPATIAL ANALYSIS OF MARKETS AND PRICES TO EARLY WARNING 3

2 CENTRAL CONCEPT OF MARKET INTEGRATION 3

2.1 DEFINITION 3
2.2 DETERMINANTS 4
2.3 PRICE TRANSMISSION 5
2.3.1 IMPLICATIONS FOR PRODUCERS AND CONSUMERS 5
2.3.2 IMPLICATIONS FOR EW ANALYSIS 6
2.3.3 IMPLICATIONS FOR EMERGENCY PROGRAMS 7
2.3.3.1 MARKET DISINCENTIVE EFFECTS 7
2.3.3.2 OPERATIONAL COSTS OF CASH VERSUS IN-KIND AID 8

3 SPATIAL ANALYSIS OF MARKETS 8

3.1 MARKET CATCHMENT ZONES (MARKET-TO-MARKET ANALYSIS) 8
Figure 1. Hypothetical regional market shed based on 'natural limits' of national and cross-border trade flows between large assembly markets and demand centres 9
3.1.1 INTEGRATING CONCEPT OF MAREKT INTEGRACTION INTO PRICE ANALYSIS (SPATIAL/TEMPORAL RELATIONSHIPS BETWEEN PRICE MOVEMENTS ACROSS MARKETS) 10
3.1.2 IDENTIFIYING "LEADING" MARKETS 10
3.1.3 CLARIFYING CONTRADITORY PRICE SIGNALS ACROSS MARKETS 11
3.1.4 PROVIDING A BROADER SPATIAL CONTEXT FOR PRICE ANALYSIS 11
3.2 PRICES FACED BY PRODUCERS AND CONSUMERES IN NON-MARKET LOCATIONS (MARKET-TO-VILLAGE ANALYSIS) 12
3.2.1 BROADER SPATIAL IMPLICATIONS OF PRICE CHANGES OBSERVED IN MARKETS 12
3.2.2 POPULATIONS/LIVELIHOOD GROUPS AFFECTED BY PRICE CHANGES 12
Figure 2. Hypothetical local market shed based on local trade flows between wholesale and retail markets or estimates based on market size 13
Figure 3. Hypothetical retail market catchment areas based on market size and access 14
3.2.3 NEED FOR CONTINUOUS PRICE SURFACES 14
3.3 MARKET INTEGRATION AND EMERGENCY PROGRAM PLANNING (ALSO A MARKET-TO-VILLAGE ANALYSIS) 15
3.3.1 NEED TO EXPLOIT MARKET STRUCTURE AND MITIGATE DISINCENTIVE EFFECTS OF TRADITIONAL FOOD AID 16
Figure 4. Hypothetical regional and local market sheds with prices known for all markets 16
3.3.2 REQUIRES A DIRECT MEASURE OF MARKET INTEGRATION FOR CRISIS AFFECTED AREAS WHERE THERE ARE NOT LIKELY TO BE OBSERVABLE PRICES NECESSARY FOR TRADITIONAL ECONOMETRIC ANALYSIS 17
Figure 5. Hypothetical regional and local market sheds with prices known only for main markets 17

4 REVIEW OF METHODS (INCLUDING EXAMPLES AND LITERATURE REVIEW) THAT LINK MARKETS TO MARKETS AND MARKETS TO COMMUNITIES/POPULATION 18

4.1 EXAMPLES/LITERATURE REVIEW 18

4.1.1 ECONOMETRIC METHODS RELY ON OBSERVED PRICE DATA. USEFUL, BUT CAN'T INFORM SPECIFIC QUESTIONS OF INTEREST. 18

4.1.1.1 Level 1: price correlation 18

4.1.1.2 Level 1: Dynamic regression 19

4.1.1.3 Level 2: Switching regime methods 19

4.1.1.4 Level 3: Price and trade flows 19

4.1.2 QUALITATIVE ASSESSMENTS SIMILARLY NOT ABLE TO COVER ALL AREAS OF INTEREST. MAPPING OF CATCHMENT ZONES IMPRECISE. QUALITATIVE MAPS CAN BE REFINED AND VALIDATED BY A DATA-DRIVEN APPROACH. 20

4.1.2.1 Expert opinion 20

4.1.2.2 Trader and community level surveys 20

4.1.2.3 Household surveys 21

4.1.3 GEOGRAPHIC MODEL OF ACCESSIBILITY USING FRICTION OF DISTANCE MODELS, MORAN'S I-STATISTIC, GRAVITY MODELS, AUGMENTED GRAVITY MODELS, HUFF MODELS, TRADE AREA ANALYSIS MODELS, KRIGING, AND SPATIAL BAYESIAN PROBABILITY MODELS. 21

4.1.3.1 Gravity models 21

Figure 6. Hypothetical trade flows (T) between main markets based on a gravity model with supply (S), demand (D) and distance (d) as inputs 24

Figure 7. Hypothetical prices per unit (P) among main markets based on a gravity model with trade flows (T), and transaction costs per unit (TC) as inputs to balance demand (D) and supply 26

Figure 8. Markets within range of village x 29

Table 1. Calculation of probabilities of exchange with markets within range for village x 29

Figure 9. Within range markets with highest probability for each village 30

Figure 10. Catchment area for each market based on comparison of probabilities (probabilities interpolated between villages using IDW distance decay exponent = 2, and 12 nearest neighbours) 32

4.1.3.2 Friction of distance 33

4.1.3.3 Continuous flow models 34

4.1.3.4 Spatial auto-correlation, Geo-statistics and Spatial Bayesian probability models 35

4.1.3.5 Agent-based models 36

4.2 NEED A METHOD THAT EMPLOYS DATA SETS WITH UNIVERSAL COVERAGE TO LINK POPULATIONS IN NON-MARKET COMMUNITIES TO MARKETS (MARKET-TO-VILLAGE ANALYSIS). 36

Figure 11. Catchment areas based on equal attractiveness and distance only 36

Figure 12. Main and local markets in Rwanda (source unknown) 39

4.3 WHICH METHOD/METHODS MOST APPROPRIATE TO THE SPATIAL ANALYSIS OF MARKETS FOR EW PURPOSES? 41

4.3.1 HOW ARE PRICE ANOMALIES LIKELY TO BE TRANSMITTED THROUGH A MARKET SHED (A MARKET-TO-MARKET ANALYSIS) TO LOCAL MARKETS WHERE PRICES ARE NOT ROUTINELY MONITORED UNDER DIFFERENT SHOCK CONDITIONS? 41

4.3.2 WHAT IS THE POPULATION THAT RELIES ON MARKETS THAT EXPERIENCE PRICE ANOMALIES? 42

4.3.2 HOW SUSCEPTIBLE AND VULNERABLE IS THE POPULATION TO ANOMALOUS PRICE RISES (A COMMUNITY-LEVEL ANALYSIS)? 43

5 PROPOSAL FOR PROOF OF CONCEPT/CASE STUDY 43

5.1 PROPOSED METHODOLOGY / ACTIVITIES 43

5.1.1. GRAVITY MODEL OF TRADE FLOWS AND PRICE FORMATION 43

5.1.1.1 First stage – balancing supply and demand 43

5.1.1.2 Second stage – price formation 44

5.1.2. HUFF RETAIL MODEL OF LOCAL MARKET CATCHMENTS 45

5.1.3. ASSESSMENT OF THE POPULATION VULNERABLE TO ANOMALOUS PRICE RISES 45

5.2. DATA REQUIREMENTS AND AVAILABILITY 45

5.2.1. MARKET LOCATION AND PRICES 45

Table 2. Number of markets with prices for maize and sorghum in East Africa (Source: FEWS NET) 46

Table 3. Sources of spatial data with number of locations, names and population in East Africa 46

5.2.2. SUPPLY AND DEMAND 48

Table 4. Sources of statistical data on crop production for maize and sorghum for selected countries in East Africa 48

5.2.3. DISTANCES, TRANSPORT COSTS AND MARKETING MARGINS 49

5.2.4. LIVELIHOOD ZONES 49

5.3. HOW WOULD WE VALIDATE THE RESULTS? COMPARE TO ECONOMETRIC ANALYSIS (IS THIS POSSIBLE)? COMPARE FEWS NET MAPS OF MARKET BASINS DERIVED FROM QUALITATIVE, KEY INFORMANT APPROACHES? 49

5.3.1. FIRST STAGE – BALANCING SUPPLY AND DEMAND 49

5.3.2. SECOND STAGE – PRICE FORMATION 49

5.3.3. HUFF RETAIL MODEL OF LOCAL MARKET CATCHMENTS 49

5.4. DELIVERABLE OUTLINE 50

5.5. TIMEFRAME 50

6. REFERENCES 51

1 PROBLEM STATEMENT

1.1 IMPLICATIONS OF PRICE CHANGES FOR FOOD ACCESS/FAMINE

The links between food prices and famine are implicit in the concept of food security which was formalised during the World Food Summit of 1996 and the subsequent declaration and plan of action (World Food Summit, 1996). Food security is a notion which has been steadily modified to reflect its widening application: from nations - where food availability is paramount (Sarris and Taylor, 1976, Weckstein, 1977, Reutlinger, 1978), to households - where access is important (Rukuni and Eicher, 1988, Campbell, 1991, Ali and Pitkin, 1991, World Bank, 1986, Sen, 1981), and thereafter to the nutritional value, preparation and utilisation of food and intra-household dynamics (Karugia, 2011). A further dimension – stability - has been proposed and reflects the fact that food security is a dynamic concept and can only be visualised and assessed over a period of time (Pingali et al., 2005, Gittelsohn et al., 1998, Coates, 2013).

Research on food commodity prices and their implications for hunger and famine have followed a similar pattern to the changing concept of food security with an early emphasis on global production and stocks of commodities and debate about the most effective ways of ensuring price stability and insurance against famines (Sarris and Taylor, 1976). It was well understood that at the global level even the most dramatic of crop failure ought to have only a limited effect on crop prices if everyone had access to the “entire supply of grain” (Weckstein, 1977). Following Sen (1981) more attention was paid to household ‘food entitlements’ and it became clear that the volatility of prices had differing impacts on both households and countries according to their purchasing power, whether a household was a net buyer or seller of food, and also according to the consumption and production patterns of the commodity itself. Consequently different groups of households were identified as being particularly vulnerable to changes in prices (Feleke et al., 2005) such as the urban poor, the rural population without land (World Bank, 1986), those dependent on remittances (Caracciolo and Santeramo, 2013), female-headed households (Karugia, 2011), or those in institutions (International Food Policy Research Institute, 2008).

The link between price changes and famine could be seen where multiple households experienced conditions whereby their assets and exchange entitlements did not enable them to acquire sufficient food. Often famines occurred not because of lack of availability but because large numbers of households experienced shifts in their food entitlements (Watts and Bohle, 1993). These shifts were often related to changes not just in commodity prices but also in the ‘terms of trade’, which implies analysis of labour markets and the relationships between prices of different commodities (Gittelsohn et al., 1998, Maxwell, 1999, Devereux, 2002, Minot et al., 2006, Araujo et al., 2012) and production inputs (e.g. WFP, 2008).

More recent research has tended to concentrate on the policy issues that can alleviate price changes of commodities, whether as part of broad social security programmes (Timmer, 2000), national commodity stock management and trade (e.g. Devereux, 2002, Haggblade et al., 2008) or international food aid (e.g. Maunder, 2006). Meanwhile the food price rises in 2007/2008 resulted in renewed interest in food security (e.g. WFP, 2009, (Karugia, 2011) not least in terms of its impact on social cohesion.

1.2 OVERVIEW OF THE CURRENT USE OF PRICE AND MARKET ANALYSIS IN EARLY WARNING

Markets are understood to be the complete system that allows for goods and services to be traded and moved from areas of surplus to areas of deficit in order to respond to demand (Mukeere, 2009). As such, they are a crucial component of food security and have historically supported labour specialisation, urbanisation and economic growth by removing the direct link between people and the production of food. However, markets which are uncompetitive, inefficient and unreliable can be a constraint to household food security (WFP, 2010).

Markets are the rules and regulations, the actors (their relationships, power and roles), the physical infrastructure, and the information that allow for the movement of goods and services. The flow of agricultural produce is often conceived of as a chain between a producer and a consumer, along which value is added by actors, for example through quality control and selection, transportation, storage, processing and packaging. At each stage the price per unit varies to reflect costs associated with value addition, profits taken by actors (Mukeere, 2009), the negotiating power of the actors (WFP, 2010) and the size of the transaction. Prices are the manifestation of the value added as well as all the available information about actual and future supply and demand. As a consequence prices – and markets - are linked to food security crises in three main ways (FEWS NET, 2009b): (1) they are affected by shocks (e.g. Tusiime et al., 2013); (2) they are part of the response to shocks (Michelson et al., 2012, WFP, 2010, Sabates-Wheeler and Devereux, 2010, Albu, 2010, (Shin, 2010)), and ; (3) they are affected by response to shocks (Lentz et al., 2013, Garg et al., 2013, Awokuse, 2011, Sabates-Wheeler and Devereux, 2010). The analysis of prices as a component of broader market studies for food security in general must consider all three of these links between markets, prices and shocks, however the first of these is most relevant for famine early warning in particular.

Prices are monitored as part of early warning systems (EWS) not just for traded food commodities (e.g. Coates, 2013) but also for other goods and services which affect the costs along the value chain (such as fuel for transportation), as well as those non-tradable goods and services which combine to form the different terms-of-trade relationships which are important for specific geographical areas or for socio-economic groups of households or individuals (e.g. WFP, 2014, WFP, 2013a, WFP, 2013b). The context of the magnitude and change in prices is extremely important, since these must be analysed in comparison to previous years at the same point in time as well as in comparison to prices elsewhere and with regard to general fluxes in supply and demand. This implies that prices need to be monitored at many different locations, at regular intervals (FEWS NET, 2009b) and for many goods and services. Price thresholds can therefore be calculated (Mukeere, 2009) and estimates made of the population that is likely to suffer food insecurity, and anomalies (WFP, 2014) can be identified before they cause long-term impacts.

Prices may reflect trader perceptions of forthcoming conditions of supply and demand but are unlikely to incorporate other more stochastic future shocks such as climatic events, political instability or the impacts of food aid itself (Sabates-Wheeler and Devereux, 2010). This implies that market studies for early warning must also consider the susceptibility of all the market components (transport, supply, storage facilities) to those kinds of shocks (FEWS

NET, 2009b, Winograd et al., 1999), and the likely impact on prices and subsequent decrease in food availability and access.

1.3 RELEVANCE OF A SPATIAL ANALYSIS OF MARKETS AND PRICES TO EARLY WARNING

Food prices reflect the general balance between supply and demand of agricultural products and the efficiency of the market. The costs of balancing supply and demand have an explicit spatial component since agricultural produce need to be transported to specific locations along the value chain. Early warning needs to analyse the flows between these locations in order to assess the changes in prices that occur and the causes of those changes (WFP, 2013), the risk of interruptions due to spatially explicit shocks (Mukeere, 2009, FEWS NET, 2009), and how individual markets respond to shocks.

Supply of food depends on the general availability of food in a certain region or country, which is dependent on both current and future levels of agricultural production within and at differing proportions outside the region. A spatial analysis of agricultural production is therefore an important component of this contribution to food prices (Brown et al., 2008). Spatially explicit seasonal weather forecasting (Patt et al., 2007) as well as within-season monitoring of weather and vegetation response are both relevant early warning tools for assessing the potential availability of food within a specific country or region (FEWS NET, 2014a) .

The demand for specific food products and the differences in terms-of-trade exchanges also vary according to the geographical context. While each household will have different needs and preferences they can be grouped according to their livelihood strategies and activities and their subsequent vulnerability to anomalies in prices (Boudreau, 1998). Livelihood zones are areas which are typified by specific groups of households and which often have well defined geographic boundaries, based on elevation, rainfall, temperature or ethnicity and which have identified market locations (e.g. (Boudreau, 2007).

Other components of the broader food assistance context which require spatial analysis are the food assistance interventions themselves. Both in-kind, and cash or voucher assistance need to be delivered to the targeted populations, implying that the size of the population (in the catchment area of a market or food distribution point) is known, and that the capacity of the market or the delivery mechanism is well understood (WFP, 2013). Spatial analysis can highlight those areas and the size of the population that is not covered by a specific intervention (Farrow et al., 2011), as well as the likely effects on prices of local procurement (for food aid) in different market locations (Garg et al., 2013, Michelson et al., 2012, Tadesse and Shively, 2009).

2 CENTRAL CONCEPT OF MARKET INTEGRATION

2.1 DEFINITION

Two types of market integration are often considered – vertical and spatial. Vertical market integration refers to the linkage of prices vertically within a market for a particular product, for example between wholesaler and a retailer (Rashid et al., 2010, Negassa, 1998). Of more relevance for famine early warning is spatial market integration, which focuses on price

relationships among geographically distinct locations where a product is bought and sold, over a (long) period of time (Mukeere, 2009). The ability of markets to respond to supply and demand for food over time via trade or arbitrage and to reduce price volatility and where price changes in one market consistently reflect changes elsewhere can be referred to as spatial market integration (Shin, 2010, Baulch et al., 2008, Van Campenhout, 2007,(Faminow and Benson, 1990, Van Campenhout, 2007). The integration of markets can provide benefits for both producers in surplus areas by allowing the movement of products and increasing farm gate prices, and for consumers in deficit areas where an influx of goods reduces prices (Fiamohe et al., 2013, Ihle et al., 2011, Mukeere, 2009, Fackler and Tastan, 2008). Similarly the effects of a supply or demand shock are transmitted to other markets via price changes more directly in an integrated market (Fackler and Goodwin, 2001), Gezahegn, 2009, Barrett and Li [2002] in Sanogo, 2008). Non-integrated markets are therefore often insulated from shocks elsewhere but a more local demand or supply crisis can have a larger impact than if the market were better integrated. Different levels of market integration exist, such as the integration of a country market with the global market but the most relevant for famine early warning where food aid can overcome a lack of access to world markets is the integration of regional and local markets within a single country.

The two components - tradability and arbitrage - are often separated in the literature and have implications on the definitions of market integration and relate to the kinds of data that need to be analysed. Some authors distinguish between *market integration* in which there is trade between markets regardless of whether other more optimal trade or arbitrage opportunities exist and are exploited, and competitive *market equilibrium* in which there is an equilibrium of prices regardless of whether goods are physically traded among markets (Barrett and Li, 2002). For famine early warning the second concept is important because of the effectiveness of the market to optimise local food availability and access, but the concept and ease of tradability is an important determinant of this equilibrium of prices and trade is essential for areas where there is insufficient food.

2.2 DETERMINANTS

The determinants of spatial market integration are essentially those factors that constrain or favour trade or arbitrage, whether the friction of distance or time, policies and regulations on trade, or the availability of information about price differences that provide an incentive for trade (Shin, 2010, Rashid et al., 2010, Gezahegn, 2009).

Many of these factors imply varying levels of transaction costs that have the potential to impede trade. Where transaction costs are greater than the difference in prices among locations then there is no incentive for trade (Alemu and Biacuana, 2006, Faminow and Benson, 1990). The other component of spatial market integration is the speed of price adjustment which depends on the communication of prices across the region (Van Campenhout, 2007).

The determinants of large transaction costs, and consequently of poor integration, are transport costs which cover the deterioration of vehicles due to poor quality roads, fuel and labour costs, bribes at checkpoints or the physical impossibility of moving between regions where there are no roads or where roads are frequently impassable due to floods or landslides (Alemu and Biacuana, 2006, Negassa, 1998, Takamatsu, 2002, Van

Campenhout, 2007). Further costs are incurred where products need to be stored (Negassa, 1998) or reloaded at intermediate points such as borders.

Other infrastructure or policies may not directly increase costs but will have an effect on the likelihood of trade at a particular location, such as a lack of risk management (credit, insurance) (Rashid et al., 2010), restrictions on the movement of agricultural products (Negassa, 1998), on pricing controls which are disincentives to trade (Jayne and Jones, 1997, Rashid et al., 2010), the volatility of government interventions (Goletti et al., 1995), or the lack of communication infrastructure to relay market information (Negassa, 1998). In contrast the existence of traditional trade routes (Fafchamps and Gavian, 1996, WFP, 2013) may enhance market integration.

2.3 PRICE TRANSMISSION

Price transmission is the result of multiple exchanges between buyers and sellers of agricultural commodities in such a way that price signals resulting from current and predicted production, demand, and transport shocks (Mofya-Mukuka and Abdulai, 2013) are transmitted throughout a market network, either through direct trade or spatial arbitrage (Fackler and Goodwin, 2001, Getnet et al., 2005, Barrett and Li, 2002). As with market integration, price transmission can occur horizontally among spatially separated markets at the same point in the value chain, and vertically among actors at different points in the value chain. In addition price transmission can occur indirectly between separate commodity supply chains by means of substitution, and between agricultural commodities and non-agricultural commodities (Vavra and Goodwin, 2005), (Listorti and Esposti, 2012).

The degree, ratio or efficiency of price transmission is one of the indicators of market integration, with more rapid and extensive transmission associated with greater market integration (Fackler and Goodwin, 2001). As a result, a great deal of empirical research has been dedicated to analysing price transmission as a means of measuring market integration, especially following market liberalisation policies of the past three decades. The topic has also received considerable attention following the global food price crisis of 2007/08 particularly the transmission of global prices to domestic and local markets (e.g. Keats et al., 2010, Benson et al., 2008) and the consequent effects on farmers and consumers.

2.3.1 IMPLICATIONS FOR PRODUCERS AND CONSUMERS

Consumers can benefit from price transmission when it provides incentives for goods from surplus areas to move to deficit areas; similarly producers can benefit from additional demand, access to niche markets and higher selling prices (Fiamohe et al., 2013). However, moving from a regime of government pricing policies to a more liberalised market can increase the risks to producers of unstable prices (Getnet et al., 2005), and the risk to consumers of price increases of staple foods. During the food price shocks of 2007/08 urban consumers in many developing countries suffered due to the transmission of increases in global food commodity prices, although the effect differed according to the commodity (Baquedano and Liefert, 2014), the individual responses of countries (Keats et al., 2010, Schüttel et al., 2011), and the sub-national integration of markets (Cudjoe et al., 2010).

Well integrated markets ought to distribute the benefits and costs of shocks equally among the market participants, and should transmit price decreases at the same speed as price

increases, in what is called symmetric price transmission (Alemu and Ogundeji, 2010). Often, however, price changes are not passed on (or price signals are not transmitted) at the same speed. This asymmetric price transmission is often the result of differences in market power where market information is not available to all, or where certain actors hold dominant positions in the market (Meyer and von Cramon-Taubadel, 2004, Fiamohe et al., 2013, McLaren, 2013).These actors are often 'middlemen' in the value chain between the producer and consumer and can act, sometimes in collusion, to reduce prices paid to producers more quickly (when central prices are lowered) than paying higher prices (when central prices are increased), or they can increase prices for goods sold to retailers more quickly than they reduce their prices (Abdulai, 2000). Other examples of market actors with dominant positions include governments who are able to influence imports, exports and prices (FAO et al., 2011). Price asymmetry can also be seen vertically within the value chain, for example where prices are transmitted efficiently between exporters and assemblers, but not to producers (Fafchamps and Hill, 2008).

Producers are also at risk of lower margins if there is more rapid price transmission of inputs (such as fertilisers), than of commodity outputs (Abbott and de Battisti, 2011).

2.3.2 IMPLICATIONS FOR EW ANALYSIS

Early warning systems (whether national or international) are responsible for monitoring food prices across time and space in order to gauge the magnitude, speed and geographical spread of prices (Badiane et al., 2010). Early warning systems must also evaluate how different levels of price transmission affect food availability, access and to a lesser extent utilisation (Brown et al., 2012).

The existence and degree of price transmission is important for famine early warning because it can be used to predict the impact of different kinds of shocks on the food security of specific groups of people in particular geographic locations. The magnitude of price transmission, i.e. the proportion of price changes that are due to price changes elsewhere, can provide an estimate of the changes in food prices and on the potential ability of households to buy specific commodities according to their current consumption patterns and the proportion of their spending on food. The speed of the transmission is also important because it will determine the time available to plan and implement interventions that can limit the negative consequences on price changes, for both consumers and producers. The direction of price transmission, from a 'leading' market to following markets, will also determine which are the crucial points in the market network to monitor (Badiane et al., 2010). This underlines the fact that price transmission occurs not just within countries but over borders between nations (Abidoye and Labuschagne, 2014), an especially important consideration for landlocked countries where price transmission and access to both import and export markets is dependent on the policies and infrastructure of neighbouring countries.

It is equally important to understand which markets are not affected by prices elsewhere and are not therefore integrated in the market system. Food availability in these locations would therefore depend more on the ability to produce food locally, so early warning systems must pay more attention to shocks to food production in these areas than to global or national prices.

The interactions between different commodities, and between traded and 'non-traded' crops, are also extremely important aspects of the wider food system which will come into play in the event of a price shock for a particular commodity (Abbott and de Battisti, 2011). These interactions need to be understood by the early warning community so that the effectiveness of common coping strategies can be estimated.

2.3.3 IMPLICATIONS FOR EMERGENCY PROGRAMS

As mentioned above changes in food prices are both a cause of reduced access to food and can also be affected by emergency food assistance programs, which seek to improve access to food. Emergency program interventions try and improve access to food by either directly providing food or by improving the terms-of-trade of households providing a cash safety net. In addition, the means of procuring food for 'in-kind' assistance has implications on the price of food commodities depending on where, how and when food is procured. A strategic combination of food assistance interventions and market price transmission can therefore have beneficial impacts on prices in potentially distant locations.

2.3.3.1 MARKET DISINCENTIVE EFFECTS

'In-kind' food assistance is the traditional form of emergency program interventions, especially by international agencies. In the past a large proportion of emergency food aid was from international stocks (Lentz et al., 2013). The distribution of these stocks within a country during an emergency could therefore have implications on prices in parts of the country or region, which might actually already have a surplus of food. Food aid should therefore be considered in situations where there is both a food availability deficit and where the market is not sufficiently integrated either internationally or locally to import or move food from surplus to deficit areas (Maxwell et al., 2008). International food assistance agencies and governments have more recently considered local and/or regional procurement (LRP) where parts of the country or neighbouring region have surplus food availability, but where poor market integration has not allowed trade to move food to move to deficit areas. The effect of LRP on prices will depend on the quantities of food aid which are bought and how well integrated is the market in general and specifically the locations from where food is procured. It is thought that in a well-integrated market the effects of LRP should not cause localised price increases although the lag between a change in price and LRP may be long (Garg et al., 2013) and the behaviour of producers and market actors should be monitored (Tadesse and Shively, 2009).

Disincentive effects can also be experienced in areas where food aid is distributed, in these areas prices are lowered which in some circumstances may cause producers to respond by relying more on food aid instead of the risks inherent in production (Tadesse and Shively, 2009).

In circumstances where markets are well integrated and there is sufficient food availability but at prices which reduce access to food of specific groups of households it is more advisable to consider targeted cash, voucher or employment interventions which will not remove the incentives to producers (by lowering prices) (Maxwell et al., 2008).

2.3.3.2 OPERATIONAL COSTS OF CASH VERSUS IN-KIND AID

There are different costs associated with cash transfer programs, food vouchers, employment for cash, LRP food aid and trans-oceanic food aid (Maxwell et al., 2013). These costs are often not easily comparable due to the different objectives of interventions which are associated with the particular food access and availability crisis, and the nutritional requirements that these imply e.g. fortified foods, or foods for specific groups such as infants (Lentz and Barrett, 2013). Costs associated with food aid include ocean freight and internal transportation, and handling (Lentz and Barrett, 2013), as well as preparation of rations where food is distributed at the household or community levels (Hoddinott, 2013). Costs that are associated with cash transfers include contract preparation and bank or 'mobile money' fees (Hoddinott, 2013, WFP, 2013), but in many contexts the costs of cash transfers are less than food transfers (Hoddinott, 2013).

High transaction costs in Africa are often a hindrance to market integration and price transmission, where these costs are due to difficulties of transporting (rather than say market power, tariffs or pricing policies) then there will also be high costs of distributing food but a more cost effective intervention such as a cash or voucher transfer might not be effective if food availability is low and markets cannot respond to increased purchasing power of households that receive cash transfers. Where food aid is appropriate the nature of price transmission can help reduce costs and increase effectiveness by determining the location of interventions. For example, a centralised strategy utilising leading market wholesalers would be more appropriate where markets are moderately well integrated but rely on a central market for setting prices and supplying commodities (Getnet et al., 2005). In contrast a decentralised strategy, where stocks need to be built up or food aid delivered to more regional markets, might be required where there is little market integration (Fackler and Goodwin, 2001).

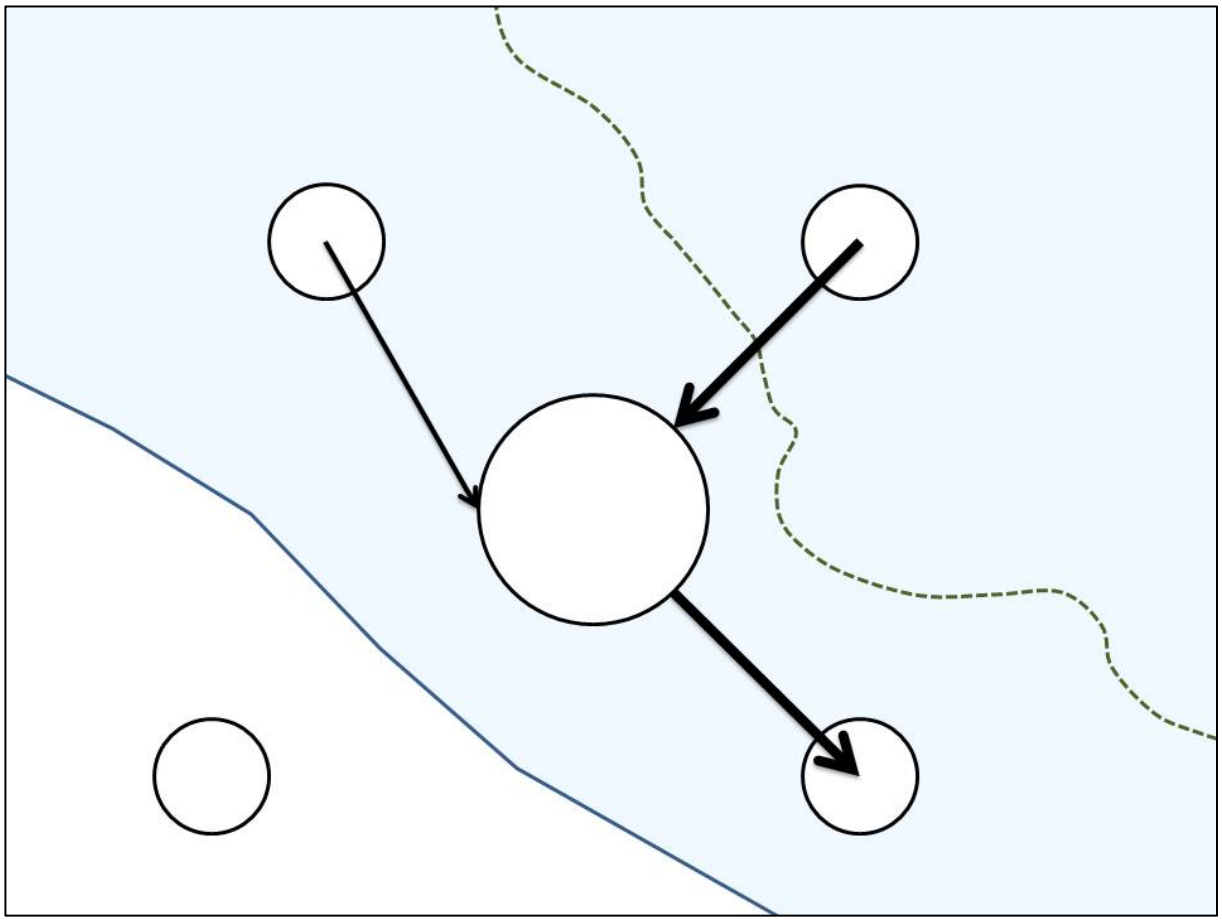
3 SPATIAL ANALYSIS OF MARKETS

3.1 MARKET CATCHMENT ZONES (MARKET-TO-MARKET ANALYSIS)

Catchment areas are also called foodsheds (Harrison et al., 1974), trade basins (FEWS NET, 2009d) and market sheds (Haggblade, 2013, Govereh et al., 2008, Haggblade et al., 2012) although there are differences in how these are defined, and applied. The application of market sheds for regional trade in Africa (Haggblade, 2013, Govereh et al., 2008) consider the market shed as *"a network of deficit markets linked by common supply lines. This definition implies common price movements within the market shed. It also suggests a formal definition from the trade literature as all supplying areas able to serve a given market within import and export parity price bands"* (Haggblade et al., 2012) This conception of market sheds includes major producing areas for a particular commodity crop and the major urban demand centres, in this sense it is consistent with the commodity specific market network maps produced at the country level by FEWS NET (2009a, 2009c). At the regional level the boundaries of particular market sheds are dynamic, changing from year to year according to the patterns and intensity of production (e.g. Aliguma et al., 2008), as well as vagaries in demand, and trade policies (Govereh et al., 2008). Nevertheless, the major market sheds in Africa are relatively stable due to slow changes in transport costs (cf. Shakya et al., 2012), production areas and consumer preferences.

The catchment zones can be considered at different levels in the supply chain and it is common to distinguish between wholesale or retail exchanges (WFP, 2011). By analysing all farm gate, aggregation, wholesale and retail trade movements over time it is possible to map the volume of and extent of commodity flows, or for specific customers it is possible to define the probability of an interaction with a specific trader based on frequency and volume (Segal, 1999). Due to the greater volumes involved in wholesale trade there are economies of scale which allow for trade over greater distances (which incur greater absolute costs) and between larger traders, as such the catchment areas for wholesale traders tend to be larger than for an individual retailer (WFP, 2013). These individual relationships can then be aggregated to produce a map of contiguous or non-contiguous catchment areas for specific traders. At the moment not all these data are collected and instead catchment areas tend to be based on an analysis of aggregate flows of trade between markets (e.g. (WFP, 2013), whose borders (Figure 1) represent the 'natural limits' of the movement of a commodity (WFP, 2011, Haggblade et al., 2008), or on assumptions of the spheres of influence of different kinds of markets (Tracey-White, 2005, Wright et al., 2002, Hoover and Giarratani, 1999, Massey Jr and Blake, 1987). Analysis of prices, however, offers a complementary means of defining market catchment areas (Zant, 2012).

Figure 1. Hypothetical regional market shed based on 'natural limits' of national and cross-border trade flows between large assembly markets and demand centres



3.1.1 INTEGRATING CONCEPT OF MAREKT INTEGRACTION INTO PRICE ANALYSIS (SPATIAL/TEMPORAL RELATIONSHIPS BETWEEN PRICE MOVEMENTS ACROSS MARKETS)

As explained above competitive market equilibrium is both measured by, and leads to, price transmission between markets. Following Haggblade et al. (2012's) definition of market sheds above, the catchment of a particular market can be determined by the degree to which prices are transmitted throughout a network. Analysing price transmission is therefore an alternative method of defining the influence of particular market centres without necessarily monitoring the origin and destination of every trade exchange, indeed spatial price analysis has been used to determine the boundaries of regional commodity markets, and forms the theoretical basis for market areas (Bressler and King, 1970) and market location.

At the same time it is necessary to look at the tradability component of market integration in order to better understand the context of the equilibrium of prices and the barriers that a lack of integration places before the effective functioning of markets.

3.1.2 IDENTIFIYING "LEADING" MARKETS

The concept of leading market incorporates explicitly the temporal dimension and presupposes that prices in the 'leading market' at a particular point in time 'cause' future prices in other spatially separate markets. Brorsen et al, 1985 in (Fackler and Goodwin, 2001) suggest that the lead market may be able to transmit price signals due to the larger volume of a commodity being traded at a particular market relative to other locations.

While actual trade flows can be measured it is difficult to collect all the information that is combined in price formation so prices, especially consistent high frequency prices are an essential useful source of data. Identifying leading markets using only price information requires the use of 'Granger causality' tests which show whether there is a statistical relationship between the prices of markets across time (Granger, 1969), and the direction of that relationship (Araujo et al., 2012). The results of these analyses do not provide information on the causes of the price changes and need to be interpreted in combination with other qualitative or quantitative information on trade flows or market structure (Fackler and Goodwin, 2001). For instance, Van Tilburg et al. (2008) show that potato market integration in Bhutan deteriorated due to the effects on competition of the closure of an auction market, or that millet markets in surplus production zones of Niger generate price signals that were transmitted to deficit zones (e.g. Essam, 2013) but that the relationships were not constant over time. Leading markets can also be the result of the pricing and purchasing policies or the inertia due to market liberalisation, where prices are set by parastatal or privatised marketing boards, and filter through to surplus markets (Badiane et al., 2010, Mason and Myers, 2013, Getnet et al., 2005). Comparisons between commodities often show differences in the lead and lag markets, for instance in northern Ethiopia differences between wheat and teff markets could be due to the local production of wheat and the poor infrastructure which inhibits efficient price transmission (Jaleta and Gebermedhin, 2009).

The identification of leading markets has been used to study the effects of food aid distribution (Tadesse and Shively, 2009), but it is also important for planning other food assistance interventions such as cash transfers (WFP, 2013). FEWS NET country price

bulletins e.g. (FEWS NET, 2014b) have identified markets according to their spatial location, but more importantly for their contribution to the trade of agricultural produce between surplus and deficit areas. In Kenya they identify markets for urban consumers, within surplus production areas, and markets surrounded by deficit areas due to marginal conditions for production and affected by natural shocks, as well as markets that are poorly integrated with dependence on livestock, cross-border trade, or in conflict areas. In a more focused assessment in northern Kenya (WFP, 2013) the main trade corridors are identified from the surplus areas of western and central Kenya. Four different types of market are identified – the capital city, hub markets in the central region, main markets in the arid land and remote markets in the arid lands. The leading markets are the capital city and the hub markets, with the remote markets at the end of the supply chain. More remote markets are characterised by fewer traders, less frequent resupplies, and less competition. Prices are set in the capital and hub markets and are transmitted along the chain, where prices rise due to transport costs and the effects of the lack of competition. Integration of markets is principally along the transport corridors but with some local integration between district and remote markets off the corridor.

3.1.3 CLARIFYING CONTRADITORY PRICE SIGNALS ACROSS MARKETS

Contradictory price signals across markets, i.e. some markets experiencing rising prices while others experience decreasing prices, could be the result of either strong market integration or weak market integration. This will depend on the context of those price changes in terms of the opportunities for trade or arbitrage, access to market information, and the subsequent perceptions and conduct of the market actors (Abdulai, 2000), (Essam, 2013) (Vavra and Goodwin, 2005). For early warning purposes it is important to know if apparently contradictory price signals are the result of lags between leading and following markets which are in the same market shed (following the definition of Haggblade et al., 2012), or whether the markets are in different market sheds, perhaps as the result of 'balkanized markets' (Gráda, 2005). If the level of market integration is known – in terms of leading/following markets, lag characteristics, and determinants – under different production and availability situations (Essam, 2013, Araujo et al., 2012) then anomalies in prices can be put in perspective by comparing with projections (e.g. WFP, 2014), and interventions can be designed to ameliorate subsequent decreases in food access.

3.1.4 PROVIDING A BROADER SPATIAL CONTEXT FOR PRICE ANALYSIS

Price analysis for famine early warning can benefit from a broader spatial context to provide an interpretation that can help the design and implementation of food assistance interventions. A greater understanding of the spatial relationships can provide the background and hypotheses about which markets would be expected to 'cause' prices elsewhere in terms of distance, trade routes, trade volumes, information flows and size of markets. With plausible links between markets, either in terms of trade or arbitrage, provided by spatial analysis it should be possible to improve the efficiency of price analysis by reducing the number of market pairs that are analysed.

Identifying leading markets and the extent of their influence can help define the boundaries of market catchment areas in which prices are transmitted with some confidence in different conditions of food availability (Butler and Moser, 2010). These catchment areas can then be analysed separately in terms of the populations who live in them, and crop and livestock production can be monitored more closely. These market catchments, and the understanding

of price transmission, can also be used to model the effects on longer term food security of different types of food assistance. Country level market catchment areas could appear similar to the East African maize market sheds (Govereh et al., 2008) but the condition that each market shed include major production areas and urban markets (Haggblade et al., 2012) need not be applied at the country level, and may not be relevant for some food crops (like rice which might be dependent on import) or for countries (e.g. Botswana) with little food crop production.

3.2 PRICES FACED BY PRODUCERS AND CONSUMERES IN NON-MARKET LOCATIONS (MARKET-TO-VILLAGE ANALYSIS)

3.2.1 BROADER SPATIAL IMPLICATIONS OF PRICE CHANGES OBSERVED IN MARKETS

Not all markets are monitored for prices, and while mobile telecommunications allow for ever more market information to be shared and discovered (USAID, 2013, Kizito et al., 2012) it is likely that, in the short-term at least, other mechanisms are needed to estimate food and agricultural commodity prices in local markets and the impact on producers and consumers in non-market locations. (Cudjoe et al., 2010) assume that price changes are related to the consumption and production patterns of households and the ability to substitute food products. They assign price changes to markets with no data using data from neighbouring administrative areas with the same agro-ecological conditions.

A number of empirical studies make note of the effects of distance on price transmission among markets. In Ghana (Cudjoe et al., 2010) more remote markets appear to be less well integrated with other markets, similarly distance and ease of transport appear to play a role in market integration in sub-Saharan Africa as a whole (Rashid et al., 2010), in the region of East Africa (Ihle et al., 2011), and within country in Mongolia (Kusano and Saizen, 2013), Nepal (Sanogo, 2008), Kenya (Versailles, 2009), Nigeria (Oladapo and Momoh, 2008), Brazil (Hernández-Villafuerte, 2012), Ethiopia (Getnet et al., 2005, Jaleta and Gebermedhin, 2009), with (Essam, 2013) and (Shin, 2010) attempting to identify distance thresholds of market integration in Niger, and (Brown et al., 2009) doing the same for the broader West African region.

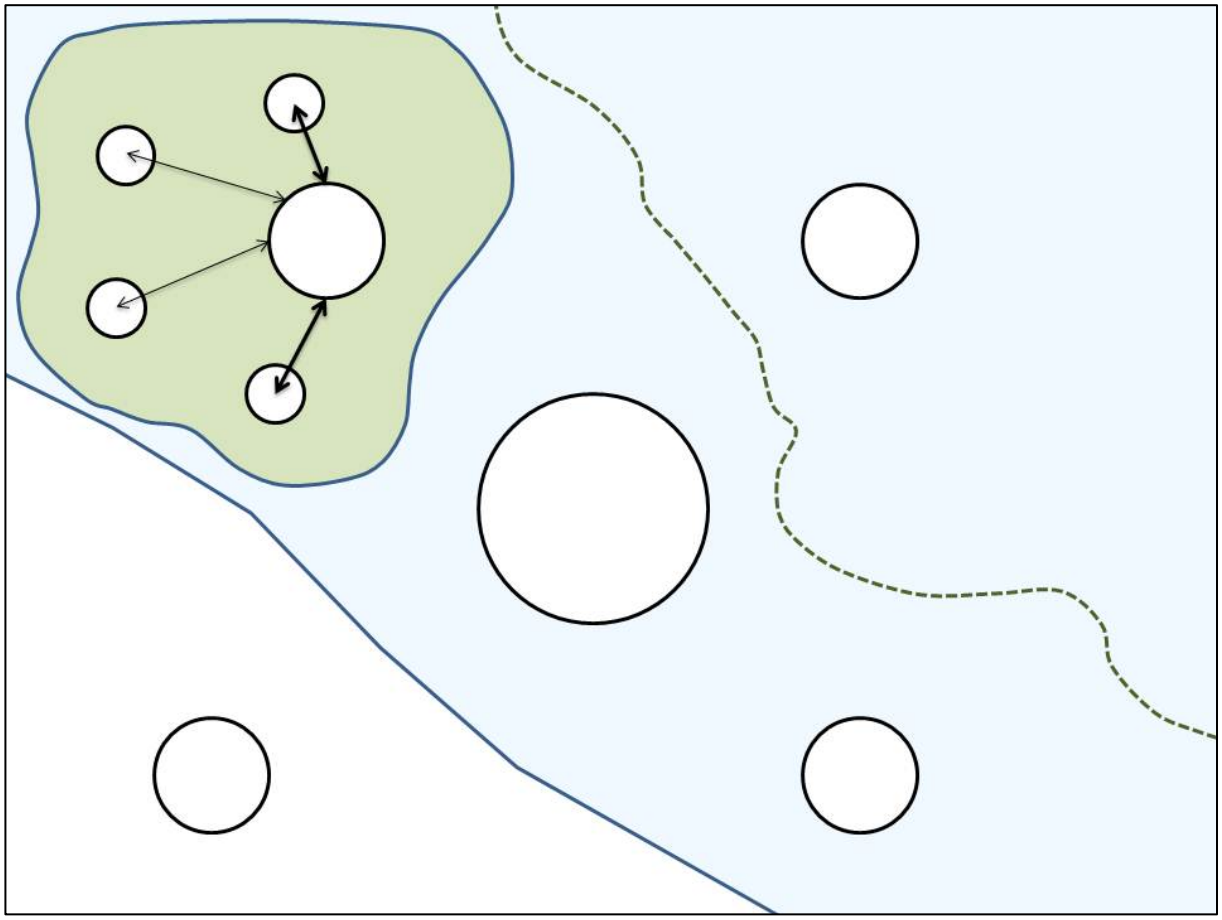
It is therefore likely that distance, ease and cost of transporting agricultural products as well as other factors that require journeys to be taken (such as administrative services, pilgrimages, or recreation) will have an impact on price transmission and can be used in combination with supplementary data on local supply and demand to extrapolate to markets which are not monitored for prices.

3.2.2 POPULATIONS/LIVELIHOOD GROUPS AFFECTED BY PRICE CHANGES

Broad market catchment areas - defined by their degree of market integration and the natural limits of trade - are replicated at the local level. In these cases the market sheds are defined as *"a geographical area and associated population that has real or potential trade relationships with a market center. Within the marketshed there may be several market outlets of varying size and scope, although usually one is dominant in terms of size and function. We use the term marketshed to give the sense of a system or network of market flows within a given area (e.g. it is not just a zone with some markets located in it, but rather*

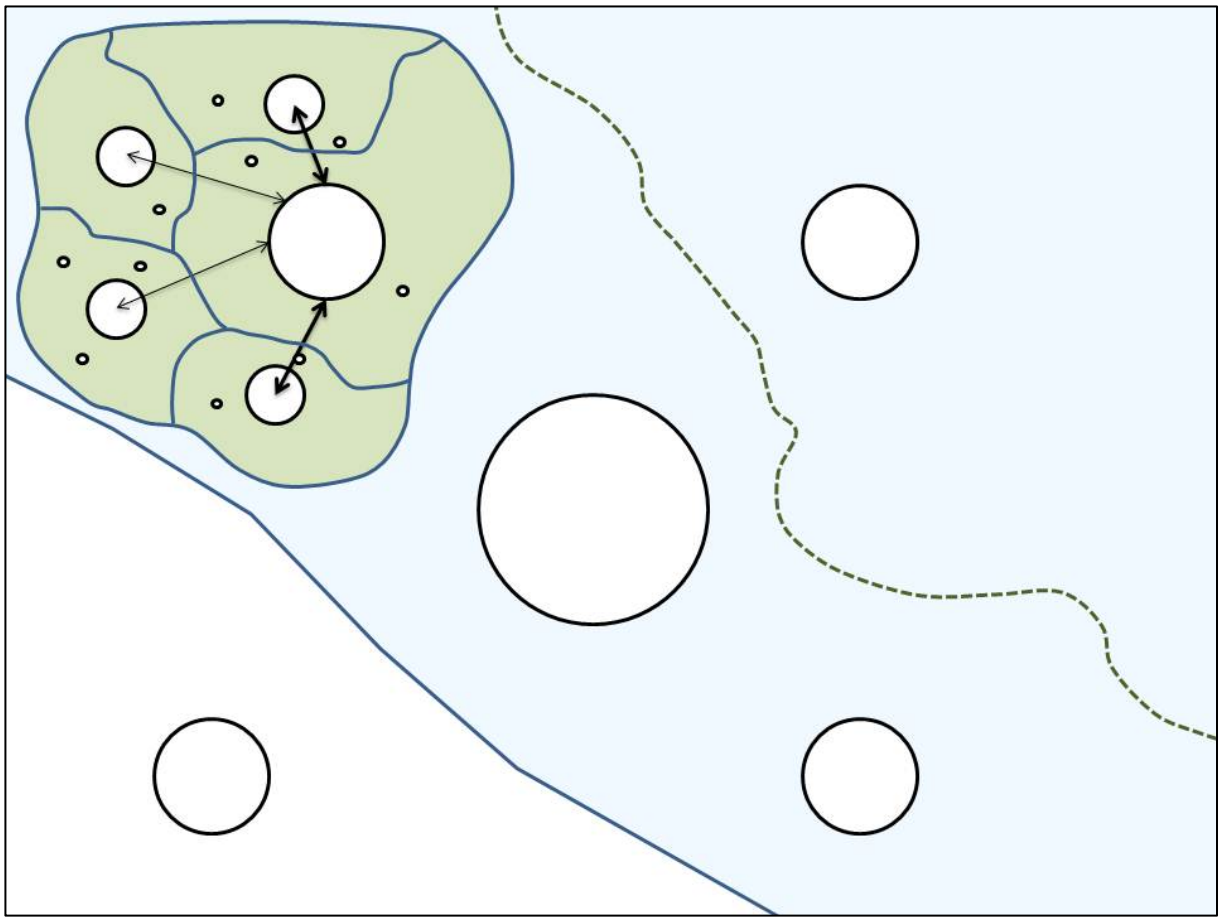
it is a trading network with links between market outlets)" Lipper et al. (2009). This definition is consistent with the idea of a catchment area used by the FEWS NET/WFP/FAO Joint Cross-Border Market and Trade Monitoring Project (FEWS NET et al., 2011) because both consider more than one level of market within the same zone (Figure 2).

Figure 2. Hypothetical local market shed based on local trade flows between wholesale and retail markets or estimates based on market size



Similarly surrounding each individual market is a zone within which are located the suppliers of traders of agricultural commodities (Marocchino, 2009) and the customers of retailers of food products (Figure 3). Often due to their lack of market power both suppliers and customers are price takers (Sexton, 1990) and are also likely to experience asymmetric price transmission, with price decreases (for producers) more rapidly transmitted than price rises. It is therefore important for early warning systems to estimate prices for these populations and evaluate the potential impacts of price anomalies which are monitored elsewhere.

Figure 3. Hypothetical retail market catchment areas based on market size and access



In many countries the livelihood zone descriptions already include an analysis of the susceptibility of different livelihood strategies to specific market shocks (Boudreau, 2007, Boudreau, 1998) and the key local markets for some zones (Livelihood Integration Unit, 2010). A potential tool to help this analysis would be the overlap of livelihood zones with prices in the local market sheds.

3.2.3 NEED FOR CONTINUOUS PRICE SURFACES

Prices in the local market sheds are often, at best, collected only for the main market, so to assess the impacts on livelihoods prices need to be estimated throughout the market shed, forming a price surface. A continuous price surface would allow for the population vulnerable to a food price shock to be quantified. A continuous price surface is intuitively a simple idea but in reality it is likely to be far from smooth, and will be temporally dynamic and spatially complex due to the individual level determinants of price, based on bargaining power

resulting from differential access to market information, and quantities to be traded (Shiferaw et al., 2008). Bearing this in mind it makes more sense to consider price surfaces for different buyers (and sellers) in the value chain – from traders (and producers) to processors and wholesalers to retailers and final consumers (Kuiper et al., 2003).

Prices and price surfaces have been a component of the theory behind economic geography for the past two hundred years. Von Thünen's 1826 treatise on the isolated state provides an analytical framework to investigate the optimal use of land for marginal gains and links land rent to transport costs, distance to market, commodity prices and the yield of land (Hall, 1966). While the output price remains fixed in von Thünen's model and there are no traders, the model shows how producers' profits vary with distance from the market. Theoretical producer price surfaces were also used to define the boundaries between different agricultural processing or storage locations (e.g. (Bressler and King, 1970). 'Site prices' received by producers were a function of actual prices offered by a processor at a central location and the transport costs, which could be linear or some other function, the resulting surface was a cone around the central market with prices reducing with distance. The corollary of this was prices paid by consumers in which the cone is replaced by a funnel with prices increasing with distance (Faminow and Benson, 1990). Boundaries between competing markets are therefore those locations where the combination of price and transfer cost are equal.

Prices are modified by transactions costs but are ultimately determined by the scarcity, demand and supply of the commodity in question. Price surfaces based on production, and the historical links between supply and price, have also been constructed in Africa (Brown et al., 2008) with the additional benefit of projecting prices into the future, however these surfaces are only effective where there is a strong link between local production and prices.

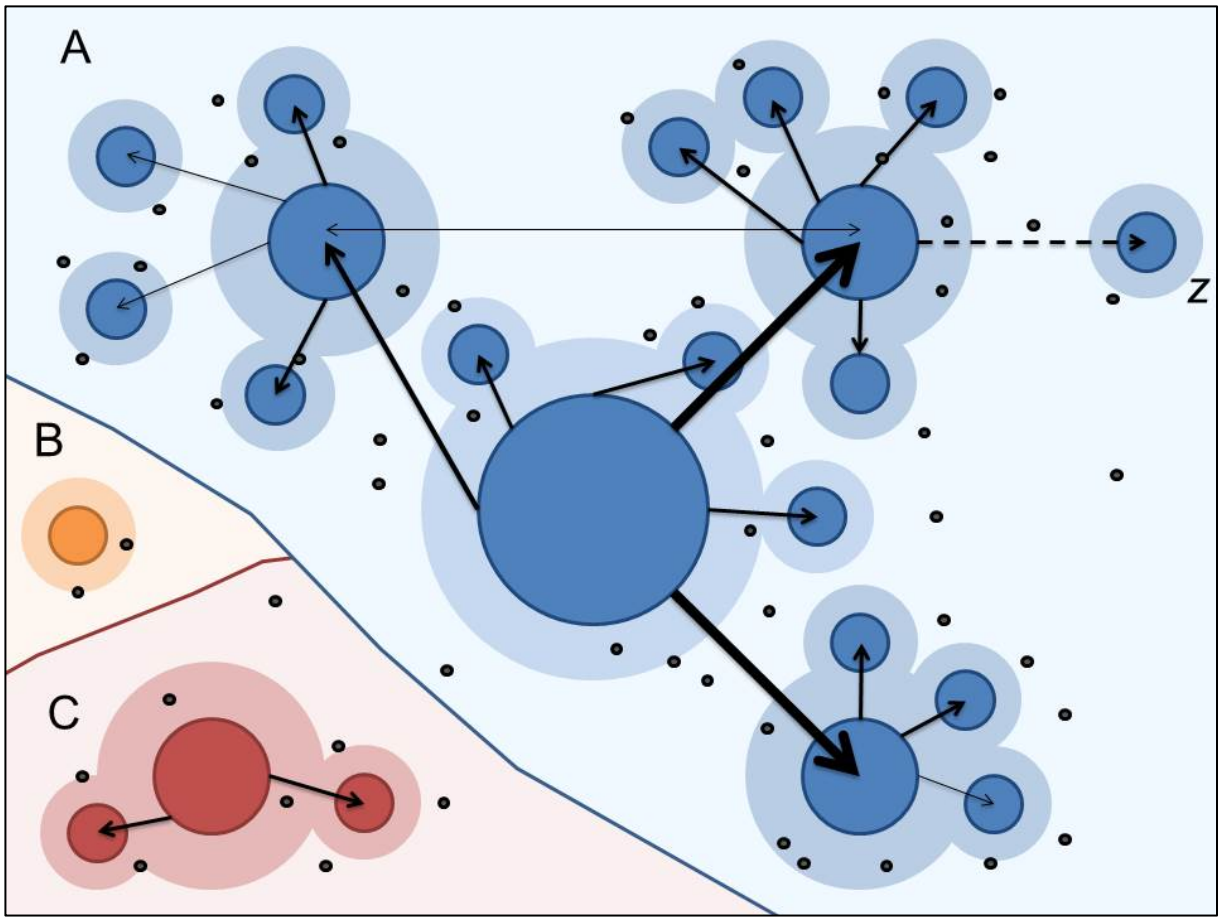
3.3 MARKET INTEGRATION AND EMERGENCY PROGRAM PLANNING (ALSO A MARKET-TO-VILLAGE ANALYSIS)

Planning for effective emergency food assistance programs depends on agencies having accurate information on: (1) Potential shocks; (2) Magnitude, spatial extent and propagation of the shock; (3) Temporal progression of the shock; (4) Population exposed to the shock; (5) Coping capacities of the population exposed to the shock; (6) Menu of food assistance interventions, and; (7) Response of the food system to food assistance interventions.
Price shocks are in fact terms of trade shocks and relate to the purchasing power of households. A price shock can occur when home production is not sufficient to cover the household's food and nutrition requirements, when wage income is no longer enough to purchase food, or when other tradable products drop in price compared to food. A local production shock can therefore translate into a price shock for some households. The magnitude of shocks can be estimated by monitoring agricultural production and prices in the regional market shed. These can be combined with information on the livelihoods and populations within specific local market catchment areas to assess the potential impact of the shock on access to food.

3.3.1 NEED TO EXPLOIT MARKET STRUCTURE AND MITIGATE DISINCENTIVE EFFECTS OF TRADITIONAL FOOD AID

'In kind' food aid is an effective response in situations where there is a local food availability deficit and where local markets are not well integrated into the national (and international) markets (Maxwell et al., 2008). There are two questions regarding market structure which are important to consider, firstly is there a threshold degree of integration (and by implication physical thresholds) beyond which markets are unable to respond to imports or production deficits which help identify zones that would benefit from 'in-kind food aid?, and secondly how does the degree of integration itself change according to different shocks?. These questions can be partly answered by analyses of the prices and price transmission under different conditions, as well as some understanding of the catchments of individual markets.

Figure 4. Hypothetical regional and local market sheds with prices known for all markets



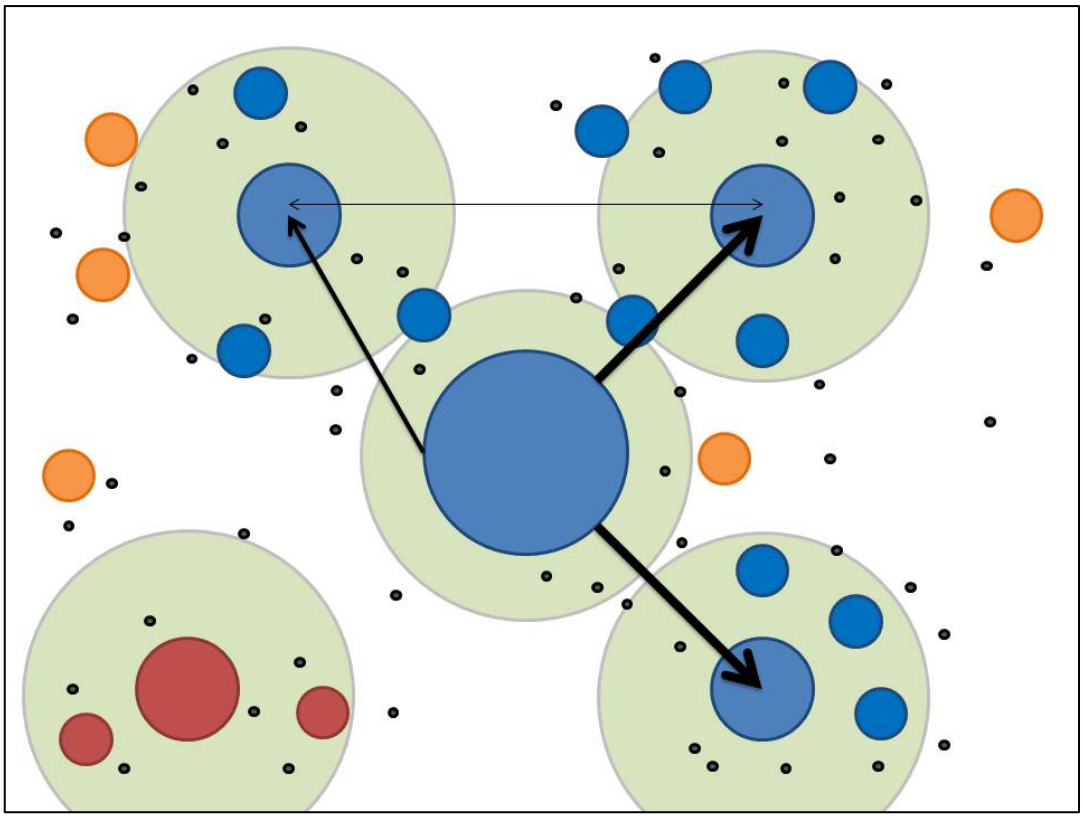
In the example in Figure 4 three regional market-sheds (A, B and C) are shown with central, district and local markets, the catchment of each individual market and villages. The arrows show the strength and direction of the price transmission and are the result of traditional econometric analyses. In this hypothetical situation for a 'normal' year without shocks market shed A is well integrated, whereas market sheds B and C are not well integrated. A price or transport shock might reduce integration, such that local markets like z, are beyond an integration threshold. If there is a general food availability problem in market shed A cash transfers would be the best response, however in market z such a cash transfer would not result in a greater supply – for this particular market catchment an 'in-kind' food aid intervention would be more effective. 'In-kind' food aid interventions in market sheds B and C

would only be effective if there are food availability problems in these market sheds, otherwise they are isolated from price shocks in market shed A and would not need cash transfers.

3.3.2 REQUIRES A DIRECT MEASURE OF MARKET INTEGRATION FOR CRISIS AFFECTED AREAS WHERE THERE ARE NOT LIKELY TO BE OBSERVABLE PRICES NECESSARY FOR TRADITIONAL ECONOMETRIC ANALYSIS

Often prices are unobserved at local markets and it is not possible to show statistically that prices are transmitted from district or central markets. In these cases it is necessary to make assumptions about price transmission based on the trade flows and market structure as well as theories of economic geography.

Figure 5. Hypothetical regional and local market sheds with prices known only for main markets



In Figure 5 prices are collected for the central and district markets allowing for degrees of market integration to be inferred; however there are no prices being routinely collected for the local markets. Instead assumptions are made about the distance over which prices are transmitted from district to local markets. In the example above two market sheds are identified and there are more local markets identified as remote and not integrated. In this example the remote markets and the villages they serve might receive food aid, whereas cash transfers might be preferred for all the other communities served by the two market sheds. It is clear that with a lack of price data the assumptions made and the models that are used are vitally important to identify the number of regional market sheds, how local markets are linked to bigger markets (local market sheds), the villages that are within the catchment of local markets and as a consequence the population that requires different kinds of food aid interventions.

4 REVIEW OF METHODS (INCLUDING EXAMPLES AND LITERATURE REVIEW) THAT LINK MARKETS TO MARKETS AND MARKETS TO COMMUNITIES/POPULATION

4.1 EXAMPLES/LITERATURE REVIEW

This section looks in more detail at potential methods and sources of data for defining the boundaries of regional and local market sheds and the catchment areas of local retail markets and the movement of prices within these zones under different supply, demand and transport scenarios. The first group of methods are econometric and rely on price data and other variables to gauge the degree of market integration and equilibrium, specifically the speed, magnitude and range of price transmission and how the market performs under different shock conditions. These methods must be able to identify leading markets where price anomalies can be detected early and predict how prices will transmit to following or lagged markets.

The second group of methods are a mixture of approaches that use expert opinion to gauge the levels of market integration, the market sheds and local market catchment boundaries. Often these assessments will make use of trader and household surveys and some analysis might indeed be based on quantitative data, however the results are often presented in a qualitative manner.

The third group of methods are spatial interaction models that seek to explain and predict spatially variable phenomena. These methods can be used to estimate the catchments and populations of specific markets but the principles and theory behind these models can also be used to model the market system as a whole.

4.1.1 ECONOMETRIC METHODS RELY ON OBSERVED PRICE DATA. USEFUL, BUT CAN'T INFORM SPECIFIC QUESTIONS OF INTEREST.

Barrett (1996) provides a useful typology of methods for analysing markets based on the types of observation that can be made. He describes three levels of analyses, where level 1 uses just price data, level 2 use both price and transaction cost data, and level 3 combine trade flow volumes and prices. Levels 1&2 methods can be used to determine market equilibrium but not tradability, but level 3 methods are required to determine market integration. In the context of leading markets and price transmission for early warning it is contestable whether level 3 methods are necessary, but given the importance of trading of goods within East Africa they will be briefly reviewed and provide a link to the qualitative studies on agricultural commodity and food trade.

4.1.1.1 LEVEL 1: PRICE CORRELATION

Much of the research on price transmission has sought to identify the relationships between prices in different market centres. Early studies considered the correlations between prices in spatially separate markets e.g. (Jones, 1968, Lele, 1967). These correlations intuitively suggest that there is a relationship between markets, and testing the strength of the correlations is easy and is still practised (Shin, 2010, Versailles, 2009, Li and Sexton, 2013). This analysis is a first step in analysing prices although the rejection of integration due to a lack of co-movement of prices (e.g. (WFP, 2008) might be premature.

It has long been known that strong correlations between prices might be due to factors other than price transmission, such as covariate production shocks (e.g. regional drought), inflation, or population growth (Fackler and Goodwin, 2001). Conversely prices may be transmitted among markets but with considerable delays due to logistical problems or bottlenecks (Barrett, 1996). Another criticism of the price correlation methods was the lack of explicit recognition of the effect of transaction costs (Harriss, 1979) and trade reversals due to seasonality.

4.1.1.2 LEVEL 1: DYNAMIC REGRESSION

Transaction costs are considered explicitly in dynamic regression methods but there are challenges in determining causality. Ravallion (1986) proposed a dynamic regression methodology to identify long and short term lags in prices among central and satellite market locations, but there were concerns about the inferences that could be made (Abidoye and Labuschagne, 2014). Dynamic models include time lags in the determination of local prices (Badiane et al., 2010) but recognise the price–setting characteristics of a central market. The presence of co-integration between prices in spatially separate markets suggests interdependence (and thus integration) but further models are required to test the direction of the causality (Badiane et al., 2010) to determine which markets 'cause' prices to vary in other markets (Jaleta and Gebermedhin, 2009). Some tests for long-run co-integration among market prices assume symmetric price transmission, but as mentioned above, market structures and the disproportionate power of some market actors often lead to asymmetric price transmission (Alemu and Ogundeji, 2010). More recent methods are able to account for asymmetric price transmission.

4.1.1.3 LEVEL 2: SWITCHING REGIME METHODS

A criticism of co-integration testing methods is that they do not consider real transactions cost data.

Switching regime methods are so named because they consider different trading regimes between markets which occur because of seasonality and changes in transaction costs. Typically three regimes are identified: (1) where the differences in price between two markets is equal to the transactions costs; (2) where the differences in prices are less than the transactions costs, and; (3) where the price differences are greater than the transactions costs .

4.1.1.4 LEVEL 3: PRICE AND TRADE FLOWS

Stephens et al. (2012) seek to combine high frequency prices, trade flows and transactions costs to assess the relative importance of information flows and trade in spatial price equilibrium in a case study for tomatoes in Zimbabwe. They consider both periods of physical trade flows and non-trade and show that prices adjust over space even without trade, highlighting the importance of information flows for price adjustment. The authors treat periods of trade and non-trade as structural breaks in the co-integration relationship.

4.1.2 QUALITATIVE ASSESSMENTS SIMILARLY NOT ABLE TO COVER ALL AREAS OF INTEREST. MAPPING OF CATCHMENT ZONES IMPRECISE. QUALITATIVE MAPS CAN BE REFINED AND VALIDATED BY A DATA-DRIVEN APPROACH.

Field based assessments can be used to augment the econometric analyses summarised above by directly providing data on prices, transaction costs or trade flows, or by providing the context that can help to pamateterise and/or validate the economic models which are then tested empirically. In addition field based assessments may be useful in their own right for explaining price formation, trade flows and patterns, market-sheds, and policies. Three sources of data are summarised here: expert opinion, trader surveys and household surveys.

4.1.2.1 EXPERT OPINION

Expert opinion has been used to provide information that helps describe the structure, conduct and performance of markets (FEWS NET, 2008), especially in situations where statistics (on prices and trade flows) are not available (Ngigi, 2008, OECD, 2013). Expert opinion for past periods is subject to the ability of informants to recall events and facts, but in some cases is considered more reliable than data, for example for defining 'normal' production and trading conditions (FEWS NET, 2009a). Expert opinion was also used extensively in the construction of regional market sheds to put statistical information on prices and trade flows into context based on knowledge on production patterns and policy development and implementation (Govereh et al., 2008).

Experts are likely to be drawn from a number of institutions with different expertise, but for market analyses will include traders, processors, transporters, trader and producer groups and associations, government officials at local and ministry levels, academics, and providers of financial services (FEWS NET, 2008).

4.1.2.2 TRADER AND COMMUNITY LEVEL SURVEYS

Traders can be surveyed separately and in a more formalised manner along with other actors in a value or supply chain. These surveys allow for transaction costs and marketing margins to be better understood and can contribute data to econometric analyses of prices (Baulch, 1997, Zant, 2010, Moser et al., 2009). Additionally the results of trader surveys provide information on local market distribution channels, market concentration, market conduct (Onu and Iliyasu, 2008) and the identification of bottle-necks such as access to credit (Hayami et al., 1988), or other barriers to entry (FEWS NET, 2008). Trader surveys are also useful for providing information on market performance when exposed to shocks (WFP, Kirimi et al., 2011), based on past experience, current food availability conditions, forecasts and perceptions. This kind of information is useful for planning food assistance interventions and can both validate and be informed by econometric analyses of price transmission.

Structured or semi-structured community level surveys have been used to provide information for small administrative areas. In the context of market and price information they can provide useful information on local transport costs (Butler and Moser, 2010) ,as well as information on local market location and accessibility (WFP, Kruseman et al., 2006, Pender et al., 2001). Surveys of producer groups are also a source of information on the performance of rural markets (Shiferaw et al., 2008) and may provide information that are useful for analysing village-to-market interactions, especially with respect to market power.

4.1.2.3 HOUSEHOLD SURVEYS

Household surveys can provide information on market structure and performance but compared to trader and community level surveys they often cover larger areas albeit with less detailed information on markets. Household surveys are particularly useful when combined with surveys at other levels in order to triangulate responses and provide an assessment of the whole value chain (Fafchamps and Hill, 2008).

Household surveys allow for an analysis of the effects of price anomalies on household welfare and food security, including livelihood activities and changes to terms-of-trade (Arndt et al., 2008). As with community level surveys there is often information on physical access to markets, which can be used to validate models of market access and the definition of market catchment areas, as well as commodity specific factors (Chamberlin and Jayne, 2011, Staal et al., 2002). Some household surveys also contain information on food consumption, preferences and purchase (Dercon and Hoddinott, 2005), as well as home production of different commodities (Benson et al., 2008, Shiferaw et al., 2008) and can provide alternatives to market prices (Deaton and Dupriez, 2011). This granularity of data allows for the identification of net food buyers and net food sellers, which is vital for planning and targeting food assistance interventions in the event of a price shock (Arndt et al., 2008 , Moser et al., 2009, WFP, 2011). A limitation of many household surveys is that the aggregate estimates of impacts of food price shocks may be representative for only a limited number of large regions, depending on the sample size (Minot and Baulch, 2005).

4.1.3 GEOGRAPHIC MODEL OF ACCESSIBILITY USING FRICTION OF DISTANCE MODELS, MORAN'S I-STATISTIC, GRAVITY MODELS, AUGMENTED GRAVITY MODELS, HUFF MODELS, TRADE AREA ANALYSIS MODELS, KRIGING, AND SPATIAL BAYESIAN PROBABILITY MODELS.

Spatial interaction models are a family of models that seek to explain and predict flows of phenomena across space (Taylor, 1983). Often these phenomena are tangible objects such as people and goods, but they can also be ideas, information, innovations (Hagerstrand, 1967) or indeed prices. What is common to many different kinds of interaction is that the probability of an interaction declines as distance between the source and the target increase. This decay in interaction often only becomes apparent when it is mapped and when distance is proposed as a determinant of reduced interaction. A more thorough investigation of the phenomenon in question often reveals that it is not distance *per se* that causes the decay in interaction, instead it might be the opportunity cost of time spent travelling further, or the actual cost required to pay a transporter that is the barrier to interactions further afield.

4.1.3.1 GRAVITY MODELS

Given the distance decay effect that is observed for many interactions it was predictable that comparisons would be made to physics, and more specifically to Newton's law of universal gravitation in which gravitational force is inversely proportional to the square of the distance between two objects. The most relevant early application was Reilly's law of retail gravitation (Reilly, 1931) which sought to describe the retail spheres of influence of cities based on the distance between them and the relative attractiveness of each city. A direct analogy of Newtonian gravity was the calculation of a demographic force between two locations based on the product of their populations (their demographic masses) divided by the square of the distance between them and multiplied by a constant (Olsson, 1965). A great deal of research

has concentrated on identifying the most appropriate distance decay functions (Taylor, 1983) (Haynes and Fotheringham, 1984) based on either regression analyses of actual data with different exponents, or an analysis of the distributions of interaction distances. In this sense the identification of the best fitting distance decay functions are data in search of a theory (Huff, 1961) relating to the 'friction of distance' in different social contexts.

To assess the potential contribution of these models to the delineation of market sheds and catchment areas, it is necessary to be clear about the interactions that are occurring and the mechanisms by which location affects interaction. Two interactions are paramount (1) the movement of goods via trade through the market sheds and (2) the movement of prices of goods via trade or arbitrage through the market sheds.

The likelihood of trade between markets, and therefore the potential for price transmission via market integration has been analysed using gravity models (Reinert, 2009, Anderson, 2011, Anderson and Van Wincoop, 2004), mainly for international trade (Bun and Klaassen, 2002, Martinez-Zarzoso and Nowak-Lehmann, 2003, Vido and Prentice, 2003, Hiscox and Kastner, 2008, Olper and Raimondi, 2008, Anderson, 2011). Nevertheless examples exist within countries using simple indicators for attractiveness (demand and supply) and distance (MIG Inc., 2012). Gravity models have been used to study market integration of financial markets (Liu, 2013) and considered market capitalization size as the mass of the market, and cross market linkages (capacity to process information and economic integration) as distance, which would determine correlations.

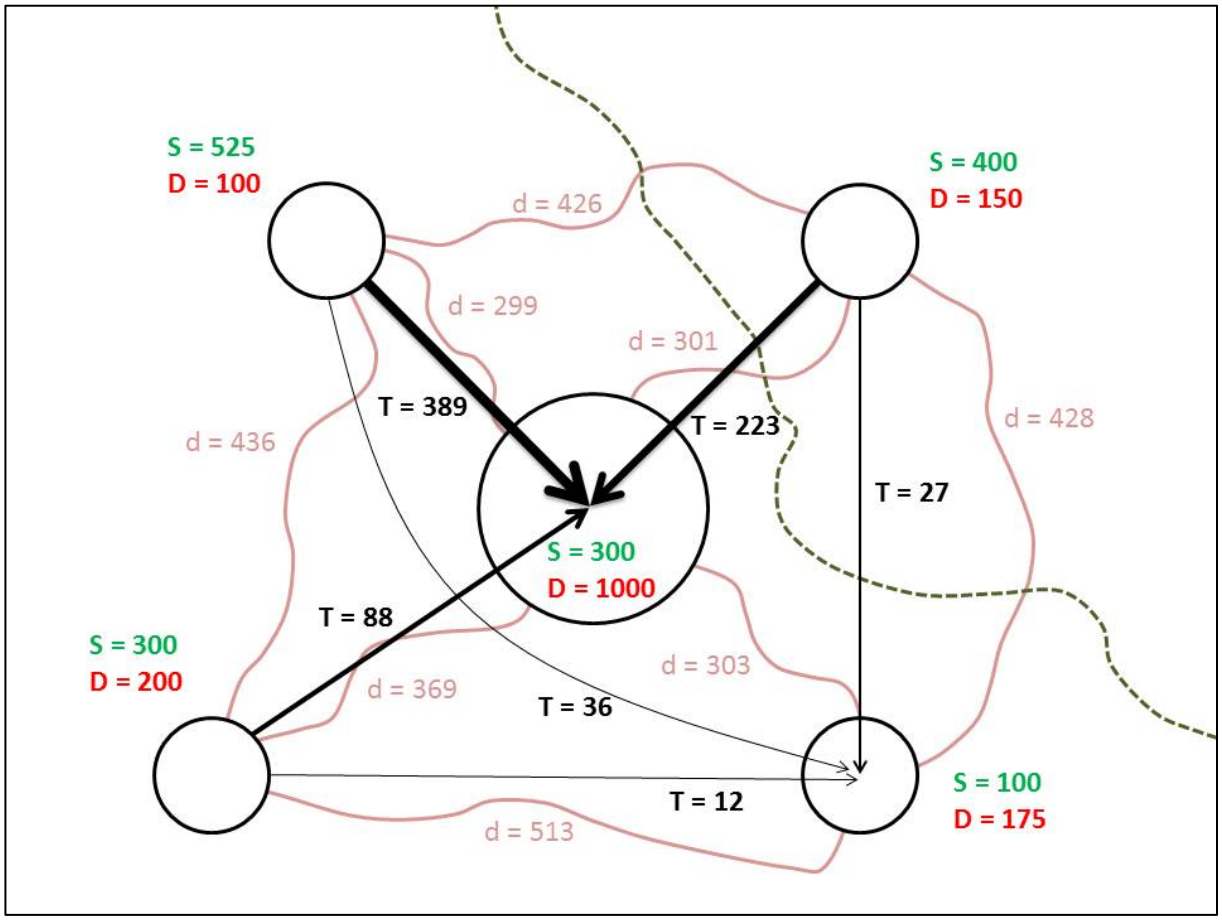
The strict analogy with Newtonian gravity gives,

$$X_{ij} = Y_i E_j / d_{ij}^2$$

Where X_{ij} is the movement of goods between markets i and j, Y_i is the mass of goods from location i which is attracted to E_j the demand for goods at market j, whose flow is affected by the 'distance' (or some impedance) d between markets i and j raised to the power 2. In practice the exponents of 1 applied to the attraction between the masses, and -2 applied to distance are generated empirically but tend to 1 and -1 respectively (Anderson, 2011). This bilateral model can be expanded to consider trade flows among multiple sources of supply and demand (

Figure 6) and solved iteratively (MIG Inc., 2012) to balance supply and demand.

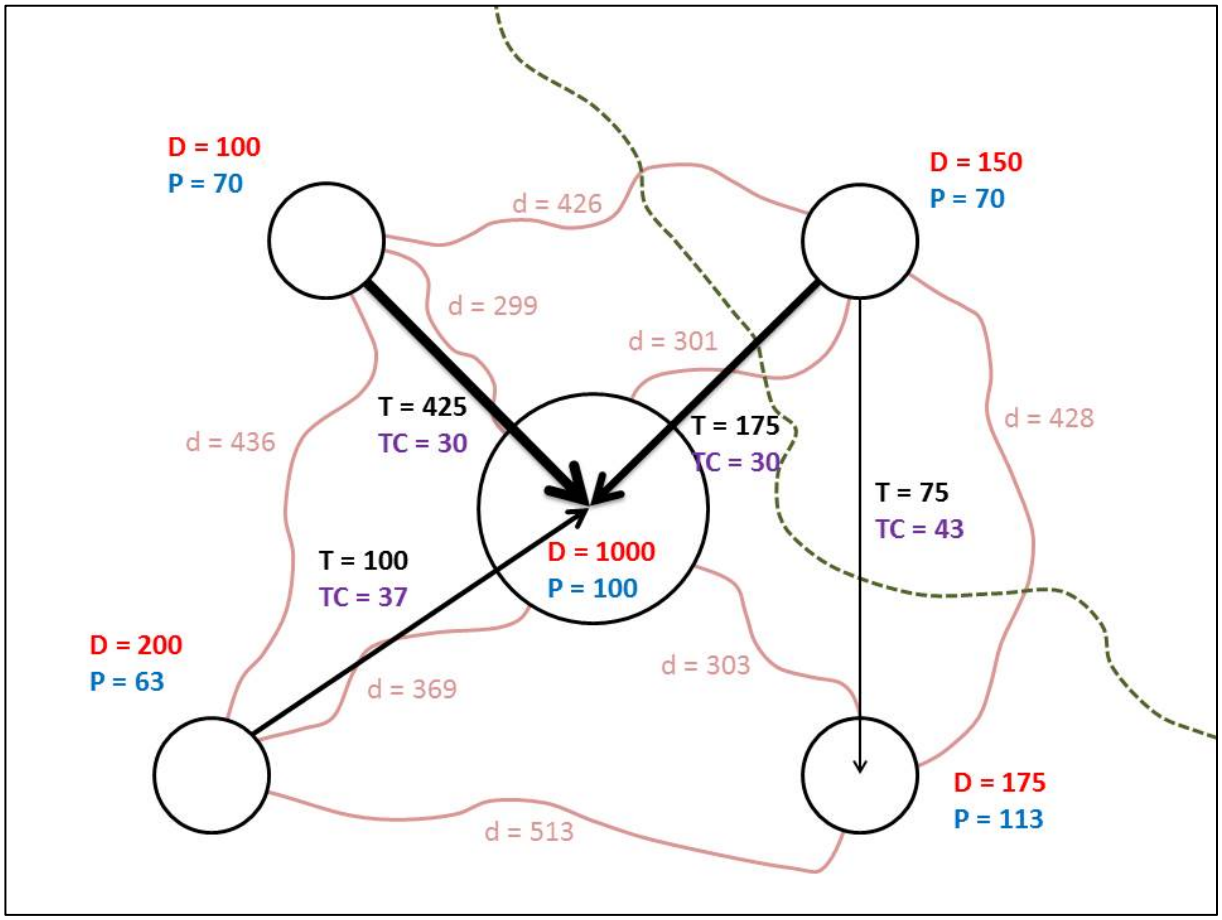
Figure 6. Hypothetical trade flows (T) between main markets based on a gravity model with supply (S), demand (D) and distance (d) as inputs



The gravity model can be modified by making assumptions about the demand curves, base price location and transport costs (Bressler and King, 1970) allowing the estimation of prices across the market shed (

Figure 7). This is a more realistic model of actual trader decisions based on price differentials rather than a system-wide market objective of balancing supply and demand.

Figure 7. Hypothetical prices per unit (P) among main markets based on a gravity model with trade flows (T), and transaction costs per unit (TC) as inputs to balance demand (D) and supply



The definition of a catchment for local retail markets depends on the trade of food products with households representing the final demand points. Huff defines five factors that affect consumer behaviour for retail transactions. These are (a) merchandise offering; (b) travel costs; (c) product types; (d) consumer income; and, (e) city (market) size (Huff, 1961).

The importance of merchandise offering is based on the uncertainty of finding a particular product in a specific market, with consumers prepared to pay more for a wider range of brands – perhaps less important for consumers of food staples in developing countries. Travel costs are an important factor for market choice and include opportunity cost of time, actual expenses for transport, other costs associated with the trip (Geurs and Ritsema van Eck, 2001). 'Product types' accounts for the substitutability of the product, the price differences between products, and the absolute price of a product. All of these are important factors for consumers in developing countries. Consumer income is meant to take into account the requirements for purchasing goods for social status and lowered cost of transport due to access to vehicles, and city size in huff's model is a proxy for density of population and increased friction. These aspects of consumer behaviour were incorporated in a spatial interaction model (Gambini et al., 1968) where the probability of a consumer at i selecting a retailer j

$$P_{ij} = \frac{A_j / D_{ij}^{\gamma}}{\sum_{j=1}^{n} A_j / D_{ij}^{\gamma}}$$

Where A_j is the attractiveness of the retailer j; D_{ij} is the distance from i to j; γ is a constant and represents the decay function of distance for a particular product, and n is the number of retailers.

In retail trade analysis in developed countries the attractiveness parameter is often the size or sales of an individual store. For rural markets in developing countries there are likely to be other factors such as price, reliability of supply, quality, number of retailers, financial and other service providers.

In the example below (

Figure 8) the probability of exchange is determined for each village with all markets in a predetermined range for the food product, using the huff model with details for one village location (

Table 1).

Figure 8. Markets within range of village x

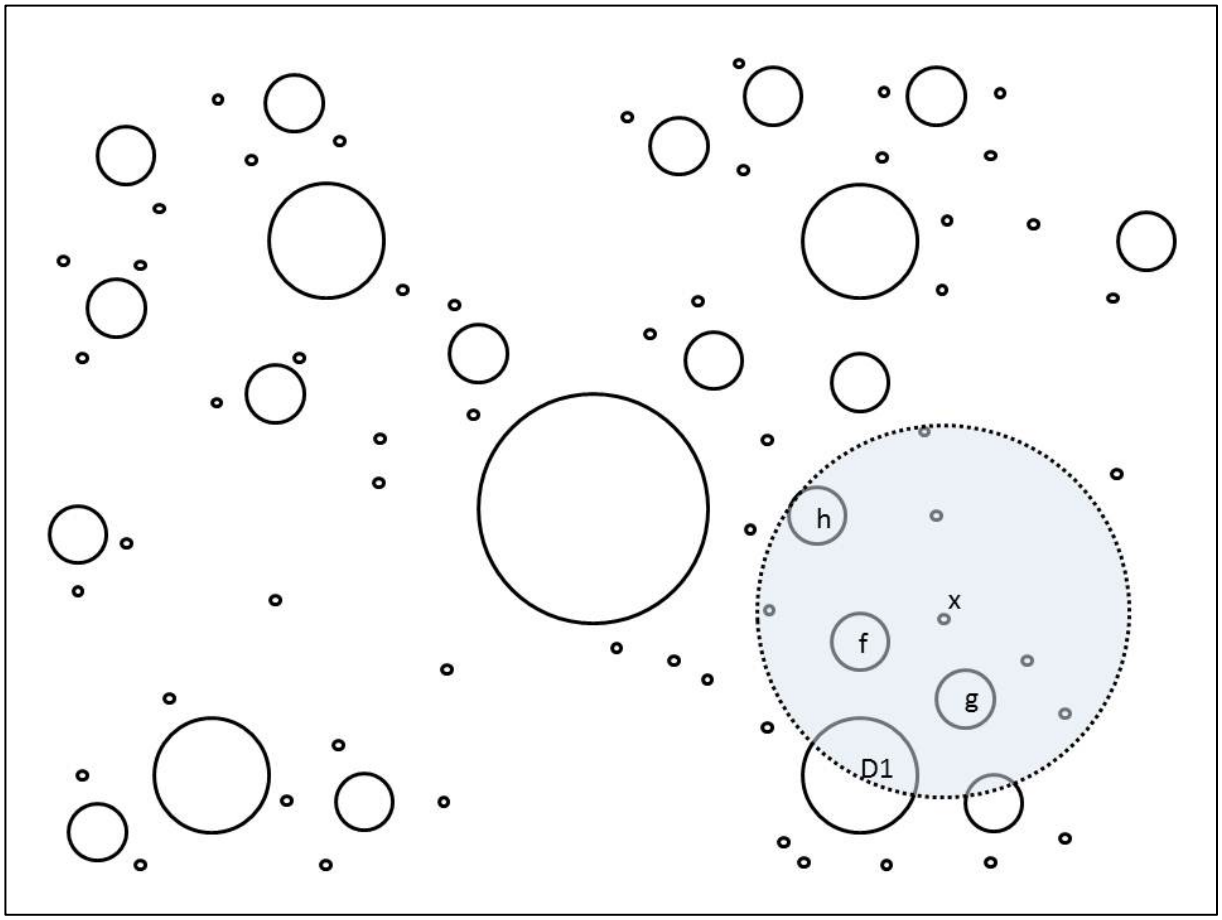


Table 1. Calculation of probabilities of exchange with markets within range for village x

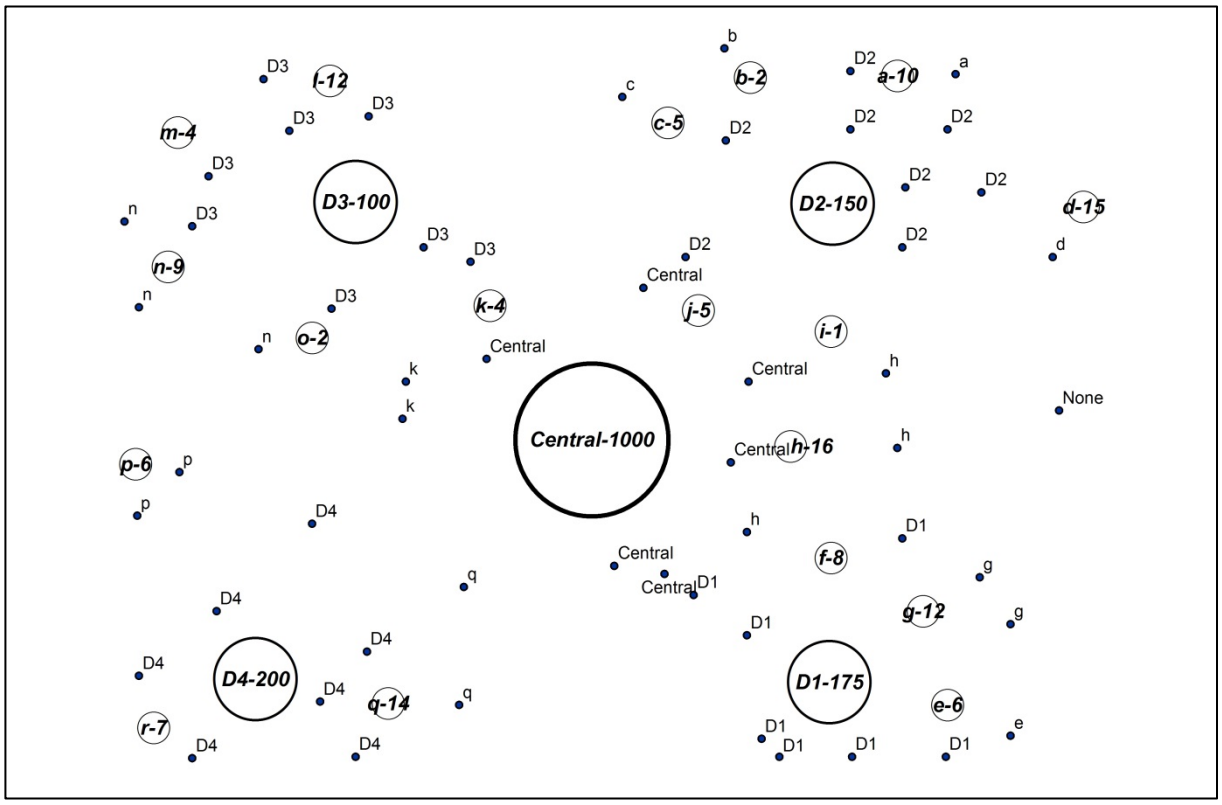
Market	Aj	dij	dij γ	Aj/ dij γ	Pij
h	16	6	15	1.1	0.07
f	8	2	3	2.7	0.18
D1	175	8	23	7.6	0.49
g	12	2	3	4	0.26

Where γ=1.5, and n is determined by maximum range

$$\sum_{j=1}^{n} A_j / D_{ij}^{\gamma} \quad = \; 15.4$$

When the model is applied for all villages it is possible to derive the most probable market that will be visited based on ‘distance’ and ‘attractiveness’ (Figure 9).

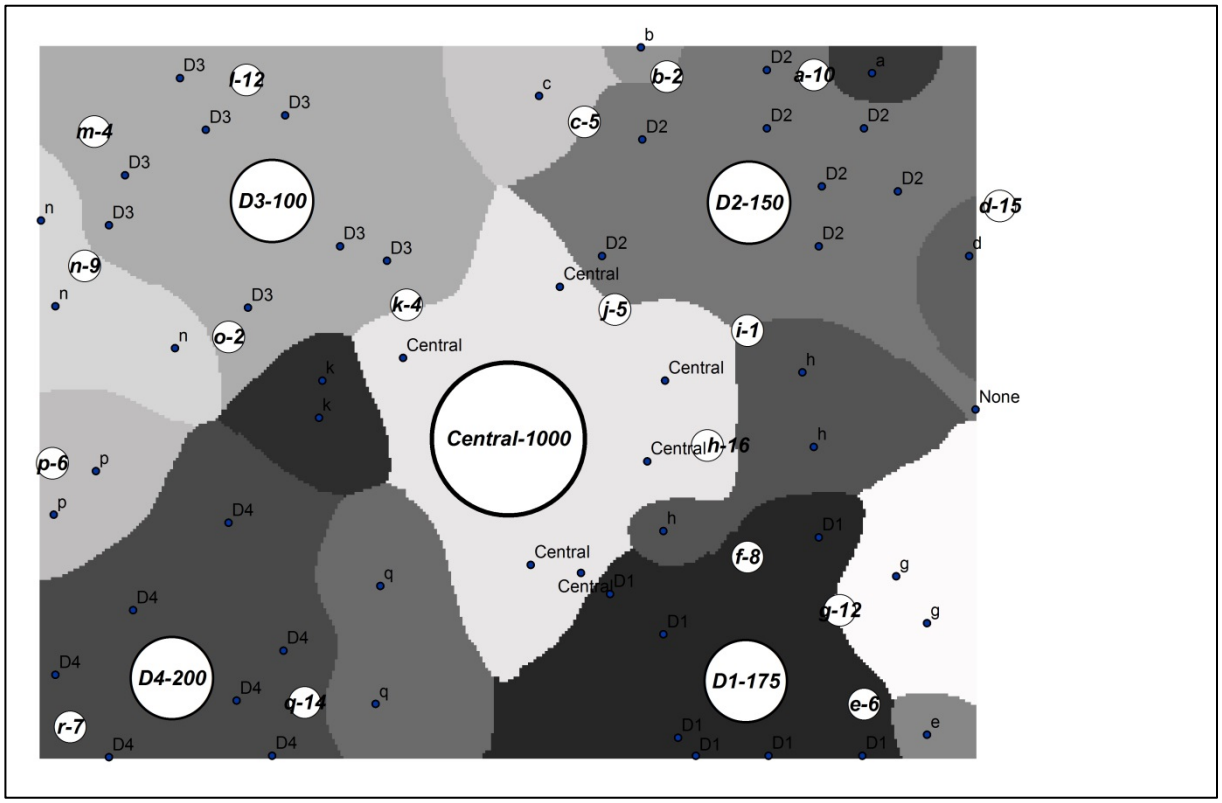
Figure 9. Within range markets with highest probability for each village



The probabilities for each village can be converted to a surface by either increasing the number of village locations, or by interpolating the probability for each market and selecting the market with the highest probability (

Figure 10).

Figure 10. Catchment area for each market based on comparison of probabilities (probabilities interpolated between villages using IDW distance decay exponent = 2, and 12 nearest neighbours)



As mentioned above distance need not be a physical distance but could be the time (opportunity cost) of the journey or the monetary expenditure on transport. There may be cultural or social norms that impose a threshold on the length of journeys such as staying away a night, in essence imposing a range. Spheres of influence are determined by the range of the good – following Christaller's central place theory (Christaller, 1933) – this then gives multiple competing spheres of influence and there is a need to determine the probability of a buyer in overlapping spheres of influence buying at a particular central location. Huff's model was considered by Drezner et al. (2011) but was discounted due to the difficulties in data collection necessary to determine the distance decay function. Alternatives include spatial Bayesian probability models (Van Brakel and Ross, 2011). Verburg et al. (2011) use instead a Gaussian function and choose arbitrary values to represent the attractiveness of their market centres with discrete classes based on population. The attractiveness of the source is only considered after the construction of the accessibility index whereby PPP is distributed throughout a country based on population density and multiplied by a nationally normalised accessibility index to give a market influence density index.

Alternative methods in the health literature include thresholds for access above which access is assumed to be 0 (Radke J and L, 2000); this is relevant in the public health field where new facilities can be located but it less relevant for access to markets unless there are clear ranges of goods beyond which people are unable or unwilling to travel. Examples in the health literature (Cheng et al., 2012, Crooks and Schuurman, 2012, Hu et al., 2013), also assume a deterioration in attractiveness as demand (for medical services) rises, this is broadly analogous with supply and demand of food products with the difference that supply

of food is likely to respond more rapidly to demand than in health contexts. Alternative assessments of attractiveness include hedonic models composed of a number of variables such as number of rooms, nurses, hygiene and infrastructure (Yao et al., 2013).

4.1.3.2 FRICTION OF DISTANCE

Gravity models explicitly use the friction of distance as a parameter that is used to calculate the probability of an interaction between a market and a village. However, in many applications the Euclidian distance between the locations is used, often because this approximates well to the context and data being used, but also because this distance is easy to calculate. A group of models that are simpler than gravity models pay more attention to the friction of distance to determine the location of the nearest markets and catchment areas. These models generally attempt to incorporate all of the factors that cause a physical impedance to travel such as the presence and quality of roads, the effect of slope, and barriers to movement such as rivers, checkpoints, or the availability of and access to public transport. The modelling is often carried out in a raster data processing environment using a cost-distance algorithm to determine the route and cost from all locations to specified targets. The cost-distance algorithm is unable to incorporate the attractiveness of the target and does not produce a probabilistic outcome for different targets, instead only the cost to the 'nearest target' is recorded for all grid cells as well as the target location and the direction of travel. The cost-distance algorithm works in a raster environment, but similar methods are applicable in vector environments (Castella et al, 2005; Deichmann, 1997; de Wolff, 2006). These models working with network links and nodes are also able to incorporate some of the attributes of the sources and targets (villages and markets) such as population and size. A conception of potential access, concerns the economic barriers to a physical location or product that is otherwise nearby. Breyer and Voss-Andreae (2013) in their study on access to healthy foods considered price and range of food in retail outlets, their distance measure was not Euclidian but instead street network. They then compared all outlets with affordable outlets. In this case price and income were considered as potential barriers to access.

In certain environments the transportation network is radically different from Euclidian distances, e.g. rainforests where river transport is the norm (Salonen et al., 2012), in this case time was considered as the most relevant indicator of range of products (due to perishability), whereas capacity and frequency of transport were factors in the intensity of trade, which itself was considered as a proxy of market integration. Seasonality is an issue in all environments and unsurfaced roads are prone to flooding in wet seasons, causing a reduction in accessibility (Blanford et al., 2012).

Other authors modify time measures of accessibility to include distance and perceptions of remoteness based on the number of rural communities that need to be traversed in order to reach an urban centre, they relate these with land use and show that proportionately more 'nature' areas are found in the more rural areas (Johansen and Nielsen, 2012).

Chamberlin and Jayne (2011) show that the different measures of accessibility and their effectiveness at describing or predicting interaction depended greatly on the kind of interaction, for example depending on the commodity specific value chain actors. Also accessibility altered the value chain structure with more accessible producers marketing collectively and bypassing local traders to sell at regional markets. Surprisingly farm gate prices received for maize did not differ significantly in accessible vs inaccessible areas. Pozzi

and Robinson (2008) also show differences in livestock-specific combinations of trade volume and modes of transportation. Perishability is an important factor for animal products, so time is an important variable, whereas for live movement of livestock security and cost are issues.

Friction of distance has often been incorporated with gravity type models to produce what is known as a potential accessibility index (Verburg et al., 2004, Yoshida and Deichmann, 2009, Pozzi et al., 2010), Deichmann, 1997). This index shows the potential for interaction at all locations based on the combination of the 'distance' to and popualtion of nearby villages, towns and cities. As with the gravity model the exponent for the distance decay needs to be estimated, although more usually a range of functions are tested, such as inverse distance, gaussian, and kernel density.

4.1.3.3 CONTINUOUS FLOW MODELS

Bigman and Deichmann (2000) link gravity models with theories of consumer behaviour and show that the distance decay effect is the marginal disutility of distance. Spatial economics provides alternative models more rooted in economic theory than the retailing models of Huff, and which tend to produce deterministic results of market exchanges. Examples include Hotelling's competitive facility location model which explores market shares of competitive locations, and the spatial choice behaviour of consumers. A key difference between deterministic and probabilistic models is that catchment areas can be developed more easily for deterministic models (Wong and Yang, 1999), although it is still possible for probabilistic models by comparing probability surfaces (

Figure 10). The models are frequently operationalised in a network environment of discrete elements (Loo et al., 2005)
Spatial economics considers economic flows and has been widely used to model the spatial equilibrium of trade flows in a single-commodity market (Beckmann and Puu, 1985) and spatial pricing. These spatial price networks link back to the concept of spatial price equilibrium and offer approaches to analyse price transmission in a more spatially explicit manner. Nevertheless there are very few applications of the models for analysing price transmission.

4.1.3.4 SPATIAL AUTO-CORRELATION, GEO-STATISTICS AND SPATIAL BAYESIAN PROBABILITY MODELS

For market to market price transmission a potential assumption is that markets which are 'closer' to each other would have prices which are more similar compared to markets which are further away. This spatial dependence can be tested globally using measures of spatial autocorrelation such as Moran's I, or locally using Local Indicators of Spatial Autocorrelation. Inferring integration from a spatially auto correlated price structure has been attempted by Shin (2010) using local Moran's I, however the method only used correlated deviations from average spot prices. Shin used various values for the number of nearest neighbouring markets to consider; an alternative method to look for anomalies of prices among markets would be to use the Geographical Analysis Machine (Openshaw, 1987) to search for price clusters which are significant across multiple scales. These methods do not seek to model the interactions in trade and arbitrage that determine price transmission, instead they measure the outcome of that process allowing inferences on the causes.

Geo-statistics are applied most frequently to continuous surfaces such as soil, and climate, and interpolation is used where the spatial sampling of the surface is incomplete. If sufficient price data points are available then it would be possible to analyse the semi-variogram to show the spatial structure of the price surface and the range of spatial dependence. Interpolation applies the information on the spatial structure of the surface to fill in the gaps between the data points. Numerous models exist to interpolate values between the data points including inverse distance weighting, spline fitting and kriging - a kind of regression analysis which has been used to interpolate land prices (Tsutsumi and Seya, 2008).

Brown et al. (2008) develop a price surface for millet in west Africa, linking trend signals of a spatially continuous but temporally dynamic surface – Normalized Difference Vegetation index (NDVI) – with Millet prices. While not utilising geo-statistics (instead using an Empirical Mode Decomposition technique) Brown et al. take advantage of remotely sensed data that are measured more regularly and for large areas, although they admit that the method is only valid in areas where local production is well coupled with the marketing system.

Gupta and Das (2008) investigated house prices in South Africa and sought to assess the degree of market integration in a similar manner to commodity prices above. They tested the Law of One Price comparing Spatial Bayesian Vector Autoregressive models with classical Vector Autoregressive models in order to test whether there are regional market sheds for housing.

4.1.3.5 AGENT-BASED MODELS

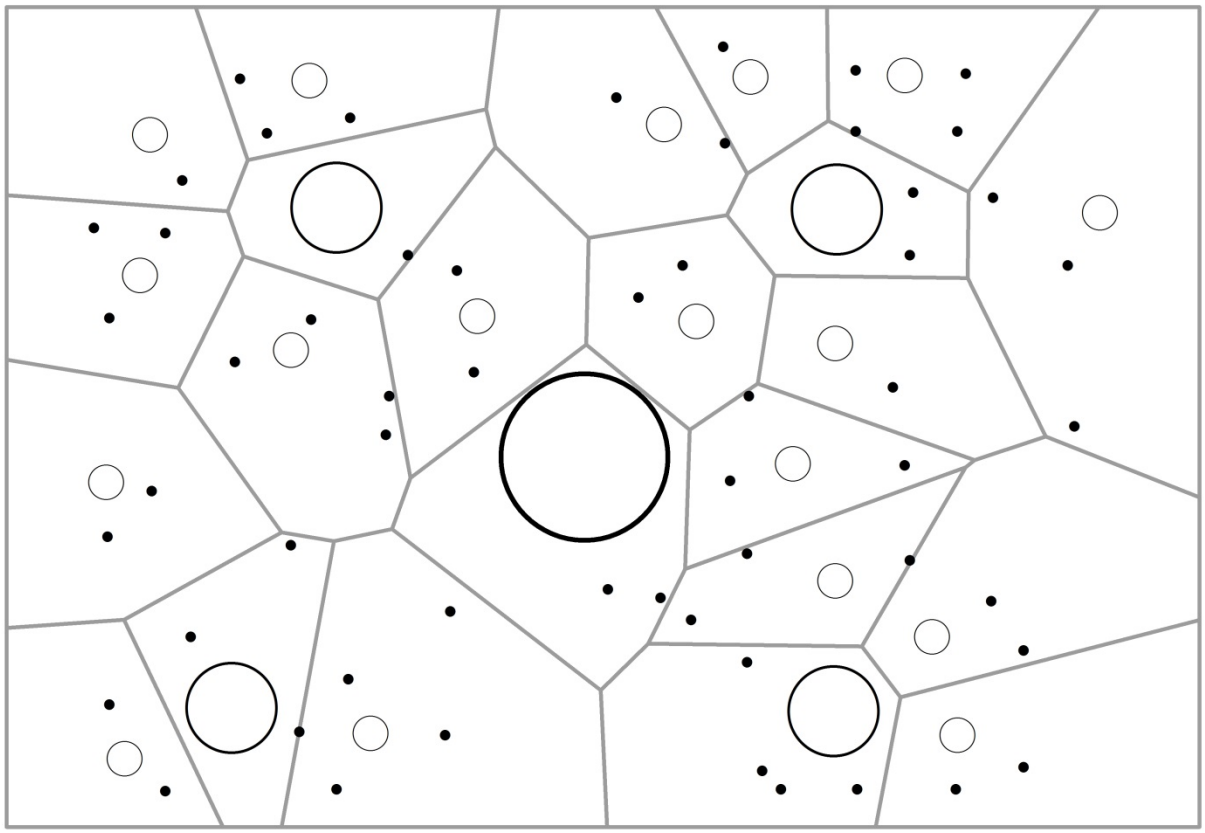
While the marketing system as a whole contributes via pricing to the balancing of supply and demand, it is made up of multiple agents making decisions on the allocation of resources for production and rationing of products in consumption (Bressler and King, 1970). Agent based models seek to capture the decisions of individual agents within a system and simulate the effects in terms of the interactions between consumers and suppliers. Heppenstall et al., (2005) demonstrate how prices of a non-differentiated product (gasoline) can be modelled spatially using agent based model. Gasoline has many similarities with staple foods, namely inelasticity and often a lack of differentiation (i.e. a commodity). The price setting behaviour of the retailers was modelled and price surfaces derived; retailer agents applied rules based on their costs, and information on the actions of their local competitors. Consumer behaviour, however, was based on a spatial interaction model which included distance and population size parameters. The spatial interaction generated information on demand and matched supply in a number of competing facilities, the agent based model used this information as inputs to the rule base to change prices which then fed into the spatial interaction model. The model was further refined to include transport network and typical journeys (e.g. commuting to work). Results on prices were compared to actual prices for 10 days after the model initialisation.

Prices are the reflection of multiple interactions between buyers and sellers, and while the catchment areas of particular markets and larger regional market sheds could be discerned from maps of all trade flows it is likely that such a map would be too complicated to interpret. Similar maps of interactions (in this case telephone conversations) have been produced, and analysed using spectral modularity optimization, which results in contiguous catchment areas (Ratti et al., 2010). This modularity is based on the proportion of interactions, which are local as opposed to those that are more distant.

4.2 NEED A METHOD THAT EMPLOYS DATA SETS WITH UNIVERSAL COVERAGE TO LINK POPULATIONS IN NON-MARKET COMMUNITIES TO MARKETS (MARKET-TO-VILLAGE ANALYSIS).

A tool for market to village analysis needs to be able to cover the whole East African region, which has implications on the type of data that can be used. The key datasets for market to village analysis regardless of the analysis environment are the locations of the demand and supply points. If assumptions are made about the relationships between supply points and population (Van Brakel and Ross, 2011) then a population density map is sufficient to create a simple supply and demand network (in a vector analysis environment) or supply points on a demand surface (in a raster analysis environment). With this minimum dataset the transaction costs between supply and demand points can be estimated based on distance alone, and the attractiveness of the supply point considered to be equal (Figure 11) or estimated from the population size.

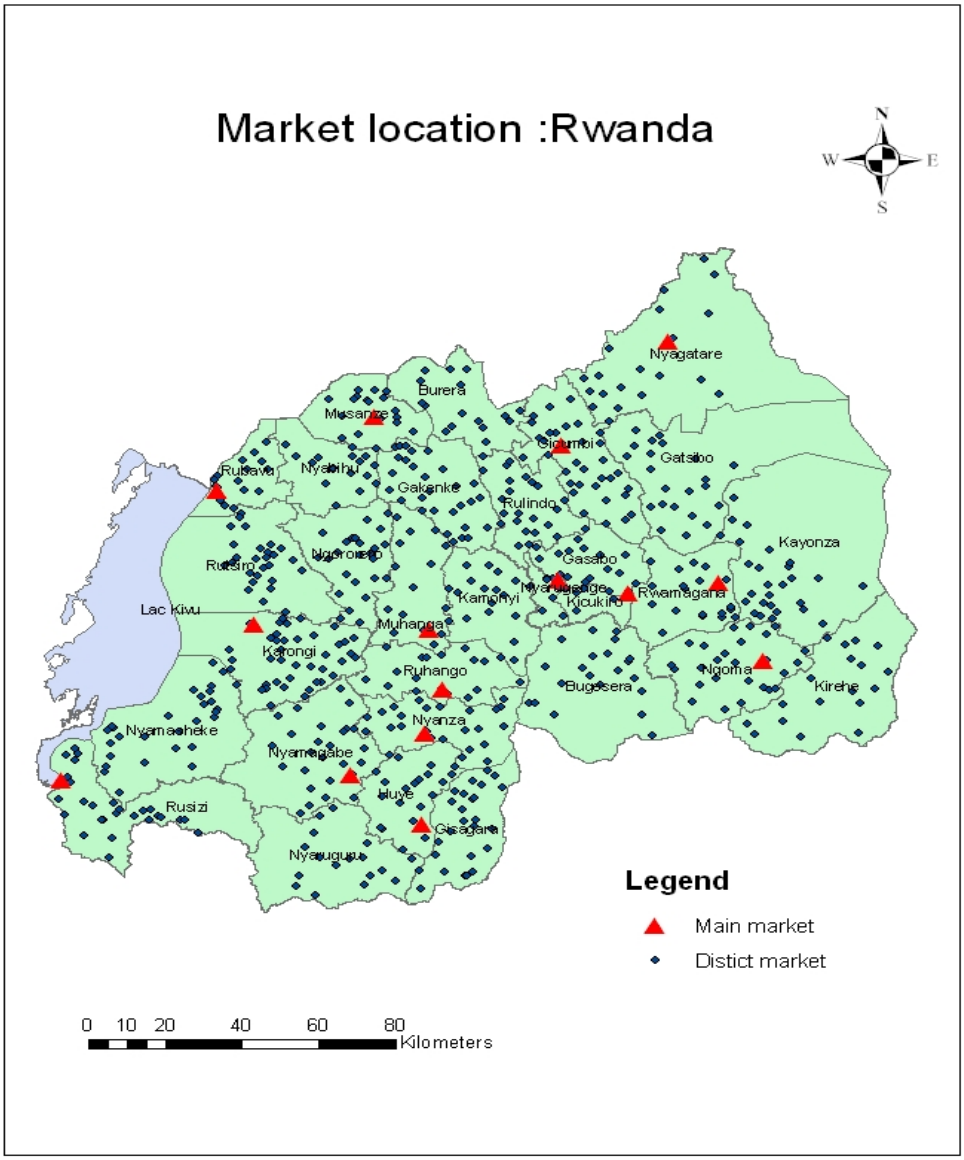
Figure 11. Catchment areas based on equal attractiveness and distance only



Information on actual market locations is available from global datasets but only larger markets tend to be captured. There exist, however, numerous data on market locations albeit from different sources for different periods in time, for different commodities and for different spatial extents (e.g.

Figure 12).

Figure 12. Main and local markets in Rwanda (source unknown)



Similarly, village locations are available from national sources but consistency among countries (e.g. on spatial accuracy/precision and with information on population size) cannot be guaranteed.

Other important datasets would allow alterations to the values of the attractiveness of the supply points and the transaction costs. A key attribute of markets in this analysis is the retail price of the commodity. Commodity prices are collected and published regularly by FEWS NET for certain markets but these are not the retail markets for all of the final demand. FEWS NET monitored markets in Rwanda[1], for example are a small sample of all the markets but are a good representation of the main markets (

[1] Kigali, Ruhuha, Kirambo, Musanze, Byumba, Mahoko, Bugarama, Muhanga, Kabaya, Ndago, and Kabacuzi

Figure 12). The selection of markets with prices represents therefore a trade-off between accurate information on the attractiveness of the market, against the likelihood, distance and cost of travelling to that particular market.

Roads allow for transaction costs to decrease in situations where consumers have access to vehicular transport or where public transport is available. If consumers are limited to walking, however, then costs can be estimated using simple distance metrics alone. Road datasets are universal throughout east Africa but vary in thematic and spatial quality and precision. Road routes allow for modifications to the transaction costs based on distance from demand to supply points, whereas information on road quality allows for maximum speeds to alter the time required to travel between demand and supply locations.

Terrain is another factor that impedes travel and can result in increased costs of moving between demand and supply points. Terrain has a topographical component due to steep slopes or abrupt changes in elevation as well as a roughness component due to vegetation. As a result of satellite imagery over the past decade high resolution elevation maps (ca 100m) are available worldwide and allow the derivation of slopes. Universal coverage of vegetation and landcover datasets has also been achieved, albeit with inconsistencies among sources.

Other barriers to movement include water bodies and rivers, which like roads have a universal coverage but with little information on the seasonality of flows, navigability or size. Models of flows based on slope are available globally at high resolution and provide information allowing the calculation of potential flow based on upstream catchment area. Livelihood zones have been developed for all countries in east Africa and are likely to be more consistent among countries than poverty indicators.

4.3 WHICH METHOD/METHODS MOST APPROPRIATE TO THE SPATIAL ANALYSIS OF MARKETS FOR EW PURPOSES?

There are three major questions that need to be answered by a spatial analysis of markets for famine early warning purposes:

(1) How are price anomalies likely to be transmitted through a market shed (a market-to-market analysis) to local markets where prices are not routinely monitored under different shock conditions?
(2) What is the population that relies on local markets that experience price anomalies (a market-to-village analysis)?
(3) How susceptible and vulnerable is the population to anomalous price rises (a community-level analysis)?

4.3.1 HOW ARE PRICE ANOMALIES LIKELY TO BE TRANSMITTED THROUGH A MARKET SHED (A MARKET-TO-MARKET ANALYSIS) TO LOCAL MARKETS WHERE PRICES ARE NOT ROUTINELY MONITORED UNDER DIFFERENT SHOCK CONDITIONS?

For markets where prices are not monitored it will be necessary to model the determinants of prices in those locations. This implies a preliminary analysis to define the boundaries of the regional market shed under different conditions, i.e. the natural limits of trade. A gravity

model considering just supply and demand can be used to model the limits of trade. The model would seek to balance supply and demand within the constraints applied by transaction costs and marketing margins.

The model would assume trade between assemblers and wholesale traders, although it could consider centrally located processors providing processed products (e.g. maize meal) for deficit areas, and local mills in supply areas.

The distance parameter in the model can be developed to better reflect the actual geographical factors that impede trade via transaction costs, such as time and cost based on road friction surfaces. The model can include actual transport costs and marketing margins where available, although this might imply a trade-off between a universal model with strict assumptions and a more locally relevant model.

The model would be based on known market locations with population a proxy for demand. Supply would be based on existing maize/sorghum production figures or estimates. Production and transport shocks could be simulated to assess the stability of the market shed.

The second stage implies a modification of the gravity model in order to estimate the transmission of prices throughout the regional market shed. Prices could be determined by plausible joint demand curves which are formed at leading markets. The leading markets could be determined according to the volume of trade or assumptions made, following Ravallion (1986), of a central market with radial markets with trade determining price formation (e.g.Carimo Abdula, 2005, Getnet, 2007). It might be necessary to consider world prices at ports for certain traded goods (Dorosh et al., 1995) and while the agency of large market players is paramount, in some cases retailers have a more significant role (Kuiper et al., 2003).

World and local price shocks would be simulated based either on changes in supply and demand (which were modelled in the first stage) or on factor prices such as fertiliser or fuel. Trade regimes, trade directionality and price regimes, (Harriss, 1979) need to take into account the different production seasons and how prices will vary as demand outstrips supply. Storage and speculation will be issues as will market power of different actors. A monthly time step could be considered with which to model the magnitude, spatial extent and propagation of the shock in the regional market shed.

The disadvantage of this method is that it is deterministic and therefore needs to be well calibrated and the parameters well specified based on an empirical analysis of the value chain for the particular commodity.

4.3.2 WHAT IS THE POPULATION THAT RELIES ON MARKETS THAT EXPERIENCE PRICE ANOMALIES?

To determine the population that relies on a specific market a different kind of gravity model – the Huff model – can be employed, and the catchments of the local market defined. Instead of a wholesale trade based on balancing supply and demand this model would seek to maximise the utility of individual households within villages by determining the probability of

buying a quantity of the commodity in a specific market. The model would need to consider the attractiveness of the market in terms of availability of the commodity, the price at different time instances and whether market is destination for other purposes. Friction impeding the interaction would be based on actual and opportunity costs. The range of the product – the maximum distance or time that a household can dedicate to making a purchase – would be based on local maximum time for travelling for food purchases, although a reduced frequency of market visits may compensate for a small range.

The identification of retail markets will be based on existing information on markets where possible although estimates based on population density could also be used (e.g. Van Brakel and Ross, 2011). Transport costs can be used directly although may not be available for all locations; in which case time – itself modelled – can be used as a proxy. Prices are unlikely to be available for all retail markets so estimates based on the trade flow and price gravity models could be used.

The Huff model determines the probability of a location and thus a population purchasing food products at a particular market at a particular time. The probabilities can be used either as a weight to show the population that depends on a particular market and which is potentially vulnerable to price anomalies, or as a means of determining the local market shed and assuming that the population within the market shed only visits a particular retail market.

4.3.2 HOW SUSCEPTIBLE AND VULNERABLE IS THE POPULATION TO ANOMALOUS PRICE RISES (A COMMUNITY-LEVEL ANALYSIS)?

The susceptibility of the population to price rises will depend on their livelihood strategies, whether they are net-buyers or sellers of agricultural products and how changes in the prices of other products or services affect their terms-of-trade. Much of this information has already been captured in the assessment of livelihoods within distinct livelihood zones.

The vulnerability of the population to anomalous price rises can be estimated by overlaying the local market catchment areas and livelihood zones. This would result in a value of the population that is susceptible to price changes, and is within the catchment of a market which would experience anomalous price changes under specific shock conditions.

5 PROPOSAL FOR PROOF OF CONCEPT/CASE STUDY

5.1 PROPOSED METHODOLOGY / ACTIVITIES

5.1.1. GRAVITY MODEL OF TRADE FLOWS AND PRICE FORMATION

5.1.1.1 FIRST STAGE – BALANCING SUPPLY AND DEMAND

- Search and Compilation of market location
- Estimation of supply of commodity at each market at monthly intervals during a typical year
- Estimation of demand for a commodity at each market at monthly intervals during a typical year
- Search and Compilation of road network quality data
- Creation of market network with markets as nodes and roads as vectors (connections, arcs or edges)

- Revision of literature or consultation with experts on physical barriers to transport followed by search and compilation of data
- Revision of literature or consultation with experts on institutional and informational barriers to trade (including borders and access to telecommunications)
- Revision of literature and surveys or consultation with experts on production, transport and policy shocks
- Extraction from GIS of distances between all market-pairs
- Run doubly-constrained gravity model for all market pairs under a normal scenario, a supply production shock scenario, a transport shock scenario, and a tariff/quota/export ban policy shock scenario
- Map the results of the different gravity models and define regional market sheds under different shock scenarios
- Validate using qualitative assessments of regional market sheds and quantitative tests of market integration

5.1.1.2 SECOND STAGE – PRICE FORMATION

- Search and Compilation of price data for market locations
- Revision of literature or consultation with experts on supply and demand curves within the case study area and for each market
- Search for data on import parity price averages and volatility
- Revision of literature or consultation with experts on transport costs at each market location
- Revision of literature or consultation with experts on marketing margins at each market location
- Construction of equilibrium cost matrices
- Map the results of the different gravity models and show price transmission under different shock scenarios
- Validate using quantitative tests of spatial market equilibrium

5.1.2. HUFF RETAIL MODEL OF LOCAL MARKET CATCHMENTS

- Search and Compilation of market locations
- Search and Compilation of village locations
- Search and Compilation of population density data
- Search and Compilation of road network quality data
- Search and Compilation of landcover and slope data
- Revision of literature or consultation with experts on transport and opportunity costs at each village location
- Construction of friction of distance (time) surface
- Estimation of demand of commodity at each village at monthly intervals during a typical year
- Estimation of supply of commodity and prices at each market at monthly intervals during a typical year
- Creation of market network with villages and markets as nodes and roads as vectors (connections, arcs or edges)
- Revision of literature or consultation with experts on physical barriers to transport followed by search and compilation of data
- Run Huff retail model for all village - market pairs under a normal scenario, a supply production shock scenario, and a transport shock scenario
- For each scenario calculate the catchment areas based on the comparison of probability surfaces of each market
- For each scenario calculate the population within the catchment areas as well as the probability-weighted population for each market using either village populations or population density maps.
- Validate using household and community surveys

5.1.3. ASSESSMENT OF THE POPULATION VULNERABLE TO ANOMALOUS PRICE RISES

- Search and Compilation of livelihood zones
- Search and Compilation of village locations
- Search and Compilation of population density data
- Overlay local market catchments and livelihood zones
- Calculate the population within each livelihood zone that are vulnerable to anomalous price rises under the production, and transport shock scenarios
- Validate using key informants and spatial data on under nutrition if available

5.2. DATA REQUIREMENTS AND AVAILABILITY

5.2.1. MARKET LOCATION AND PRICES

Market locations are stored in databases by a wide number of different agencies. The World Food Programme (WFP) VAM have data on market locations and prices for a number of countries, access to these is directly via WFP. For example in Niger WFP have data on location and name for 74 markets, while national agencies hold information including monthly and weekly prices for 100 markets (Angeluccetti, 2014).

In East Africa FEWS NET have data on market locations and monthly prices for 202 market locations with prices. For maize and sorghum the number of markets with prices is smaller (Table 2), with a mix of retail and wholesale prices.

Table 2. Number of markets with prices for maize and sorghum in East Africa (Source: FEWS NET)

Country	Markets	Retail	Wholesale
Maize			
Ethiopia	43	27	16
Uganda	8	2	6
Rwanda	28	28	0
Burundi	6	6	0
Tanzania	15	2	13
Kenya	11	7	4
Somalia	18	18	0
Djibouti	0	0	0
South Sudan	2	2	0
Sudan	0	0	0
Yemen	0	0	0
Sorghum			
Ethiopia	25	20	5
Uganda	5	3	2
Rwanda	0	0	0
Burundi	6	6	0
Tanzania	6	0	6
Kenya	5	0	5
Somalia	22	22	0
Djibouti (flour)	6	6	0
Sudan	11	11	1
South Sudan	6	6	0
Yemen	0	0	0

Household surveys, such as the World Bank Living Standards Measurement Survey – Integrated Survey on Agriculture (LSMS-ISA) have data on market locations although only from a sample of households. In East Africa LSMS-ISA surveys have been carried out for Uganda, Tanzania and Ethiopia. Prices are also measured in the surveys but are only cross-sectional and are therefore likely to be out of date.

Spatial data from other varied sources is also available although there is little consistency between sources and countries, with varied levels of thematic details (Table 3).

Table 3. Sources of spatial data with number of locations, names and population in East Africa

Country and source	# of Locations	Markets	Name	Population	Comment
Ethiopia – Atlas of the	937	Y	Y	N	Markets
	935	N	Y	Y	Towns

Ethiopian Rural Economy (AERE)	1062	N	456	456	Populated places
Ethiopia – CIESSIN	427	N	Y	Y	Settlements, some differences in location and population values with AERE
Uganda– humanitarian (unknown)	5330	N	Y	N	Uganda_villages_27Jan 09
	199	N	Y	N	Uganda_Towns with status
	5238	N	Y	N	Uganda parishes 2006 points of parish centres
	6255	N	Y	N	Uganda parishes 2010 (polys)
	964	N	Y	Y	Uganda sub-counties 2010 (polys) excel population projections
Uganda-national (unknown)	4055	N	Y	Y	Uganda parishes 1991 (polys)
Uganda-IFAD (IFAD unknown)	69	N	Y	Y	Settlements– some differences in location between this and Uganda-national and with population values for 1991 and estimates for 2003-15
Uganda-IITA (IITA unknown)	90	N	Y	Y	Uganda_all_towns_population_2003
	83	N	Y	Y	Uganda_cities_population_2003
	6211	N	Y	N	DEMpppoint populated places
	312	N	158	N	Uganda_towns_villages
	11783	N	Y	N	Towns_villages_nima points but not all populated places and many duplicates
Kenya (ILRI unknown)	28815	N	2927	N	Vilages_topo_ilri
	188	N	Y	N	Ken_towns
	6624	N	Y	Y	Kensublocations plys population (1999) and density
	5432	Y	Y	260	Markets
Burundi	34,	N	19	N	

	114	N	Y	N	Cntrs_dist
Tanzania	2635	N	Y	N	Wards2002
	18421	N	Y	Y	Villages (polys) 2002

5.2.2. SUPPLY AND DEMAND

Data on the production of agricultural commodities is available from a number of sources but is in most cases an estimate, based on household surveys and censuses (

Table 4) or on expert knowledge of district agricultural officers. Alternative sources seek to distribute national or regional estimates within a country based on the agro ecological suitability for particular crops or livestock (HarvestChoice, 2011). National estimates of annual production are available but do not reflect production differences within the country.

Table 4. Sources of statistical data on crop production for maize and sorghum for selected countries in East Africa

Country	Production statistics
Maize	
Ethiopia	Woreda – 2001/2002 (also proportion sold)
Uganda	District – 2008/09 per season
Rwanda	Province – 2010/11 (also proportion sold and principal market) District – 2010/11 % of households producing
Burundi	
Tanzania	District – 2007/08 per season
Kenya	
Somalia	
Djibouti	
South Sudan	
Sudan	
Yemen	
Sorghum	
Ethiopia	Woreda – 2001/2002 (also proportion sold)
Uganda	District – 2008/09 per season
Rwanda	Province – 2010/11 (also proportion sold and principal market) District – 2010/11 % of households producing
Burundi	
Tanzania	District – 2007/08 per season
Kenya	
Somalia	
Djibouti	
Sudan	
South Sudan	
Yemen	

(Uganda Bureau of Statistics, 2010, Ministry of Agriculture Food Security and Cooperatives et al., 2012, National Institute of Statistics of Rwanda, 2012)

The final demand is a function of the consuming population and for the case of white maize and sorghum we assume that livestock feed does not represent a significant demand. Intermediate demand is represented by traders and processors but for this study only the final consumer demand is considered. In addition to the demand represented by the market and village locations (Table 3) there is a more dispersed demand which is potentially not captured in the point locations. Examples of these population surfaces include Landscan (Bright et al., 2007), AfriPop (Linard et al., 2012) and the Gridded Population of the World.

5.2.3. DISTANCES, TRANSPORT COSTS AND MARKETING MARGINS

Distances will be measured directly using market locations and the road network. Examples of these road networks can be found in the following reports (Farrow, 2014b, Farrow, 2014a, Farrow, 2014c).

Information on transport costs and marketing margins must be sought from the literature (e.g. Teravaninthorn and Raballand, 2009, Renkow et al., 2004, World Bank, 2009, Kirimi et al., 2011, Sitko and Jayne, 2014).

5.2.4. LIVELIHOOD ZONES

Spatial data on livelihood zones are available for Ethiopia, Uganda, Tanzania (Farrow, 2014b, Farrow, 2014a, Farrow, 2014c) and can be obtained for the other countries in East Africa from FEWS NET. Livelihood descriptions are available for each zone but livelihood matrices may be required to assess quantitatively the vulnerability of the population within each zone to anomalous food prices.

5.3. HOW WOULD WE VALIDATE THE RESULTS? COMPARE TO ECONOMETRIC ANALYSIS (IS THIS POSSIBLE)? COMPARE FEWS NET MAPS OF MARKET BASINS DERIVED FROM QUALITATIVE, KEY INFORMANT APPROACHES?

5.3.1. FIRST STAGE – BALANCING SUPPLY AND DEMAND

Regional market sheds would be compared to existing market sheds for East Africa (Haggblade, 2013, Govereh et al., 2008, Haggblade et al., 2012) as well as country specific trade flow maps (e.g. FEWS NET, 2009c) and value chain analysis reports (e.g. Kirimi et al., 2011, WFP, 2013).

5.3.2. SECOND STAGE – PRICE FORMATION

Validation using switching regimes dynamic regression models with trade flow data, or estimation of transaction costs, or co-integration analyses. It is assumed that the econometric analysis would be conducted by FEWS NET and therefore does not form part of this concept note.

5.3.3. HUFF RETAIL MODEL OF LOCAL MARKET CATCHMENTS

Validation can be provided by household and community surveys that include market names, showing actual interactions between geo-located households, villages and markets.

Examples of these surveys include the World Bank Living Standards Measurement Survey – Integrated Survey on Agriculture (LSMS-ISA) which are freely available for three countries in the East African region: Uganda (2011-2012), Ethiopia (2011-2012, 3917 households, 333 communities) and Tanzania (2012-2013).

5.4. DELIVERABLE OUTLINE

Based on the data and information that are available for the different countries in East Africa for both the modelling and the validation the most appropriate location for a case study to prove the concept of the trade flow and retail gravity models are the countries of Ethiopia, Uganda or Tanzania. Ethiopia has perhaps more comprehensive coverage of markets and population but for proving the concept of the trade and price flow models for the regional/national market sheds it is preferable to choose a country with more than one market shed, and where one of the target crops – maize or sorghum – is nationally important. The Tanzania maize market has therefore been chosen as the test case study.

The outputs of the case study are the following:

Gravity model of trade flows and price formation

First stage – balancing supply and demand

- Monthly maize trade flows among Tanzanian markets (including border markets) under 'normal' conditions, production shock conditions, transport shock conditions, and policy shock conditions
- Maps of Tanzanian market sheds under 'normal' conditions, production shock conditions, transport shock conditions, and policy shock conditions
- Validation report of trade flows

Second stage – price formation

- Monthly maize trade flows and prices among Tanzanian markets (including border markets) under 'normal' conditions, production shock conditions, transport shock conditions, and policy shock conditions
- Maps of Tanzanian market integration under 'normal' conditions, production shock conditions, transport shock conditions, and policy shock conditions
- Validation report of trade flows and prices

Huff retail model of local market catchments

- Catchment areas based on the comparison of probability surfaces of each market under 'normal' conditions, production shock conditions, and transport shock conditions
- Population within the catchment areas as well as the probability-weighted population for each market using either village populations or population density maps under 'normal' conditions, production shock conditions, and transport shock conditions
- Validation report of local market catchments

5.5. TIMEFRAME

Gravity model of trade flows and price formation

First stage – balancing supply and demand 5 months

Second stage – price formation 6 months

Huff retail model of local market catchments 7 months

Assessment of the population vulnerable to anomalous price rises 2 months

6. REFERENCES

ABBOTT, P. & DE BATTISTI, A. B. 2011. Recent global food price shocks: Causes, consequences and lessons for African governments and donors. *Journal of African Economies,* 20**,** i12-i62.

ABDULAI, A. 2000. Spatial price transmission and asymmetry in the Ghanaian maize market. *Journal of Development Economics,* 63**,** 327-349.

ABIDOYE, B. O. & LABUSCHAGNE, M. 2014. The transmission of world maize price to South African maize market: A threshold cointegration approach. *Agricultural Economics (United Kingdom)*.

ALEMU, Z. G. & BIACUANA, G. R. Measuring Market Integration in Mozambican Maize Markets: A Threshold Vector Error Correction Approach. International Association of Agricultural Economists Conference, August 12-18, 2006 2006 Gold Cost, Australia.

ALEMU, Z. G. & OGUNDEJI, A. A. 2010. Price transmission in the South African food market. *Agrekon,* 49**,** 433-445.

ALI, R. & PITKIN, B. 1991. Searching for household food security in Africa. *Finance & Development,* 28**,** 3-6.

ALIGUMA, L., ASHIMOGO, G., MWALE, G. S., NYORO, J., PHIRI, A. & NDIBONGO TRAUB, L. 2008. Country Annexes. *In:* GOVEREH, J., HAGGBLADE, S., NIELSON, H. & TSCHIRLEY, D. (eds.) *Report 1. Maize Market Sheds in Eastern and Southern Africa.*

ANDERSON, J. E. 2011. The Gravity Model. *Annual Review of Economics,* 3**,** 133-160.

ANDERSON, J. E. & VAN WINCOOP, E. 2004. Trade costs. *Journal of Economic Literature,* 42**,** 691-751.

ANGELUCCETTI, I. 2014. *Vulnerability analysis in an Early Warning System for drought.* PhD, Politecnico di Torino.

ARAUJO, C., ARAUJO-BONJEAN, C. & BRUNELIN, S. 2012. Alert at Maradi: Preventing Food Crises by Using Price Signals. *World Development,* 40**,** 1882-1894.

ARNDT, C., BENFICA, R., MAXIMIANO, N., NUCIFORA, A. M. D. & THURLOW, J. T. 2008. Higher fuel and food prices: Impacts and responses for Mozambique. *Agricultural Economics,* 39**,** 497-511.

BADIANE, O., ULIMWENGU, J. M. & WOUTERSE, F. 2010. Spatial Price Transmission and Market Integration in Senegal's Groundnut Market. *IFPRI Discussion Paper* IFPRI West and Central Africa Office.

BAQUEDANO, F. G. & LIEFERT, W. M. 2014. Market integration and price transmission in consumer markets of developing countries. *Food Policy,* 44**,** 103-114.

BARRETT, C. B. 1996. Market analysis methods: Are our enriched toolkits well suited to enlivened markets? *American Journal of Agricultural Economics,* 78**,** 825-829.

BARRETT, C. B. & LI, J. R. 2002. Distinguishing between equilibrium and integration in spatial price analysis. *American Journal of Agricultural Economics,* 84**,** 292-307.

BAULCH, B. 1997. Transfer costs, spatial arbitrage, and testing for food market integration. *American Journal of Agricultural Economics,* 79**,** 477-487.

BECKMANN, M. J. & PUU, T. 1985. *Spatial economics: density, potential, and flow*.

BENSON, T., MUGARURA, S. & WANDA, K. 2008. Impacts in Uganda of rising global food prices: The role of diversified staples and limited price transmission. *Agricultural Economics,* 39**,** 513-524.

BLANFORD, J. I., KUMAR, S., LUO, W. & MACEACHREN, A. M. 2012. It's a long, long walk: accessibility to hospitals, maternity and integrated health centers in Niger. *International Journal of Health Geographics,* 11.

BOUDREAU, T. 1998. The Food Economy Approach: a framework for understanding rural livelihoods. *Relief and Rehabilitation Network Paper.* London: Overseas Development Institute.

BOUDREAU, T. 2007. Putting the 'ability' back in Vulnerability: Food Security Early Warning Systems and The Livelihoods Integration Unit in Ethiopia. F.E.G. Consulting.

BRESSLER, R. G. & KING, R. A. 1970. *Markets, Prices and Interregional Trade* New York, John Wiley and Sons.

BREYER, B. & VOSS-ANDREAE, A. 2013. Food mirages: Geographic and economic barriers to healthful food access in Portland, Oregon. *Health and Place,* 24**,** 131-139.

BRIGHT, E. A., COLEMAN, P. R. & KING, A. L. 2007. LandScan 2006. Oak Ridge, TN: Oak Ridge National Laboratory.

BROWN, M. E., HIGGINS, N. & HINTERMANN, B. 2009. A Model of West African Millet Prices in Rural Markets. *CEPE Working Paper.* Zurich: CEPE.

BROWN, M. E., PINZON, J. E. & PRINCE, S. D. 2008. Using satellite remote sensing data in a spatially explicit price model: Vegetation dynamics and millet prices. *Land Economics,* 84**,** 340-357.

BROWN, M. E., TONDEL, F., ESSAM, T., THORNE, J. A., MANN, B. F., LEONARD, K., STABLER, B. & EILERTS, G. 2012. Country and regional staple food price indices for improved identification of food insecurity. *Global Environmental Change,* 22**,** 784-794.

BUN, M. J. G. & KLAASSEN, F. J. G. M. 2002. The Importance of dynamics in Panel Gravity Models of Trade. *Discussion Paper.* Amsterdam: Department of Quantitative Economics, Faculty of Economics and Econometrics, Universiteit van Amsterdam.

BUTLER, J. S. & MOSER, C. 2010. Structural model of agricultural markets in developing countries. *American Journal of Agricultural Economics,* 92**,** 1364-1378.

CAMPBELL, C. C. 1991. Food insecurity: A nutritional outcome or a predictor variable? *Journal of Nutrition,* 121**,** 408-415.

CARIMO ABDULA, D. 2005. *IMPROVING MAIZE MARKETING AND TRADE POLICIES TO PROMOTE HOUSEHOLD FOOD SECURITY IN SOUTHERN MOZAMBIQUE.* MASTER OF SCIENCE, Michigan State University.

CHAMBERLIN, J. & JAYNE, T. 2011. Unpacking the Meaning of "Market Access". *Staff Paper.* Department of Agricultural, Food and Resource Economics, MICHIGAN STATE UNIVERSITY.

CHENG, Y., WANG, J. & ROSENBERG, M. W. 2012. Spatial access to residential care resources in Beijing, China. *International Journal of Health Geographics,* 11.

CHRISTALLER, W. 1933. *Die zentralen Orte in Suddeutschland. English translation, C.W. Baskin, 1966, Central places in southern Germany. ,* Englewood Cliffs, Prentice-Hall.

COATES, J. 2013. Build it back better: Deconstructing food security for improved measurement and action. *Global Food Security,* 2**,** 188-194.

CROOKS, V. A. & SCHUURMAN, N. 2012. Interpreting the results of a modified gravity model: examining access to primary health care physicians in five Canadian provinces and territories. *BMC Health Services Research***,** 230.

CUDJOE, G., BREISINGER, C. & DIAO, X. 2010. Local impacts of a global crisis: Food price transmission, consumer welfare and poverty in Ghana. *Food Policy,* 35**,** 294-302.

DEATON, A. & DUPRIEZ, O. 2011. Using unit-values to assess spatial price differences: evidence from India and Brazil. Princeton University

World Bank.
DERCON, S. & HODDINOTT, J. 2005. Livelihoods, Growth, and Links to Market Towns in 15 Ethiopian Villages. *FCND Discussion Paper* Washington, DC: IFPRI , FOOD CONSUMPTION AND NUTRITION DIVISION.
DOROSH, P., DEL NINNO, C. & SAHN, D. E. 1995. Poverty alleviation in Mozambique: a multi-market analysis of the role of food aid. *Agricultural Economics,* 13**,** 89-99.
DREZNER, T., DREZNER, Z. & KALCZYNSKI, P. 2011. A cover-based competitive location model. *Journal of the Operational Research Society,* 62**,** 100-113.
ESSAM, T. M. 2013. *Analyzing Millet Price Regimes and Market Performance in Niger with Remote Sensing Data.* Doctor of Philosophy, University of Maryland.
FACKLER, P. L. & GOODWIN, B. K. 2001. SPATIAL PRICE ANALYSIS. *In:* GARDNER, B. L. & RAUSSER, G. C. (eds.) *Handbook of agricultural economics.* Elsevier.
FACKLER, P. L. & TASTAN, H. 2008. Estimating the degree of market integration. *American Journal of Agricultural Economics,* 90**,** 69-85.
FAFCHAMPS, M. & GAVIAN, S. 1996. The spatial integration of livestock markets in Niger. *Journal of African Economies,* 5**,** 366-405.
FAFCHAMPS, M. & HILL, R. V. 2008. Price transmission and trader entry in domestic commodity markets. *Economic Development and Cultural Change,* 56**,** 729-766.
FAMINOW, M. D. & BENSON, B. L. 1990. Integration of spatial markets. *American Journal of Agricultural Economics,* 72**,** 49-62.
FAO, IFAD, IMF, OECD, UNCTAD, WFP, BANK, W., WTO, IFPRI & HLTF, U. 2011. Price Volatility in Food and Agricultural Markets: Policy Responses.
FARROW, A. 2014a. Managing factors that affect the adoption of grain legumes in Ethiopia in the N2Africa project. Wageningen, Netherlands.
FARROW, A. 2014b. Managing factors that affect the adoption of grain legumes in Tanzania in the N2Africa project. Wageningen, Netherlands.
FARROW, A. 2014c. Managing factors that affect the adoption of grain legumes in Uganda in the N2Africa project. Wageningen, Netherlands.
FARROW, A., RISINAMHODZI, K., ZINGORE, S. & DELVE, R. J. 2011. Spatially targeting the distribution of agricultural input stockists in Malawi. *Agricultural Systems,* 104**,** 694-702.
FELEKE, S. T., KILMER, R. L. & GLADWIN, C. H. 2005. Determinants of food security in Southern Ethiopia at the household level. *Agricultural Economics,* 33**,** 351-363.
FEWS NET 2008. Structure-Conduct-Performance and Food Security. *FEWS NET Markets Guidance.* Washington DC: FEWS NET.
FEWS NET 2009a. Commodity Market Maps and Price Bulletins: Tools for Food Security Analysis and Reporting. *FEWS NET Markets Guidance.* Washington DC: FEWS NET.
FEWS NET 2009b. Markets, Food Security and Early Warning Reporting. *FEWS NET Markets Guidance.* Washington DC: FEWS NET.
FEWS NET. 2009c. *PRODUCTION AND MARKET FLOW MAPS: ETHIOPIA FIRST SEASON MAIZE*. FEWSNET.
FEWS NET 2009d. Sahel and West Africa Food Security Update. Washington, D.C.: FEWS NET.
FEWS NET. 2014a. *East Africa: Seasonal Monitor* [Online]. FEWS NET. Available: http://www.fews.net/%C3%A1frica-del-este/seasonal-monitor/thu-2014-04-24 [Accessed April 24, 2014 2014].
FEWS NET 2014b. KENYA Price Bulletin. FEWS NET.

FEWS NET, WFP & FAO 2011. Gambella - Ethiopia Market Profile Report. FEWS NET/WFP/FAO Joint Cross-Border Market and Trade Monitoring Project.

FIAMOHE, R., SECK, P. A., ALIA, D. Y. & DIAGNE, A. 2013. Price transmission analysis using threshold models: An application to local rice markets in Benin and Mali. *Food Security,* 5**,** 427-438.

GAMBINI, R., HUFF, D. L. & JENKS, G. F. 1968. Geometric properties of market areas. *Papers of the Regional Science Association,* 20**,** 85-92.

GARG, T., BARRETT, C. B., GÓMEZ, M. I., LENTZ, E. C. & VIOLETTE, W. J. 2013. Market Prices and Food Aid Local and Regional Procurement and Distribution: A Multi-Country Analysis. *World Development,* 49**,** 19-29.

GETNET, K. 2007. Spatial equilibrium of wheat markets in Ethiopia. *African Development Review,* 19**,** 281-303.

GETNET, K., VERBEKE, W. & VIAENE, J. 2005. Modeling spatial price transmission in the grain markets of Ethiopia with an application of ARDL approach to white teff. *Agricultural Economics,* 33**,** 491-502.

GITTELSOHN, J., MOOKHERJI, S. & PELTO, G. 1998. Operationalizing household food security in rural Nepal. *Food and Nutrition Bulletin,* 19**,** 210-222.

GOLETTI, F., AHMED, R. & FARID, N. 1995. Structural determinants of market integration: the case of rice markets in Bangladesh. *Developing Economies,* 33**,** 185-202.

GOVEREH, J., HAGGBLADE, S., NIELSON, H. & TSCHIRLEY, D. 2008. *Report 1. Maize Market Sheds in Eastern and Southern Africa*.

GRÁDA, C. Ó. 2005. Markets and Famines in Pre-Industrial Europe. *Journal of Interdisciplinary History,* 36**,** 143-166.

GRANGER, C. W. J. 1969. INVESTIGATING CAUSAL RELATIONS BY ECONOMETRIC MODELS AND CROSS-SPECTRAL METHODS. *Econometrica,* 37**,** 414-&.

HAGERSTRAND, T. 1967. *Innovation diffusion as a spatial process. ,* Chicago translated and with a postscript by Allan Pred. (Originally published in 1953.). , University of Chicago Press.

HAGGBLADE, S. 2013. Unscrambling Africa: Regional Requirements for Achieving Food Security. *Development Policy Review,* 31**,** 149-176.

HAGGBLADE, S., LONGABAUGH, S., BOUGHTON, D., DEMBELÉ, N., DIALLO, B., STAATZ, J. & TSCHIRLEY, D. 2012. Staple Food Market Sheds in West Africa. *MSU International Development Working Paper.* Department of Agricultural, Food, and Resource Economics, Department of Economics, MICHIGAN STATE UNIVERSITY.

HAGGBLADE, S., NIELSON, H., GOVEREH, J. & DOROSH, P. 2008. Report 2. Potential Consequences of Intra-Regional Trade in Short-Term Food Security Crises in Southeastern Africa. Michigan State University.

HALL, P. (ed.) 1966. *Von Thünen's Isolated State (English translation by Carla M. Wartenberg, with an introduction by the editor). The Isolated State, Volumes I, II and III (1826, 1850, 1867).* Pergamon Press.

HARRISON, K., HENLEY, D., RILEY, H. & SHAFFER, J. 1974. Improving Food Marketing Systems in Developing Countries Experiences from Latin America. *Research Report* Latin American Studies Center, Michigan State University.

HARRISS, B. 1979. There is Method in My Madness: Or is it Vice Versa? Measuring Agricultural Market Performance. *Food Research Institute Studies*.

HARVESTCHOICE. 2011. *Maize production (mt) (2000)*. Washington, DC. and St. Paul, MN: International Food Policy Research Institute and University of Minnesota

HAYAMI, Y., KAWAGOE, T. & MOROOKA, Y. 1988. Middlemen and peasants: the structure of the Indonesian soybean market. *Developing Economies,* 26**,** 51-67.

HAYNES, K. E. & FOTHERINGHAM, A. S. 1984. *Gravity and Spatial Interaction Models*, SAGE Publications.

HERNÁNDEZ-VILLAFUERTE, K. 2012. Relationship Between Spatial Price Transmission and Geographical Distance in Brazil. *International Association of Agricultural Economists (IAAE) Triennial Conference.* Foz do Iguaçu, Brazil.

HISCOX, M. J. & KASTNER, S. 2008. A General Measure of Trade Policy Orientations: Gravity-Model-Based Estimates for 76 Nations, 1960 to 2000.

HODDINOTT, J. 2013. Cash, Food, or Vouchers? Evidence from a Four-Country Experimental Study

HOOVER, E. M. & GIARRATANI, F. 1999. An Introduction to Regional Economics THIRD EDITION ed.: Regional Research Institute, WVU.

HU, R., DONG, S., ZHAO, Y., HU, H. & LI, Z. 2013. Assessing potential spatial accessibility of health services in rural China: A case study of Donghai county. *International Journal for Equity in Health,* 12.

HUFF, D. L. 1961. Ecological characteristics of consumer behavior. *Papers of the Regional Science Association,* 7**,** 19-28.

IHLE, R., VON CRAMON-TAUBADEL, S. & ZORYA, S. 2011. Measuring the Integration of Staple Food Markets in Sub-Saharan Africa: Heterogeneous Infrastructure and Cross Border Trade in the East African Community. *CESifo Working Paper Series*

JALETA, M. & GEBERMEDHIN, B. 2009. Price Cointegration Analyses of Food Crop Markets: The case of Wheat and Teff Commodities in Northern Ethiopia. *International Association of Agricultural Economists Conference.* Beijing, China.

JAYNE, T. S. & JONES, S. 1997. Food marketing and pricing policy in eastern and Southern Africa: A survey. *World Development,* 25**,** 1505-1527.

JONES, W. O. 1968. The Structure of Staple Food Marketing in Nigeria as Revealed by Price Analysis. *Food Research Institute Studies*.

KARUGIA, J. 2011. High and Volatile Food Prices: Drivers and Impacts on Food Security in Eastern and Central Africa. *Paper prepared for the 1st ASARECA General Assembly, Entebbe, Uganda.* Nairobi, Kenya: ILRI.

KEATS, S., WIGGINS, S., COMPTON, J. & VIGNERI, M. 2010. Food price transmission: rising international cereals prices and domestic markets. *Project Briefing.* Overseas Development Institute.

KIRIMI, L., SITKO, N. J., JAYNE, T. S., KARIN, F., MUYANGA, M., SHEAHAN, M., FLOCK, J. & BOR, G. 2011. A Farm Gate-to-Consumer Value Chain Analysis of Kenya's Maize Marketing System. *Food Security International Development Working Papers.*

KIZITO, A. M., DONOVAN, C. & STAATZ, J. M. 2012. Impact of Agricultural Market Information Systems Activities on Market Performance in Mozambique. Michigan State University, Department of Agricultural, Food, and Resource Economics.

KRUSEMAN, G., RUBEN, R. & TESFAY, G. 2006. Diversity and development domains in the Ethiopian highlands. *Agricultural Systems,* 88**,** 75-91.

KUIPER, W. E., LUTZ, C. & VAN TILBURG, A. 2003. Vertical price leadership on local maize markets in Benin. *Journal of Development Economics,* 71**,** 417-433.

KUSANO, E. & SAIZEN, I. 2013. Spatial market integration of livestock products and road conditions in Mongolia. *Japan Agricultural Research Quarterly,* 47**,** 423-433.

LELE, U. J. 1967. Market Integration: A Study of Sorghum Prices in Western India. *Journal of Farm Economics,* 49**,** 147-159.

LENTZ, E. C. & BARRETT, C. B. 2013. The economics and nutritional impacts of food assistance policies and programs. *Food Policy,* 42**,** 151-163.

LENTZ, E. C., BARRETT, C. B., GÓMEZ, M. I. & MAXWELL, D. G. 2013. On The Choice and Impacts of Innovative International Food Assistance Instruments. *World Development,* 49**,** 1-8.

LI, C. & SEXTON, R. J. 2013. Grocery-retailer pricing behavior with implications for farmer welfare. *Journal of Agricultural and Resource Economics,* 38**,** 141-158.

LINARD, C., GILBERT, M., SNOW, R. W., NOOR, A. M. & TATEM, A. J. 2012. Population distribution, settlement patterns and accessibility across Africa in 2010. *PLoS ONE,* 7**,** e31743.

LIPPER, L., ANDERSON, C. L. & DALTON, T. J. 2009. *Seed Trade in Rural Markets Implications for Crop Diversity and Agricultural Development*, Routledge.

LISTORTI, G. & ESPOSTI, R. 2012. Horizontal Price Transmission in Agricultural Markets: Fundamental Concepts and Open Empirical Issues. *Bio-based and Applied Economics,* 1**,** 81-96.

LIU, L. 2013. International stock market interdependence: Are developing markets the same as developed markets? *Journal of International Financial Markets, Institutions and Money,* 26**,** 226-238.

LIVELIHOOD INTEGRATION UNIT 2010. The Livelihoods Atlas for Ethiopia The Livelihoods Integration Unit. Livelihood Integration Unit of the Disaster Risk Management and Food Security Sector of the Ministry of Agriculture, Government of Ethiopia.

LOO, B. P. Y., HO, H. W. & WONG, S. C. 2005. An application of the continuous equilibrium modelling approach in understanding the geography of air passenger flows in a multi-airport region. *Applied Geography,* 25**,** 169-199.

MAROCCHINO, C. 2009. A guide to upgrading rural agricultural retail markets. *AGRICULTURAL MANAGEMENT, MARKETING AND FINANCE WORKING DOCUMENT.* Rome: Agricultural Management, Marketing and Finance Service (AGSF), Rural Infrastructure and Agro-Industries Division, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS.

MARTINEZ-ZARZOSO, I. & NOWAK-LEHMANN, F. 2003. Augmented Gravity Model: An Empirical Application to Mercosur-European Union Trade Flows. *Journal of Applied Economics,* VI**,** 291-316.

MASON, N. M. & MYERS, R. J. 2013. The effects of the Food Reserve Agency on maize market prices in Zambia. *Agricultural Economics (United Kingdom),* 44**,** 203-216.

MASSEY JR, T. K. & BLAKE, F. W. 1987. Estimating market boundaries for health care facilities and services. *Journal of Health Care Marketing,* 7**,** 15-24.

MAXWELL, D. G., LENTZ, E. C. & BARRETT, C. B. 2008. Cash, Local Purchase, and/or Imported Food Aid?: Market Information and Food Insecurity Response Analysis. *Research Brief.*

MAXWELL, D. G., PARKER, J. W. & STOBAUGH, H. C. 2013. What drives program choice in food security crises? Examining the "response analysis" question. *World Development,* 49**,** 68-79.

MCLAREN, A. 2013. Asymmetry in price transmission in agricultural markets. *Working Paper Series.* University of Geneva, Département d'Economie Politique.

MEYER, J. & VON CRAMON-TAUBADEL, S. 2004. Asymmetric price transmission: A survey. *Journal of Agricultural Economics,* 55**,** 581-611.

MIG INC., -. 2012. IMPLAN's Gravity Model and Tradeflow RPCs.

MINISTRY OF AGRICULTURE FOOD SECURITY AND COOPERATIVES, MINISTRY OF LIVESTOCK DEVELOPMENT AND FISHERIES, MINISTRY OF WATER AND IRRIGATION, MINISTRY OF AGRICULTURE LIVESTOCK AND ENVIRONMENT ZANZIBAR, PRIME MINISTER'S OFFICE, REGIONAL ADMINISTRATION AND LOCAL GOVERNMENTS, MINISTRY OF INDUSTRIES, T. A. M., THE NATIONAL BUREAU OF STATISTICS & OFFICE OF THE CHIEF GOVERNMENT STATISTICIAN ZANZIBAR 2012. National Sample Census of Agriculture 2007/2008 Small Holder Agriculture Volume II: Crop Sector - National Report.

MINOT, N. & BAULCH, B. 2005. Spatial patterns of poverty in Vietnam and their implications for policy. *Food Policy,* 30**,** 461.

MOFYA-MUKUKA, R. & ABDULAI, A. 2013. Policy reforms and asymmetric price transmission in the zambian and tanzanian coffee markets. *Economic Modelling,* 35**,** 786-795.

MOSER, C., BARRETT, C. & MINTEN, B. 2009. Spatial integration at multiple scales: rice markets in Madagascar. *Agricultural Economics,* 40**,** 281-294.

NATIONAL INSTITUTE OF STATISTICS OF RWANDA 2012. EICV3 THEMATIC REPORT: Agriculture.

NEGASSA, A. 1998. Vertical and Spatial Integration of Grain Markets in Ethiopia: Implications for Grain Market and Food Security Policies. *GRAIN MARKET RESEARCH PROJECT.* ADDIS ABABA, Ethiopia: MINISTRY OF ECONOMIC DEVELOPMENT AND COOPERATION.

NGIGI, M. 2008. STRUCTURE, CONDUCT AND PERFORMANCE OF COMMODITY MARKETS IN SOUTH SUDAN: Linkages Food Security.

OECD 2013. Settlement, Market and Food Security. *West African Studies.* Sahel and West Africa Club.

OLADAPO, M. O. & MOMOH, S. 2008. Price transmission and market integration in Oyo State, Nigeria. *African Development Review,* 20**,** 497-504.

OLPER, A. & RAIMONDI, V. 2008. Agricultural market integration in the OECD: A gravity-border effect approach. *Food Policy,* 33**,** 165-175.

OLSSON, G. 1965. Distance and Human Interaction. A Review and Bibliography. *Regional Science Research Institute, Bibliographic Series.* Philadelphia.

ONU, J. I. & ILIYASU, H. A. 2008. An Economic Analysis of the Food Grain Market in Adamawa State, Nigeria. *World Journal of Agricultural Sciences,* 4**,** 617-622.

OPENSHAW, S. 1987. An automated geographical analysis system. *Environment and Planning A,* 19**,** 431-436.

PATT, A. G., OGALLO, L. & HELLMUTH, M. 2007. Sustainability: Learning from 10 years of climate outlook forums in Africa. *Science,* 318**,** 49-50.

PENDER, J., GEBREMEDHIN, B., BENIN, S. & EHUI, S. 2001. Strategies for sustainable agricultural development in the Ethiopian highlands. *American Journal of Agricultural Economics,* 83**,** 1231-1240.

PINGALI, P., ALINOVI, L. & SUTTON, J. 2005. Food security in complex emergencies: Enhancing food system resilience. *Disasters,* 29**,** S5-S24.

POZZI, F. & ROBINSON, T. 2008. Accessibility Mapping in the Horn of Africa: Applications for Livestock Policy. *IGAD LPI Working Paper.* IGAD Livestock Policy Initiative.

POZZI, F., ROBINSON, T. & NELSON, A. 2010. Accessibility Mapping and Rural Poverty in the Horn of Africa. *IGAD LPI Working Paper.* IGAD Livestock Policy Initiative.

RADKE J & L, M. 2000. Spatial decomposition, modeling and mapping service regions to predict access to social programs. *Geographic Information Sciences,* 6**,** 105 - 112.

RASHID, S., MINOT, N., LEMMA, S. & BEHUTE, B. Are Staple Food Markets in Africa Efficient? Spatial Price Analyses and Beyond. Comesa policy seminar - Food price variability: Causes, consequences, and policy options, 2010 Maputo, Mozambique. Comesa-MSU-IFPRI African Agricultural Markets Project (AAMP).

RATTI, C., SOBOLEVSKY, S., CALABRESE, F., ANDRIS, C., READES, J., MARTINO, M., CLAXTON, R. & STROGATZ, S. H. 2010. Redrawing the Map of Great Britain from a Network of Human Interactions. *PLoS ONE,* 5**,** e14248.

RAVALLION, M. 1986. TESTING MARKET INTEGRATION. *American Journal of Agricultural Economics,* 68**,** 102-109.

REILLY, W. J. 1931. *The Law of Retail Gravitation,* New York, W.J.Reilly, Inc.

REINERT, K. A. 2009. gravity models. *In:* REINERT, K. A., RAJAN, R. S., GLASS, A. J. & DAVIS, L. S. (eds.) *The Princeton Encyclopedia of the World Economy. (Two volume set).* Princeton: Princeton University Press.

RENKOW, M., HALLSTROM, D. G. & KARANJA, D. D. 2004. Rural infrastructure, transactions costs and market participation in Kenya. *Journal of Development Economics,* 73**,** 349.

REUTLINGER, S. 1978. Food insecurity: Magnitude and remedies. *World Development,* 6**,** 797-811.

RUKUNI, M. & EICHER, C. K. 1988. The food security equation in Southern Africa. *Poverty, policy, and food security in Southern Africa***,** 133-157.

SALONEN, M., TOIVONEN, T., COHALAN, J.-M. & COOMES, O. T. 2012. Critical distances: Comparing measures of spatial accessibility in the riverine landscapes of Peruvian Amazonia. *Applied Geography,* 32**,** 501-513.

SANOGO, I. 2008. Spatial Integration of the Rice Market: Empirical Evidence from Mid-west and Far-west Nepal, and the Nepalese-Indian Border. *Asian Journal of Agriculture and Development,* 4**,** 139-156.

SARRIS, A. H. & TAYLOR, L. 1976. Cereal stocks, food aid and food security for the poor. *World Development,* 4**,** 967-976.

SCHÜTTEL, C., KLEINWECHTER, U., IHLE, R. & GRETHE, H. 2011. Domestic policy responses to the food price crisis: The case of Bolivia. *Journal of Agriculture and Rural Development in the Tropics and Subtropics,* 112**,** 125-139.

SEGAL, D. B. 1999. Retail Trade Area Analysis: Concepts and New Approaches. Vienna, VA: Spatial Insights, Inc.

SEN, A. K. 1981. *Poverty and Famines: an essay on entitlement and deprivation,* Oxford, Oxford University Press.

SEXTON, R. J. 1990. Imperfect competition in agricultural markets and the role of cooperatives: a spatial analysis. *American Journal of Agricultural Economics,* 72**,** 709-720.

SHAKYA, S., WILSON, W. W. & DAHL, B. Pulsating market boundaries and spatial arbitrage in US Gulf Region: Impact of Panama Canal expansion on US agriculture. 53rd Annual Transportation Research Forum, TRF 2012, 2012 Tampa, FL. 569-606.

SHIFERAW, B., OBARE, G. & MURICHO, G. 2008. Rural market imperfections and the role of institutions in collective action to improve markets for the poor. *Natural Resources Forum,* 32**,** 25-38.

SHIN, M. 2010. A geospatial analysis of market integration: The case of the 2004/5 food crisis in Niger. *Food Security,* 2**,** 261-269.

SITKO, N. J. & JAYNE, T. S. 2014. Exploitative Briefcase Businessmen, Parasites, and Other Myths and Legends: Assembly Traders and the Performance of Maize Markets in Eastern and Southern Africa. *World Development,* 54**,** 56-67.

STAAL, S. J., BALTENWECK, I., WAITHAKA, M. M., DEWOLFF, T. & NJOROGE, L. 2002. Location and uptake: integrated household and GIS analysis of technology adoption and land use, with application to smallholder dairy farms in Kenya. *Agricultural Economics,* 27**,** 295.

STEPHENS, E. C., MABAYA, E., CRAMON-TAUBADEL, S. V. & BARRETT, C. B. 2012. Spatial Price Adjustment with and without Trade. *Oxford Bulletin of Economics and Statistics,* 74**,** 453-469.

TADESSE, G. & SHIVELY, G. 2009. Food aid, food prices, and producer disincentives in ethiopia. *American Journal of Agricultural Economics,* 91**,** 942-955.

TAKAMATSU, S. 2002. *Economic Analysis of Rice Market Integration in Laos.* Masters, Graduate School of International Cooperation Studies, Kobe University.

TAYLOR, P. J. 1983. *DISTANCE DECAY IN SPATIAL INTERACTIONS*, Geo Books, Regency House, 34 Duke Street, Norwich NR3 3AP, England.

TERAVANINTHORN, S. & RABALLAND, G. 2009. *Transport Prices and Costs in Africa: A Review of the International Corridors,* Washington DC, World Bank, The.

TIMMER, C. P. 2000. The macro dimensions of food security: Economic growth, equitable distribution, and food price stability. *Food Policy,* 25**,** 283-295.

TRACEY-WHITE, J. 2005. Rural-urban marketing linkages: An infrastructure identification and survey guide. *FAO AGRICULTURAL SERVICES BULLETIN.* Rome: Food and Agricultural Organization of the United Nations, FAO.

UGANDA BUREAU OF STATISTICS 2010. UGANDA CENSUS OF AGRICULTURE 2008/2009 VOLUME IV: CROP AREA AND PRODUCTION REPORT.

USAID 2013. An Assessment of Market Information Systems in East Africa.

VAN BRAKEL, M. L. & ROSS, L. G. 2011. Aquaculture development and scenarios of change in fish trade and market access for the poor in Cambodia. *Aquaculture Research,* 42**,** 931-942.

VAN CAMPENHOUT, B. 2007. Modelling trends in food market integration: Method and an application to Tanzanian maize markets. *Food Policy,* 32**,** 112-127.

VAN TILBURG, A., KUIPER, W. E. & SWINKELS, R. 2008. Market performance of potato auctions in bhutan. *Journal of International Food and Agribusiness Marketing,* 20**,** 61-87.

VAVRA, P. & GOODWIN, B. K. 2005. Analysis of Price Transmission Along the Food Chain. *OECD Food, Agriculture and Fisheries Working Papers.*

VERBURG, P., H., ELLIS, E. C. & LETOURNEAU, A. 2011. A global assessment of market accessibility and market influence for global environmental change studies. *ENVIRONMENTAL RESEARCH LETTERS,* 6**,** 034019.

VERBURG, P. H., OVERMARS, K. P. & WITTE, N. 2004. Accessibility and land-use patterns at the forest fringe in the northeastern part of the Philippines. *Geographical Journal,* 170**,** 238-255.

VERSAILLES, B. 2009. Market Integration, Distance and Ethnicity in Kenya- The Maize market in Kenya. Centre for the Study of African Economies (CSAE), Department of Economics, University of Oxford.

VIDO, E. & PRENTICE, B. E. 2003. The Use of Proxy Variables in Economic Gravity Models: A Cautionary Note. *Transportation Quarterly,* Winter 2003, Vol. 57

WATTS, M. J. & BOHLE, H. G. 1993. Hunger, famine and the space of vulnerability. *GeoJournal,* 30**,** 117-125.

WECKSTEIN, R. S. 1977. Food security: Storage vs exchange. *World Development,* 5**,** 613-621.

WFP Market Analysis Tool - How to Conduct a Trader Survey?

WFP 2008. PDPE Market Analysis Tool: Market Integration.

WFP 2011. Market Analysis Framework. Rome: World Food Programme Food Security Analysis Service (ODXF).

WFP 2013. Market Dynamics and Financial Services in Kenya's Arid Lands.

WFP. 2014. *Alert for Price Spikes (ALPS)* [Online]. Available: http://foodprices.vam.wfp.org/ALPS-chart.aspx?iso=NER&mid=603&cid=50.

WINOGRAD, M., FARROW, A. & NELSON, A. Hurricane Mitch: What happens to Accessibility when Natural Disasters take out your Transport System? , // 1999 Washington D.C.

WONG, S. C. & YANG, H. 1999. Determining market areas captured by competitive facilities: A continuous equilibrium modeling approach. *Journal of Regional Science,* 39**,** 51-72.

WORLD BANK, T. 1986. *Poverty and Hunger: Issues and Options for Food Security in Developing Countries,* Washington, DC.

WORLD BANK, T. 2009. EASTERN AFRICA: A STUDY OF THE REGIONAL MAIZE MARKET AND MARKETING COSTS. Agriculture and Rural Development (AFTAR), Sustainable Development Department, Country Department 1, Tanzania, Uganda and Burundi, Africa Region.

WORLD FOOD SUMMIT 1996. Rome Declaration on World Food Security and World Food Summit Plan of Action. Rome: Food and Agriculture Organization of the United Nations (FAO) FAO.

WRIGHT, J., STEPHENS, T., WILSON, R. & SMITH, J. 2002. The effect of local livestock population changes on auction market viability - A spatial analysis. *Journal of Rural Studies,* 18**,** 477-483.

YAO, J., MURRAY, A. T. & AGADJANIAN, V. 2013. A geographical perspective on access to sexual and reproductive health care for women in rural Africa. *Social Science and Medicine,* 96**,** 60-68.

YOSHIDA, N. & DEICHMANN, U. 2009. Measurement of Accessibility and Its Applications. *Journal of Infrastructure Development,* 1**,** 1-16.

ZANT, W. 2010. Market Integration with Transaction Costs in Developing Country Staple Food Markets: the Case of the Malawi Maize market. *Joint 3rd African Association of Agricultural Economists (AAAE) and 48th Agricultural Economists Association of South Africa (AEASA) Conference.* Cape Town, South Africa.

ZANT, W. 2012. The economics of food aid under subsistence farming with an application to malawi. *Food Policy,* 37**,** 124-141.