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Rainfall Shocks, Markets, and Food Crises: Evidence from the Sahel

By Jenny C. Aker

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Keywords: Markets, food crisis, Africa, climate change, vector autoregressive model

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(In Bangladesh), a group of sharks, hoarders, smugglers, profiteers and black-marketeers were trading on human miseries.
Mujibur Rahman, *The Bangladesh Observor,* September 23, 1974, on the 1974 famine in Bangladesh

In (Niger)…the suffering caused by a poor harvest has been dramatically compounded by a surge in food prices and….profiteering by a burgeoning community of traders, who in recent years have been freed from government price controls.
"The Rise of a Market Mentality Means Many go Hungry in Niger", *Washington Post*, April 11, 2005, on the 2005 food crisis in Niger

1. Introduction

Rural households in sub-Saharan Africa are subject to a variety of risks, including illness, crop or income losses, price variations and conflict (Maccini and Yang 2008). Many of these risks are associated with natural shocks, such as weather and insect infestations. A substantial body of empirical work in development economics measures the impact of such shocks – and in particular, weather variation – on household and individual-level outcomes (Rose 1999, Jensen 2000, Miguel 2005, Maccini and Yang 2008). Yet empirical studies measuring the impact of weather variation on agro-food markets in developing countries are less common. From a public policy standpoint, it is important to determine how such shocks affect market outcomes, as spatial and intertemporal arbitrage can be strongly associated with famines (Sen 1981, Ó Gráda 2007).

This paper examines the effect of weather shocks on measures of grain market performance in Niger, a landlocked country in sub-Saharan Africa. In addition, it attempts to shed light on the pathways connecting rainfall variation to food crises and famine. Niger is subject to frequent and increasingly common droughts, due partly to climate change (Zeng 2003). Such droughts are strongly associated with crop failures, an increase in the price of staple food crops and a reduction in incomes for rural populations. Droughts are also strongly (but not perfectly) correlated with severe food crises and famines; over the past decade, droughts and crop failures occurred in 2000 and 2004, yet only the latter drought resulted in a severe food crisis.

This investigation requires a considerable amount of data, such as information on weather shocks over several time periods, as well as data on prices and transaction costs, trader-level marketing behavior and geographic areas affected by food crises. I therefore construct several datasets. The first is market-level price data between 1996-2006 across 42 domestic and cross-border markets in Niger, collected from Niger's *Système d'Informations sur le Marché Agricole* (SIMA). This includes the geographic location of each market, road distances and transport costs. The second is market-level rainfall data over the same period, obtained from Niger's Meteorological Service. The final datasets are a panel survey of traders collected by the author between 2005-2007 and the classification of food crisis regions in 2005.

I examine the impact of drought during the primary growing season on a range of market-level outcomes between 1997-2006. I find that drought has a heterogeneous impact on grain price dispersion and hence market performance. Consistent with theoretical predictions (Ó Gráda 2007), I find that the presence of drought in both markets is associated with a reduction in grain price dispersion across markets, representing -5 CFA/kg reduction. This represents 5 percent of average millet prices over the time period. Drought in one market is associated with a positive and statistically significant increase in price dispersion between two markets. Drought also has a larger impact on price dispersion when a higher percentage of markets are affected by drought, as was the case in 1997-98 and 2004-05.

A central concern with the estimates is the possibility of alternative explanations for the empirical results. Specifically, one may question whether income or health shocks, changing degrees of market power or other infrastructure improvements could explain the reduction in price dispersion during drought years. Income and health surveys suggest that the Nigerien population did not become significantly poorer between 2000 and 2005, providing support that reductions in price dispersion are not due to demand shocks. Recognizing that the results could be due to collusive behavior, I calculate an index of market concentration, which suggests that grain traders are highly competitive (Aker 2008). And finally, while the introduction of cell phone towers is associated with a reduction in price dispersion across markets between 2001 and 2006 (Aker 2008), drought and cell phone coverage are not correlated.

I provide suggestive evidence on the intermediate pathways connecting extreme rainfall, grain price levels and consumer welfare in Niger, with a particular focus on the differences between 2000 and 2004. While aggregate and per capita grain production were higher in 2004, a larger percentage of departments were affected by drought, especially Granger-causing markets in Niger and Nigeria. These climatic shocks also affected import parity prices from Nigeria, thereby making imports from Nigeria unprofitable.

This paper is broadly related to a body of research in economics on the relationship between natural shocks and individual and household measures of well-being. Nevertheless, several features help to distinguish this paper from existing research in the field. First, this paper examines exogenous shocks in several periods and across several markets, which provides an opportunity to partially distinguish the impact of drought on from potentially confounding omitted variables. Second, I exploit the exogeneity of rainfall to measure its impact on market-level outcomes, rather than relying upon traditional time-series approaches. And finally, I correct for potential endogeneity associated with a vector autoregressive model (VAR) with fixed effects by using a generalized method of moments (GMM) estimator.

This paper also speaks to the scarce empirical literature on markets and famines (Sen 1981, Ravallion 1985, Ravallion 1987, von Braun, Teklu and Webb 1999, Ó Gráda 2005). The findings of this paper are consistent with the strong association – although not perfect correlation – between extreme weather, crop failures and food crises (Ó Gráda 2007). It also supports the theoretical prediction that, as long as transport costs remain constant, the Law of One Price (LOP) implies that the variation in food prices across markets should decline during famines (Drèze and Sen 1989, Ó Gráda 2007). This paper adds to the existing literature by documenting the impact of extreme rainfall on market performance, and suggests that traders did not hoard during the 2005 food crisis, as implied by previous findings (Sen 1981, Ravallion 1987).

The remainder of this paper proceeds as follows. Section 2 discusses conceptual issues, and Section 3 provides an overview of drought, grain markets and food crises in Niger. Section 4 describes the dataset .and provides some descriptive statistics. Section 5 outlines the empirical strategy, whereas Section 6 provides the main estimation results. Section 7 explores alternative explanations and the specific mechanisms behind the effects. Section 8 discusses the policy implications, and Section 9 concludes.

2. Rainfall, Grain and Food Crises in Niger

Niger, a landlocked country located in West Africa, is one of the poorest countries in the world. With a per capita GNP of US$230 and an estimated 85 percent of the population living on less than US$2 per day, Niger is ranked 174th (out of 177) on the United Nations' Human Development Index (UNDP 2008). Rainfall is the most important dimension of weather variation in Niger. As the country spans the Saharan, Sahelian and Sudano-Sahelian agro-ecological zones, rainfall ranges from 200 millimeters (mm) per year in the northern regions to 800 mm in the south. Precipitation varies substantially across the country both within year and across years (Nicholson et al 2000).[1] Staple food crops consist of millet, sorghum and fonio, with cash crops including cowpeas, peanuts, cotton and sesame.

Inter-annual deviations in rainfall are positively associated with fluctuations in grain output, as millet production depends upon the timing and quantity of rainfall.[2] Niger experienced six droughts between 1980 and 2005. [3] Table 1 shows annual grain (millet and sorghum) production between 1985 and 2004; years of relatively higher rainfall have higher grain output, and years of unusually low rainfall have lower grain output. Nevertheless, the spatial distribution of drought also varies considerably by year. For example, droughts occurred in both 2000 and 2004. While grain output was higher in 2004, only 15 percent of the departments experienced a crop failure (a per capita decrease in grain production of more than 50 percent as compared to the department-level mean) in 2000, as compared with 25 percent of departments in 2004.[4]

A variety of agents are involved in moving grains from the source of production to final consumption points in Niger. These include farmers, who produce, sell and buy grains; traders, including retailers, intermediaries, semi-wholesalers and wholesalers; transporters; and rural and urban consumers.[5] Grains are produced by farmers, who sell their production directly to intermediaries located in the village. These intermediaries in turn sell directly to wholesalers. Wholesalers are primarily responsible for inter-regional trade, selling the commodity to other wholesalers, retailers or consumers. Retailers sell directly to both urban and rural consumers. Traders buy and sell grains through a system of traditional markets, each of which is held on a weekly basis.[6] As there is only one harvest per year (October-November), traders begin

[1] Niger's rainfall is unimiodal, with the rainy season beginning in May and ending in October.
[2] Extreme rainfall can be defined as drought or flood. While flooding does occur in Niger, it is relatively rare and limited in its geographic coverage. Consequently, this paper focuses on extreme rainfall as drought, defined as annual rainfall lower than one standard deviation from the mean.
[3] Since the 1960s, Niger has experienced drought in 1966 (Bandabari), 1973 (Dakoussou), 1984 (El Bohari), 1990, 1993, 1997 (Matche mai), 2000 and 2004 (Wazaka gaya ma). Government of Niger. 2007.
[4] During non-drought years, less than 3 percent of all departments experience a crop failure.
[5] Intermediaries are responsible for purchasing grains directly from farmers and selling it to wholesalers or retailers. Wholesalers and semi-wholesalers have greater financial resources, with total sales between 1-3 metric tons (MT)(semi-wholesalers) or greater than 3 MT (wholesalers). Retailers are small-scale traders who sell only in small quantities, usually less than one bag.
[6] The number of traders per market ranges from 24 to 353, with retailers accounting for over 50 percent of all traders.

importing grains from neighboring countries (Benin, Burkina Faso, Mali and Nigeria) in April, once the local supply is depleted.

Because of the importance of rainfall for grain output, drought in positively associated with food crises and famine.[7] An estimated one-third of the country's population died during the "great famine" of 1931 (Fuglestad 1974), with approximately 250,000 drought-related human fatalities occurring in the Sahelian region between 1968-1974 and 1983-1984. Nevertheless, drought is not perfectly correlated with severe food crises. For example, Niger experienced three droughts between 1995 and 2005 (1997, 2000 and 2004), yet only 1997/1998 and 2004/2005 were identified as years of severe food crisis (Government of Niger 2007).[8] In 2005, an estimated 2.4 million Nigeriens were affected by severe food shortages, with more than 800,000 of these classified as critically food insecure (FEWS NET 2005).[9] The gross mortality rate in 2005 reached 1.5 deaths per 10,000 per day in targeted regions, whereas the child mortality rate reached 4.1 deaths per 10,000 per day (Médecins sans Frontières 2005).[10]

3. Conceptual Issues

Since Sen's seminal work on "Poverty and Famines" (Sen 1981), a large body of literature has emerged, in an effort to explain how an improved understanding of markets can prevent or mitigate food crises. Economists have long argued that, since crop failures nearly always vary in intensity across regions and countries, spatial and temporal arbitrage should help mitigate or reduce the cost of famines (Ó Gráda 2007, Persson 1999, Arrow 1982). However, natural and artificial obstacles have often impeded the scope for arbitrage (Ó Gráda 2007).[11] Research on the famines in Bengal (1942-44) and Bangladesh (1974-95) shows that food markets worked "poorly" in these instances, in the sense of inadequate regional arbitrage and "excessive" hoarding on the part of producers and traders (Sen 1981, Ravallion 1987).

[7] In this article, famine is defined as a "widespread lack of food leading directly to excess mortality from starvation or hunger-induced illnesses" (Gràda 2007). Alternative definitions are provided by Ravallion 1997 and Webb, von Braun and Teklu 1999.
[8] Because of the importance of the seasonal cycle of rain, food security also tends to vary on a seasonal basis. It tends to be highest during the rainy season (June to August), when stocks from the previous harvest are low and physical demands are high with the initiation of planting.
[9] There is considerable debate as to whether a "famine" occurred in Niger in 2004/2005. Local, regional and international early warning systems classified the situation as "a very severe, but localized, food security crisis" (FEWS NET 2005).
[10] Both of these indicators exceed the threshold established for emergency situations, which is one death per 10,000 people per day.
[11] Economists have also noted that famines can occur in the presence of perfect markets (Newbury and Stiglitz 1981, Arrow 1982) and that famines themselves may lead to market failures (Ravallion 1985, Sobhan 1979).

The economic literature on food markets and food crises is rooted in the basic trade theory on spatial market equilibrium (Enke 1951, Samuelson 1952, Stigler 1966, and Takayama and Judge 1971), and later modified by Williams and Wright (1991) to include storage. The simplest form of these models can be represented as follows. Consider two markets (*i* and *j*) that engage in trade for a homogeneous commodity (millet). Autarky prices at time *t* can be represented as P_{it} and P_{jt}, with transaction costs between the two markets at time *t* represented as $TC_{ij,t}$.[12] The two markets are in long-run competitive equilibrium when the "no spatial arbitrage" conditions hold:

$$P_{it} - P_{jt} + TC_{ij,t} = 0,\ Q_{ji,t} > 0 \tag{1}$$

$$P_{it} - P_{jt} + TC_{ij,t} \leq 0,\ Q_{ji,t} = 0 \tag{2}$$

where $Q_{ji,t}$ is the volume of trade between two markets. Equations 1 and 2, known as the Euler equations, represent the conditions for competitive equilibrium with perfect integration. Either marginal profits to spatial arbitrage are zero and trade is occurring (Equation 1), or marginal profits are less than or equal to zero but trade does not occur (Equation 2).[13] In either case, the Euler equations can be thought of as the null hypothesis of a competitive spatial equilibrium.

Equations (1) and (2) can be used to derive comparative static predictions for the impact of extreme rainfall on grain market performance. If $TC_{ij,t}$ remains constant and a negative supply shock affects both markets *i* and *j* simultaneously, but increasing P_{it} and P_{jt} at different rates, equilibrium price dispersion could decrease. If a negative supply shock affects only market *i*, then the comparative static predictions are ambiguous; price dispersion could decrease if P_{jt} is unaffected, but increase if there are other permanent factors that increase $\bar{P}_{jt}$. Finally, policies or shocks affect transaction costs, such as gas prices, will be positively associated with equilibrium price dispersion.

4. Data and Measurement

[12] In the trade literature, autarky prices are a function of supply and demand shifters in the local markets and a stochastic disturbance term. As trade in millet is unidirectional for most market pairs in Niger, I make the simplifying assumption that $TC_{ij,t}=TC_{ji,t}$.

[13] The equivalent condition in the presence of storage is: $\frac{E_t(P_{t+1})}{1+r} - P_t - k = 0, S_t > 0$, where P_t is the price in the market at time *t*, P_{t+1} is the price at time $t+1$, *k* is the constant marginal cost of storing the commodity between the two periods, S_t is the quantity stored, *E* is the expectation of price and *r* is the interest rate. The condition states that the price in the current period should never be below the price expected for the next period by more than the cost of storage (Williams and Wright 1991).

4.1. Data Used

In order to test the impact of drought on market performance, this paper constructs four primary datasets. The first is historical rainfall data for weather stations across Niger from the Niger Meterological Service. The data include monthly records for each station between May and September for each year between 1997 and 2006, as well as its latitude and longitude. For each month between 1997 and 2006, I use the station location information to match each market in the sample with the closest weather station. The number of stations over time remains relatively stable during this time period.

The second dataset is includes monthly grain (millet and sorghum) data over a ten-year period (1996-2006) across 42 domestic and cross-border markets in Niger, as well as the latitude and longitude for each market. In addition, data on monthly gas prices, cell phone coverage, road quality, trade flows and district-level population and agricultural production were also collected.

The third dataset is a unique and detailed panel survey of traders, transporters and market resource persons collected in Niger by the author between 2005-2007. The survey contains responses of 395 traders located in 35 markets across six geographic regions of Niger. The traders and market resource persons who participated in the survey provided detailed information about their demographic background and commercial operations during the 2005-06 and 2006-07 marketing seasons. Enumerators also asked a subset of questions about the 2004-05 marketing season, specifically with respect to the quantities marketed, sales prices, markets and assets.

The final dataset includes the classification of the geographic areas affected by the 2005 food crisis. Governmental, non-governmental and international organizations conducted a series of vulnerability surveys between January and May 2005, which were used to develop a list of villages affected by the food crisis.[14]

4.2. Grain Prices

Figure 3 shows average deflated grain (millet) prices in Niger and in Nigeria between 1996-2006, with summary statistics of grain prices provided in Table 2.[15] Overall, grain prices in Niger are subject to a high

[14] The Government of Niger, in collaboration with the World Food Program, divided villages into five categories: extremely critical, critical, very difficult, difficult, and secure. The classification of regions is provided in Figure 2.

degree of inter- and intra-annual variation, with years of above-average rainfall and high-production harvests followed by relatively lower prices, and years of below-average harvests and crop failures followed by relatively higher prices.[16] Average grain prices in 2004-05 were 25 percent higher than the ten-year average, with grain prices representing more than 27 percent of per capita income. By contrast, prices during the 2000-01 marketing season were only 12 percent higher than the ten-year average.

While inter-annual price fluctuations are strong, the seasonal variation of prices is also important. Millet prices range from 20-89 percent higher in the hungry period (August) as compared to harvest period (October), with an average intra-seasonal price difference of 44 percent. Figure 4 shows the seasonal price variation for millet across drought and non-drought years. Millet prices increased by 89 percent between October 2004 and August 2005, and by 75 percent between October 2000 and August 2001. Grain prices in 2004-05 initially followed a similar pattern to that of other drought years, but experienced a significant price increase during the last four months of the marketing season.[17]

Table 4 describes key trader and market-level variables from the panel data survey. The average number of grain traders per market is 137, with 71 percent of markets located next to a paved road (Panel A). Market infrastructure changed very little between 2000 and 2005, with 15 percent of markets having access to a new paved road during this period. Drought occurs once every 3 to 4 years; 50 percent of markets suffered from drought in 2004, as compared with 32 percent in 2000. 78 percent of markets had cell phone coverage by the end of the 2005-06 marketing season.

Grain traders in Niger are predominately from the Hausa ethnic group (65 percent) and are primarily male (Panel B). Although 62 percent of traders have no education, they have over 16 years' of experience.

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[15] Grain prices are deflated by the Nigerien Consumer Price Index (CPI). As the CPI might not necessarily be relevant for rural households, all summary statistics and regressions are also estimated using nominal grain prices, with similar results.

[16] Monthly grain price fluctuations in Niger appear to co-move with prices in northern Benin (Malanville) and northern Nigeria (Illela, Jibia, Konni). The overall trend is similar for sorghum prices, although sorghum is only produced in the southwestern regions of Niger.

[17] Grain prices in 2005 were 8 percent higher in food crisis regions as compared to non-crisis regions, and this different is statistically significant. However, the equality of means across food crisis and non-crisis regions for most variables cannot be rejected, including road quality, market size and per capita grain production. There are statistically significant differences in terms of the presence of a cell phone tower and the market's location in an urban center (Aker 2008).

Grain traders trade primarily in agricultural outputs (as opposed to inputs or livestock), have limited commercial assets and store for relatively short periods of time (less than one month).

5. Main Estimation Strategy

Spatial market integration has typically been thought of in terms of the co-movements or long-run relationships between spatial prices (Cummings, Jr 1967; Lele 1967, Fackler 1996). While price correlations are a simple way to test for market integration, they suffer from serious weaknesses, especially if price data are non-stationary or in markets where storage takes place (Barrett 1996, Williams and Wright 1991).

Several methods have been proposed as an alternative to price correlation tests (Ravallion 1986, Delgado 1986, Baulch 1997, Engle and Granger 1987). Most of these are vector autoregressive (VAR) models, including Granger causality, Ravallion's method, variance decomposition and cointegration analyses. Such models usually involve tests for market "failures" that can be expressed as restrictions of the basic model. In general, these methods often assume stationary transaction costs, as well as unidirectional and/or continuous trade patterns. These assumptions are often violated, especially in a developing country context, thereby suggesting spurious and misleading results (Barrett 1996, Fackler 1996, Barrett and Li 2002, Fackler and Goodwin 2001).

Two alternative econometric approaches to analyzing market performance are the threshold autoregressive (TAR) and parity bounds models (PBM). TAR models are a class of regime-switching models that allow the behavior of the dependent variable to depend upon different states; in the case of market performance, the different regimes are defined by whether price differences are less than, equal to or greater than transactions costs (Goodwin and Piggott 2001, Goodwin and Harper 2000). While the TAR model does not require observations on transactions costs, it is highly parameterized and often assumes fixed transaction costs (Fackler and Goodwin 2001).[18] The PBM, on the other hand, identifies statistically-determined upper and lower bounds of transfer costs, with spatial efficiency implying that the price differential occurs within those bounds. As the PBM allows for transaction costs and autarky, this allows the analyst to determine whether the market is efficient and the extent of this efficiency (Sexton et al 1991, Baulch 1997, Barrett and

[18] Nevertheless, the model can be modified to include actual and time-varying transaction costs.

Li 2002). Nevertheless, as there is no link between economic theory and the distributional assumptions used in PBM, the consistency of the results relies heavily on the validity of the distributional assumptions.[19] In addition, the PBM can only handle a limited number of markets, which is not appropriate for the Nigerien context.

To address some of these empirical weaknesses, this paper employs a two-part empirical strategy. During the first part of the analysis, I rely upon conventional time-series tests – such as conditional correlations, cointegration tests, and Granger causality – in order to identify the degree of grain market integration and key price patterns during different states. Such tests are often unreliable under a set of commonly-occurring conditions, such as nonstationary transaction costs, discontinuous or bi-directional trade and the presence of storage. In the second part of the analysis, I exploit the exogenous variation in extreme rainfall to estimate the impact of natural shocks on grain market performance, namely, grain price dispersion across markets.[20] This involves estimating a difference-in-difference framework with pooled and separate treatments.

The most commonly used measure of market performance is intermarket price differences, or the comparison of intermarket price differences against transaction costs (Spiller and Wood 1988, Sexton, Kling and Carmen 1997, Baulch 1997). As the focus of this paper is on estimating the impact of extreme rainfall on price dispersion, the primary measure of market performance is the price difference between markets i and j at time t, defined as $Y_{ij,t} = | p_{it} - p_{jt} |$.[21] I also use alternative measures of price dispersion, namely the Law of One Price and the intra-annual coefficient of variation (CV) for market i, as robustness checks.[22]

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[19]Monte Carlo experiments can be used to test for the sensitivity of the results to distributional assumptions (Baulch 1997, Barrett and Li 2002).

[20]While anthropogenic factors such as overgrazing and conversion of forest to agriculture could question the exogeneity of drought, I argue that drought is exogenous in the Sahelian context. Zeng (2003) and Giannini et al (2003) show that rainfall in the Sahel is most closely related to a largely tropical sea surface temperature anomaly pattern that spans the Pacific, Atlantic, and Indian oceans.

[21]We observe the direction of trade flow is observed for most market pairs in most periods. However, the absolute value minimizes potential misclassification of the direction of trade flow.

[22] Empirical studies of market performance during famines use dependent variables that measure the degree of spatial and temporal integration (Sen 1981, Webb and von Braun 1994).

To exploit the variation across time and space in extreme rainfall, I augment the standard difference-in-differences (DD) framework by estimating a double DD specification (Bertrand et al 2005).[23] Letting $Y_{ij,t}$ represent the value of the outcome in market pair ij at time t, I examine the change in $Y_{ij,t}$ before and after a drought in each market pair. I first pool the treatments and estimate a multi-period DD equation:

$$Y_{ij,t} = \alpha + \beta_1 R_{ij,t} + \gamma X^{'}_{ij,t} + a_{ij} + \theta_t + u_{ij,t} \qquad (3)$$

where $Y_{ij,t}$ is the absolute value of the price difference of millet between market i and market j at time t. The price difference between two markets is a function of $X_{ij,t}$, including transport costs between the two markets and the presence of cell phone coverage. Price dispersion is also a function of extreme rainfall, $R_{ij,t}$ which takes on a value of one if a drought occurred in both markets i and j at time t, 0 otherwise.[24] Drought is defined as rainfall less than or equal to two standard deviations below a market's mean rainfall level during the rainy season (July and September) or 15 consecutive days without rainfall during this period, 0 otherwise.[25] The idiosyncratic market pair-year disturbance term, $u_{ij,t}$, is included in all specifications, and I allow regression disturbance terms to be correlated across years for the same market pair. Market pair fixed effects ($a_{ij,t}$) capture time-invariant omitted variables -- most obviously geographic factors, such as road quality and distance – that could be correlated with both rainfall and price dispersion. To control for broader economic factors that also lead to changes in price dispersion across markets, and I include time-varying unobserved factors (θ_t) in all specifications.[26]

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[23] The control structure is twofold: temporal, as we compared drought years with non-drought years; and cross-sectional, as we compare drought-affected markets with non-drought markets at time t.

[24] In an alternative specification, two separate indicator variables for drought are included: $R1$, which takes on a value of one if either market experienced drought at time t; and $R2$, which takes on a value of one if both markets experienced drought at time t.

[25]Drought is defined as "temporary reduction in water or moisture availability significantly below the normal or expected amount for a specified period." The assumptions inherent in this definition are that the reduction is temporary and significant; defined in relation to an expectation; and that the period taken as the basis for the expectation is specified. July-September are the wettest months in the Sahelo-Saharan, Sahelian and Soudanian zones, with August contributing approximately 32-40 percent of the annual mean rainfall in Niger (Nicholson et al 2000).

[26] Equation (3) can be estimated via fixed effects transformation or first differencing. While both will be unbiased and efficient under standard assumptions, first differencing can help to address potential serial correlation or nonstationarity problems (Wooldridge 2002). I therefore transform equation (3) via first differences to remove the unobserved heterogeneity.

I modify equation (3) in a variety of ways. As it is reasonable to assume that market performance in period t might depend upon performance in period t-1, I include a lagged dependent variable, which yields a vector autoregressive (VAR) estimating equation:

$$Y_{ij,t} = \alpha + \beta_1 R_{ij,t} + \rho Y_{ij,t-1} + \gamma X'_{ij,t} + a_{ij} + \theta_t + u_{ij,t} \tag{4}$$

where $Y_{ij,t\text{-}1}$ is the lagged price difference between markets i and j. In this model, ρ can be interpreted as the speed of adjustment, with ρ=0 consistent with market efficiency (Levin and Lin 1993, Caner and Hansen 2001).[27] I control for potential endogeneity associated with the first-differenced transformation by using the past values of the explanatory variables as instruments for the lagged dependent variable in a Generalized Method of Moments (GMM) framework (Arellano and Bond 1991, Caselli, Esquivel and Lefort 1996).[28]

Unlike other papers examining the relationship between early-life rainfall and adult outcomes, I am less concerned with potential measurement error in the rainfall variable. First, data from the rainfall stations is closely correlated with actual rainfall at the market-level. Second, to the extent that weather reports are "noisy", the resulting bias will be towards zero as long as the error is not too severe.[29] Thus, the coefficient estimates will serve as a lower bound on the true rainfall effect.

6. Empirical Results

6.1. Market Integration

Before turning to the regression specifications outlined in equations (3) and (4), I examine whether millet prices in Niger co-move. As the time-series properties of the data have important implications for the robustness of our results, I first test for integration of degree zero by conducting an Augmented Dickey-Fuller test, using a time trend and three lags (Engle and Granger 1987, Goodwin and Schroeder 1991). Over 93 percent of markets have test statistics whose absolute values are greater than the reported critical value of

[27] This implies that information observed about price differences in the previous period does not help to predict market differences in period t.

[28] The consistency of the estimation procedure is based upon the assumption that there is no τ -order serial correlation in the error terms after first differencing (i.e. $E[\varepsilon_{ij,t}\ \varepsilon_{ij,t-\tau}]=0$]). To address these concerns, the Sargan test of overidentifying restrictions and testing for no serial correlation in the errors are required.

[29] The exact condition is that *Pr(Type I error) + Pr(Type II error)*<1*).* Aigner 1973.

the Dickey-Fuller test at the 1 percent confidence interval. Of the remaining 7 percent, the price series are close to the critical value. I therefore conclude that our millet price series are integrated of degree one (I(1)).[30]

Table 5 shows the intra- and inter-regional correlations by region and by drought year. The average correlation coefficient for all markets from 1996-2006 is .56, with a majority of coefficients between .4 and .6. This is well below price correlation coefficients computed for other agricultural products in the developing world (Jones 1968, Blyn 1973, Fafchamps and Gavian 1995, Timmer 1974, Trotter 1991). Inter-market correlations during drought years are significantly higher than those in non-drought years, suggesting that grain markets are more integrated during years of below-average rainfall.[31] The degree of integration between markets in Niger and those in border countries (Benin, Burkina Faso, Chad and Nigeria) follows the same pattern. The highest degree of integration occurs between Niger, Benin and Nigeria, with correlation coefficients averaging .65.[32] Grain markets in Niger are more integrated with Benin and Nigeria during drought years, with the highest degree of integration occurring in 2005.[33]

To assess whether price movements in Niger follow well-defined paths, i.e. start around demand or production centers and then spread across the country, I test for Granger causality between each pair of price series (Granger 1969, Schimmelpfennig and Thirtle 1994, Dercon 1995).[34] Figure 5 shows the percentage of times that a market Granger-causes another market in Niger, whereas Figure 6 shows the percentage of times that a market is Granger-caused by another market in Niger or in the sub-region. The results of these tests provide some important insights into price movements within Niger. First, the results suggest that markets located in deficit regions (the northern and western parts of the country) are Granger-caused more frequently than they Granger-cause. At the same time, markets located in surplus regions (the southern and eastern

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[30] I also tested the series for integration of degree zero for monthly gas prices. The gas price series has a test statistics whose absolute value is greater than the critical value of the test. I therefore conclude that gas prices are integrated of degree zero (I(0)).

[31] The 2005 food crisis regions have lower correlation coefficients than non-crisis regions, and this difference is statistically significant across five of the six years under consideration. The only year when this pattern did not hold was 2000-01, when the food crisis regions actually had higher correlation coefficients.

[32] On average, the degree of integration between Chad and Niger is small, averaging .25. Similarly, the degree of integration between Burkina Faso and Niger is also quite limited, averaging .47 between 1999-2006.

[33] As many authors have found the use of correlation coefficients as a measure of market integration to be fraught with problems, I conduct cointegration tests for all market pairs (not shown). The results are consistent with the correlation coefficients in Table 5.

[34] Granger causality tests use the following error correction model: $\Delta P_{it} = \lambda_0 + \sum_{m=1}^{n} \lambda_m \Delta P_{i,t-m} + \sum_{m=1}^{n} \bar{\lambda}_m \Delta P_{j,t-m}$. If price movements in market j precede price movements in market i, then the $\Delta P_{j,t-m}$ terms should have a significant effect on $\Delta P_{i,t}$. The test is conducted for all market pairs.

parts of the country) are useful for predicting price changes in other markets.[35] This suggests that price movements in Niger respond to supply shocks.

Second, and perhaps most importantly, sub-regional markets strongly predict price movements within Niger. The cross-border markets of Malanville (Benin) and Jibia, Illela and Mai-Adua (Nigeria) Granger-cause over 75 percent of the markets in Niger. Overall, these results suggest that supply shocks and price movements in surplus regions can be useful in predicting grain price changes in Niger.

6.2. The Initial Impact of Drought

Deviations of rainfall from the department-level mean are positively associated with deviations of grain output from the department-level mean in Niger. Regressing per capita grain production on an indicator for drought indicates that higher rainfall leads to higher per capita grain output, and this effect is statistically significant at the 1 percent level (Table 6, Column 1).[36] This result is robust to the inclusion of year and geographic fixed effects (Columns 2 and 3). Millet prices in the previous marketing year are associated with a positive but modest increase in per capita grain output, suggesting that grain production is highly inelastic in Niger. Drought is also positively associated with food insecurity in 2005 (Column 4); however, the effect is not statistically significant when other controls are included. Higher millet prices are associated with a positive and statistically significant increase in the probability of food insecurity; this effect is robust to OLS and probit specifications (Columns 5 and 6).[37]

Table 7 presents the regression results of the DD model using a first-differenced transformation (equation 3), controlling for exogenous regressors, market-pair and time fixed effects.[38] The results show that drought has a statistically significant impact on price dispersion.[39] However, the sign of this effect depends upon whether one or both markets are affected by extreme rainfall. Drought in both markets is associated

[35]A market can be simultaneously Granger-causing and can be Granger-caused.

[36] The empirical analysis involves estimating via OLS regressions of the following form for per capita millet output in department i and year t: $Y_{it} = \alpha_0 + \alpha_1 R_{it} + \mu_i + \delta_t + \varepsilon_{it}$. This is similar to the specification used by Levine and Yang (2006) measuring the impact of extreme rainfall on rice output in Indonesia, although without the natural log of the dependent variable.

[37]As the regression results in Columns 4-6 are only for the 2004-05 marketing year, they could suffer from simultaneity bias, as food insecurity could, in turn, also cause higher prices via higher demand.

[38] For all specifications, the Law of One Price (price differences net transport costs) was also used as an alternative dependent variable. The coefficients were nearly identical, and so these results are not reported.

[39] Food aid distribution during drought years can complicate the interpretation of the coefficient estimate on extreme rainfall if food aid blunts its impact. In this case, the coefficient estimates should be interpreted as a lower bound on the effect. Food aid was not provided in substantial quantities in either 1997-98 or 2000-01, but was provided in the later parts of the 2004-05.

with a -5 CFA/kg decrease in price dispersion across markets, and this effect is significant at the 1 percent level (Table 7, Column 1). However, drought in one market is associated with a positive and statistically significant increase in price dispersion across markets. This suggest that, on average, extreme rainfall affects low-supply markets, thereby increasing prices on those markets and increasing price dispersion between low- and high-supply regions. Overall, the rainfall coefficients suggest that the spatial distribution of drought has an important impact on market performance in Niger.

The results are robust to the inclusion of additional controls (Column 2). Transport costs are associated with a positive (.6 CFA/kg) and statistically significant effect on price dispersion, accounting for 3 percent of the variation in price dispersion across markets. This suggests that factors affecting transport costs in Niger – such as gas prices, distance and road quality – have a statistically significant but economically limited impact on grain market performance.[40] The presence of cell phone coverage is associated with a statistically significant reduction in price dispersion across markets, with price dispersion in cell phone markets 22 percent lower as compared to those in non-cell phone markets (Aker 2008).

Including market-specific time trends (Column 3) and monthly time dummies (Column 4) reduces the value of the point estimates for drought slightly, but does not change the sign or the statistical significance. Column 5 includes cross-border markets (Benin, Burkina Faso and Nigeria) in the regression analyses, in light of the importance of cross-border trade in Niger. While the sign and statistical significance of the impact of drought on price dispersion does not change, the value of the point estimates falls for most variables.[41]

Columns 6 and 7 use an alternative measure of price dispersion, the intra-annual coefficient of variation for market i. Drought is associated with a -.0002 and statistically significant impact on the coefficient of variation, suggesting that markets affected by drought have .01 percent lower intra-annual price dispersion as compared to non-drought markets. While the magnitude of the coefficient on drought

[40] This result is supported by regressing inter-market correlation coefficients on distance (Timmer 1975, Faminow and Benson 1990). Distance is negatively associated with price correlations, and this effect is statistically significant at the 1 percent level. This suggests that neighboring markets are more likely to be integrated than distant ones. Distance is also negatively associated with Granger-causality, and the effect is statistically significant at the 1 percent level (not shown).

[41] Including a lagged variable for drought yields similar results (not shown).

increases slightly (from -.0002 to -.004) once a variable for drought in the previous period is included, the effect is only a 2 percent decrease.

6.3. Long-Term Impact of Drought

Until now, a key assumption of our identification strategy has been that the $\Delta u_{ij,t}$ are uncorrelated with the first-differenced regressors. Nevertheless, it is reasonable to assume that grain price dispersion in period t might depend upon dispersion in period t-1. Table 8 presents the results of the model with a lagged dependent variable. Controlling for drought, cell phone coverage, transport costs and time fixed effects, the coefficient on the lagged dependent variable is negative and statistically significant in both models, implying that it takes 2.5 months for price differences across markets to adjust (Column 1).[42] The coefficient on drought in both markets is still negative and statistically significant at the 1 percent level, representing the initial impact of drought. However, in the presence of a lagged dependent variable, the long-run effect of drought is measured as $\frac{\delta_1}{1-\rho}$. Using this formula, drought in both markets is associated with a 4.5 CFA/kg reduction in price dispersion in the long-term, and this effect is statistically significant at the 1 percent level. The magnitude and statistical significance of the effect is robust to the inclusion of monthly fixed effects and a market-specific time trend (Column 2).

Using the Arellano-Bond GMM estimator to control for endogeneity yields similar results (Columns 3 and 4).[43] The coefficient on the lagged dependent variable is negative yet no longer statistically different from zero, suggesting that markets adjust fairly quickly. The impact of drought remains negative and statistically significant, suggesting that extreme rainfall reduces grain price dispersion across markets.

6.4. Heterogeneous Effects

The specification in equation (3) measures the average impact of drought on price dispersion, thereby assuming a homogenous treatment effect. It is also instructive to examine the impact of drought across time

[42] The coefficient on the lagged dependent variable can be interpreted as the speed of adjustment. As the Arellano-Bond regression is run in first differences, the regression is second-differenced. This explains why the coefficient on the lagged dependent variable is negative. We use the concept of a "half-life" to interpret the results, calculated as $\ln(.5)/\ln(1+\rho)$.

[43] The consistency of the estimator depends upon the assumption that the lagged variables and other explanatory variables are valid instruments. A necessary condition in this respect is the lack of τ -order serial correlation in the error terms after first-differencing. We conduct the Sargan test of overidentifying restrictions and test for no serial correlation in the errors. The z-statistic of the Sargan test is -.19, so we cannot reject the null hypothesis of no autocorrelation of order 2 in the residuals.

and space. As the spatial nature and magnitude of rainfall varies across years, it is reasonable to assume that the effect of drought on price dispersion might vary as a greater number of markets are affected. I therefore interact the drought variable with a variable that measures the percentage of markets affected by drought during a particular year (Table 9). The interaction term is strongly negative (-5.6 CFA/kg) and statistically significant at the 1 percent level (Table 9, Column 4), suggesting that the average effect of drought on price dispersion is stronger as more market pairs are affected. For example, when 10 percent of market pairs were affected by drought in 2000, price dispersion was .59 CFA/kg lower between drought-affected markets. When over 76 percent of market pairs were affected by drought in 2004, price dispersion in those markets was 4.24 CFA/kg lower. Such findings are intuitive: the impact of drought is stronger as the percentage of markets affected increases.

7. Alternative Explanations and Mechanisms

7.1. Alternative Explanations

The identifying assumption for the empirical strategy is that, had it not been for drought, there would have been no differential changes in the market outcomes across these markets over this period. While the experimental nature of extreme rainfall ensures balance between drought and non-drought markets, several potential sources of bias exist. I discuss four potential areas of concern.

The first concern is whether there were differential changes across drought and non-drought markets that could be explaining these results. One of the most important of these is the introduction of cell phones into Niger between 2001 and 2006, which lead to a 22-percent reduction in grain price dispersion across markets (Aker 2008). While this is possible, drought and cell phone coverage are not strongly correlated. In addition, the negative impact of drought on price dispersion is evident even in 1997-98 and 2000-01, prior to the introduction of cell phones in Niger.

The second concern is whether drought affected traders' entry and exit, in response to the profitability of grain trading. Higher (or lower) profits during drought years could lead to entry (exit), thereby changing supply in the local market and hence price dispersion during these years. Based upon the trader censuses conducted by the author between 2004 and 2006, with secondary data in 2000-01, the number of traders per market did not vary significantly on an intra- or inter-annual basis.[44] In addition, there was no correlation between changes in the number of traders per market and drought-affected regions.

A related concern is whether price dispersion was reduced because drought enabled traders to engage in price collusion across markets. Using the trader survey to calculate the four-firm concentration ratios (CR4s) suggest that the grain market structure is fairly competitive (Aker 2008). Nationally, the largest traders accounted for 26 percent of all grain traded in 2004-05. Markets appear to be fairly competitive across regions as well, with most regions having a CR4 less than 25 percent. These results provide evidence that reductions in price dispersion are not driven by collusive behavior.

A final concern is whether drought affected the quantity of grains produced. For example, if higher millet prices during a drought year resulted in higher farm-gate prices, this could encourage farmers to increase the total area planted and the total quantity of millet produced. Under such behavior, the variability of the quantity produced across and within markets would be reduced, even in the absence of spatial arbitrage. This scenario seems unlikely for several reasons. First, according to production statistics in Table 1, the area planted per capita has remained relatively constant between 1980-2004, and there is not a positive relationship between the area planted after a drought year. Second, regression results in Table 5 suggest that, while the per capita quantity of millet produced increases in response to a price change, the magnitude of this impact is relatively small (less than .01 kg/hectare/capita).[45] This suggests that the production system for grains is fairly rigid, and hence general equilibrium effects related to increased supply should not be a primary concern.

7.2. Mechanisms

The previous results suggest that a market failure did not occur in 2004-05, as markets were more integrated during this period. Nevertheless, these results only suggest an improvement in consumer welfare if price levels decrease. In 2004-05, average millet prices were the highest on record, severely affecting the

[44] A census of traders on each market was conducted during the 2005/2006 and 2006/2007 marketing seasons. Data on the number of traders on each market in 2004/2005 was retrospective, collected during the author's interviews with market resource persons. Over the survey period, there was a moderate amount of entry and exit, from 3,320 traders in 2004/2005 to 3,342 traders in 2005/2006 and 3,370 in 2006/2007. In assessing the number of traders by market, there does not appear to be a correlation between changes in the number of traders and the introduction of cell phones.

[45] In addition, according to the Niger farmer survey conducted by the author, less than 14 percent of farmers surveyed considered farm-gate prices when deciding whether to produce millet and in their production decisions.

purchasing power of poor rural households. This section attempts to explain some of the mechanisms affecting grain price levels in Niger during the year of the food crisis.

Although per capita grain output was higher in 2004 as compared to 2000, the spatial distribution of drought differed significantly. In 2000, approximately 32 percent of departments were affected by drought, with 15 percent of these suffering a reduction in per capita production of more than 50 percent. By contrast, 50 percent of markets were affected by drought 2004, with over 25 percent of departments suffering a reduction in crop output of more than 50 percent. Consistent with the regression results in Table 9, this suggests that drought had a relatively stronger impact on grain price dispersion across markets in 2004.

How is the spatial distribution of drought related to higher price levels in 2004? Unlike 2000, the departments affected by drought in 2004 were key surplus-producing (and Granger-causing) markets in Niger and the sub-region. Figure 7 shows real millet prices for key Granger-causing markets in Benin, Niger and Nigeria in October 2000 and October 2004. Average millet prices in these markets were 15 CFA/kg higher in October 2004 as compared to October 2000, and this difference is statistically significant at the 1 percent level.[46] Thus, even though total and per capita grain production was higher in 2004, price levels in Granger-causing markets were 17 percent higher during the harvest period.

Nevertheless, the presence of drought on key Granger-causing markets does not explain the price spike during the 2005 food crisis. While grain prices in 2004-05 initially followed a similar seasonal pattern to that of other drought years, there was a sharp price increase during the last four months of the marketing season. Millet prices increased by 89 percent in 2004-05, with an 18-percent increase between June and August 2005.[47]

A common explanation for the sharp seasonal price rises in 2004-05 is "excessive hoarding" (*Washington Post,* April 11, 2005). In other words, traders (and producers) held back supplies early in the season in the hopes that prices would rise later. This asymmetry in traders' expectations – as is implied by the findings of Sen (1981) and Ravallion (1987) -- is absent in the trader-level data. The average duration of

[46] The forecasting markets included those markets that Granger-cause more than 75 percent of markets in Niger: Gaya, Maradi, Guidan Roumdji, Tessaoua, Tounfafi and Zinder (Niger); Jibia, Illela and Mai Adua (Nigeria); and Malanville (Benin).

[47] By contrast, grain prices increased by 75 percent in 2000-01.

traders' storage in Niger is fairly short, less than one month (Table 4). While storage duration varies considerably according to trader type (wholesalers, semi-wholesalers, intermediaries and retailers), wholesalers and semi-wholesalers store an average of two months. The length of storage was considerably shorter in 2004-05 as compared to 2005-06, a year of above-average rainfall. This suggests that traders were not "holding back" supplies in the hopes that prices would rise.

Why did prices rise so drastically in 2004-05? The strong intra-annual price variation appears to be associated with three primary factors (Figure 8). First, in response to widespread drought and crop failures in the region, several of Niger's neighbors (such as Burkina Faso) issued a temporary ban on exports into Niger in early 2005. This unofficial ban reduced imports into the country (albeit temporarily) and reduced supply on markets in the western regions of Niger. Grain prices in Niamey, the capital city, increased by more than 12 percent between February and March 2005.

In response to this price increase in February and March, several governmental and non-governmental actors issued calls for local purchases of grains (millet and sorghum) between March and April 2005. While official statistics vary, it is estimated that the total quantity purchased was 50,000 MT. Local purchases took place in several Granger-causing markets in Niger (Maradi) and northern Nigeria (Jibia, Mai Adua). Shortly after the tender for these purchases took place, grain prices on these markets increased by more than 13 percent. This was then followed by a 7 percent increase in national average millet prices in Niger in May (Figure 8).

The increase in grain prices in Niger could have been mitigated by increased supply from other surplus-producing regions in the sub-region (Benin, Nigeria). On average, import parity prices for millet from Nigeria are actually *higher* than millet prices in Niger between October and May. This relationship usually reverses during the pre-harvest period in Niger, thereby making imports from Nigeria profitable. This was the case in 1997-98 and 2000-01. In 2004-05, however, import parity prices remained higher than domestic millet prices for the entire marketing season (Figure 9). While import parity prices for millet from Niger's other neighbors, such as Benin, Burkina Faso and Mali, were lower than domestic millet prices, it is unclear whether traders would have been able to import sufficient quantities from these countries.[48]

8. Policy Implications

These results have important implications for policy, particularly preparing for and responding to food crises in the Sahelian region of sub-Saharan Africa. This section outlines some of the relevant lessons learned for future food crises.

8.1. A More Strategic Early Warning System

There is considerable debate as to the appropriate design of early warning systems for predicting drought and famine in sub-Saharan Africa. Much of the debate centers on the ability of current or prospective indicators to provide timely, location-specific and cost-effective information. Rainfall and agricultural production indicators are timely and easy-to-use, especially in countries where rainfall and crop output are positively correlated with food crises. Nevertheless, as experience has shown in Niger, droughts are not perfectly correlated with food crises and famines Effective early warning indicators should generate few responses to situations where food crises do not actually develop ("false positives") and should not fail to respond when an actual famine is approaching ("false negatives") (De Waal 1998). Relying solely upon drought and agricultural production as early warning indicators for Niger would have generated a "false positive" in 2000, but yielded a "false negative" in 2004.

Nevertheless, these climatic indicators can be strengthened by changing the level of analysis. Rather than aggregate rainfall or agricultural production during a particular year, a more appropriate early warning indicator in Niger is rainfall and crop failures at the departmental level, in order to determine how many and which regions were affected. Similarly, in light of the importance of Niger's neighbors for grain market

[48]Niger imports grains (millet, sorghum, rice and maize) from its neighbors, namely Benin, Burkina Faso, Mali and Nigeria. Trade data for Niger are highly unreliable, due in part to the informal trade that occurs in the sub-region. Official millet imports averaged 34,000 MT between 2000 and 2005, representing approximately 1 percent of total millet availability. Nigeria plays a dominant role in imports: on average, Nigeria supplies 75 percent of Niger's millet and sorghum imports and 35 percent of total maize imports. Benin, Burkina Faso and Mali represent 11 and 35 percent of all imports respectively. Consequently, even if it is difficult to confirm that total grain imports were lower in 2004-05, the higher relative prices in Nigeria suggest that imports were reduced from a key trading partner.

performance, drought and production levels should also be monitored in the northern regions of Benin and Nigeria.

In addition to these climatic indicators, early warning systems should focus on grain prices in strategic markets, as not all markets affect grain prices to the same degree. First, early warning systems should monitor grain prices on key forecasting markets within Niger and in the sub-region, defined as those markets that "Granger-cause" a significant number of markets in Niger (e.g., over 75 percent), including those located in Benin and Nigeria. Second, prices should not only be monitored (and analyzed) during the pre-harvest period, but also during the harvest period (October). For example, the relatively higher prices in Granger-causing markets in October 2004 could have served as a leading indicator of the 2005 food crisis. And finally, local early warning systems should monitor the difference between import parity and domestic prices between June and September of each year, in order to determine whether imports will be profitable.[49] If import parity prices – especially from northern Nigeria – are higher than those in Niger during the pre-harvest period, this suggests that Niger would need to import from other countries.

8.2. Local Purchases versus Imported Food Aid: Which is Right?

In recent years, international donors and organizations have shifted towards local and triangular purchases of food aid (food aid purchases or exchanges in developing countries), as opposed to imported food aid. Despite the increasing frequency of and interest in local and regional purchases, their effects on local markets are multiple, diverse and not well-understood. Both imported and local food aid were used in response to the 2005 food crisis in Niger. Without data on the timing, location, quantities and purchase prices of local food aid procurements, it is difficult to draw any conclusions between such purchases and higher grain prices in Niger. However, the correlation between the timing of local purchases and higher grain prices highlights the need for additional research in this area.

There are limited guidelines and standards in terms of local and triangular purchases. Those guidelines that exist do not provide concrete recommendations on whether and how to conduct local purchases. In order to inform policy decisions and minimize potential negative impacts of local and regional

[49] Prices should be compared between the following markets: Malanville (Benin)-Gaya, Illela (Nigeria)-Konni, Jibia (Nigeria)-Maradi, Mai Adua (Nigeria)-Zinder, and Kantchari (Burkina Faso)-Torodi.

purchases, a comprehensive "how to" guide is necessary. In the short-term, this would require that all agencies involved in local purchases conduct impact evaluations of these interventions on local market performance, collecting pre- and post-data on price levels, market structures and quantities traded in purchase and recipient markets. In the medium-to-long term, these results should be used to develop comprehensive guidelines that provide: 1) best practices and lessons learned; 2) specific criteria and/or conditions to assist international agencies, donors and host country governments in determining whether local purchases are appropriate during a particular year; 3) criteria for determining the appropriate quantity, geographic location and purchase prices if local purchases are appropriate.

9. Conclusion

This paper assesses the impact of drought on grain market performance in Niger, one of the world's poorest countries. The results suggest that grain markets in Niger are partially integrated, and that prices respond to supply (as opposed to demand) shocks. Consistent with the theoretical predictions of the Law of One Price (LOP), drought in both markets is associated with a decrease in price dispersion across markets. However, a natural shock in one market is associated with an increase in price dispersion. The effect of drought is stronger when a higher percentage of markets are affected by drought, as was the case in 2004-05, the year of a severe food crisis.

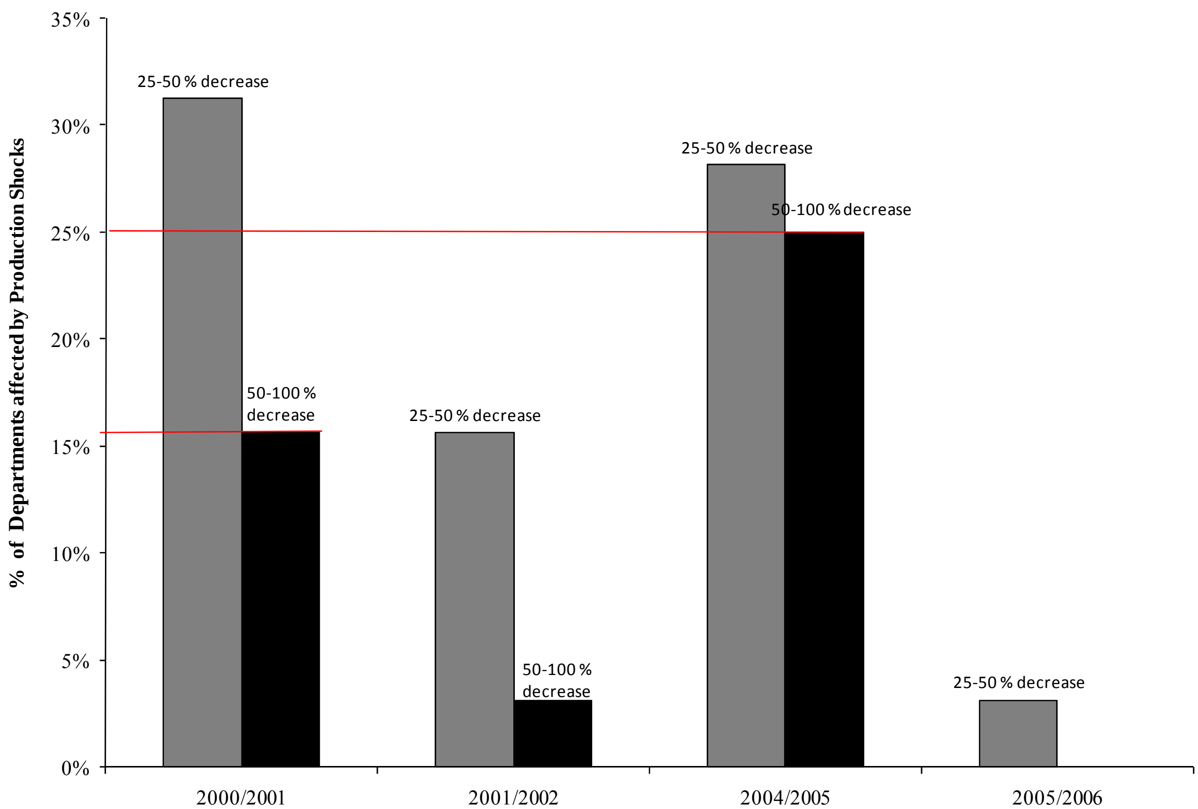
The most plausible explanation for these results, as suggested by the patterns in the data, is that rainfall is positively associated with agricultural output. Thus, lower than average agricultural production during drought years necessitates the need for improved spatial arbitrage within Niger and between Niger and its neighbors. Analysis of trader-level data do not suggest that traders collude, thereby reducing price dispersion. In addition, although cell phones are associated with a negative and statistically significant reduction in price dispersion across markets (Aker 2008), drought and cell phone coverage are not highly correlated. In addition, this pattern was observed in 1997-98 and 2000-01, prior to the introduction of cell phones in 2001.

These results relate to literature in development economics that documents grain market performance during famines (Sen 1981, Ravallion 1987, Drèze and Sen 1989, Webb and von Braun 1994, Ó

Gráda 2005). Several of these papers find that food markets worked "poorly" during famines, primarily due to natural (poor communications) and artificial obstacles (war, trade restrictions and price controls, civil unrest) (Ó Gráda 2007). The evidence in this paper should not be taken to imply that grain markets worked "perfectly" in Niger during the 2005 food crisis. Rather, this paper's results suggest that markets were partially integrated in 2005. However, factors other than a market "failure" and trader hoarding appear to be responsible for the grain price spike and food crisis in 2005, such as the spatial distribution of drought, temporary trade restrictions and few incentives to import from Nigeria.

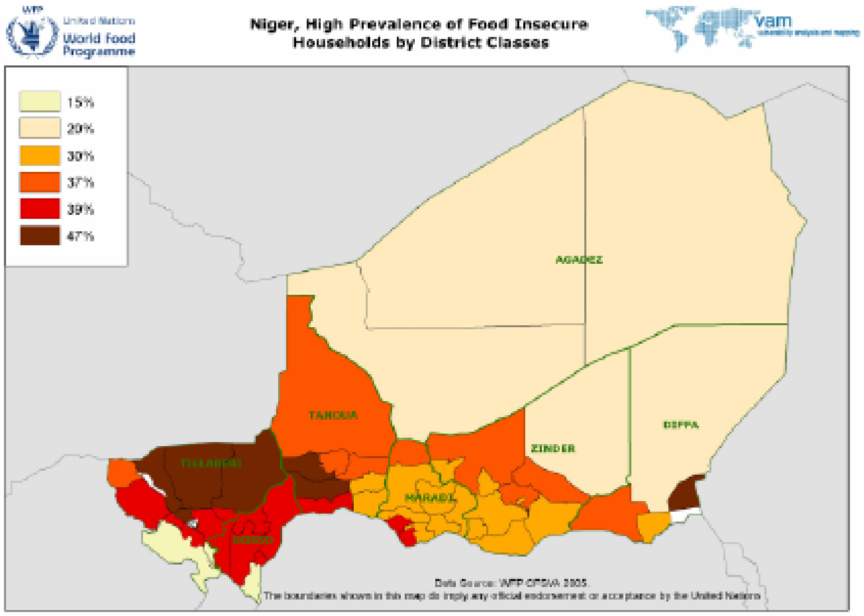
These results have important implications for policy. They suggest that, while climatic indicators such as drought and agricultural output are appropriate as early warning indicators, they need to be monitored and analyzed at a disaggregated level. The timing of the price spike in 2005 also implies that grain prices on Granger-causing markets should be monitored, especially those in northern Nigeria. And finally, the correlation between local purchases and higher prices suggests that such purchases merit greater attention and research.

Figure 1. Percentage of Departments Affected by Production Shocks by Year, 2000-2005



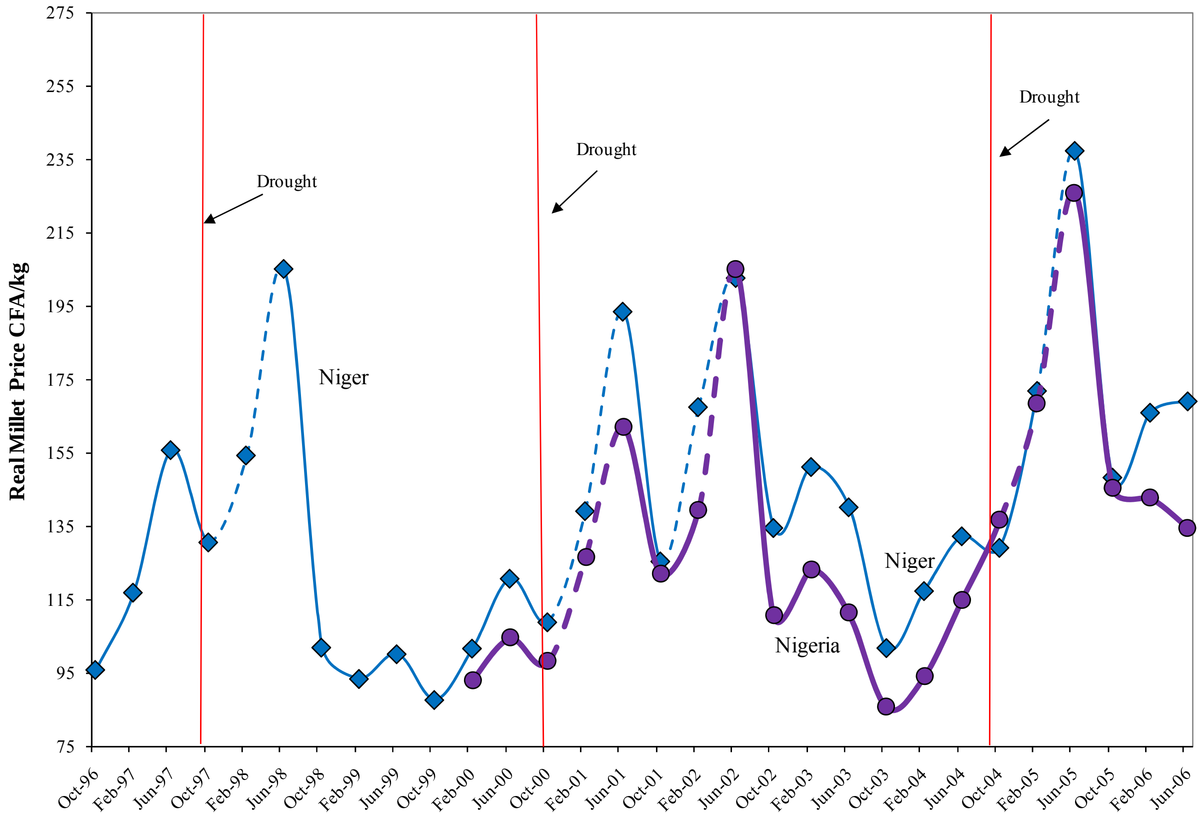
Notes: Each column represents the percentage of departments affected by a decrease in per capita production of more than 25 percent as compared to the ten-year average. There are a total of thirty-six (36) departments in Niger, divided into eight geographic regions. In 2000, only 15 percent of the departments experienced a per capita decrease of more than 50 percent. By contrast, in 2004, over 25 percent of departments suffered a per capita decrease in grain production of more than 50 percent.

Figure 2. Geographic Areas Affected by the 2004/2005 Food Crisis in Niger



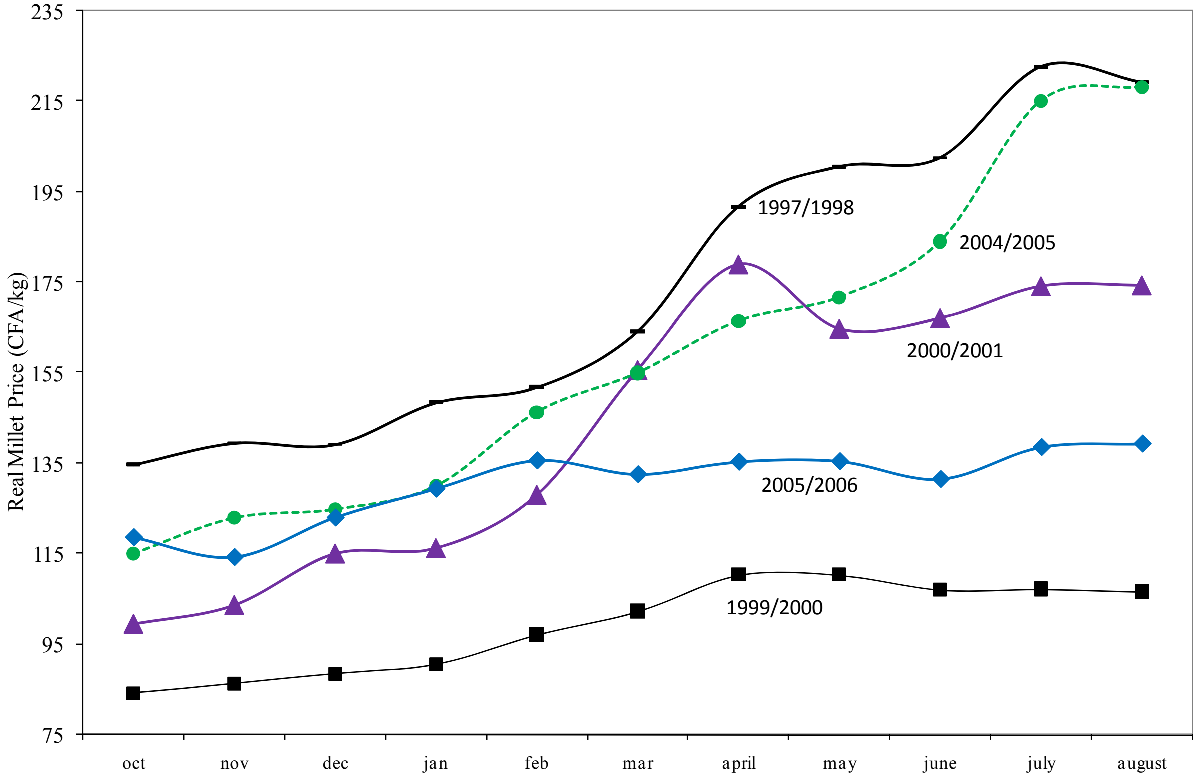
Notes: The map is provided by WFP's Food Security Assessment (2005), and coincides with the list of vulnerable regions provided.

Figure 3. Average Monthly Millet Prices and drought in Niger, 1996-2006 (CFA/kg)



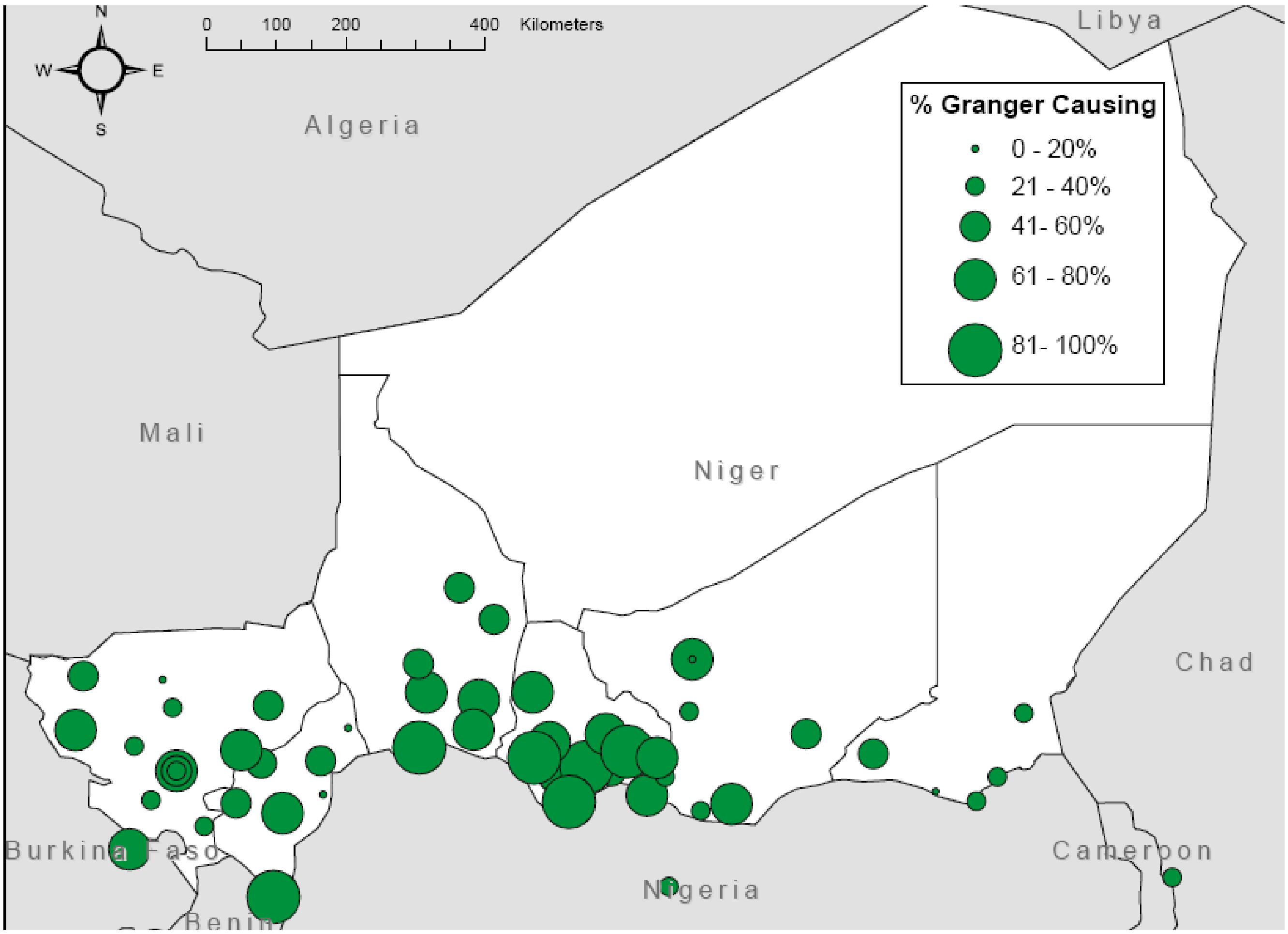
Notes: Prices are the average millet prices across all domestic markets in Niger, deflated by the Nigerien consumer price index (2001). Prices are provided by the Agricultural Market Information System. The dashed lines represent prices in Niger and Nigeria following the drought.

Figure 4. Intra-Annual Variation in Millet Prices (CFA/kg) for Various Years



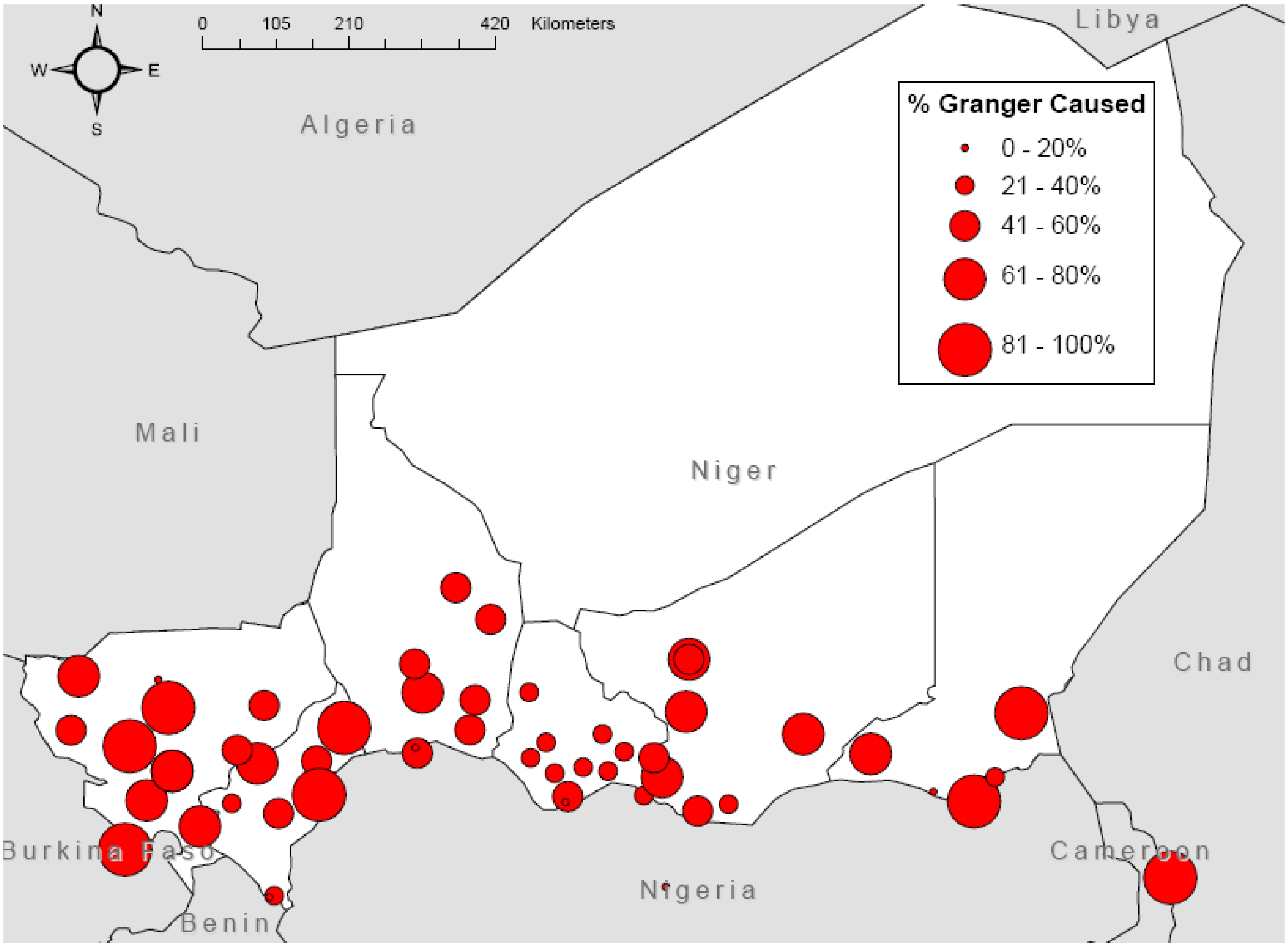
Notes: Prices are the average millet prices across all domestic markets in Niger, deflated by the consumer price index (2001). Prices are provided by the Agricultural Market Information System. 1997/1998, 2000/2001 and 2004/2005 were years of extreme rainfall (drought), whereas 1999/2000 and 2005/2006 were years of normal rainfall.

Figure 5. Granger-Causing Markets in Niger and the Sub-Region (Benin, Burkina Faso, Nigeria)



Notes: Granger causality tests were conducted using the following error correction model: $\Delta P_{i,t} = \lambda_0 + \sum_{m=1}^{3} \lambda_m \Delta P_{i,t-m} + \sum_{m=1}^{3} \overline{\lambda}_m \Delta P_{j,t-m}$. If price movements in market *j* precede price movements in market *i*, then the $\Delta P_{j,t-m}$ terms should have a significant effect on $\Delta P_{i,t}$. Granger-causing markets are those markets (*j*) that have a significant effect on price changes in market *i*.

Figure 6. Markets that are Granger-Caused in Niger and in the Sub-Region (Benin, Burkina Faso and Nigeria)

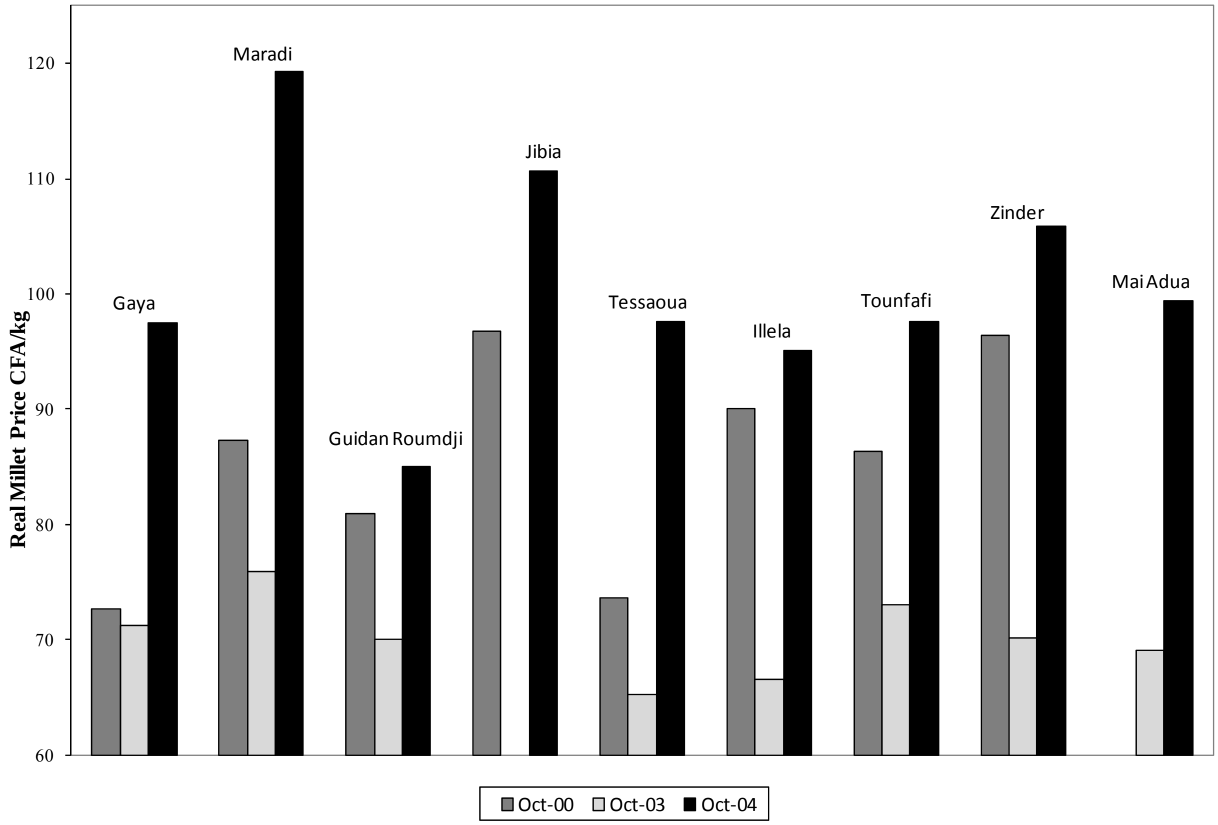


Notes: Granger causality tests were conducted using the following error correction model:

$$\Delta P_{i,t} = \lambda_0 + \sum_{m=1}^{3} \lambda_m \Delta P_{i,t-m} + \sum_{m=1}^{3} \overline{\lambda}_m \Delta P_{j,t-m}$$

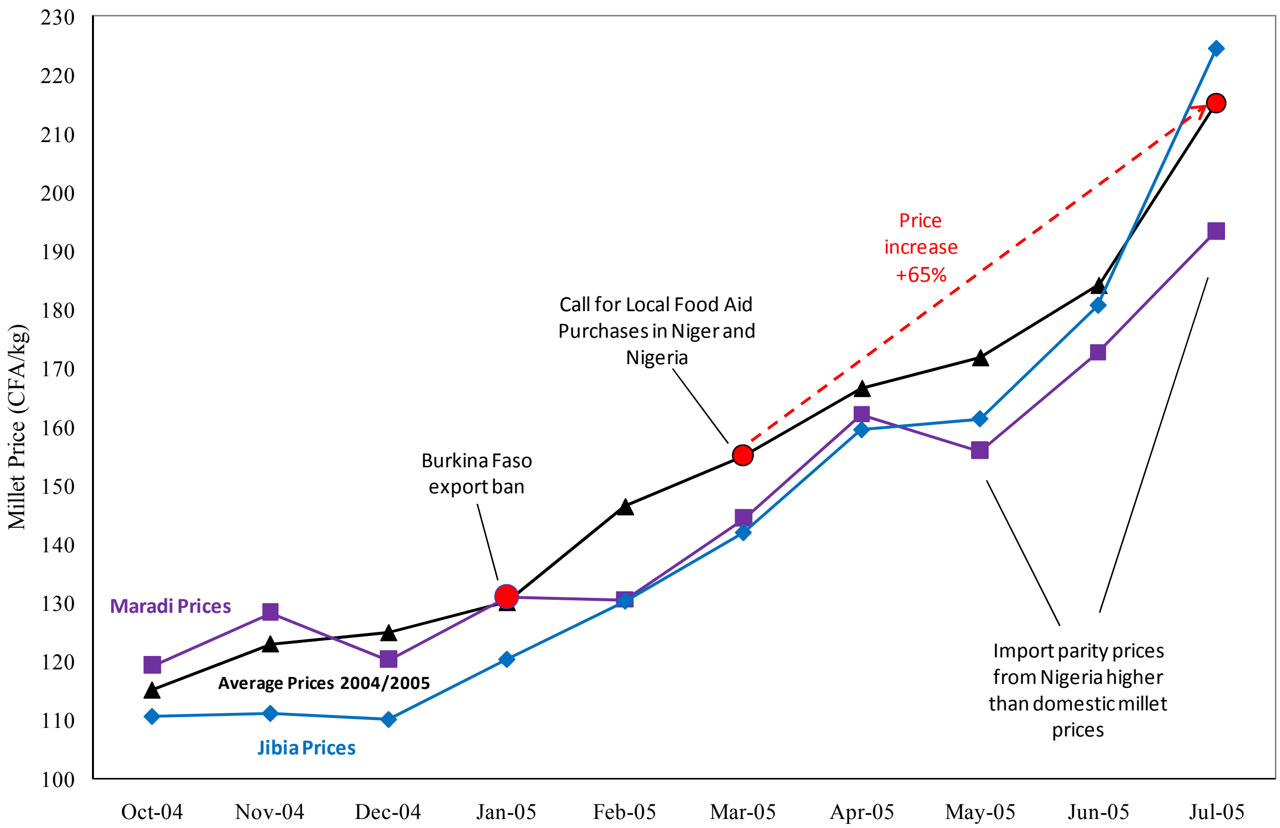
. If price movements in market *j* precede price movements in market *i*, then the $\Delta P_{j,t-m}$ terms should have a significant effect on $\Delta P_{i,t}$. Granger-caused markets are those markets (*i*) that are predicted by price changes in market *j*.

Figure 7. Millet prices (CFA/kg) in Key Granger-Causing Markets in October 2000, October 2003 and October 2004



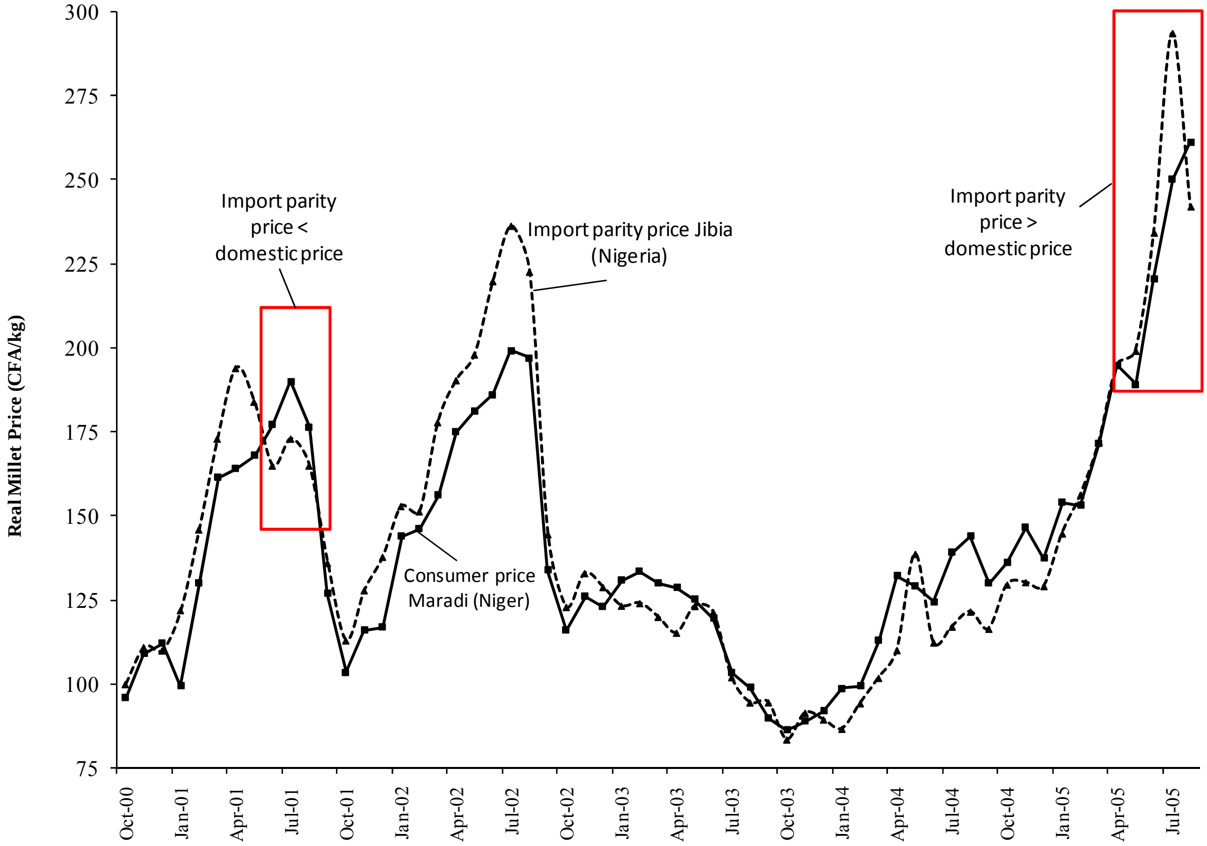
Notes: Prices are the millet price (CFA/kg) in the market during the harvest period (October), deflated by the consumer price index. Prices are provided by the Agricultural Market Information System. 2000 and 2004 were years of extreme rainfall (drought), whereas 2003 was a year of normal rainfall.

Figure 8. Millet prices (CFA/kg) in Key Granger-Causing Markets in 2004/2005



Notes: Prices are the millet price (CFA/kg) during the 2004/2005 marketing season, deflated by the consumer price index. Prices are provided by the Agricultural Market Information System.

Figure 9. Import Parity Price and Domestic Millet Prices between Jibia, Nigeria and Maradi (Niger)



Notes: Import parity prices are the domestic price of millet in Nigeria (Jibia) plus transaction costs (transport costs, taxes) between the two countries. Prices are deflated by the Nigerien Consumer Price Index and provided by the Agricultural Market Information System.

Table 1: Millet and Sorghum Production in Niger, 1985-2004

Year	Population	Cultivated Areas (ha)	Production (MT)	Area per Capita	Production per capita
1985	6 565 000	4 310 931	1 774 113	0,7	270
1986	6 783 000	4 348 597	1 743 559	0,6	257
1987	7 008 000	4 359 029	1 362 777	0,6	194
1988	7 240 000	4 995 768	2 326 505	0,7	321
1989	7 480 000	5 094 042	1 754 605	0,7	235
Average (85-89)		4 621 673	1 792 312	0,7	256
1990	7 728 000	6 942 899	2 045 960	0,9	265
1991	7 967 568	6 456 771	2 314 991	0,8	291
1992	8 214 563	7 519 314	2 171 693	0,9	264
1993	8 469 214	6 099 128	1 714 310	0,7	202
1994	8 731 760	6 950 251	2 368 538	0,8	271
Average (90-94)		6 793 673	2 123 098	0,8	259
1995	9 002 444	7 164 356	2 034 983	0,8	226
1996	9 286 395	7 138 358	2 172 213	0,8	234
1997	9 574 274	6 386 922	1 641 530	0,7	171
1998	9 871 071	7 607 398	2 894 013	0,8	293
1999	10 177 080	7 449 871	2 772 346	0,7	272
Average (95-99)		7 149 381	2 303 017	0,7	239
2000	10 492 569	7 306 951	2 049 890	0,7	195
2001	11 060 291	7 835 456	3 022 350	0,7	273
2002	11 403 160	7 816 590	3 236 927	0,7	284
2003	11 756 658	8 041 222	3 502 464	0,7	298
2004	12 121 114	7 823 260	2 637 242	0,6	218
Average (00-04)		7 764 696	2 889 775	0,7	254
Average (80-04)		6 085 875	2 128 794	0,72	253

Notes: Production statistics are provided by the Ministry of Agriculture from various years. Grain production per capita is the total production of millet and sorghum divided by the population.

Table 2. Average Millet Prices in Niger, 1996-2006 (CFA/kg)

Variable	Obs	Mean	Std. Dev.
Average Prices Niger (CFA/kg)	120	145.98	40
Niger (Region)			
Diffa	120	167.51	47.88
Dosso	120	151.58	40.33
Maradi	120	124.20	38.50
Niamey	120	143.36	30.90
Tahoua	120	155.99	42.39
Tillaberi	120	158.10	41.62
Zinder	120	129.02	41.82
1997/1998 Prices	12	173.25	33.35
2000/2001 Prices	12	160.76	36.89
2004/2005 Prices	12	194.10	53.40

Notes: Prices are deflated by the consumer price index (CPI). The difference in prices between the 1997/1998, 2000/2001 and 2004/2005 marketing seasons are statistically significant at the 1 percent level. Price data are average consumer prices collected during the market day by the Agricultural Market Information System (AMIS).

Table 3. Comparison of Observables by Food Crisis and Non-Crisis Region (2004/2005)

	(1) Food Crisis		(2) Non-Food Crisis		(3) Difference in Means	(4) Difference in Distributions	
	Mean (s.d.)	**Obs**	**Mean (s.d.)**	**Obs**	**s.e.**	**D-statistic**	**p-value**
Grain price level (CFA/kg)	164.96(43.4)	183	151.8(39.0)	155	13.10***(6.5)	0.148	0.051
Intra-annual CV for millet prices	0.232(.042)	156	0.251(.037)	192	-.0181(.015)	0.3137	0
Road Quality (1=paved, 0=unpaved)	.6953(.085)	168	.2663(.043)	192	.4289(.324)	0.317	0
Market Size	1(.792)	168	1.571(1.05)	192	-0.6*(.335)	0.2589	0
Urban center (>=35,000 people)	0.25(.331)	168	0.6428(.480)	192	-.475***(.155)	0.475	0
Cell Phone Tower (1=cell tower, 0=none)	0.244(.431)	168	0.8392(.368)	192	-.605***(.131)	0.605	0
Drought in 2004 (1=drought, 0=no drought)	.75(.434)	168	0.2857(.453)	192	.483***(.165)	0.483	0
Per capita millet production 2004 (kg)	122.63(26.69)	168	173.63(24.78	192	-51.00(36.39)	0.3968	0.17

Note: Food crisis regions are those villages and markets categorized as "extremely vulnerable" and "highly vulnerable" by the Government of Niger and the WFP during the 2005 food crisis. The Kolmogorov-Smirnof test tests for the equality of the distribution functions. S.e. are corrected for clustering and serial correlation.

Table 4. Description of Key Variables: Grain Trader and Market Baseline Characteris

Variable Name	Sample Mean (s.d.)	# of obs
Panel A. Market-Level Characteristics		
Type of market		35
Collection	0.19	7
Wholesale	0.36	13
Retail	0.30	10
Border	0.15	5
Number of traders per market	137(99.6)	35
Road quality (1=paved road, 0=otherwise)	.71(.45)	35
Market located more than 50 km from paved road	.07(.26)	35
New paved road in past 5 years	.15(.37)	35
Located in an urban center (>35,000 people)	.39(.48)	35
Cell phone coverage 2005/2006	.78(.41)	35
Cell phone coverage 2004/2005	.62(.48)	35
Cell phone coverage 2000/2001	0.00	35
Drought in 2004/2005	.51(.50)	35
Drought in 2000/2001	.32(.46)	35
Food crisis region in 2004/2005	.38(.48)	35
Panel B: Trader-Level Characteristics		
Socio-Demographic Characteristics		
Ethnicity		395
Hausa	0.65	255
Zarma	0.17	65
Other	0.19	75
Age	45.71(12.2)	395
Gender(male=0, female=1)	0.11(.32)	395
Education (0=elementary or above, 1=no education)	0.62(.48)	395
Trader type		395
Wholesaler	0.17	67
Semi-wholesaler	0.15	61
Intermediary	0.15	61
Retailer	0.53	206
Years' of Experience	16.0(10.2)	395
Commercial Characteristics		
Engage in trading activities all year round	.94(.22)	395
Trade in agricultural output products only	0.98(.02)	395
Engage in activities outside of trade	0.92(.28)	395
Types of income-generating activities		395
Farmer	0.84	319
Herder	0.05	20
Private or public sector employee	0.01	2
Chauffeur	0.01	3
Co-ownership of commerce	.19(.40)	395
More than 75 percent of commerce sold in principal marke	.59(.49)	395
Changed "principal market" since he/she became a trader	.10(.31)	395
Number of markets where trade goods	4.42(2.84)	395
Number of markets where follow prices	3.87(3.0)	395
Number of days of storage	7.14(9.8)	395
Own cell phone	.29(.45)	395
Own means of transport (donkey cart, light transport)	.11(.32)	395

Notes: Data from the Niger trader survey collected by the author. Sample means are weighted by inverse sampling probabilities. All prices are in 2001 CFA.

Table 5. Conditional Correlations by Year and Region (1996-2006)

	Drought Years			Non-Drought Years			Average Correlation (1996-2006)
	1997/1998	2000/2001	2004/2005	1999/2000	2003/2004	2005/2006	
Mean Correlation across Markets	0.55	0.66	0.71	0.35	0.48	0.5702	0.56
Correlations of Markets within a Region with other Markets							
Agadez	0.54	0.59	0.82	0.17	0.35	0.64	0.72
Diffa	0.65	0.42	0.64	0.39	0.41	0.62	0.70
Dosso	0.49	0.62	0.57	0.36	0.46	0.50	0.48
Maradi	0.64	0.56	0.73	0.40	0.54	0.58	0.48
Tahoua	0.51	0.68	0.78	0.33	0.55	0.58	0.62
Tillaberi	0.47	0.66	0.68	0.35	0.46	0.54	0.67
Zinder	0.55	0.70	0.78	0.33	0.55	0.64	0.52
Niamey	0.61	0.72	0.72	0.37	0.46	0.64	0.64
External markets							0.66
Nigeria		0.68	0.80	0.34	0.43	0.50	0.65
Benin		0.75	0.82	0.24	0.59	0.49	0.65
Burkina Faso			0.49		0.26	0.56	0.47
Chad	0.33	0.35	0.32	0.25	0.31	0.25	0.25
2005 Non-Crisis Region	0.56*	0.64**	0.75***	0.34	0.52**	0.63***	0.67***
2005 Crisis Region	0.53*	0.66**	0.71***	0.36	0.49**	0.57***	0.58***

* signifies that the equality of means is rejected for crisis and non-crisis regions at the 10 percent level, ** at the 5 percent level, and *** at the 1 percent level.
Data on cross-border markets in Benin, Burkina Faso and Nigeria are not available prior to 1999/2000

Table 6. Estimated Effects of Drought on Production and Food Crisis

	Dependent Variable					
	Per Capita Production			Famine		
Explanatory Variable	**(1) OLS**	**(2) OLS**	**(3) OLS**	**(4) OLS**	**(5) OLS**	**(6) Probit (df/dx)**
Drought	-80.05*** (16.07)	-80.05*** (14.87)	-99.39*** (29.47)	.244** (.092)	.068 (.069)	.101 (.091)
Cell Phone Dummy					-.435** (.165)	-.478** (.164)
Average millet price			1.79** (.82)		.007* (.003)	.010* (.005)
Average millet price, previous year						
Constant					-.286 (.700)	
Common Time Trend	Yes	Yes	Yes	Yes	Yes	Yes
Group-specific time trend	No	Yes	No	No	No	No
Market Fixed Effects	No	Yes	Yes	Yes	Yes	Yes
Department Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Yearly time dummy	Yes	Yes	Yes	No	No	No
# of observations	174	174	135			
# of cross-sectional observations				31	31	31
Mean of dependent variable	219	219	219	0.52	0.52	0.52
R^2	0.7885	0.2337	0.8255	0.0098	0.3115	0.2616

Notes: Data from the Niger trader survey and secondary sources collected by the author. Drought=1 in period t when a market has rainfall less than or equal to 2 standard deviations below its average rainfall level during the rainy season (June-September), or 15 consecutive days without rainfall during the rainy season, 0 otherwise. Cell phone dummy =1 in period *t* when a market has cell phone coverage, 0 otherwise. Column 4 contains data for 2004/2005, the only year in which detailed data on food crisis regions were collected. Huber-White robust standard errors clustered by market pair-month (price difference) and market-month (CV) are in parentheses. * is significant at the 10% level, ** significant at the 5% level, *** is significant at the 1% level. All prices are in 2001 CFA.

Table 7. Estimated Effects of Drought on Price Dispersion: DD Estimation with First Differences

Dependent variable	(1) P_{it}-P_{jt}	(2) P_{it}-P_{jt}	(3) P_{it}-P_{jt}	(4) P_{it}-P_{jt}	(5) Pit-Pjt	(6) Coefficient of Variation	(7) Coefficient of Variation
Drought (both markets)	-4.98*** (1.23)	-4.70*** (1.23)	-4.62*** (1.24)	-4.56*** (1.24)	-4.15*** (1.14)	-.0002*** (.000)	-.004*** (.001)
Drought one market	6.44*** (1.18)	6.34*** (1.18)	6.35*** (1.18)	6.14*** (1.19)	5.77*** (1.09)		-.009*** (.001)
Cell Phone Dummy		-4.65*** (1.06)	-4.77*** (1.06)	-4.43*** (1.05)	-3.90*** (.990)	-.039* (.020)	-.039* (.020)
Transport costs (CFA/kg)		.625*** (.139)	.630*** (.142)	.754*** (.141)	1.27*** (.132)		
Gas prices (CFA/kg)						-.0001*** (.000)	-.0001*** (.000)
Constant	.808*** (.080)	.756*** (.080)					
Common Time Trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Group-specific time trend	No	No	Yes	Yes	Yes	Yes	Yes
Market-Pair Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Yearly time dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Monthly time dummy	No	No	No	Yes	Yes	Yes	Yes
Cross-border markets	No	No	No	No	Yes	No	No
# of observations	27342	27342	27342	27342	37918	2421	2421
# of cross-sectional observations	433	433	433	433	625	35	35
Mean of dependent variable	22.08	22.08	22.08	22.08	22.3	0.2	0.2
R^2	0.0073	0.0087	0.0087	0.0098	0.1003	0.0929	0.0949

Notes: Data from the Niger trader survey and secondary sources collected by the author. Drought=1 in period t when a market has rainfall less than or equal to 2 standard deviations below its average rainfall level during the rainy season (June-September), or 15 consecutive days without rainfall during the rainy season, 0 otherwise. For market pairs, cell phone dummy =1 in period *t* when both markets have cell phone coverage, 0 otherwise. For markets, cell phone dummy =1 when the market has cell phone coverage in time *t*, 0 otherwise. Huber-White robust standard errors clustered by market pair-month (price difference) and market-month (CV) are in parentheses. * is significant at the 10% level, ** significant at the 5% level, *** is significant at the 1% level. All prices are in 2001 CFA.

Table 8. Estimated Effects of Drought on Price Dispersion: VAR Estimation

Dependent variable	(1) P_{it}-P_{jt}	(2) P_{it}-P_{jt}	(3) P_{it}-P_{jt} Arellano-Bond GMM Estimator	(4) P_{it}-P_{jt} Arellano-Bond GMM Estimator
Drought (both markets)	-4.89*** (1.27)	-4.81*** (1.27)	-5.813*** (1.25)	-5.813*** (1.25)
Drought (one market)	6.87*** (1.18)	6.58*** (1.19)	6.22*** (1.17)	6.23*** (1.17)
Cell Phone Dummy (both treated)	-5.26*** (1.01)	-4.80*** (.989)	-1.85** (.938)	-1.91** (.943)
Transport costs (CFA/kg)	.564*** (.12)	.745*** (.124)	.625*** (.148)	.648*** (.144)
Lagged dependent variable	-.346*** (.008)	-.348*** (.008)	-.008 (.026)	-.008 (.026)
Constant				
Common Time Trend	Yes	Yes	Yes	Yes
Group-specific time trend	No	No	No	No
Market-Pair Fixed effects	Yes	Yes	Yes	Yes
Yearly time dummy	Yes	Yes	Yes	Yes
Monthly time dummy	No	Yes	No	No
# of observations	25942	25942	25942	25942
# of cross-sectional observations	433	433	433	433
R^2	0.1247	0.1269		
Wald Chi-squared			376.25	427.84
Long-term effect of drought	-4.54** (1.27)	-4.54** (1.27)	-5.77*** (1.43)	-5.77*** (1.23)

Notes: Data from the Niger trader survey and secondary sources collected by the author. Drought=1 in period t when a market has rainfall less than or equal to 2 standard deviations below its average rainfall level during the rainy season (June-September), or 15 consecutive days without rainfall during the rainy season, 0 otherwise. Cell phone dummy =1 in period *t* when both markets have cell phone coverage, 0 otherwise. Huber-White robust standard errors clustered by market pair-month (price difference) and market-month (CV) are in parentheses. * is significant at the 10% level, ** significant at the 5% level, *** is significant at the 1% level. All prices are in 2001 CFA.

Table 9. Heterogeneous Impact of Drought on Price Dispersion

Dependent variable	(1) Pit-Pjt	(2) Pit-Pjt	(3) Pit-Pjt	(4) P_{it}-P_{jt}	(5) P_{it}-P_{jt}	(6) Pit-Pjt
Drought (both markets)	-55.12 (8.61)	-54.83*** (8.58)	-45.75*** (7.60)	-1.00 (1.76)	-1.02 (1.76)	-.756*** (1.71)
Drought (one market)	6.34*** (1.18)	6.13*** (1.18)	5.77*** (1.19)	6.35*** (1.18)	6.14*** (1.18)	5.78*** (1.09)
Drought*gas prices	.167*** (.027)	.166*** (.027)	.137*** (.024)			
Drought*Percentage of Markets				-5.65*** (1.84)	-5.55*** (1.84)	-5.15*** (1.82)
Cell Phone Dummy	-4.58*** (1.06)	-4.23*** (1.05)	-3.73*** (.980)	-4.65*** (1.06)	-4.31*** (1.05)	-3.80*** (.980)
Transport costs (CFA/kg)	.618 (.140)	.742*** (.140)	1.25**** (.130)	.608*** (.138)	.731*** (.138)	1.25 (.129)
Constant	.766 (.080)	1.70*** (.158)	1.72 (.133)	.750*** (.080)	1.68*** (.158)	1.71*** (.133)
Common Time Trend	Yes	Yes	Yes	Yes	Yes	Yes
Group-specific time trend	No	No	No	No	No	Yes
Market-Pair Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Yearly time dummy	Yes	Yes	Yes	Yes	Yes	Yes
Monthly time dummy	No	Yes	Yes	No	Yes	Yes
Cross-border markets	No	No	Yes	No	No	Yes
# of observations	27342	27342	37918	27342	27342	37918
# of cross-sectional observations	433	433	625	433	433	625
Mean of dependent variable	22.08	22.08	22.3	22.08	22.08	22.3
R^2	0.0098	0.0108	0.0101	0.0089	0.01	0.1003
Joint effect	-6.78***(1.34)	-6.72***(1.34)	-6.09***(1.23)	-1.18(1.72)	-1.19(1.72)	-0.92(1.66)

Notes: Data from the Niger trader survey and secondary sources collected by the author. Drought=1 in period t when a market has rainfall less than or equal to 2 standard deviations below its average rainfall level during the rainy season (June-September), or 15 consecutive days without rainfall during the rainy season, 0 otherwise. For market pairs, cell phone dummy =1 in period *t* when both markets have cell phone coverage, 0 otherwise. Huber-White robust standard errors clustered by market pair-month (price difference) and market-month (CV) are in parentheses. * is significant at the 10% level, ** significant at the 5% level, *** is significant at the 1% level. All prices are in 2001 CFA.

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