Rainfall Shocks, Markets and Food Crises: The Effect of Drought on Grain Markets in Niger

Jenny C. Aker*

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Abstract. How do grain markets respond to extreme rainfall in West Africa? This paper examines the effect of weather on grain market performance in Niger, a country affected by droughts, crop failures and famines since the 1930s. Using a dataset that combines information on rainfall, agricultural production, prices and transaction costs, I exploit rainfall variation to estimate the impact of drought on grain market performance between 1996 and 2006. I find that drought reduces grain price dispersion across markets, suggesting that market integration is higher during drought years. This impact is stronger as a higher percentage of markets are affected by drought. I then provide suggestive evidence of the link between drought and the 2005 food crisis in Niger. The results suggest that early warning systems in West Africa should focus on the spatial impact of drought at the sub-regional level, as well as monitor prices in key forecasting markets.

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

JEL Classifications: O1,O15,Q1, Q5

** Economics Department, Fletcher School of Law and Diplomacy, Tufts University and Center for Global Development. 1776 Massachusetts Avenue, NW Suite 301 Washington, DC 20036. Tel: (510) 219-1663. Email: Jenny.Aker@tufts.edu. This research was partially funded by Rocca Dissertation Fellowship, Catholic Relief Services, CARE, World Vision, the Ford Foundation, UC-Berkeley's CIDER, the World Bank and USAID. I am grateful to Ali Abdoulaye, Erin Baldridge, Ousseini Sountalma, Lisa Washington-Sow and the data collection team for their support and patience in Niger. I would like to thank Maximilian Auffhammer, Guido Imbens, Kristin Kiesel, Edward Miguel, C. Peter Timmer, Brian Wright, two anonymous referees and seminar participants at the University of California-Berkeley, Northeast Universities Development Consortium Conference (NEUDC) and Brooks World Poverty Institute/Columbia University course for comments on theoretical and empirical issues. All errors are my own.

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 natural and man-made risks, including illnesses, crop failures, price variations and conflicts. A substantial body of empirical work in development economics measures the impact of natural shocks on household and individual-level outcomes (Rose 1999, Jensen 2000, Miguel 2005, Maccini and Yang 2009). Yet empirical studies measuring the impact of weather variation on agro-food market performance in developing countries are less common. From a public policy standpoint, it is important to determine how such shocks affect market outcomes, as food market performance can be strongly correlated with famines (Sen 1981, Ó Gráda 2007).

This paper examines the effect of weather shocks on agricultural price dispersion in one of the world's poorest countries, Niger. A landlocked country in sub-Saharan Africa, Niger is subject to frequent and increasingly common droughts, due partly to climate change (Zeng 2003). Such droughts are strongly correlated 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; for example, droughts and crop failures occurred in 1997, 2000 and 2004, yet only the latter drought resulted in a severe food crisis.

I exploit the exogenous variation in extreme rainfall to measure its impact upon grain price dispersion across markets between 1996 and 2006. This involves estimating a difference-in-differences (DD) model with pooled treatments. 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 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.

For the empirical application, I construct three primary datasets. The first is market-level price data between 1996 and 2006 across 42 domestic and cross-border markets, collected from Niger's *Système d'Informations sur le Marché Agricole* (SIMA). This includes the geographic location of each market, road and Euclidean distances between markets and transport costs. A second dataset is market-level rainfall data obtained from Niger's Meteorological Service. The final dataset is a panel survey of traders collected by the author between 2005 and 2007.

I find that the presence of drought in both markets reduces agricultural price dispersion across markets by 2-4 CFA per kg, representing 6 to 20 percent of average millet price dispersion across markets over the time period. The effect is larger when a higher percentage of markets in the country are affected by drought, as was the case in 1997 and 2004. These findings suggest that the variance of grain prices between markets decreases in response to an extreme shock, implying that markets are more efficient.[1] I also examine alternative explanations for the empirical results, such as changing degrees of market power over time or other infrastructure improvements, but find little evidence.

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). As reductions in price dispersion will only improve consumer welfare if both price levels and variances decrease, I provide suggestive evidence on the intermediate pathways connecting extreme rainfall, grain price

[1]This result 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). For a broader discussion of the relationship between markets and famines, see Sen 1981, Ravallion 1985, Ravallion 1987, von Braun, Teklu and Webb 1999, Ó Gráda 2005.

levels and consumer welfare in Niger. In particular, I investigate the conditions under which drought is correlated with higher price levels and severe food crises, as was the case in 2004/2005.

The remainder of this paper proceeds as follows. Section 2 provides an overview of drought, grain markets and food crises in Niger, and Section 3 discusses conceptual issues.. Section 4 describes the datasets and provides some descriptive statistics. Section 5 outlines the empirical strategy, whereas Section 6 provides the main empirical results. Section 7 explores alternative explanations of reductions in price dispersion, as well as the mechanisms linking drought, higher prices and food crises. Section 8 discusses the policy implications, and Section 9 concludes.

2. Rainfall, Agricultural Markets 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 last on the United Nations' Human Development Index (UNDP 2009). 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 between May and August. Precipitation varies substantially across the country both within year and across years (Nicholson, Some and Kone, 2000). Niger experienced six droughts between 1980 and 2005 (Government of Niger 2007).[2]

A majority of households in Niger depend upon rainfed agriculture, with staple food crops consisting of millet, sorghum and fonio, and cash crops including cowpeas, peanuts, cotton and sesame. Inter-annual deviations in rainfall are positively associated with fluctuations in grain output,

[2] Olsson, Eklundh and Ardo (2005) documented a consistent trend of increasing vegetation in the Sahel and higher rainfall between 1997 and 2004 in the region. However, most of these improvements were in Burkina Faso.

as millet production depends upon the timing and quantity of rainfall.[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, while droughts occurred in both 2000 and 2004, only 15 percent of departments experienced a crop failure in 2000 (defined as a per capita decrease in grain production of more than 50 percent as compared to the department-level mean), as compared with 25 percent of departments in 2004 (Figure 1).[4] Nevertheless, overall per capita grain output was higher in 2004.

A variety of agents are involved in moving grains from producers to consumers 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. Grains are produced by farmers, who sell their production directly to intermediaries. 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. Trade often takes place through a system of traditional markets, each of which is held on a weekly basis. As there is only one harvest per year (October-November), traders begin importing grains from neighboring countries (Benin, Burkina Faso, Mali and Nigeria) in April, once the local supply is depleted.

Because of the correlation between rainfall and grain output, drought is often positively associated with food crises and famine.[5] An estimated one-third of the country's population died

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[3]Extreme rainfall can be defined as drought or flood. Flooding is relatively rare in Niger and limited in its geographic coverage. Consequently, this paper focuses on drought, defined as rainfall less than or equal to two standard deviations below the mean rainfall during the primary rainy season (July and September) or 15 consecutive days without rainfall during this period.
[4]During non-drought years, less than 3 percent of all departments experience a crop failure.
[5]In this article, famine is defined as a "widespread lack of food leading directly to excess mortality from starvation or hunger-induced illnesses" (Ó Gráda 2007). Alternative definitions are provided by Ravallion (1997) and von Braun, Teklu and Webb (1999).

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 1983-84. 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 1997-98 and 2004-05 were identified as years of severe food crisis (Government of Niger 2007). 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).[6] The gross mortality rate 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).[7]

3. Conceptual Framework for Extreme Rainfall and Agricultural Market Performance

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. Since crop failures often vary in intensity across regions, 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). Empirical research on the famines in Bengal (1942-44) and Bangladesh (1974-95) suggests that food markets worked "poorly" in these instances, defined as inadequate regional arbitrage and "excessive" hoarding (Ó Gráda 2007, Sen 1981, Ravallion 1987).

The economic literature on 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

[6] There is considerable debate as to whether a "famine" occurred in Niger in 2004-05. Local, regional and international early warning systems classified the situation as "a very severe, but localized, food security crisis" (FEWS NET 2005).
[7] Both of these indicators exceed the threshold established for emergency situations, which is one death per 10,000 people per day.

a homogeneous commodity. 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 $TC_{ij,t}$.[8] 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 represent the conditions for a competitive spatial 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).[9]

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.[10] If, however, 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 the mean of P_{jt}. Finally, policies or shocks that affect transaction costs, such as gas prices, will be positively associated with equilibrium price dispersion.

4. Data and Measurement

4.1. Data Used

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[8]As trade in millet in Niger is unidirectional for most market pairs, I make the simplifying assumption that $TC_{ij,t}=TC_{ji,t}$.
[9]The equivalent condition in the presence of storage is: , 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 (Williams and Wright 1991).
[10]While the assumption of constant transport costs is not necessarily valid, increases in transport costs are primarily a function of distance between markets and gas prices. Gas prices in Niger are fixed by the government at the national level on a monthly basis since the mid-1990s, and changes are strongly correlated with changes in international gas prices.

In order to test the impact of rainfall shocks on market performance, this paper constructs three primary datasets. The first is historical rainfall data for weather stations across Niger from the Niger Meteorological Service. The data include decadal records for each station between May and September between 1996 and 2006. I use data on the latitude and longitude of each station to match each market in the sample with the closest weather station.

The second dataset includes monthly grain data between 1996 and 2006 across 42 domestic and cross-border markets in Niger, as well as the latitude and longitude for each market. In addition to price data, I also collected data on monthly gas prices, the date of mobile phone coverage, road quality, trade flows, district-level population and agricultural production.

The third dataset is a panel survey of traders, transporters and market resource persons collected in Niger between 2005 and 2007. The survey includes data from 395 traders located in 35 markets across six geographic regions of Niger. The traders who participated in the survey provided detailed information about their commercial operations during the 2005-06 and 2006-07 marketing seasons, as well as retrospective data about the 2004-05 marketing season.

4.2. Descriptive Statistics

Figure 2 shows average deflated millet prices in Niger and in Nigeria between 1996 and 2006, with summary statistics of grain prices provided in Table 2.[11] Overall, grain prices in Niger are subject to a high 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 unusually low levels of rainfall and crop failures followed by relatively higher prices. Average grain prices in 2004-05 were 25 percent higher than the ten-year average, with grain prices representing more than 27 percent of

[11]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.

annual 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 to 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 3 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.

Table 3 describes key trader and market-level variables from the trader 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 in the sample suffered from drought in 2004, as compared with 32 percent in 2000. 78 percent of markets had mobile 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. 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. Estimation Strategy

Measuring market performance 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). Vector autoregressive (VAR) models, including Granger causality, Ravallion's method, variance decomposition and cointegration analyses have been proposed as an alternative to price correlation tests (Ravallion 1986, Delgado 1986, Baulch 1997, Engle and Granger 1987). These methods often assume stationary transaction costs, as well as unidirectional and/or continuous trade patterns, which are often violated in a developing country context (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). While these are improvements over traditional approaches, they still have important weaknesses. The TAR model does not require observations on transactions costs, but it is highly parameterized and often assumes fixed transaction costs (Fackler and Goodwin 2001). The PBM, on the other hand, identifies statistically-determined upper and lower bounds for transfer costs. As the link between economic theory and the distributional assumptions used in the PBM is tenuous, the consistency of the results relies heavily on the validity of the distributional assumptions (Baulch 1997, Barrett and Li 2002). In addition, the PBM can only handle a limited number of markets.

To address some of these empirical shortcomings, this paper employs a two-part empirical strategy. During the first part of the analysis, I rely upon conventional time-series tests to provide suggestive evidence of degree of grain market integration in Niger. Since such tests are often unreliable under a set of commonly-occurring conditions -- such as nonstationary transaction costs, discontinuous trade and the presence of storage -- I exploit the exogenous variation in extreme rainfall to estimate the impact of natural shocks on grain price dispersion across markets in a difference-in-differences framework. The exogeneity of local rainfall variation is therefore central to the identification strategy.[12]

The most commonly used measure of market performance is inter-market price differences, or the comparison of these price differences against transaction costs (Spiller and Wood 1988, Sexton, Kling and Carmen 1991, 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 absolute value of price difference between markets i and j at time t, defined as $Y_{ij,t}=|p_{it}-p_{jt}|$.[13] I also use alternative measures of price dispersion, namely the absolute value of the log of price differences.

To exploit the temporal and spatial variation in extreme rainfall, I estimate a double DD specification (Bertrand, Duflo, and Mullainathan, 2004).[14] 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 using the following equation:

$$Y_{ij,t} = \beta_0 + \beta_1 R_{ij,t} + \gamma X'_{ij,t} + a_{ij} + \theta_t + u_{ij,t} \tag{3}$$

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 $X'_{ij,t}$, which includes transport costs between the two markets and the presence of mobile phone coverage. Price dispersion is also a function of an indicator variable for 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. Drought is defined as rainfall less than or equal to two standard deviations below a market's mean rainfall level during the rainy season

[12]Although overgrazing and forest conversion could question the exogeneity of drought, Zeng (2003) and Giannini et al (2003) show that rainfall in the Sahel is closely correlated with a largely tropical sea surface temperature anomaly pattern.
[13]While I observe the direction of the trade flow between market pairs in most periods, the absolute value minimizes a potential misclassification error during a particular period.
[14] The first difference is cross-sectional, as we compare drought-affected markets with non-drought markets, whereas the second difference is temporal, as we compared drought periods with non-drought periods.

(July and September) or 15 consecutive days without rainfall during this period.[15] 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}) capture time-invariant omitted variables 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.[16] The parameter of interest is β_1.

I modify equation (3) in a variety of ways. Assuming that market performance in period t might depend upon performance in period t-1, I include a lagged dependent variable to the right-hand side of equation (3), controlling for potential endogeneity by using the Arellano-Bond estimator (Arellano and Bond 1991, Caselli, Esquivel and Lefort 1996).[17] As there are potential concerns with measuring drought as a discrete event that affects both markets, I include indicator variables for drought affecting only one market in a pair.

As equation (3) is a time-series dyadic linear regression, the standard errors must be corrected for spatial and temporal dependence. I first cluster the standard errors at the market pair level, which allows for dependence between market pairs over time. I then include market-specific fixed effects and cluster by quarter, which corrects for spatial dependence and allows for some dependence between months. As a robustness check, I employ dyadic standard errors (Fafchamps and Gubert 2007), which correct for spatial dependence but do not allow for temporal independence.

[15]July through September are the wettest months in Niger, with August contributing 32-40 percent of the annual mean rainfall (Nicholson et al 2000).
[16] While equation (3) can be estimated via fixed effects or first-differencing, I use first differences to allow for a possible non-stationary process.
[17] 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. To address these concerns, I test for serial correlation in the errors.

Unlike other papers examining the relationship between rainfall and development 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. Thus, the coefficient estimates will serve as a lower bound on the true rainfall effect.

6. Empirical Results

6.1. Time-Series Tests for Market Integration

Before turning to the regression specifications outlined in equation (3), I examine whether millet prices in Niger co-move. I first test for integration of degree zero by conducting an Augmented Dickey-Fuller test (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, and the remaining 7 percent of the price series are close to the critical value. I therefore conclude that our millet price series are integrated of degree one.[18]

Table 4 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 1996, Timmer 1974). 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. 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. Grain markets in

[18] I also test the gas price data series and conclude that gas prices are integrated of degree zero (I(0)).

Niger are more integrated with Benin and Nigeria during drought years, with the highest degree of integration occurring in 2005.

To assess whether price movements in Niger follow well-defined paths, I test for Granger causality between each pair of price series (Granger 1969, Schimmelpfennig and Thirtle 1994, Dercon 1995). Figure 4 shows the percentage of times that a market Granger-causes another market in Niger, whereas Figure 5 shows the percentage of times that a market is Granger-caused by another market in Niger or in the sub-region. 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 parts of the country) are useful for predicting price changes in other markets. 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 price movements within Niger respond to supply shocks, and that supply shocks in surplus regions can be useful in predicting grain price changes in Niger.

6.2. The Impact of Drought

Deviations of rainfall from the department-level mean are strongly associated with deviations of grain output from its mean in Niger. Regressing per capita grain production on an indicator for drought indicates that average per capita grain output in departments affected by extreme rainfall is 80 kg lower (Table 5, Column 1).[19] This result is robust to the inclusion of year and geographic fixed effects (Column 2), as well as the lagged value of drought (Column 3). Millet prices in the previous marketing year are associated with a positive but economically insignificant increase in per capita grain output (Column 4), suggesting that grain production is highly inelastic in

[19] Table 5 presents the results from the following equation: $Y_{it} = \alpha_0 + \alpha_1 R_{it} + \mu_i + \delta_t + \varepsilon_{it}$, where Y_{it} is department-level per capita grain output, R_{it} is a department-level indicator variable for drought, and μ_i and δ_t are geographic and time fixed effects.

Niger. Using the log of per capita millet production as the dependent variable yields similar results (Columns 5-8).

Table 6 presents the regression results of equation (3). Overall, the results show that drought has a statistically significant impact on price dispersion in Niger.[20] Drought in both markets is associated with a 1.43 CFA/kg decrease in price dispersion across markets, representing a 10 percent decrease as compared with mean price dispersion (Column 1). This result is robust to the inclusion of other covariates (Column 2), as well as a group-specific time trend (Column 3). I also redefine the effect of drought to include a dummy variable for one market in a pair is affected by extreme rainfall (Column 4). The coefficient on drought on both markets remains negative and statistically significant, suggesting that extreme rainfall leads to an 11 percent reduction in price dispersion across markets. The results are robust to alternative specifications of the dependent variable, namely the log of price dispersion across markets and the intra-annual coefficient of variation for market *i* (Aker 2008b).

Most of the specifications in Table 5 control for other variables that could affect price dispersion across markets, including mobile phone coverage and transport costs. Overall, a 1 CFA/kg per km increase in transport costs between markets increases price dispersion across markets by .48 CFA/kg. This suggests that factors affecting transport costs in Niger – such as gas prices, distance and road quality – have a statistically significant impact on grain price dispersion across markets. Consistent with related research, the presence of mobile phone coverage in both markets reduces price dispersion between markets (Aker 2010).

Until now, a key assumption of the identification strategy has been that the $\Delta u_{ij,t}$ are uncorrelated with the first-differenced regressors. Column 5 presents the results of the model with a

[20] 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 distributed in the later parts of the 2004-05.

lagged dependent variable as an additional regressor, using the Arellano-Bond estimator. Controlling for transport costs, mobile phone coverage and monthly time fixed effects, the coefficient on the lagged dependent variable is positive, implying that it takes approximately 2.7 months for price differences across markets to adjust.[21] The coefficient on drought is still negative and statistically significant, representing the initial impact of drought in both markets. The long-run impact of drought is measured as $\frac{\beta_1}{1-\rho}$, where ρ is the coefficient on the lagged dependent variable. Using this formula, the presence of drought in both markets reduces price dispersion by 3.5 CFA per kg in the long-term.

6.3. Heterogeneous Effects

The specification in equation (3) assumes there is a homogenous impact of drought on grain market performance. As the spatial location of extreme rainfall varies across years, it is reasonable to assume that the effect of drought 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. The interaction term is strongly negative and statistically significant (Column 6), 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 between drought-affected markets was 3.70 CFA/kg lower than between non-drought-affected market pairs. When over 76 percent of market pairs were affected by drought in 2004, price dispersion between drought markets was 4.35 CFA/kg lower. Such findings are intuitive: the impact of drought is stronger as the percentage of markets affected by drought increases.

[21] The coefficient on the lagged dependent variable can be interpreted as the speed of adjustment. The concept of a "half-life" can be used to interpret the results, calculated as $\frac{\ln(.5)}{\ln(1+\rho)}$.

As gas prices increased substantially between 2001-2006, changes in gas prices could impact price dispersion across markets. To test whether the impact of drought varies according to exogenous changes in transport costs, I include an interaction term between drought and gas prices (gas prices are set at the national level). The interaction term is positive but not statistically significant, suggesting that gas price increases are not correlated with drought.

7. Alternative Explanations and Mechanisms

7.1. Alternative Explanations of Reductions in Price Dispersion

The key 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 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 five potential areas of concern.

The first concern is whether differential trends between drought and non-drought markets could explain the results. One of the most important of these is the rollout of mobile phone coverage in Niger between 2001 and 2006, which led to a 15-percent reduction in grain price dispersion across markets (Aker 2010). Nevertheless, this seems unlikely for two reasons. First, drought and mobile phone coverage are not strongly correlated between 2001 and 2006, as mobile phones were first rolled out in urban centers and border markets. Second, the negative relationship between drought and price dispersion is evident even in 1997-98 and 2000-01, prior to the introduction of mobile 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 trader 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 2005 and 2007, as well as secondary data from 2000 and 2001, the number of traders per market did not vary significantly on an intra- or inter-annual basis (Aker 2008a).[22] 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 2008a). CR4s at the market level show that grain markets in Niger are fairly competitive across drought and non-drought markets, with most markets having a CR4 less than 25 percent. [23] These results provide evidence that reductions in price dispersion are not driven by collusive behavior.

A fourth 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 the following year. Under such behavior, the variability of the quantity produced both across and within markets could 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 remained relatively constant between 1980 and 2004, and there was not a positive relationship between the area planted after a drought year. Second, regression results in Table 4 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) and not statistically significant. 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.

A final concern is whether the measurement of drought as a discrete binary variable, as opposed to a continuous variable, affects the interpretations of our results. Using a continuous

[22]Trader census data by market are available from secondary and primary sources between 2000 and 2006. There is no correlation between changes in the number of traders and the presence of drought in a particular market.
[23] Kohls and Uhl (1985) suggest that a CR4 less than or equal to 33 percent is indicative of a competitive market structure, while a CR4 of 33-50 percent and above 50 percent may indicate a weak and strongly oligopolistic market structures, respectively.

variable of drought between the months of May and September, I first normalize the rainfall variable by subtracting its mean and dividing by the standard deviation. Regressing the absolute value of the log of price differences on the deviation of rainfall from its mean, I find that 2 SD decrease in rainfall in both markets is associated with a 25 percent reduction in price dispersion across markets. This is robust to a variety of specifications (not shown), thereby suggesting that measuring drought as a discrete event is not biasing the results.

7.2. Mechanisms

The previous results suggest that grain price dispersion across markets was lower in 2004/2005, the year of the severe food crisis. Nevertheless, increased integration will only improve consumer welfare if both price levels and variances decrease. In 2004-05, average millet prices were the highest on record, severely affecting the 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 (Figure 1). In 2000, approximately 32 percent of departments were affected by drought, with 15 percent of departments 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 6, 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? The departments affected by drought in 2004 were key surplus-producing (and Granger-causing) markets in Niger and in the sub-region. Comparing real millet prices for key Granger-causing markets in Benin, Niger and Nigeria during the harvest periods of 2000 and 2004, I find that average millet prices in these markets were 15 CFA/kg higher in October 2004 as compared to October 2000, with a statistically significant difference between the two.[24] Thus, even though total and per capita grain production was higher in 2004, price levels in Granger-causing markets were already 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, with an 18-percent price increase between June and August 2005.

A common explanation for the sharp seasonal price rises in 2004-05 is "excessive hoarding" (*Washington Post,* April 11, 2005), implying that traders held back supplies early in the season in the hopes that prices would rise later. This asymmetry in traders' expectations is absent in the trader-level data. The average duration of traders' storage in Niger is fairly short, less than one month (Table 4). While storage duration varies considerably by trader type, 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 two factors. First, in response to widespread drought and crop failures in the region, several of Niger's trading partners (such as Burkina Faso) issued a temporary ban on exports into Niger in early 2005. This unofficial ban reduced supply (albeit temporarily) and increased prices on markets in the western regions of Niger. For example, grain prices in Niamey, the capital city, increased by more than 12 percent between February and March 2005 (Figure 6), immediately after the border closure.

[24] The forecasting markets in Figure 7 are 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).

The increase in grain prices in Niger could have been mitigated by increased supply from other countries in the sub-region, such as Nigeria. On average, import parity prices for millet from Nigeria are *higher* than millet prices in Niger for most of the year. This relationship usually reverses during the pre-harvest period in Niger (June through August), 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 7). While import parity prices for millet from Niger's other neighbors (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. [25]

8. Policy Implications

There is considerable debate surrounding 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 strongly 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.

[25]Niger imports grains from its neighbors, namely Benin, Burkina Faso, Mali and Nigeria. Official millet imports averaged 34,000 MT between 2000 and 2005, representing approximately 1 percent of total millet availability. On average, Nigeria supplies 75 percent of Niger's millet and sorghum imports and 35 percent of total maize imports. Higher relative prices in Nigeria suggest that imports were reduced from a key trading partner during 2004/2005.

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 a more disaggregated level (ie, the department), in order to determine how many areas were affected. Similarly, in light of the importance of Niger's neighbors on domestic grain market 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 be more "strategic" in their monitoring of grain prices. 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). Second, prices should not only be monitored during the pre-harvest period, but also during the harvest period. 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.[26] If import parity prices – especially from northern Nigeria – are higher than domestic prices in Niger during the pre-harvest period, this suggests that Niger would need to import from other countries.

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. The effect of also 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.

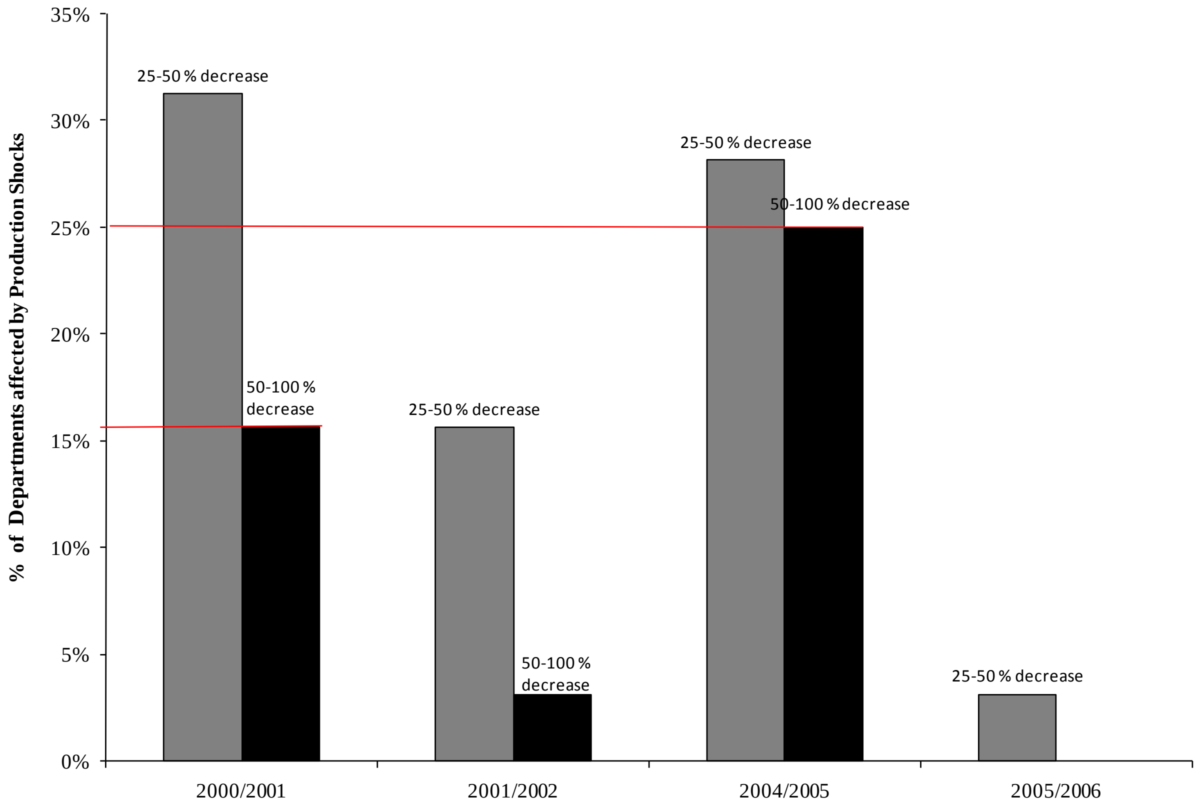
[26] Prices should be compared between the following markets: Malanville (Benin)-Gaya, Illela (Nigeria)-Konni, Jibia (Nigeria)-Maradi, Mai Adua (Nigeria)-Zinder, and Kantchari (Burkina Faso)-Torodi.

The most plausible explanation for these results 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 mobile phones are associated with a negative and statistically significant reduction in price dispersion across markets (Aker 2010), drought and mobile phone coverage are not highly correlated.

The evidence in this paper should not be taken to imply that grain markets worked "perfectly" in Niger during the 2005 food crisis. However, factors other than a market failure, in the sense of poor spatial integration and "excessive" hoarding, appear to be responsible for the price spike and food crisis in 2005. These include the spatial distribution of drought and few incentives to import from Nigeria.

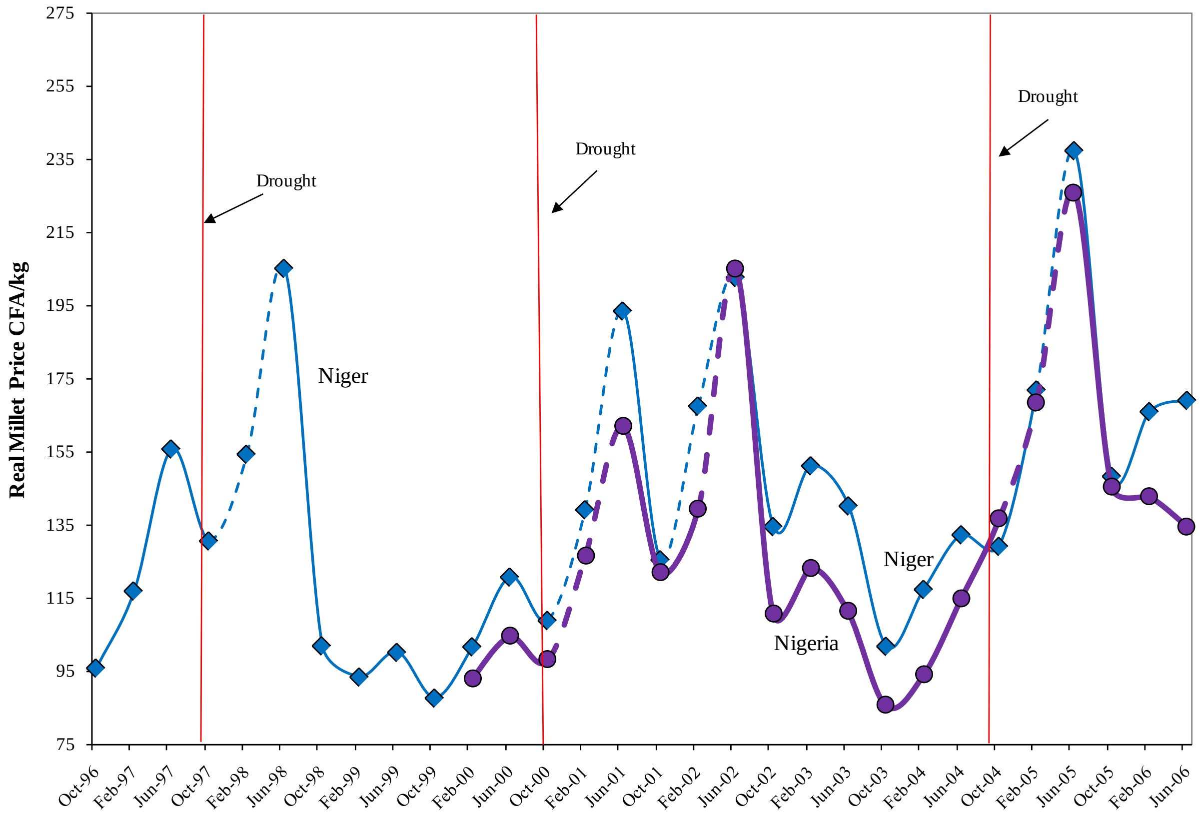
These results have important implications for policy. They suggest that, while climatic indicators such as drought and agricultural output are appropriate as early warning indicators, they need to be monitored and analyzed at a disaggregated level. The timing of the price spike in 2005 also suggests that grain prices need to be monitored on Granger-causing markets, and that relative prices between Niger and Nigeria should be followed during the pre-harvest period.

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



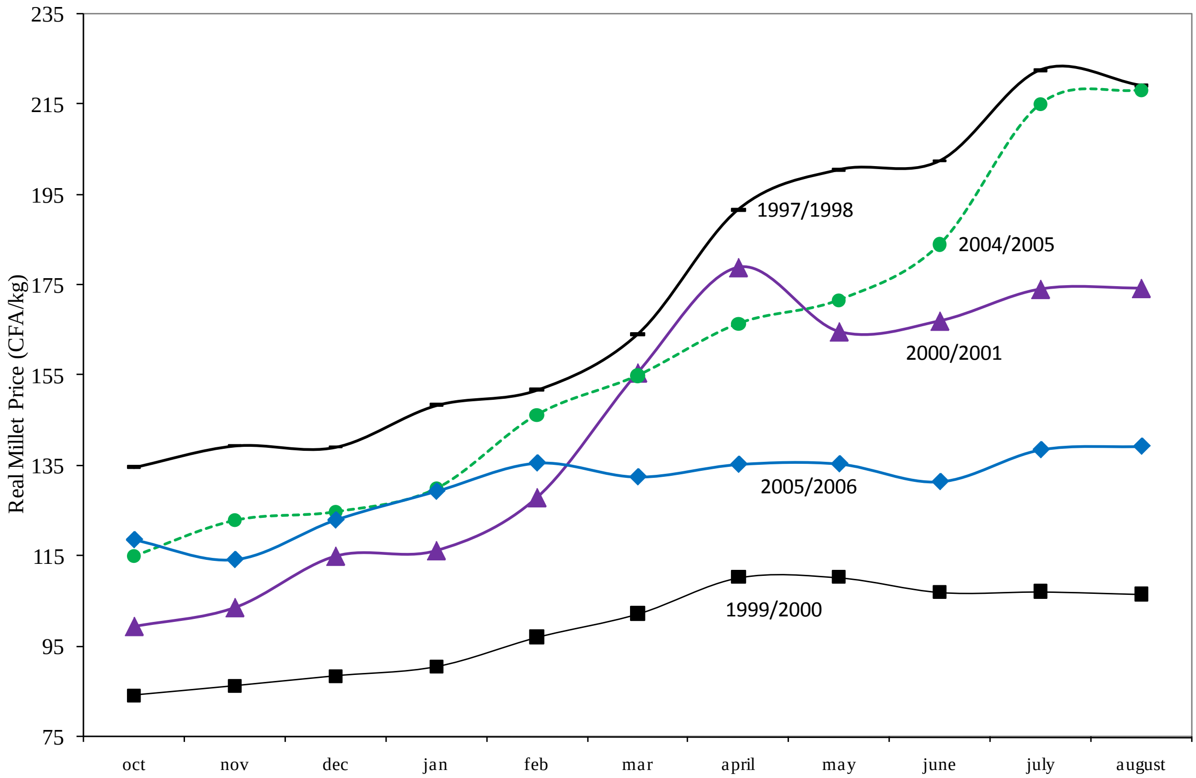
Notes: Each column represents the percentage of departments affected by a decrease in per capita production as compared to the ten-year average. There are a total of thirty-six (36) departments in Niger in eight geographic regions. In 2000, only 15 percent of the departments experienced a per capita 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. Average Monthly Millet Prices and drought in Niger, 1996-2006 (CFA/kg)



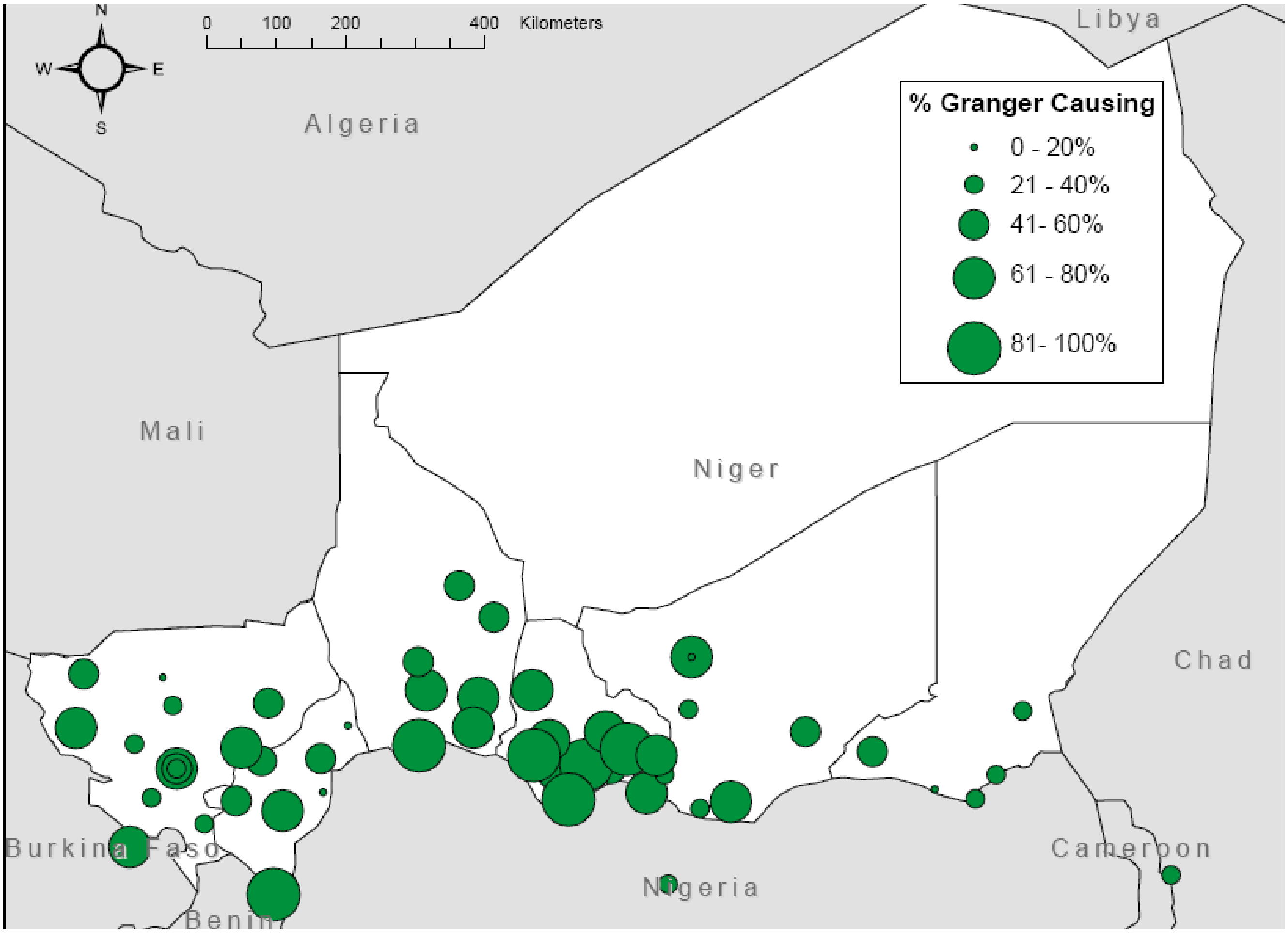
Notes: Prices are the average millet prices across all domestic markets in Niger, deflated by the Nigerien consumer price index (2001). Prices are provided by the Agricultural Market Information System. The dashed lines represent prices in Niger and Nigeria following the drought.

Figure 3. 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 unusually low rainfall (drought), whereas 1999/2000 and 2005/2006 were years of normal rainfall.

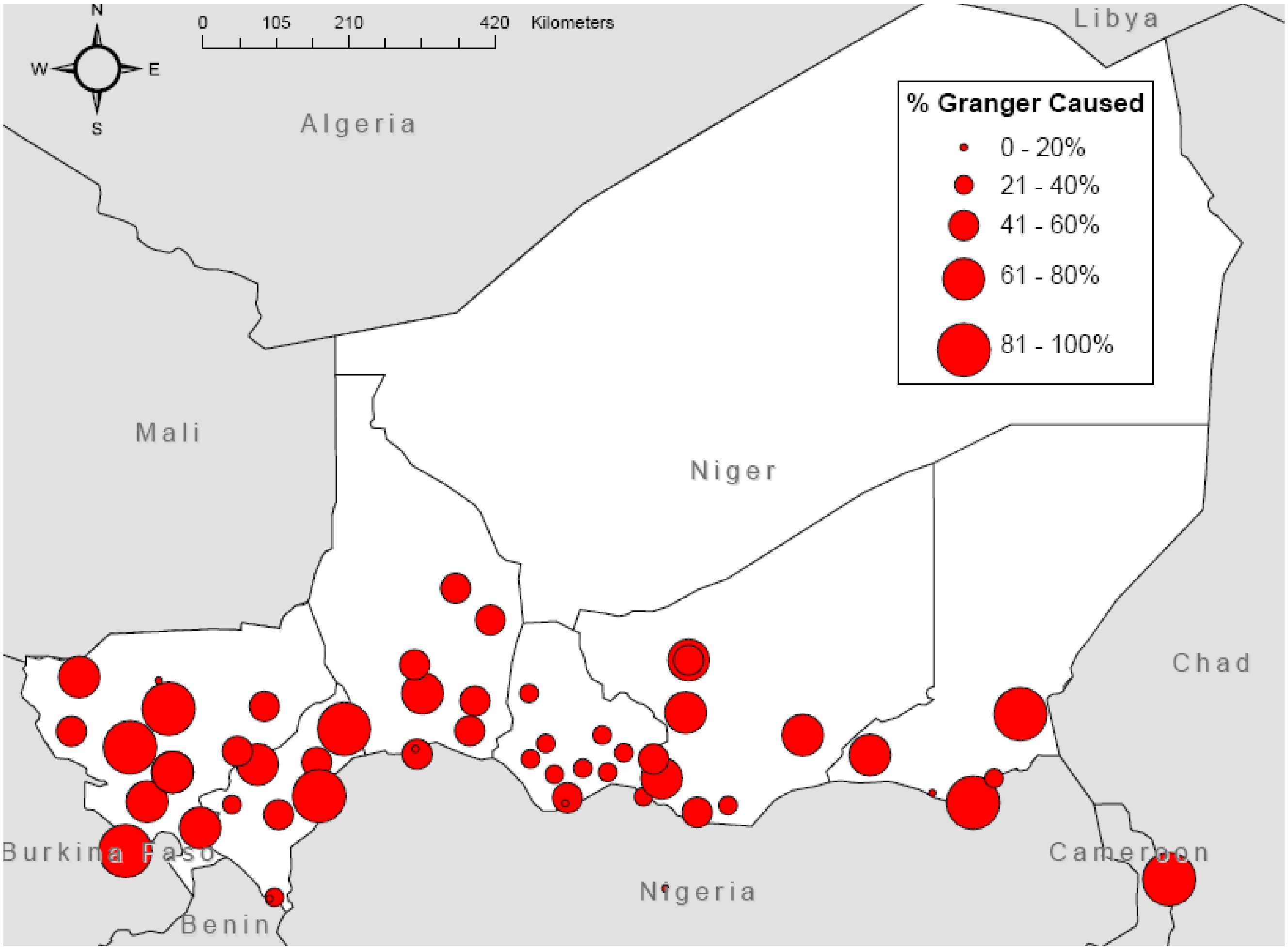
Figure 4. Granger-Causing Markets in Niger and the Sub-Region (Benin, Burkina Faso, Nigeria)



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

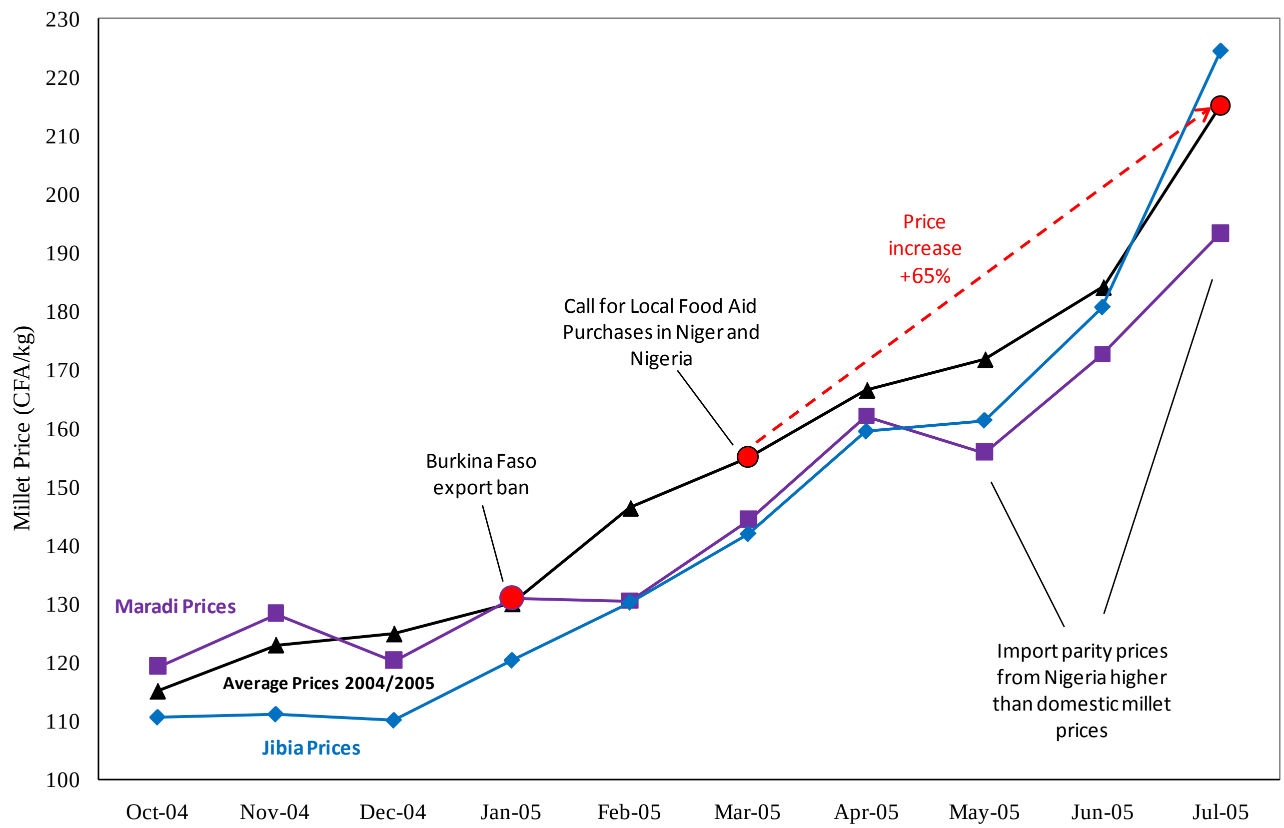
$\Delta P_{i,t} = \lambda_0 + \sum_{m=1}^{3} \lambda_m \Delta P_{i,t-m} + \sum_{m=1}^{3} \overline{\lambda}_m \Delta P_{j,t-m}$. If price movements in market *j* precede price movements in market *i*, then the $\Delta P_{j,t-m}$ terms should have a significant effect on $\Delta P_{i,t}$. Granger-causing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

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



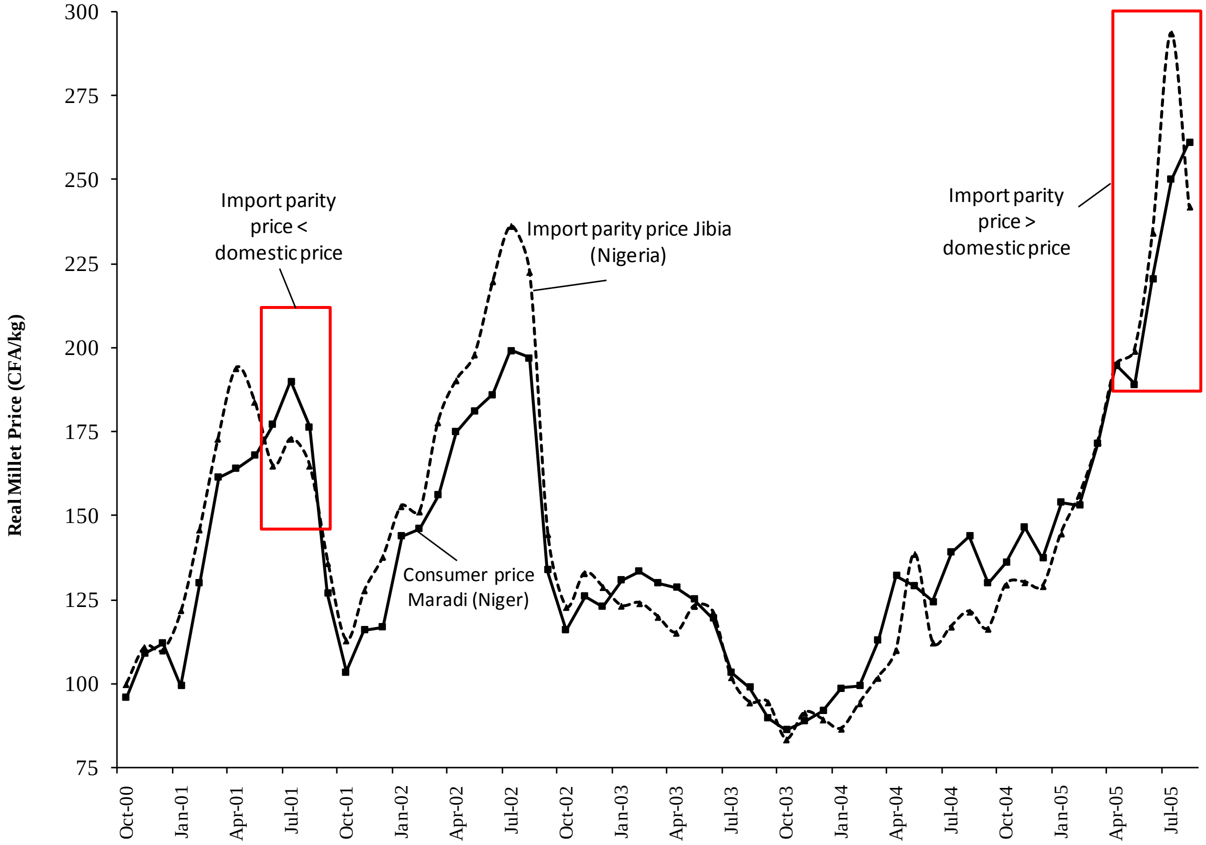
Notes: Granger causality tests were conducted using the following error correction model: $\Delta P_{i,t} = \lambda_0 + \sum_{m=1}^{3} \lambda_m \Delta P_{i,t-m} + \sum_{m=1}^{3} \overline{\lambda}_m \Delta P_{j,t-m}$. If price movements in market *j* precede price movements in market *i*, then the $\Delta P_{j,t-m}$ 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 6. 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 7. 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. Millet Prices in Niger, 1996-2006 (CFA/kg)

Variable	Obs	Mean	Std. Dev.
Average Prices (CFA/kg)	120	145.98	40
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. Grain Trader and Market Characteristics

Variable Name	Sample Mean (s.d.)	# of obs
Panel A. Market-Level Characteristics		
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
Mobile phone coverage 2005/2006	.78(.41)	35
Mobile phone coverage 2004/2005	.62(.48)	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
Co-ownership of commerce	.19(.40)	395
More than 75 percent of commerce sold in principal market	.59(.49)	395
Changed "principal market" since became 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 Mobile 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 4. 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

* 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 5. Estimated Effects of Drought on Production and Food Crisis

Dependent Variable	Per Capita Millet Production (kg)				ln(Per capita millet production)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Drought (drought=1, 0 otherwise)	-80.05*** (16.07)	-80.05*** (14.87)	-102*** (26.95)	-99.39*** (29.47)	-.628*** (.225)	-.628*** (.208)	-.823*** (.362)	-.754*** (.359)
Lagged drought variable			5.98 (10.75)				.042 (.073)	
Lagged Millet price				1.79** (.82)				.018** (.006)
Constant	335*** (8.96)	335*** (8.96)	322*** (11.45)	54 (125)	5.96*** (.061)	5.35*** (.057)	5.83*** (.068)	3.17 (.962)
Common Time Trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Group-specific time trend	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Market Fixed Effects	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Department Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Yearly time dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# of obs	174	174	145	135	174	174	145	135
Mean of dependent variable	219	219	219	219	5.13	5.13	5.13	5.13
R^2	0.7885	0.2337	0.7987	0.8255	0.8066	0.8066	0.795	0.8166

Notes: Data from the Niger trader survey and secondary sources collected by the author. The dependent variable is per capita millet production at the departmental level for a particular year, obtained from the Ministry of Agriculture. Drought=1 in year t when a department 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. Mobile phone dummy =1 in period *t* when a market has cell phone coverage, 0 otherwise. Huber-White robust standard errors clustered by department are in parentheses. * is significant at the 10% level, ** significant at the 5% level, *** is significant at the 1% level.

Table 6. Estimated Effects of Drought on Price Dispersion: DD Estimation with First Differences

Dependent variable: |*Pit-Pjt*|	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Drought (both markets)	-1.43** (.604)	-1.43** (.604)	-1.37** (.607)	-2.43* (1.36)	-2.43*** (.752)	4.20** (2.54)	-19.34* (11.13)
Drought one market				1.13 (1.29)		-.270 (1.18)	1.03 (1.28)
Transport costs (CFA/kg)		.482** (.263)	.482** (.263)	.483** (.281)	.557* (.308)	.460*** (.088)	.483** (.281)
Lagged dependent variable					.292*** (.015)		
Drought*Percentage of Markets						-11.25*** (4.37)	
Drought*gas prices							.057* (.037)
Constant	5.11*** (.752)	5.12*** (.751)	5.12*** (.751)	2.82*** (.982)	3.42 (4.43)	5.12*** (.751)	5.12*** (.751)
Common Time Trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other covariates	No	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
Monthly time dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cross-border markets	No	No	No	No	No	No	No
Long-term effect					-3.44*** (1.06)		
Join effect						-6.85*** (2.63)	-19.28* (11.13)
# of observations	27342	27342	27342	27342	27342	27342	27342
# of cross-sectional observations	433	433	433	433	433	433	433
Mean of dependent variable	22.08	22.08	22.08	22.08	22.08	22.08	22.08
R^2	0.0073	0.1003	0.1003	0.1003	0.1012	0.1307	0.1004

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.

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