Do Borders Matter? Borders and Markets in West Africa

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June 2009

PRELIMINARY DRAFT. PLEASE DO NOT CITE.

Abstract. The aggregate welfare-enhancing effects of international trade are widely agreed upon by economists. There is more debate about the ease with which trade takes place across national borders, with wide estimates of the relative difficulty of international trade as compared to intra-national trade. As a result, border effects have been cited as one of the "great puzzles" in international economics. Nevertheless, understanding the magnitude and significance of the border effect is more than a theoretical concern, as it can have important implications for market performance and welfare, especially in the landlocked countries of sub-Saharan Africa. This research assesses the extent to which international borders segment markets for staple food and cash crops across West Africa, focusing on Niger and its primary trading partners (Benin, Burkina Faso and Nigeria). Rather than simply comparing within-country to cross-country price dispersion, we exploit the "artificial" nature of geographic borders in West Africa to estimate the border effect in a regression-based framework, with preliminary results using a regression discontinuity design (RDD) approach. Also, recognizing the manner in which national borders in West Africa both divided ethnic groups and included, in a single nation, diverse ethnicities, we assess whether intra-national ethnic borders contribute to market segmentation within countries or market integration across countries. Preliminary findings suggest that markets for grains and cash crops are fairly well-integrated across countries, even those that span the CFA-Naira border. The border effect is more pronounced across internal borders, as compared with international borders, for all commodities. Cell phones appear to mitigate the international border effect, but have less of an impact on internal borders.

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1. Introduction

There is general agreement among economists that free trade promotes an efficient allocation of resources, and, conversely, that policies that impede trade reduce a country's standard of living. There is also evidence that trade contributes to economic growth (Frankel and Romer 1999, Feyrer 2008). Debate continues, however, on the degree to which national borders affect the integration of goods across markets in the absence of conventional restrictions on trade. The seminal contribution to this issue is Engel and Rogers (1996), who compare city-to-city price differences for homogeneous commodities in Canada and the US. Controlling for distance, they find that price differences are considerably larger when two cities are separated by the international border. Similar research on industrial countries has consistently found a relatively large border effect, although the magnitude and significance of this effect has varied considerably (Gorodnichenko and Tesar 2008). Consequently, border effects have been cited as one of the "great puzzles" in international economics (Obstfeld and Rogoff 2000).

Less is known about the border effect in low-income countries, where the stakes are arguably greater in terms of consumer and producer welfare. In this paper we assess the extent to which international borders segment markets for staple foods and cash crops in West Africa. The focus of this study is Niger, sub-Saharan Africa's second-largest country by land area and one of the poorest countries in the world. Of Niger's seven contemporary neighbors, we focus on three that lie along its densely-populated western and southern borders and constitute its main regional trading partners. To the west, Benin and Burkina Faso were part of French West Africa and share a common currency with Niger, the *Communauté Financière Africaine* (CFA) franc. To the south, Nigeria was a British possession during the colonial period and remains by far the largest economy in West Africa.

An extensive literature emphasizes the role of national trade policies on the trade of goods sourced from, or destined for, overseas markets (Deardorff and Stolper 1990, Azam 2007, Golub and Mbaye 2008). Our focus is rather on staple grains (sorghum and millet) and the primary cash crop (cowpea), which play a

major role in producer and consumer welfare in West Africa. While these commodities have been largely free of formal trade restrictions during the period of our study (1999-2007), borders may nonetheless impose important costs in the form of delays, harassment or banditry, or costs associated with changing currencies and communicating across languages.

To assess these costs, we employ several of the regression-based techniques developed in the international economics literature on border effects. Using monthly prices for fifty-five consumer, wholesale and producer markets located in Niger and in neighboring countries (Benin, Burkina Faso and Nigeria), we assess the impact of international and internal borders on price dispersion across market pairs. To do so, we examine price differentials across pairs of markets, distinguishing pairs located within Niger from those separated by an international border. For market pairs located within Niger, we also distinguish between pairs within a single ethnic region from those located within different ethnic regions, that is, those separated by an internal border. Finally, we measure the border effect using the regression discontinuity approach, exploiting the fact that borders within West Africa were drawn without reference to natural socio-cultural, geographic or economic divisions.

Our results suggest that an international border effect exists between Niger and its neighbors, but that its magnitude is relatively limited. This result contrasts with the border effect literature on industrialized countries, where large border effects have been found between the U.S. and Canada (Engel and Rogers 1996, Gopinath, Gorinchas and Hseih 2008), the U.S. and Japan (Parsley and Wei 2001), and between EU countries (Crucini and Shintani 2006, Crucini, Telmer and Zachariadis 2005). Interestingly, we find evidence of more market integration between ethnically homogeneous regions of Niger and its neighboring countries than across ethnic regions within Niger. Consistent with recent literature assessing the impact of information technology (mobile phones) in improving market integration (Aker 2008), we find that the border effect is significantly reduced with the introduction of cell phones, especially across international borders.

The rest of the paper is structured as follows. Section 2 provides a context for our analysis by discussing the establishment of Niger's international borders and their relationship to the country's ethnic

groups. Section 3 offers a discussion of previous research on the effects of borders on price divergences. Section 4 describes the data set that we have constructed, whereas Section 5 presents our empirical strategy. Section 6 presents the main results and Section 7 concludes.

2. Background on Niger and Intra-Regional Trade

2.1. Pre-Colonial Trade within the West African Sub-Region

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). Agriculture employs more than 80 percent of the total population and contributes approximately 40 percent to Gross Domestic Product (GDP). The majority of the population consists of rural subsistence farmers, who depend upon rain-fed agriculture as their main source of food and income. The main grains cultivated are millet, sorghum, rice, fonio and maize, with cash crops including cowpea, peanuts, cotton and sesame.

As a landlocked country, Niger depends heavily upon trade with its coastal neighbors – namely Benin and Nigeria – to meet its food and income needs. The inter-regional trade routes between what is now Nigeria and Niger have a long and rich pre-colonial history. In the centuries prior to the arrival of the colonial powers, the Hausa ethnic group in modern-day Northern Nigeria and Niger was linked to the rest of the continent through a series of trading routes. The first was the trans-Saharan trade route, connecting Katsina and Kano (Nigeria) to Tripoli (Libya), as well as the desert in northern Niger. This route was based primarily upon the trade of slaves, textiles, livestock, grains and salt. The second trade route was the westward trade route of kola nuts, linking Niger and Nigeria with Ghana (Hashim and Meager 1999).[1]

There were a number of significant changes in these circuits during the 1800s (Hashim and Meager 1999). First, the slave trade became less important in the export portfolio of the West African states, and European goods became increasingly important as imports. Nevertheless, the direction and composition of the trade circuits were still primarily based upon ecological specialization and comparative advantage.

[1] In addition to these primary trading circuits, there was also an east-west route between Kano and Mecca, whereby pilgrimage was combined with trade.

Simultaneously, an eastward shift in the trans-Saharan trade route coincided with a dramatic expansion of the economy of Sudan and a growing dominance of the Hausa trading networks. During this time, Hausa became the *lingua franca* along the east-west trading routes (Lovejoy 1980).

2.2. Ethnicity and Borders in West Africa

International borders within Sub-Saharan Africa created ethnically fragmented countries that also separated common ethnic groups among contiguous countries (Alesina, Easterly and Matuszeski 2006). This is particularly true within the West African sub-region, where borders were drawn to reflect the interests of the colonial powers. Following the "Scramble for Africa" of the 1884-1885 Berlin Conference, the French and the British colonial powers established Niger's southern border in 1890.

The 1,500-km border between Niger (a former French colony) and Nigeria (a former British colony) reached its current configuration within twenty years of the Berlin Conference. The geographic placement of the border reflected two simultaneous processes, which have been described as "artificial" with respect to African interests (Alesina, Easterly and Matuszeski 2006).[2] The French government wanted access to Chad across southern Niger, thus moving the border from the northern desert regions to a location farther south, within the arable zone. The British government insisted that the Hausa-Fulani kingdoms of northern Nigeria be kept intact, in light of previous civil conflict between the groups. Figure 1 shows the current international borders between Niger, Nigeria and other countries within the sub-region.

The border that emerged in 1906 passed through political, ethnic, and economic groupings in both countries. Within Niger alone, there are eight ethnic groups, including the Hausa (55 percent of the population), the Songhai/Zarma (21 percent), the Toureg (9.3 percent), the Fulani (8.5 percent), the Kanuri (5 percent) and Arab, Toubou and Gourmantche (1.2 percent). As a semi-nomadic population, the Fulani are interspersed among different ethnic groups throughout the country. While there are over 250 ethnic groups in Nigeria, the Hausa, Fulani and Kanuri ethnic groups are dominant in the northern states, from 11° longitude (north) and between 4° and 14° latitude (east).

[2] Alesina, Easterly and Matuszeski (2009) refer to "artificial states" as those in which political borders do not coincide with a division of nationalities desired by the people on the ground.

Thus, the international border created between Niger and Nigeria created ethnically fragmented countries, while simultaneously separating common ethnic groups (Hausa, Zarma, Fulani and Kanuri) between two countries. This is evident in Figure 2, which shows a map of the ethnic groups within and across countries within the sub-region.[3] The division of ethnic groups is shown in greater detail in Figure 3, which shows the spatial location of towns on either side of the Niger-Nigeria border.[4] Contrary to concerns that the border is in the middle of a "no-man's land", this figure shows that the border effectively divided ethnic groups, families and economic activities.[5]

The political salience of intra-francophone borders was of course much less fundamental during the colonial period than that of the Anglo-French border between Nigeria and Niger. The division of ethnic groups across ethnic and political borders nonetheless took place within French West Africa, between Niger and its western neighbors (Benin, Burkina Faso and Mali). There were similar divisions across ethnic lines, primarily the Songhai/Zarma (located in northern Benin and southwestern Niger, as well as western Niger and eastern Mali) and the Gourmantché ethnic groups (Burkina Faso and Niger).

2.3. Inter-Regional Trade in the Post-Colonial Period

On account of limited road networks linking the two colonies, by the time of independence in 1960 there were relatively few official border crossing stations. Building more stations was a low priority for the newly decolonized and relatively poor states of Nigeria and Niger. Borders remained porous, patrolling haphazard, and smuggling a major economic activity. Skirting customs duties, "unofficial traders" have long brought petroleum and farm-chemical products into Niger and livestock into Nigeria (Charlick 1991). Grains have also constituted an important commodity of cross-border trade (Collins 1976).

[3] A map of Nigeria in 1957-58 (not shown) also suggests that the geographic location of ethnic groups in Niger and Nigeria seems to be time-invariant, as it is similar to the ethnographic maps for 2008.

[4] These towns were both present during the 1905 border demarcation.

[5] For example, Asiwaju (1985) states that the Niger/Nigeria border created a 'partitioned culture area' among Hausa and Fulani populations. Miles (2005) reports that, at the outset of the international demarcation, inhabitants with farmland straddling the boundary had to choose one colonial side or the other. French subjects were not supposed to farm on 'English' territory, and vice versa. The British completed a railway between Lagos and Kano in 1911, unifying Nigeria's coast with its north-eastern interior and undermining the long-distance trade between Kano and Tripoli (Hopkins 1973).

In 1971, a Nigeria–Niger Joint Commission (NNJC) was created with the purpose of harmonizing relations between the two neighboring states. Despite a series of border closings between 1983 and 1986, often related to political instability in Nigeria, both the National Boundary Commission of Nigeria and the NNJC have convened trans-border workshops to address issues of cross-border trade. In the sub-region, West African states have also attempted to mitigate a potential border effect through a system of monetary and trade unions. These include the West African Economic and Monetary Union (or UEMOA), a customs and monetary union created in 1994 that shares a common currency (the CFA franc) and a common external tariff.[6] UEMOA is also part of the Economic Community of West African States (ECOWAS), a trade union created in 2001 among all West African states. Figure 4 shows the each country's membership in UEMOA, ECOWAS or both.

3. Literature on Estimating the Border Effect

The motivation for using prices in different locations to test for market integration across national boundaries is straightforward; if borders impose costs that undermine trade, then conditional on distance and other factors, price differences between markets located in different countries should be larger than those between markets in the same country. Nevertheless, there are subtle issues related to the implementation of this strategy. In this section we discuss various ways in which research has been conducted to use prices to test for a border effect.

An influential contribution to this literature is Engel and Rogers (1996). They compare price volatility for fourteen categories of goods among 228 pairs of cities located within the US, Canada or both, estimating a regression of the following form:

$$\sigma_{i,j} = \beta_1 \ln\left(d_{i,j}\right) + \beta_2 B_{i,j} + \sum_{m=1}^{N} \gamma_m D_m + \varepsilon_{i,j} \quad (1)$$

where $\sigma_{i,j}$ is a measure of price volatility between cities i and j, $d_{i,j}$ is the distance between these cities, $B_{i,j}$ equals 1 if cities i and j are in different countries and 0 otherwise, and D_m is a set of city-specific dummy

[6] The actual CFA franc was created in 1945, with two devaluations in 1948 and 1994 (changing the relative value of the CFA to the French franc). The current CFA franc is pegged to the Euro.

variables. The estimated coefficient β_2 represents the conditional change in price variability between two cities due to the fact that they are in different countries. The estimated border effect, that is, the distance-equivalent effect of the border, is $exp\frac{\beta_1}{\beta_2}$.

Engel and Rogers find a very large effect of the international border on price variability. One estimate puts the distance-equivalent effect at over 70,000 km. Other research following this basic strategy includes Parsley and Wei (2001), who considered prices in the US and Japan, and Ceglowski (2003) who looked at cross-provincial prices in Canada. Both of these analyses also found striking distance-equivalent border effects.

The border effect estimated using equation (1), however, may reflect factors other than the border itself. Gorodnichenko and Tesar (2009) show that differences in underlying price volatility in two countries can result in a biased estimate of the border effect. For example, price volatility among pairs of cities in the US is about twice that among pairs of cities in Canada. This contributes to a positive estimate of the border effect, as comparing a cross-country pair of prices reflects both underlying heterogeneity in price variability in the two countries as well as the costs associated with crossing the border. Nevertheless, it is not possible to correct this problem through the introduction of a dummy variable for both US – US pairs and Canada – Canada pairs in equation (1), since these would be collinear with the city-specific fixed effects and the US – Canada fixed effect. Gorodnichenko and Tesar therefore augment equation (1) by controlling for Canada – Canada fixed effects, or $CC_{i,j}$:

$$\sigma_{i,j} = \beta_1 \ln(d_{i,j}) + \beta_2 B_{i,j} + \beta_3 CC_{i,j} + \sum_{m=1}^{N} \gamma_m D_m + \varepsilon_{i,j} \; . \tag{2}$$

This results in an estimate of β_2 (the border effect) that is much smaller than its estimate in equation (1); using the same data, Gorodnichenko and Tesar find a distance-equivalent border effect of 47 km. When the regression is modified to include a dummy variable for US – US city pairs instead, the estimated distance-

equivalent border coefficient becomes 108 million km. This large difference in the magnitude of the border effect reflects the large differences in within-country price variability.[7]

An alternative to this methodology has been proposed by Gopinath, Gourinchas, Hsieh, and Li (2009) and Holmes (1998), who employ the regression discontinuity design (RDD) approach. Common in the treatment effects literature, the RDD methodology uses a regression of the form:

$$Y_i = \alpha + \gamma T_i + \theta Z_i + \beta X_i + \varepsilon_i \tag{3}$$

where the assignment variable (Z) that determines the level of treatment (T), and the question of interest is the effect of the treatment on the outcome, Y. The level of treatment jumps discontinuously at Z_0, such that, in the neighborhood of Z_0 there is a discontinuous jump in the outcome of interest (Y) (known as the sharp discontinuity design). RDD is used to estimate the effect of the treatment, conditional on other factors, in the neighborhood of the assignment variable being equal to the cutoff value.

It is often the case that the assignment variable reflects some underlying characteristic that is relevant for the treatment. For example, Thistlewaithe and Campell (1960) estimated the impact of awarding a National Merit Award on enrollment in graduate studies, whereby the scholarship assignment is determined by students' scores on a standardized test.[8] The treatment effect can be studied in the neighborhood of the cutoff value of the assignment variable to analyze the effect of the assignment on the outcome. In order to infer a causal effect in the outcome due to an abrupt change in treatment, a key assumption of RDD methodology is that unobserved characteristics do not vary discontinuously around the cutoff value of the assignment variable. In practice, an additional consideration is the choice implementing these methods is the choice of an appropriate bandwidth, that is, the distance from the cutoff value (Imbens and Kalyanaraman 2009).

[7] For example, controlling for low intra-Canadian volatility means that the border effect reflects both the actual effect of crossing the border and the effect of moving from high intra-US volatility to low intra-Canada volatility. At the same time, controlling for high intra-US volatility causes the effect of moving from low-volatility Canada to high-volatility US to be confounded with the border effect.

[8] Other studies include estimating the impact of an anti-poverty program on political support in Uruguay (Manacorda, Miguel and Vigorito 2009), among others.

Gopinath, Gourinchas, Hsieh, and Li (2009) use the RDD approach to estimate the magnitude of the US-Canada border effect on prices. In this context, the assignment variable (Z) is a market's distance from the international border, which determines it's treatment status, i.e. whether the market is located in the US or Canada. They estimate a regression of the following form:

$$\ln p^i_{jt} = \alpha + \gamma B_j + \theta D_j + \delta B_j D_j + \beta_j X_j + \varepsilon_j \quad (4)$$

where p^i_{jt} is the price of a particular good i in market j at time t, B_j is a dummy variable that equals 1 if market j is in Canada and 0 if it is in the US, D_j is the distance to the border from market j, with $D_j < 0$ for markets in Canada and $D_j > 0$ for markets in the US, and X_j is a vector of variables that affect supply or demand in particular markets.[9] The border (treatment) effect in this case is γ.

To our knowledge, there is very little previous research that uses high-frequency price data for narrowly-defined commodities to assess the border effect in low-income countries. Cross-border trade in West Africa has been studied extensively, but comparisons have typically been restricted to a few locations and time periods. Daubrée (1995) compares the prices of a range of consumer goods between Niamey (the capital of Niger), Maradi (Niger) and Kano (Nigeria), and finds tighter co-movements between Maradi and Kano than between Maradi and Niamey. Oyejide *et al.* (2008) compare prices in Kano and Abuja (Nigeria) with those in Niamey, Lome (Togo) and Cotonou (Benin) and find suggestive evidence of a border effect. Golub and Mbaye (2008) compare wholesale prices of individual items between Banjul (The Gambia) and Dakar (Senegal) and argue that the variation in price differentials across commodities reflects, in part, differences in relative customs duties and other aspects of national tax treatment.

The paper closest to our own is Araujo-Bonjean *et al.* (2008), who estimate a vector autoregression in monthly market-level millet prices for 25 markets in Niger, Mali and Burkina Faso. They compute generalized impulse responses and interpret the size of the resulting dynamic coefficients as indicators of the degree of

[9] The RD approach has been used with geographic data and distance to the border in the case of right-to-work laws on employment across states in the US by Holmes (1998).

pairwise integration between markets. Cross-sectional regressions on these estimated coefficients uncover a statistically significant border effect – evidence, as they put it, of a poorly integrated regional market in millet despite the operation of a customs and monetary union.

4. Data and Measurement

To estimate the magnitude of international and internal border effects within the West African sub-region, this paper constructs three primary datasets. The first is a dataset at the market level obtained from both primary and secondary sources in Niger. This dataset includes monthly grain (millet and sorghum) and cash crop (cowpea) data over a ten-year period (1999-2007) across 42 domestic markets in Niger and 12 cross-border markets in Benin, Burkina Faso and Nigeria. In addition, time-series data on gas prices, cell phone coverage, rainfall, road quality, trade flows, district population levels, cell phone rollout and coverage and the Naira-CFA exchange rate were also collected.

The second dataset includes the latitude and longitude of each market, the location of the international border and the road distances between market pairs. This dataset enables us to calculate the distance to the international and internal border of each market in the dataset, but also to construct the actual road distances between market pairs, rather than Euclidean distances.

The third dataset is a unique panel survey of traders, farmers, transporters and market resource persons collected in Niger by one of the authors between 2005-2007. The survey interviewed 415 traders and 200 farmers located in 35 markets and 40 villages across six geographic regions of Niger, as well as in four (4) cross-border markets. A census of all grain traders was conducted on these markets, and traders and market resource persons who participated in the survey provided detailed information about their demographic and socio-economic background and commercial operations. This allows us to construct measures of the ethno-linguistic fractionalization (ELF) for each market, village and region, to construct ethnic "borders" and to measure the number of traders operating in these markets over time.

Table 1 presents summary statistics between 1999-2007 for markets located within a 150-km radius of the Niger-Nigeria border. In general, prices for staple grains (millet and sorghum) are higher in Niger as compared to Nigeria, with a statistically significant difference between the two. This lends support to the

direction of trade flows between the two countries, with Niger importing grains from Nigeria. By contrast, cowpea prices are lower in Niger, as Niger primarily exports to Nigeria. We do not reject the equality of means or distributions for most other observable characteristics, with the exception of the Zarma ethnic group and cell phone coverage. However, the difference in cell phone coverage as of 2007 is only statistically significant at the 10 percent level. In addition, the Nigerian markets in our sample our not located within Zarma regions.[10]

Table 2 presents similar statistics for markets located within the Hausa or Zarma regions of Niger.[11] On average, prices for all commodities (millet, sorghum and cowpea) are higher in the Zarma regions, and these differences are statistically significant. However, most other observable covariates for Hausa and Zarma markets are not statistically significant from zero, with the exception of cell phone coverage and transport costs between markets, which are relatively higher in the Hausa regions.

5. Empirical Strategy

In order to assess the magnitude of the border effect on both cross-country and internal market performance for a variety of commodities, this paper employs a three-part empirical strategy. During the first part of the analysis, we compare the kernel distributions of conditional price differences both within and across regions, whereby a "region" represents a country or an ethnic region. The kernel distributions allow us to determine whether an estimated border effect exists, and whether this effect might be attributed to differences in underlying price distributions across regions. During the second part of the strategy, we use a regression-based estimate of the border effect, using the equation provided in equation (1). Similar to the approach used by Gorodnichenko and Tesar, we modify the estimating equation to include country-specific fixed effects in separate regressions. During the third part of our strategy, we use the RDD approach, estimating the effect from moving from one country (or region) to another. We conduct each of these analyses for millet, sorghum, and cowpeas, as well as across international and internal borders. All of these

[10] While members of the Zarma ethnic group live within Nigeria, it represents a small percentage of the population (approximately 88,000 people, or less than .0007 percent) and is geographically focused in the far northwestern region of the country on the border with Benin and Niger (Birin n'Kebbi region). There are no markets from this region within our sample.

[11] Hausa and Zarma "markets" were identified based upon trader and farmer surveys conducted by one of the authors between 2005-2007. A census of grain traders and farmers was conducted and households were asked about their ethnic composition. These data were used to identify ethnic "border markets" between two distinct ethnic regions.

commodities are produced and consumed in both countries, are heavily traded on an annual basis and are fairly homogeneous in terms of their quality. However, current data constraints for markets in Nigeria somewhat limit the validity of our results.[12]

5.1. Kernel Distributions

During the first part of the analysis, we use the time series market-level panel data to estimate kernel distributions for conditional price differences. This involves estimating a regression of the following form:

$$|\ln(p^i_{jt}/p^i_{kt})| = \beta_0 + \beta_1 \ln(TC_{jkt}) + \beta_2 urban_{jkt} + \beta_3 drought_{jkt} + \theta_t + a_{jk} + \varepsilon_{jkt} \quad (5)$$

where p^i_{jt} is the price of good i in market j at time t, p^i_{kt} is the price of good i in market k at time t, TC_{jkt} is the transport costs between markets j and k at time t; $urban_{jkt}$ is a variable equal to 1 if one of the two markets is greater than 35,000 people and the other is not, otherwise 0; $drought_{jkt}$ is a dummy variable that equals 1 if there is a drought in one of the two markets at time t (and is otherwise 0); and θ_t are time fixed effects. In some specifications, market-pair fixed effects, α_{jk}, are also included. We then plot the residuals ε_{jkt} using a kernel distribution as a measure of the deviation from the Law of One Price. These kernel distributions are presented both for market pairs within each country or each ethnic region, and also for cross-border or cross-region pairs.

While kernel distributions can provide suggestive evidence of an international border effect, they do not allow us to plot these potential changes over time. If markets are perfectly integrated, the exchange rate should not affect price dispersion between countries. However, if markets are not perfectly integrated, then exchange rate movements will change the relative prices in both markets.

Figure 5 shows the changes in CFA/Naira exchange rate between October 1999 and April 2007. There was a strong appreciation of the CFA (as compared to the Naira) during this time, with the greatest appreciation taking place between 1999-2001 and 2002-2004.[13] In order to measure potential changes in conditional price dispersion over time, we therefore estimate equation (5) on a yearly basis and without the

[12] The authors are currently collecting market-level and price data from additional markets in Northern Nigeria.
[13] There was a 16 percent appreciation of the CFA against the Naira between 1999 and 2001.

absolute value of the price difference between two markets.[14] A close tracking of the relative price to the exchange rate, with an increase in the relative price of goods in Niger as compared to those in Nigeria when the CFA franc appreciates, would suggest market segmentation.[15]

5.2. Regression-Based Estimates of the Border Effect

In order to provide a more formal measure of the border effect, we estimate an equation of the following form:

$$\ln | p^{i}_{jt} / p^{i}_{kt} | = \beta_1 \ln(d_{ij}) + \beta_2 B_{ij} + \beta_x X_{ij,t} + \sum_{m=1}^{N} \gamma_m D_m + \varepsilon_{ij,t} \quad (6)$$

where $d_{i,j}$ is the road distance between markets i and j, B_{ij} is equal to 1 if there is an international border between two markets i and j, 0 otherwise; $X_{ij,t}$ is a vector of variables that might affect price dispersion between two markets, such as drought, road quality, transport costs and other time-varying factors; and D_m is a set of market-specific fixed effects, which are included in some specifications. In this specification, borders are defined as both international borders (e.g. Niger-Nigeria) and internal "ethnic" borders within Niger.

As discussed by Gorodnichenko and Tesar, the estimates of β_2 can differ drastically if the underlying price dispersions in two regions are different. Consequently, we will also estimate equation (7) using, in separate specifications, a dummy variable that equals 1 for pairs where j and k represent one country or region (e.g. Niger), and another where j and k represent the other country or region (e.g. Nigeria).

In addition, in some specifications, we modify equation (6) to include a variable $cell_{jk,t}$, which is equal to 1 if both markets j and k have cell phone coverage at time t, 0 otherwise. The key identifying assumption is that the introduction of cell phone towers is quasi-experimental rollout in nature, and that the arrival of cell phone coverage is not associated with a contemporaneous change in the intra-region volatility.[16]

[14] As we are interested in assessing how relative prices change in Niger as compared to Nigeria with changes in the exchange rate, the modified equation does not include the absolute value of price dispersion.

[15] This follows the analysis of Gopinath, Gourinchas, Hsieh, and Li (2009) who plot the time path of the median cost component of goods' prices against the USD/ Canadian dollar exchange rate. They find that costs in Canada relative to those in the US closely tracks the exchange rate. In future research, we hope to track the prices in Niger relative to those in Benin and Mali over the same period to determine if there is a similar change in relative prices across countries that share the use of the CFA franc.

[16] In these specifications, the border effect is interacted with the cell phone variable.

5.3. Regression Discontinuity Design

A common criticism of the regression-based estimates of the border effect is the potential for bias in the results, since borders are not randomly assigned. As discussed previously, the RD methodology is common in the treatment effects literature, whereby there is an assignment variable (Z) that determines the level of treatment (T). The same type of analogy can apply to measure the border effect. In this context, the assignment variable (Z) is a market's latitude and longitude, which determines its geographic location and hence it's "treatment" status – i.e., its location within or outside Niger. At Z_0 (the international border), the market's treatment status jumps discontinuously, moving from Niger to Nigeria. The treatment effect is analogous with the border effect, and any discontinuous jump in the outcome of interest (price levels or changes) can be attributed to a change in the level of treatment.

Applying the RDD approach to measure the border effect, we estimate the following equation:

$$\ln p_{jt}^{i} = \alpha + \gamma N_j + \theta D_j + \delta C_j D_j + \beta_j X_j + \varepsilon_i \quad (7)$$

where p_{jt}^{i} is the price of a particular good in market j at time t; N_j is a dummy variable equal to 1 if market j is in Niger and 0 if it is in Nigeria; D_j is the distance from market j to the border (international or internal), with $D_j < 0$ for markets in Nigeria and $D_j > 0$ for markets in Niger; and X_j is a vector of variables that affect supply or demand in particular markets, such as urban status, drought or cell phone coverage. The border effect in this case is therefore measured by the conditional price discontinuity as the distance approaching the border equals zero.

The key variable of interest in equation (7) is γ, which measures the border effect. We estimate this equation using a local linear regression framework, whereby the regression is estimated for prices in those markets that are within a certain distance (bandwidth) from the border (Imbens and Kayanaraman 2009). A key identifying assumption in this approach is that the observed characteristics, X_j, are not discontinuous at the border, and that unobserved characteristics are a continuous function of the distance from the border.

While we cannot directly check these assumptions, we can check for the discontinuity of observables on either side of the border as a proxy.

There are two important differences in using the RDD methodology to estimate the presence of the border effect as compared with the traditional program evaluation approach. First, the distance to the border may not be correlated with the outcome, the way in which a test score may be correlated with the likelihood of seeking a graduate degree.[17] This can be addressed by including covariates that are likely to affect prices and testing that these are not themselves discontinuous at the border. Another difference in using RDD to analyze a border effect is dimensionality: while a test score or income are one-dimensional, geography is two-dimensional variable. Consequently, while Detroit, Seattle and Vancouver are all close to the US-Canada border, it is more meaningful to compare prices between Seattle and Vancouver than between Detroit and Vancouver. This dimensionality problem can be addressed by using a bandwidth that takes into consideration not only the distance to the border, but also the distance to other markets.

6. The International Border Effect

6.1. Kernel Distributions and Exchange Rate Fluctuations

Figure 6 shows the kernel distributions for millet, sorghum and cowpea from 1999-2007, plotting the $\varepsilon_{jk,t}$ from a regression of equation (5). The kernel distributions show the residuals from regressions of intra-Niger market pairs, intra-Nigeria market pairs, and cross-border (Niger-Nigeria) market pairs for each commodity. Visual inspection of the kernel distributions suggests that the underlying price dispersions for grains and cowpeas in both countries are similar, which is a key concern when estimating the border effect. Thus, the kernel distributions suggest that there is a potential border effect, but that it might not be economically important.

The kernel distributions in Figure 6 provide only a cross-sectional analysis of the border effect. To explore this relationship further, we estimate the same regressions over time. If markets between Niger and northern Nigeria are not perfectly integrated, then exchange rate movements between the Naira and CFA

[17] Gopinath et al. (2009) attempt to address this criticism by developing a model of competition on a circle in which location does matter for prices.

would change relative prices. As the CFA appreciated strongly against the Naira between 1999 and 2007, we would therefore expect to see a rightward shift in the kernel distributions for price dispersion of cross-border market pairs.[18]

Figure 7 shows the kernel distributions for millet, sorghum and cowpea between 1999-2001, the period of greatest appreciation of the CFA/Naira exchange rate. Unlike the kernel distributions in Figure 6, Figure 7 plots the $\varepsilon_{jk,t}$ from regressions of the log of cross-border prices differences, rather than the absolute value. For millet and sorghum, the densities gradually shift rightward between 1999-2001, suggesting that relative prices follow the CFA-Naira exchange rate. Niger is a net importer of both of these grains from Nigeria. For cowpeas, an export crop, the pattern is quite different: the densities shift left between 1999 and 2001, and then shift rightwards from 2001/2002. This suggests that cowpeas initially became less expensive in Niger as compared to Nigeria during the appreciation.

6.2. The Magnitude of the Border Effect

The kernel distributions provided in Figures 6 and 7 suggest that agricultural markets in Niger and Nigeria are not perfectly integrated. We attempt to assess the magnitude and statistical significance of this border effect using a regression-based framework. Table 3 shows the results of the regressions from equation (6) for all commodities. In general, transport costs are associated with a positive and statistically significant percentage change in price dispersion across markets, ranging from an increase of 3.6 percent for sorghum to 6.3 percent for cowpeas. Drought in one market has a positive and significant impact upon percentage changes in price dispersion for grains, but a negative and statistically significant effect for cowpeas. The presence of a market in a urban center is associated with a percentage decrease in price dispersion for all commodities, although this effect appears to be economically insignificant (less than .1 percent).

Consistent with the kernel distributions, the presence of an international border between Niger and Nigeria is associated with a positive and statistically significant for all commodities. Column 1 of each regression shows that the border is associated with a 2.5 percent increase in price dispersion across markets,

[18]In other words, as prices in Niger decrease during a appreciation, then changes in ln (p^i_{jt}/p^i_{kt}) would increase. This would therefore result in a rightward shift in the distribution, assuming that *j* is a market in Niger, *k* is a market in Nigeria.

ranging from 2.3 percent for sorghum to 2.9 percent for cowpea. These magnitude and statistical significance of the border effect is robust to the inclusion of country-specific fixed effects for Niger (Column 2) and Nigeria (Column 3), thereby controlling for underlying differences in price dispersion in each country. This is in stark contrast to Gorodnichenko and Tesar's findings for the US and Canada, whereby the border effect varied considerably after controlling for country-specific effects. This suggests, therefore, that country-specific differences in price dispersion are not driving the results.

Column 4 includes additional variables for cell phone coverage and an interaction term between cell phones and the border. For all commodities, the magnitude and statistical significance of the border effect remains the same, although its magnitude increases for cowpeas. Cell phone coverage is associated with a percentage decrease in price dispersion across markets for all commodities, ranging from a .05 percent decrease for millet to 1.9 percent for cowpeas. These findings consistent with previous results in Aker (2009), who found that cell phones were associated with a negative and statistically significant reduction in price dispersion across millet markets within Niger. Aker also found that the impact of cell phone coverage on price dispersion was the strongest for markets located between 200 and 550 km apart.

The interaction term between cell phones and the border is negative and statistically significant for millet and cowpeas, suggesting that cell phone coverage is associated with a percentage decrease in cross-border price dispersion. While the interaction term does not tell us much, the joint effect of the international border and the interaction term tells us that whether the border still "matters" once there are cell phones. Similarly, the joint effect of cell phones and the interaction term provide evidence as to whether cell phones still matter across the border. For millet and cowpea, the joint effect of cell phones and the interaction term is negative and statistically significant: This suggests that cell phones are associated with a decrease in the price dispersion, resulting in a cross-border price decrease of 2.1 percent (for millet) to 5 percent (for cowpeas). The effect is not statistically significant for sorghum, which is less frequently traded between the two countries.

6.3. Is there a discontinuity at the Niger-Nigeria Border?

As mentioned previously, a common criticism of the regression-based estimates of the border effect is the potential for bias in the results, as international borders – while arguably "artificial" with respect to African interests – were not randomly assigned by the former colonial powers. An alternative approach is to test for a price discontinuity at the border, using market pairs located within a specific distance (bandwidth). To use the RDD methodology, we rely upon the assumption that assignment to Niger or Nigeria was nearly "as good as" random.

As a first check of the assumption of "as good as" random assignment, we test for discontinuity of at the threshold (border) for market-level covariates. We fail to find evidence of a statistically significant difference for most market-level covariates, including market size, the frequency of drought, road quality, transport costs and the ethnic composition of markets (Table 1). The notable exceptions are cell phone coverage and the Zarma ethnic group, although the magnitude of the difference in urban status is only significant at the 10 percent level.[19] Figure 8 tests for evidence of a discontinuity in market size, one of the few continuous covariates in the sample. Using a bandwidth of 50 km, we cannot reject the null of no discontinuity in the market size at the border.

Figure 9 plots the log of prices for different commodities (millet, sorghum and cowpea). The discontinuity at the border (zero) provides an estimate of the change in commodity prices over time, in Niger versus Nigeria. Prices in Niger are likely to proportion of markets shows millet prices at either side of the Niger-Nigeria border. Consistent with the kernel distributions and regression-based estimates of the border effect, these plots show that prices in Niger are relatively higher for all commodities, but that the discontinuity at the border is not large in magnitude. The figure provides that a border effect exists, but that it is economically insignificant.

[19] A more robust analysis of the potential overlap problem is a comparison of the difference in means with the standard deviation. Comparing the difference in average means with the standard deviations, the dataset is well-balanced; the difference in means between Niger and Nigeria groups is never more than 0.24 standard deviations for any covariate. The only exception to this case is the difference in means for the Zarma ethnic group. However, as our analysis of the international border effectively drops any "Zarma" markets in Niger, this is a lower-order concern.

To refine the analysis, we present regression results to examine robustness to different parametric specifications and to the inclusion of control variables.[20]

7. The Internal Border Effect

The previous analyses suggest that a border effect exists between Niger and Nigeria, albeit limited in magnitude as compared with research in industrialized countries. Nevertheless, the artificial process through which borders were established in West Africa resulted in multiple ethnic groups within one country. In recent times there has been a growing interest within economics in the role that ethnic or cultural diversity can play in explaining socio-economic outcomes. A number of empirical studies have found that ethnic diversity is associated with lower growth rates (Easterly and Levine 1997), more corruption (Mauro 1995), lower contributions to local public goods (Alesina, Baqir and Easterly, 1999) and lower participation in groups and associations (Alesina and La Ferrara 2000). Consequently, it is plausible that ethnic diversity could create "internal borders" to trade and market segmentation.

In an effort to assess the presence and magnitude of these internal borders, we repeat many of the same analyses as in Section 6, but using market pairs with varying ethnic composition within the country. A key part of this analysis is defining ethnic "borders". In order to define such borders, we first use primary data collected by the authors to analyze the ethnic composition of different markets in Niger. We then assess the degree of ethnic diversity by market, using this to define an internal border. This border is identified as a market that borders two markets with a low degree of ethno-linguistic fractionalization (ie, a majority of Hausa or majority of Zarma), but which itself has a high degree of ethno-linguistic fractionalization. In the Nigerien context, this often means having traders and farmers from two ethnic groups.[21]

7.1. Kernel Distributions

[20] Following Card and Lee (2008), we regress the variable of interest (here being a market in Niger) for market *i*, on a constant, an indicator for the border, and two parametric polynomials in the price on each side of the threshold. The impact of program assignment is captured by β_1, i.e., the change in p at the threshold.

[21] The measure of ethnic diversity used almost universally in the empirical literature is the index of ethno-linguistic fractionalization (ELF), which is a decreasing transformation of the Herfindahl concentration index. In particular, if we consider a society composed of $K \geq 2$ different ethnic groups and let p_k indicate the share of group k in the total population, the resulting value of the ELF index is given by $1 - \sum(p_k)^2$

Figure 10 shows the kernel distributions of the ε_{jkt} of equation (5) for Hausa-Hausa market pairs, Zarma-Zarma market pairs and cross-border (Hausa-Zarma) market pairs. Visual inspection of the kernel distributions suggests that the underlying price dispersions for grains and cowpeas in both regions are similar for all commodities, with the exception of cowpeas. Nevertheless, unlike the kernel distributions for Niger-Nigeria market pairs, the distribution of price dispersion between Zarma and Hausa markets is significantly different than the distributions for intra-Hausa and intra-Zarma market pairs. This suggests, at first glance, that internal borders could exist within Niger, and that they could be of a higher magnitude when compared with international borders.

6.2. The Magnitude of the Border Effect

To refine this analysis, we attempt to assess the magnitude and statistical significance of this effect using a regression-based framework. Table 4 shows the regression estimates of equation (6) for all commodities; however, now the relevant border variable is an internal border, with B_{ij} is equal to 1 if there is an internal border between two markets i and j. In general, transport costs are associated with a positive and statistically significant percentage change in price dispersion across markets, ranging from an increase of 4 percent for sorghum to 6 percent for cowpeas. Drought in one market has a positive and significant impact upon percentage changes in price dispersion for grains, but, similar to the previous results, a negative and statistically significant effect for cowpeas. The presence of a market in an urban center is associated with a percentage decrease in price dispersion for all commodities, although this effect appears to be economically insignificant (less than .1 percent).

Consistent with the kernel distributions, the presence of an internal border is associated with a positive and statistically significant for all commodities. Column 1 of each regression shows that the internal (Zarma-Hausa) border is associated with a 2.5 percent increase in price dispersion for sorghum, but a 5 percent increase in price dispersion across millet and cowpea markets. This is almost twice the magnitude of the international border, which averaged a 2.5-percent increase in price dispersion for all commodities. The magnitude and statistical significance of the internal border effect for grains is robust to the inclusion of country-specific fixed effects for intra-Hausa (Column 2) and intra-Zarma (Column 3) market pairs.

However, the border effect varies considerably for cowpeas conditional on the inclusion of intra-Hausa or intra-Zarma market pairs. This is consistent with the visual inspection of the kernel distributions in Figure 10, which suggested that the underlying price dispersion for cowpeas differed considerably in intra-Hausa and intra-Zarma regions.

Column 4 controls for additional variables that could affect price dispersion across markets, namely cell phone coverage and an interaction term between information technology and the internal border. For all commodities, the magnitude and statistical significance of the border effect remains the same, although its magnitude increases for cowpeas. Cell phone coverage is associated with a percentage decrease in price dispersion across markets for all commodities, ranging from a 1.2 percent decrease for millet to a 4.4 percent for cowpeas. These findings consistent with previous results in Aker (2009) for the impact of cell phones on price dispersion, especially for short-haul markets (less than 150 km, as is the case here).

Unlike the international border, however, the interaction term between cell phones and the internal border is *positive* and statistically significant for all commodities. This suggests that cell phones are associated with a percentage increase in price dispersion across internal borders. The joint effect of the international border and the interaction term tells us that whether the border still "matters" once there are cell phones. Similarly, the joint effect of cell phones and the interaction term provide evidence as to whether cell phones still matter across the border. Unlike the case of the international border, cell phones do not appear as effective in reducing price dispersion across internal borders; conditional on an internal border, cell phones only reduce price dispersion for sorghum, with no statistically significant effect for millet and cowpeas. This is not surprising, in light of the bandwidth of the markets under consideration (within 100 km of the border) and potential bias associated with the estimates of the border effect for cowpeas.

7. Conclusion

This paper provides some initial evidence of the magnitude and statistical significance of international borders on price dispersion in West Africa. The results suggest that an international border effect exists between Niger and Nigeria, but that the magnitude of this effect is much smaller than that found

in industrialized countries. The results are robust to a variety of specifications, including kernel distributions, regression-based estimates and preliminary RDD results.

These results suggest that perhaps existing regional economic commissions have been somewhat successful in promoting cross-border trade, even among different currency unions. However, whether the limited border effect is due to regional economic policies or the strength of longstanding trade routes between ethnic groups – namely the Hausa of Northern Nigeria and Niger – is difficult to untangle. Recognizing the manner in which national borders in West Africa included, in a single nation, diverse ethnicities, there exists some evidence of an internal border along ethnic lines within Niger. It is not clear whether these effects are due to current social cleavages, longstanding policies or social networks that have been used to replace missing markets in Niger, namely in the area of credit and insurance.

There is some evidence that information technology, namely cell phones, mitigate the international border effect, but have less of an impact on internal borders. Further research in this area will not only focus on the impact of other factors on the border effect, but also explaining why such an effect exists. To shed light on this, we will attempt to address whether a similar border effect can be found between Niger and its CFA franc neighbors to the west and south, namely Benin and Burkina Faso.

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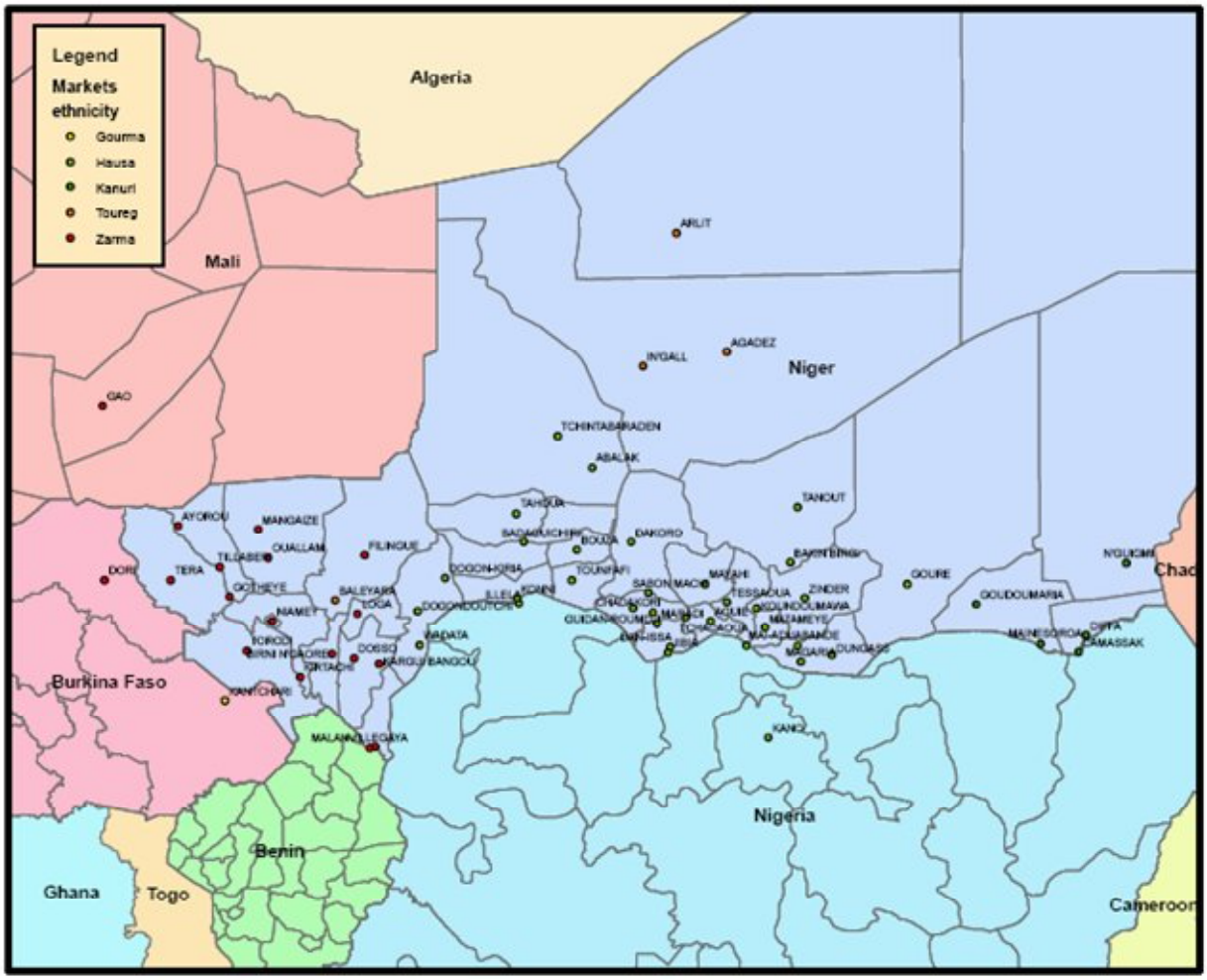
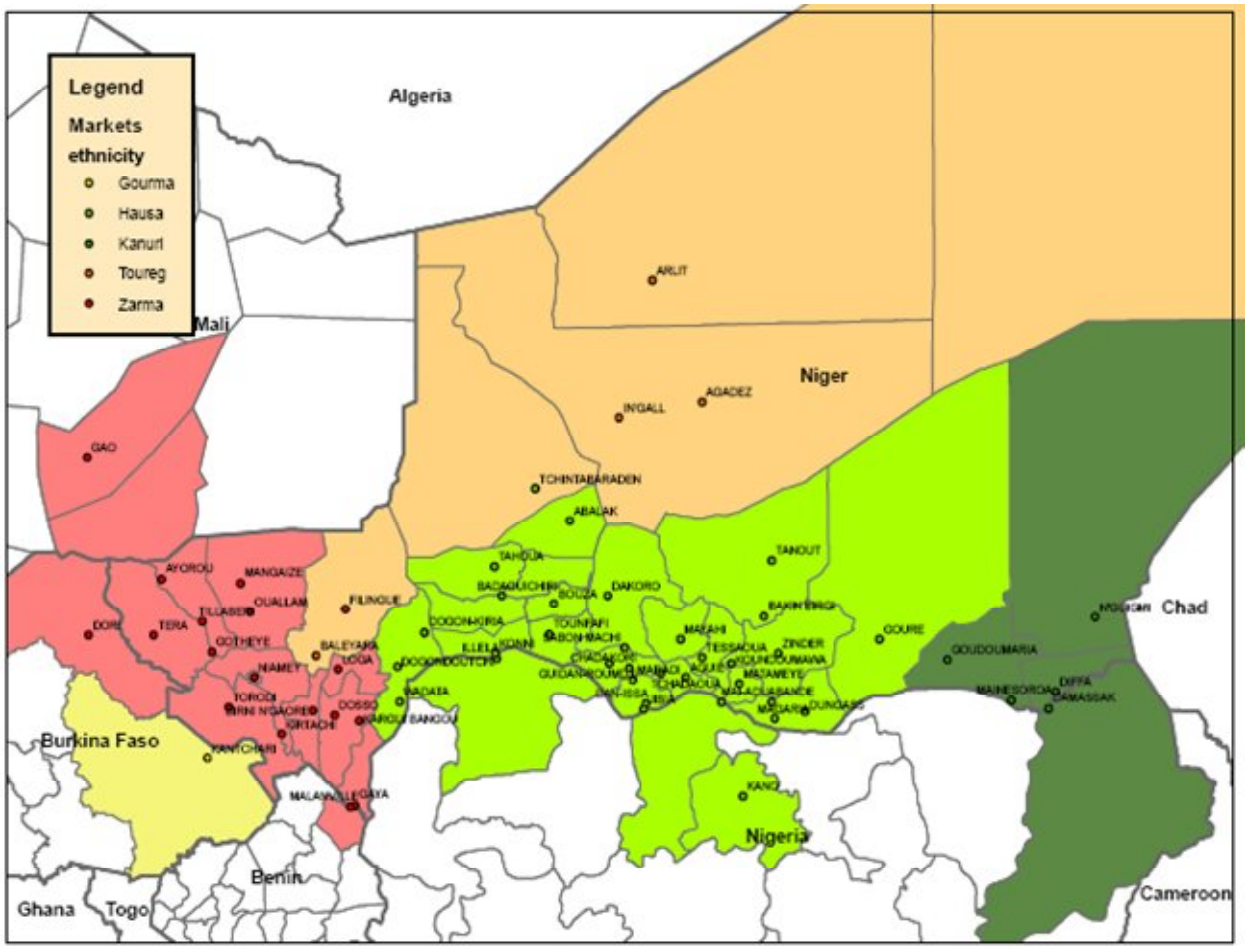
Figure 1. International Borders between Niger, Nigeria, Mali, Burkina Faso and Benin



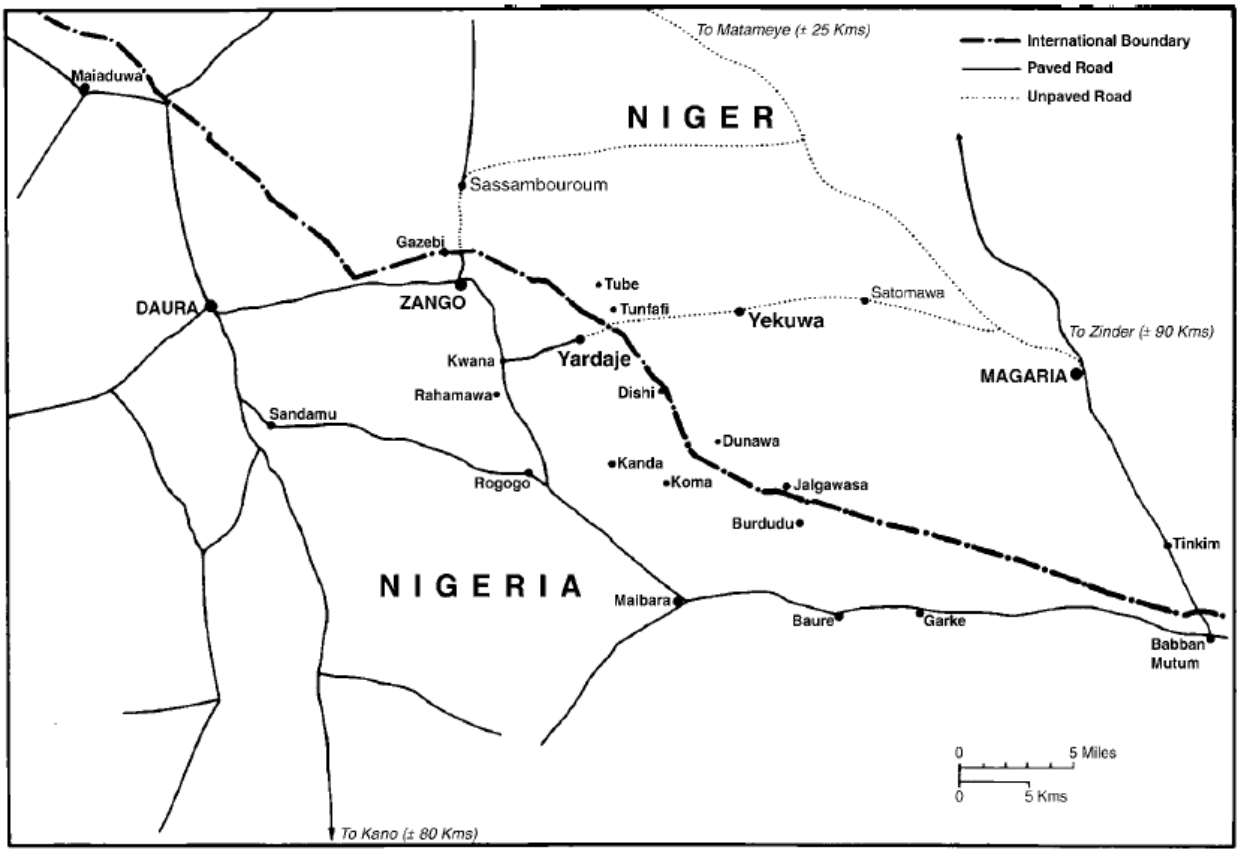
Notes: A map of the current international borders for Benin, Burkina Faso, Mali, Niger and Nigeria, as well the geographic location of major grain markets in these countries. Created from the authors' own data sources.

Figure 2. International Borders and Ethnic Groups in Niger and northern Nigeria



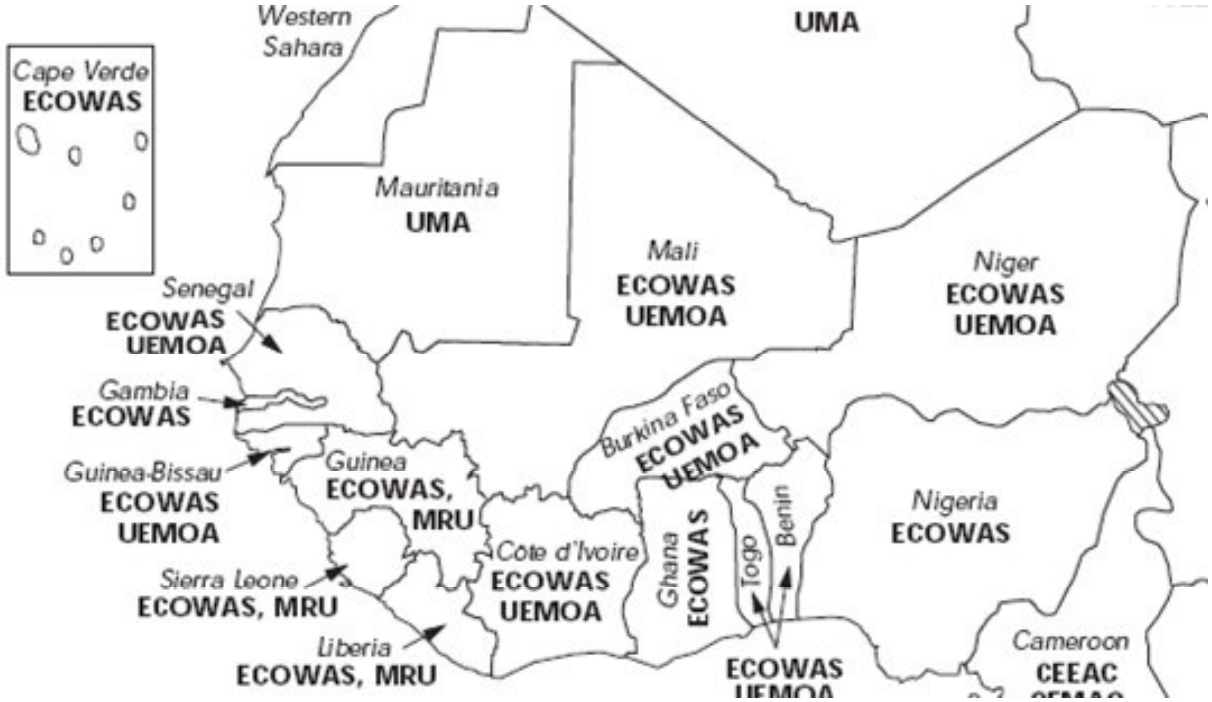
Notes: A map of the ethnic and international borders for Benin, Burkina Faso, Mali, Niger and Nigeria. Created from the authors' household and trader-level data collected between 2005-2007, as well as secondary data for markets in Burkina Faso and Mali.

Figure 3. Map of the Daura (Nigeria)-Magaria (Niger) Region



Notes: Map provided in Miles (2005).

Figure 4. Country Membership in UEMOA and ECOWAS



Notes: ECOWAS refers to the Economic Community of West African States. UEMOA is the West African Economic and Monetary Union, MRU is the Mano River Union, and UMA is Arab-Maghreb Union.

Figure 5. CFA/Naira Exchange Rate, October 1999-April 2007

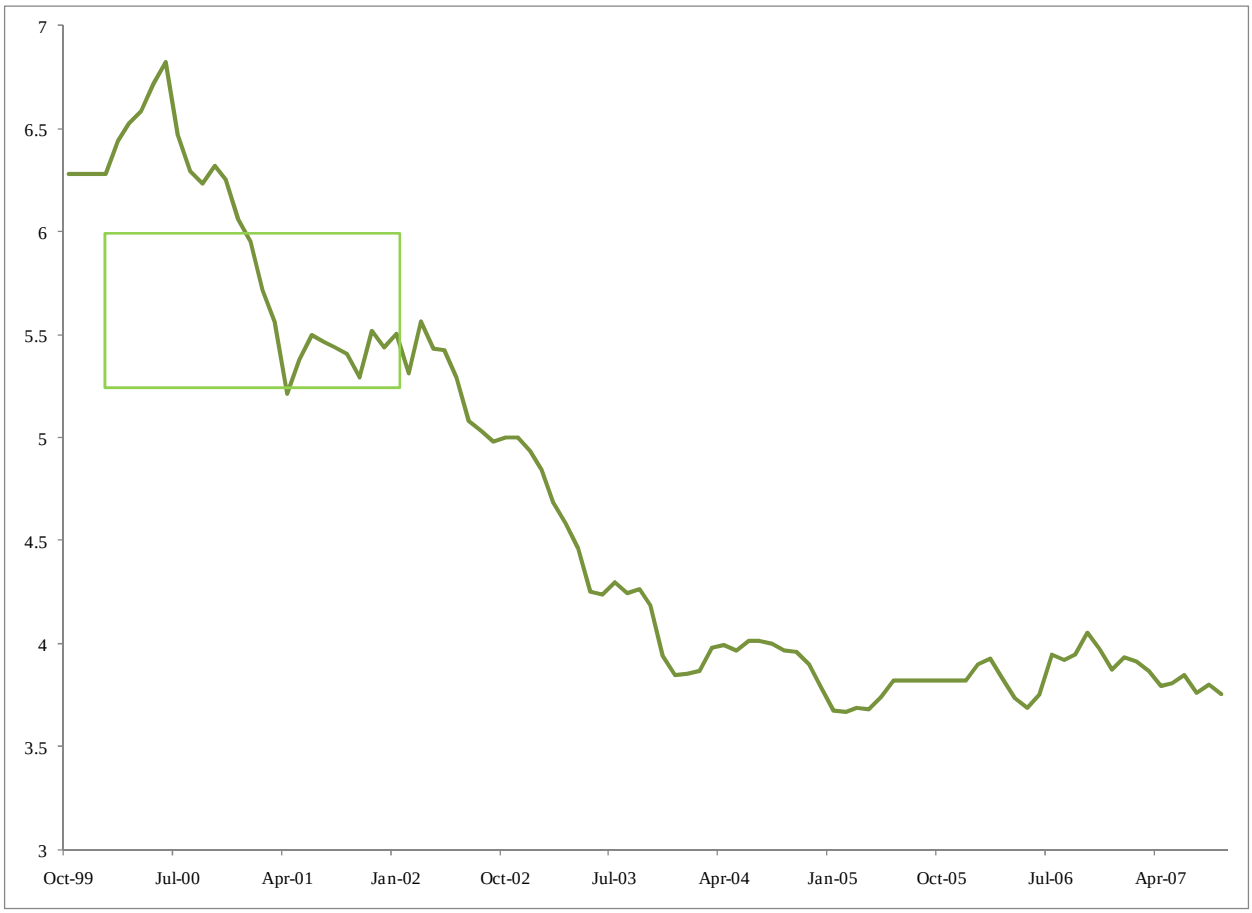
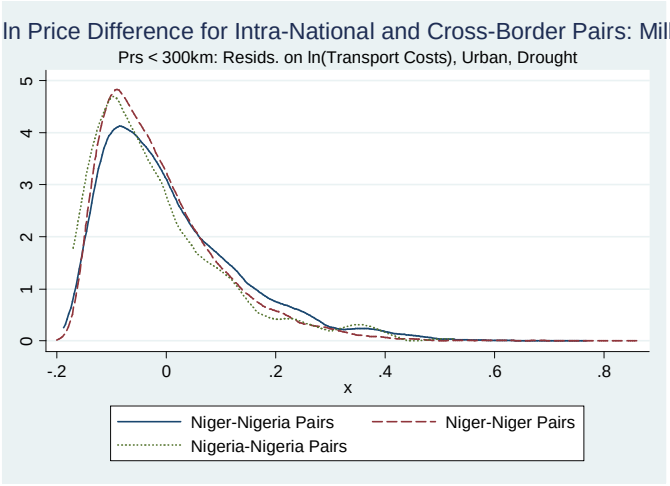
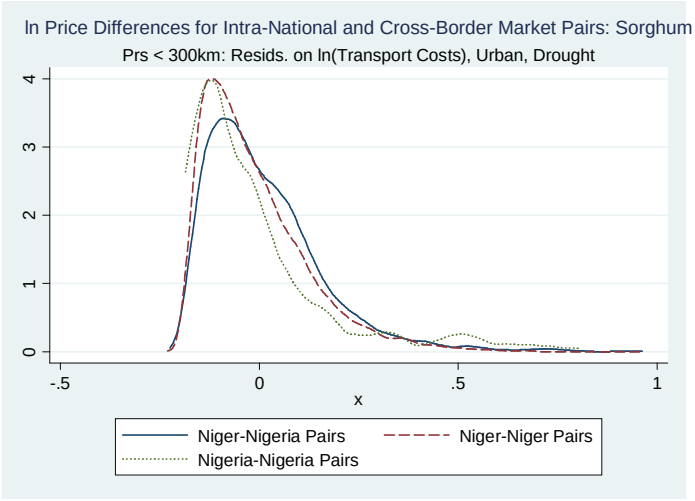


Figure 6. Kernel Distributions of Millet, Sorghum and Cowpeas for Niger and Nigeria, 1999-2006





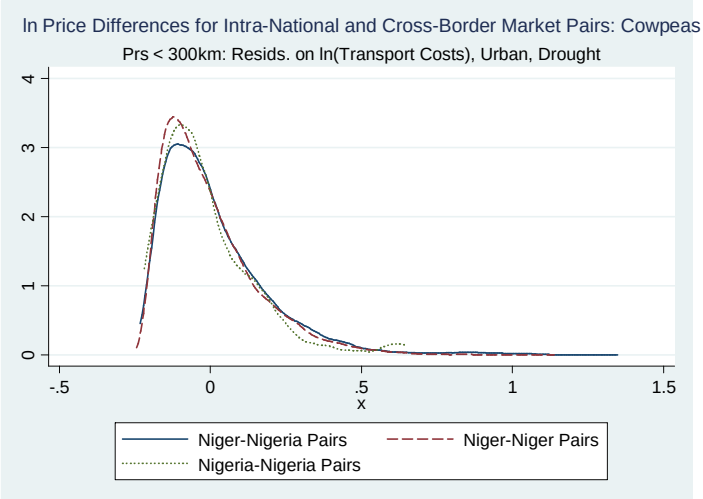
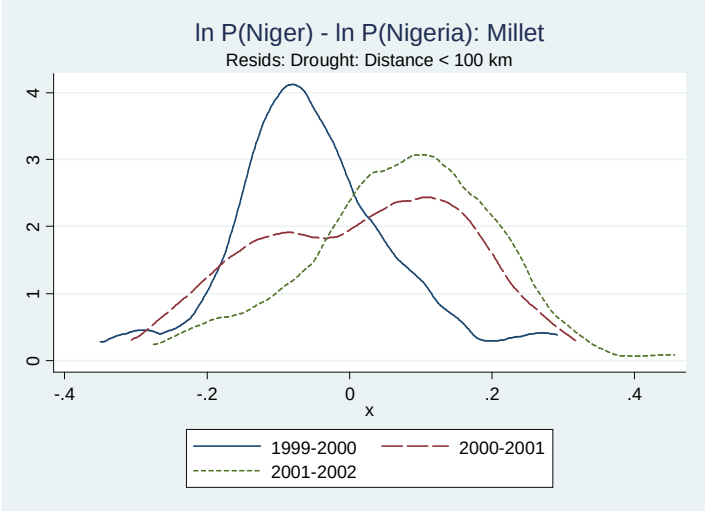
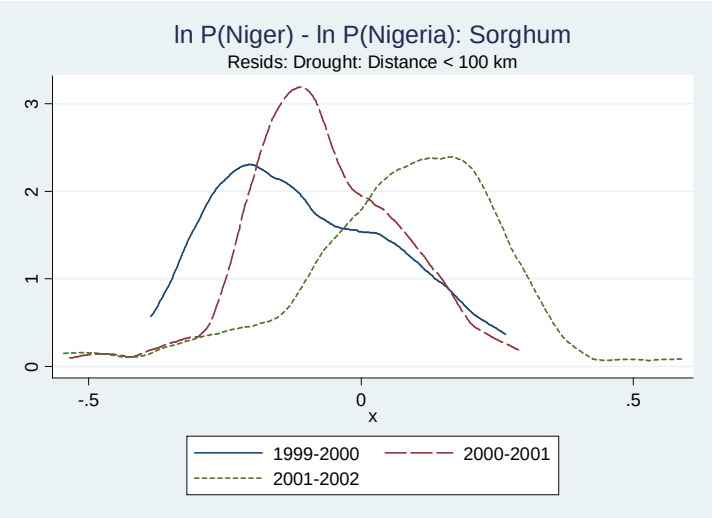


Figure 7. Kernel Distributions for Niger-Nigeria Market Pairs by Year, 1999-2001





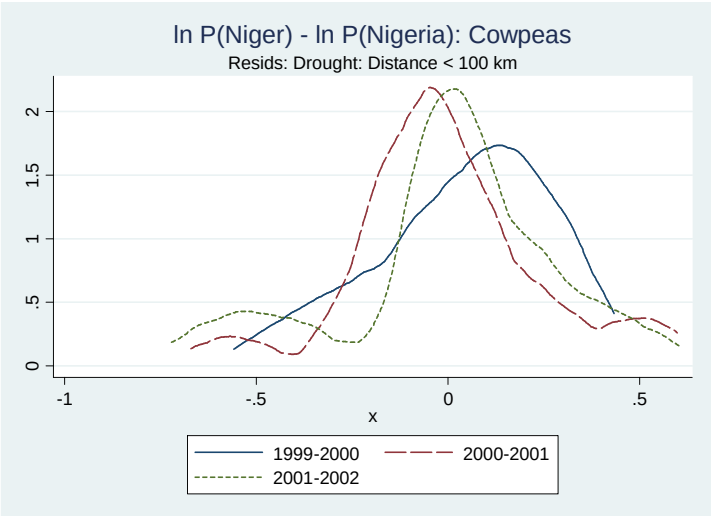


Figure 8. International Border and Market Characteristics

Market Size

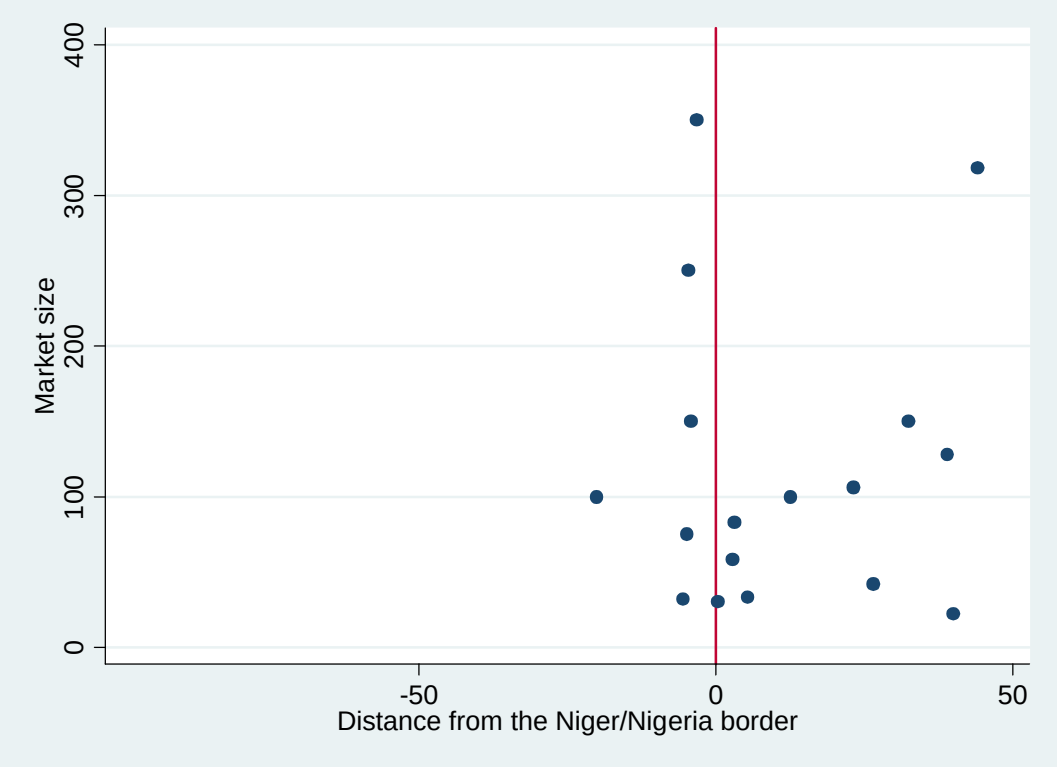


Figure 9. Price Discontinuity Across the Niger-Nigeria Border

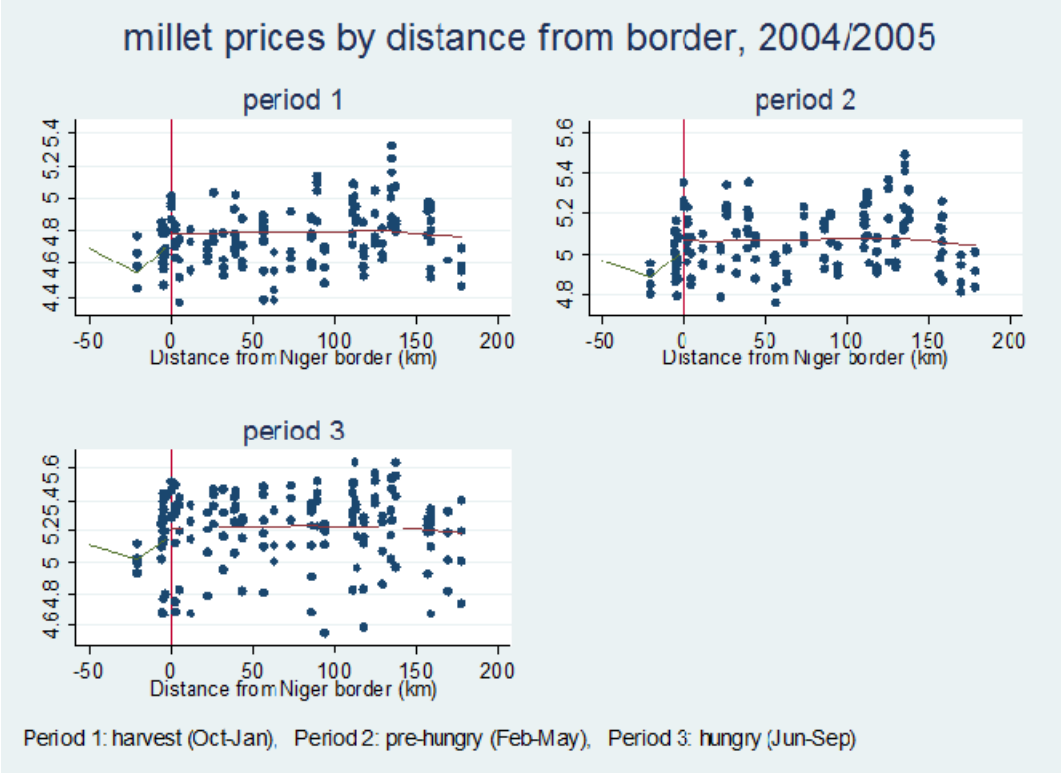
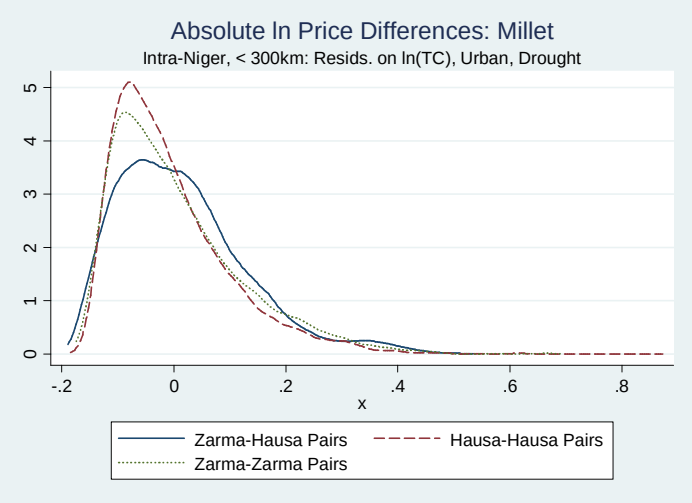
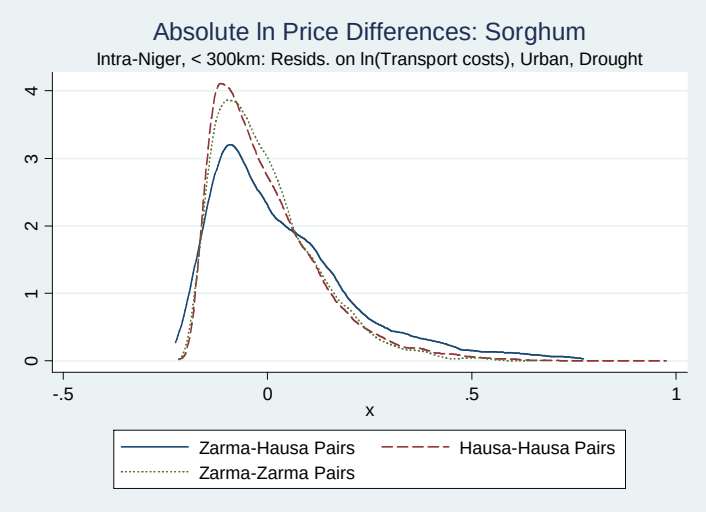


Figure 10. Kernel Distributions for Zarma and Hausa Market Pairs





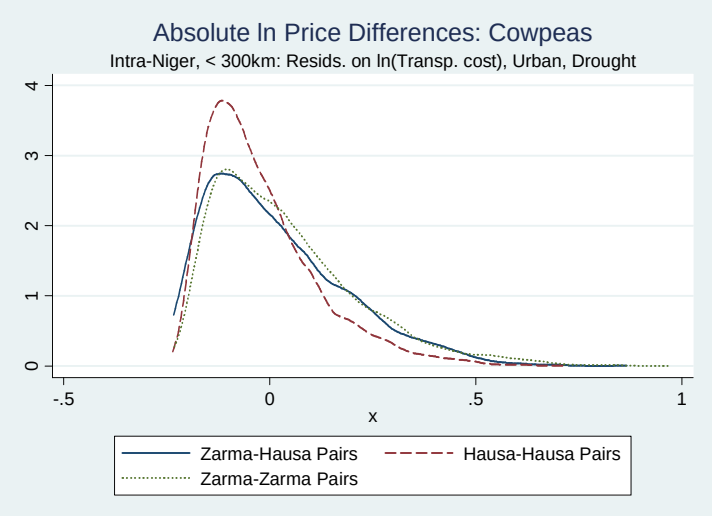


Table 1. Comparison of Observables by Country (Niger-Nigeria)

Observables	Unconditional Mean				Difference in Means
	Niger		(Northern) Nigeria		Unconditional
	Mean (s.d.)	Obs	Mean (s.d.)	Obs	s.e.
Panel A. Market Pair Level Data					
Distance between markets (km)	375.29(207)	601	369(271)	10	5.38(65)
Road Quality between markets	.37(.49)	601	.6(.52)	10	-.22(.16)
Cell Phone Coverage (2007)	.89(.32)	601	.6(.52)	10	.29*(.16)
Transport Costs between Markets (CFA/kg)	12.35(6.72)	40704	12.19(6.67)	960	.16(.22)
Panel B. Market Level Data					
Millet Price level (CFA/kg)	124.33(33)		112.96(31)		11.60***(1.83)
Sorghum Price level (CFA/kg)	119(36)		104(34.8)		14.35***(2.04)
Cowpea Price Level (CFA/kg)	173(56)		176 (56)		-3.21(3.36)
Ethnic composition of traders					
Hausa	.58(.51)	29	.8(.447)	9	'-.21(.21)
Zarma	.29(.464)	29	0	9	.29***(.096)
Kanuri	.08(.27)	29	.2 (.447)	9	-.12(.19)
Road Quality to Market	.71(.46)	29	.75(.5)	9	.041(.25)
Market Size	105.08(90)	29	176.75(149)	9	'-71.66(69)
Cell Phone Coverage (2007)	.95(.020)	29	.8(.447)	9	.158(.19)
Drought between 1999-2007	.027(.162)	2780	.025(.156)	480	.002(.007)
Urban center(>=35,000)	.35(.49)	29	0.8 (.45)	9	.45*(.21)

Notes: Data from secondary sources and the the Niger trader survey collected by the authors. In Panel A, "Niger" market pairs are pairs where both markets are located in Niger; "border" market pairs are those pairs where both markets are located in a border country (Nigeria, Benin, Burkina Faso). In Panel B, "Niger" markets are those that are located within Niger (150 km from the international border), whereas "border" markets are those markets located outside of Niger (but within 150km of the border). Huber-White robust standard errors clustered by market pair-month (Panel A) and by market-month (Panel B) are in parentheses. * is significant at the 10% level, ** significant at the 5% level, *** is significant at the 1% level. Prices are deflated by the Nigerien Consumer Price Index. The Kolmogorov-Smirnov test tests for the equality of the distribution functions.

Table 2. Comparison of Observables by Ethnicity (Within Niger)

Observables	Unconditional Mean				Difference in Means
	Hausa		Zarma		Unconditional
	Mean (s.d.)	Obs	Mean (s.d.)	Obs	s.e.
Panel A. Market Pair Level Data					
Distance between markets (km)	234.08(134)	210	216.42(161)	68	17.66(21.54)
Road Quality between markets	.43(.49)	210	.41(.49)	68	.02(.07)
Cell Phone Coverage	.81(.39)	210	.98(.12)	68	-.17***(.03)
Transport Costs between Markets (CFA/kg)	8.08(4.34)	20160	7.54(5.06)	6528	.53***(.07)
Panel B. Market Level Data					
Millet Price level (CFA/kg)	123.23(30)	921	139.01(32)	744	-15.77***(1.56)
Sorghum Price level (CFA/kg)	112.84(32)	691	134.82(36)	635	-21.98***(1.90)
Cowpea Price Level (CFA/kg)	162.58(48.9	717	197.94(55)	908	-35.37***(2.60)
Road Quality to Market	.87(.35)	8	.6(.52)	10	.28(.21)
Market Size	107.63(86)	8	70.1(50)	10	37.53(34.43)
Cell Phone Coverage (2007)	.43(.50)	768	.35(.48)	960	.08***(.02)
Drought between 1999-2007	.031(.174)	768	.031(.174)	960	-.0000(.008)
Urban center(>=35,000)	.5(.53)	8	.4(.52)	10	.1(.25)

Notes: Data from secondary sources and the the Niger trader survey collected by the authors. In Panel A, "Hausa" market pairs are pairs where both markets are located in Hausa regions of Niger; "Zarma" market pairs are those pairs where both markets are located in the Zarma region of Niger. In Panel B, "Hausa" markets are markets with a majority of Hausa traders within Niger, and "Zarma" markets are markets with a majority of Zarma traders within Niger. Huber-White robust standard errors clustered by market pair-month (Panel A) and by market-month (Panel B) are in parentheses. * is significant at the 10% level, ** significant at the 5% level, *** is significant at the 1% level. Prices are deflated by the Nigerien Consumer Price Index. The Kolmogorov-Smirnov test tests for the equality of the distribution functions.

Table 3. Estimated International Border Effects

	Millet				Sorghum				Cowpea			
Dependent variable: |ln (Pit/Pjt)|	**(1)**	**(2)**	**(3)**	**(4)**	**(1)**	**(2)**	**(3)**	**(4)**	**(1)**	**(2)**	**(3)**	**(4)**
	.026***	.026***	.026***	.030***	.023***	.021***	.024***	.024***	.029***	.029***	.029***	.044***
Niger-Nigeria border	(.002)	(.002)	(.002)	(.003)	(.003)	(.003)	(.003)	(.003)	(.003)	(.003)	(.003)	(.003)
	.045***	.045***	.045***	.045***	.036***	.036***	.036***	.036***	.063***	.063***	.063***	.063***
Transport Costs	(.002)	(.002)	(.002)	(.002)	(.003)	(.003)	(.003)	(.003)	(.003)	(.003)	(.003)	(.003)
	.004	.004	.004	.004	.046***	.045***	.045***	.046***	-.040***	-.040***	-.040***	-.036***
Drought Dummy	(.007)	(.007)	(.007)	(.007)	(.011)	(.011)	(.011)	(.011)	(.009)	(.009)	(.009)	(.009)
	-.009***	-.009***	-.009***	-.009***	-.008***	-.008***	-.008***	-.008***	-.009***	-.009***	-.009***	-.011***
Urban status	(.001)	(.001)	(.001)	(.001)	(.002)	(.002)	(.002)	(.002)	(.002)	(.002)	(.002)	(.002)
		.002				.001						
Niger Market		(.008)				(.011)						
			-.002				-.001				-.006	
Nigeria Market			(.008)				(.011)				(.010)	
				-.0005				-.015***				-.019***
Cell Phone Coverage				(.002)				(.003)				(.003)
				-.011**				.008				-.033***
Border*Cell Phone Coverage				(.004)				(.005)				(.006)
Constant												
Market-Pair Fixed effects	No	No	No	No	No	No	No	No	No	No	No	No
Monthly time dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# of observations	21460	21460	21460	21460	15662	15662	15662	15662	20421	20421	20421	20421
# of cross-sectional observations												
R^2	0.0797	0.0797	0.0897	0.0801	0.108	0.1081	0.1081	0.1091	0.1036	0.1036	0.1036	0.1079
				-.021***				'-.007				-.051***
Joint Effect of Cell Phones and Interaction				(.008)				(.005)				(.006)
				-.011**				.016				-.065***
Joint Effect of Border and Interaction				(.004)				(.011)				(.012)

Notes: Data from the Niger trader survey and secondary sources collected by the author. For market pairs, cell phone dummy =1 in period *t* when both markets have cell phone coverage, 0 otherwise. Drought dummy=1 in period *t* when one market in a pair has rainfall less than or equal to 2 standard deviations below its average rainfall level during the rainy season, or 15 consecutive days without rainfall during the rainy season, 0 otherwise. Urban status =1 if one market in a pair is an urban center (>=35,000 people), 0 if both or neither are urban centers. Huber-White robust standard errors clustered by market pair-month (price difference) are in parentheses. * is significant at the 10% level, ** significant at the 5% level, *** is significant at the 1% level. All prices are deflated by the Nigerien Consumer Price Index (CPI).

Table 4. Estimated Internal Border Effects

	Millet				Sorghum				Cowpea			
Dependent variable: |ln (Pit/Pjt)|	**(1)**	**(2)**	**(3)**	**(4)**	**(1)**	**(2)**	**(3)**	**(4)**	**(1)**	**(2)**	**(3)**	**(4)**
Hausa-Zarma Border	.056***	.061***	.043***	.052***	.026***	.024***	.037***	.026***	.047***	.060***	.018***	.037***
	(.006)	(.006)	(.006)	(.007)	(.003)	(.003)	(.004)	(.003)	(.006)	(.006)	(.01)	(.01)
Transport Costs	.041***	.040***	.040***	.040***	.053***	.052***	.052***	.052***	.060***	.060***	.060***	.060***
	(.003)	(.003)	(.003)	(.003)	(.002)	(.002)	(.002)	(.002)	(.003)	(.003)	(.003)	(.003)
Drought Dummy	.009	.011	.011	.009	.022**	.022**	.022**	.022**	-.024**	-.023**	-.023**	-.024**
	(.011)	(.010)	(.010)	(.011)	(.010)	(.010)	(.010)	(.010)	(.011)	(.011)	(.011)	(.011)
Urban status	-.006***	-.006***	-.006***	-.006***	.009***	.009***	.009***	.009***	-.007**	-.007**	-.007**	-.006**
	(.002)	(.002)	(.002)	(.002)	(.002)	(.002)	(.002)	(.002)	(.002)	(.002)	(.003)	(.002)
Hausa Market		-.018***				.012***				-.041***		
		(.002)				(.003)				(.003)		
Zarma Market			.018***				.012***				.041***	
			(.002)				(.003)				(.003)	
Cell Phone Coverage				-.012***				-.017***				-.044***
				(.003)				(.003)				(.004)
Border*Cell Phone Coverage				.019				.004				.052***
				(.016)				(.005)				(.014)
Constant												
Market-Pair Fixed effects	No	No	No	No	No	No	No	No	No	No	No	No
Monthly time dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# of observations												
# of cross-sectional observations	10829	10829	10829	10829	26262	26262	26262	26262	13195	13195	13195	13195
R^2	0.0873	0.0935	0.0935	0.0844	0.2362	0.2362	0.2362	0.2371	0.1176	0.1329	0.1329	0.1248
Joint Effect of Cell Phones and Interaction				.007				-.013***				.007
				(.016)				(.004)				(.014)
Joint Effect of Border and Interaction				.071***				.029***				.090***
				(.014)				(.004)				(.012)

Notes: Data from the Niger trader survey and secondary sources collected by the author. For market pairs, cell phone dummy =1 in period *t* when both markets have cell phone coverage, 0 otherwise. Drought dummy=1 in period *t* when one market in a pair has rainfall less than or equal to 2 standard deviations below its average rainfall level during the rainy season, or 15 consecutive days without rainfall during the rainy season, 0 otherwise. Urban status =1 if one market in a pair is an urban center (>=35,000 people), 0 if both or neither are urban centers. Huber-White robust standard errors clustered by market pair-month (price difference) are in parentheses. * is significant at the 10% level, ** significant at the 5% level, *** is significant at the 1% level. All prices are deflated by the Nigerien Consumer Price Index (CPI).