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**A Dynamic Spatial Model of Agricultural  
Price Transmission**

**Evidence from the Niger Millet Market**

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## **ABSTRACT**

Spatial interactions are essential drivers of price transmission mechanisms and may significantly affect any food's policy outcomes. However, spatial aspects seem to be generally overlooked when analyzing price transmission. This paper attempts to fill this gap by highlighting the usefulness of spatial interaction and models for market integration analysis. A spatial dynamic panel data model is presented and applied to Niger's millet market. Empirical results show that (1) the millet market is partly integrated, (2) locally traded commodities (millet and sorghum) are linked by a cross-commodity price transmission, (3) most imported cereals prices, which for Niger is maize and rice, did not affect the millet market, and (4) no cross-regions price transmission occurred for the millet market.

**Keywords:** spatial econometrics; panel data; agricultural commodities; market integration; Niger

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# 1. INTRODUCTION

In recent years, agricultural products have undergone huge price variation in international markets. Such variation in world markets is not without effect on local markets. The extent of these shocks vary across countries as some are more dependent on international markets than others. A number of factors determine the degree of price transmission in a country, such as trade flows, transactions costs, trade policies, availability of price information across markets, and installed infrastructures. For example, if domestic products dominate the local markets, price transmission will be less severe than in markets where foreign goods dominate local goods. In addition, high transaction costs and trade barriers reduce price transmission by limiting trade flows.

Price transmission analysis measures how well different spatially separated markets are connected because a price change in one market affects other markets. If markets are perfectly integrated, price signals are transmitted from a selected location to other locations. This implies a price adjustment in response to existing excess supply and demand conditions in other locations of the integrated area.

There is extensive theoretical and applied research on the mechanisms of price transmission. As applied studies often focus on policy implications, a large portion of the literature deals with methodological improvements in the fields of price transmission analysis. Therefore, various approaches can be found in the literature. The first studies began using correlation coefficients of prices to test market integration between spatially separated markets (Ejiga 1977; Jones 1972; Lele 1967; Loveridge 1991). Other research employed regression-based models (Isard 1977; Gardner and Brooks 1994; Monke and Petzel 1984; Mundlak and Larson 1992;) or time-series analysis techniques such as dynamic regression (Ravallion 1986; Timmer 1987), Granger Causality (Alexander and Wyeth 1994; Koontz et al. 1990; Mendoza and Rosegrant 1995; Uri et al. 1993), impulse response functions of vector autoregressive models (VAR) (Goodwin et al. 1999), and cointegration techniques (Barrett 2001; Baulch 1997; Goodwin and Piggott 2001). Furthermore, a number of studies have proposed nonlinear approaches (Meyer and Cramon-Taubadel 2004, Greb et al. 2013). The common feature of these approaches is that they are mainly based on time-series analysis.

It is important to note that price transmission is an economic phenomenon that takes place across locations that are spatially separated. The failure to take this fact into account can bias the results of an analysis. For example, Lesage (1999) stated that, due to spatial dependence and heterogeneity, Gauss-Markov assumption is violated. Therefore, an alternative approach to traditional econometrics is needed. Spatial econometrics that successfully model those issues and draw appropriate inferences is a straightforward solution. Unfortunately, this tool seems to be rarely used in price transmission analysis. To the best of our knowledge, Keller and Shiue (2007) presented the only research that used the spatial econometric approach to study market integration for China's rice market.

Therefore, the main aim of this paper is to add to the literature by highlighting the usefulness of the spatial econometrics approach for analyzing price transmission. Alternatively, we will also use this model to study the market integration of cereals in Niger, with a special focus on the millet market. Niger is a country in Africa south of the Sahara that usually faces major problems of chronic, seasonal, and acute food insecurity and malnutrition. The attention paid to the millet market is justified because it is the most consumed commodity and represents 78 percent of cereal consumption and 62 percent of food consumption in Niger (FAO 2009).

The remainder of this paper continues as follows: Section 2 shows how relevant spatial modeling is in the price transmission framework. The dynamic spatial panel model is presented in Section 3. Section 4 presents data used for application, which is monthly agricultural commodities across Niger's regions. Section 5 provides an application of the model for the millet market in Niger. The final section is devoted to conclusion and policy implications.

## 2. DO SPATIAL LINKAGES MATTER IN PRICE TRANSMISSION ANALYSIS?

Price transmission examines how price shocks are conveyed between markets in geographically separated locations and provides information on the existence of market integration. Market integration ensures that price signals and information are transmitted from one market to another (Chirwa 2001; Ghosh 2011). When this occurs, trade flow moves from food surplus to food deficit (Chirwa 2001). This leads to more stable prices, and trade policies are more effective. Market integration is a prerequisite for the success of trade policies such as staples' price stabilization (Rashid et al. 2008). If markets are integrated, economic agents (producers and consumers) can benefit from liberalization policies (Ghosh 2011; Rashid et al. 2008). In food emergency situations, policy makers need to decide whether to resort to cash transfers or food aid. If markets are well integrated, cash transfers will be more appropriate than food aid. Therefore, price transmission analysis may contribute to an improvement of decision making (Shin 2010; Beekhuis and Laouali 2007).

The level of market integration is closely related to several factors, such as trade flows, transaction costs (transport, margins, risk premium, cost of information), distance, and quality of infrastructure. Policy makers can target some of these factors in order to achieve better integrated markets. Price transmission models the dynamics of price levels between two or multiple regions.

LeSage and Pace (2009) pointed out five reasons to include spatial features (spatial autoregression) in a regression model. The five *motivations* are: (1) a time-dependence motivation; (2) an omitted variables motivation; (3) a spatial heterogeneity motivation; (4) an externalities-based motivation; and (5) a model uncertainty motivation. Interestingly, these motivations are relevant in market integration analysis. In fact, economic agents often make current period decisions that are influenced by the behavior of other agents in previous periods. The current price level in a region might be correlated with the prices observed in neighboring regions in previous time periods. Then, the price dynamic would exhibit a pattern of spatial dependence. In addition, in the context of market integration, it is not unreasonable to imagine that accessibility of a market, existence of a highway, weather, and many other factors may influence price level. Furthermore, the assumptions of the linear model, such as the independence of errors between observation units and between the error and the explanatory variables, are more than strong assumptions for empirical modeling. These aspects could easily be included in a spatial model.

Spatial features are important, as geographical distances influence trade and possible arbitrage. Also, spillover effects exist because a given region's price dynamic is influenced by its neighboring markets' prices (Keller and Shiue 2007). Such spillover effects could be explained by information sharing between regions. This information sharing is made possible by traders and the rise of mobile phones (Aker 2010). By using mobile phones, a consumer or producer can be informed about prices in nearby or remote markets without traveling to them. Moreover, in most developing countries, the costs of communication are decreasing.

Agricultural commodities traders search for arbitrage opportunities in different markets. Due to information flow, because of higher prices, trade flow should move from surplus to deficit. Transaction costs between markets should be the main barriers to trade. A possible proxy for these costs is the distance between regions. Thus, considering geographical proximity in market integration analysis would provide more precise results than in the previous studies.

In addition to the price transmission for a given product (intracommodity price transmission) across locations, it is also possible to imagine price transmission from one product to another (cross-commodity price transmission) over space and time. This could be explained by the behavior of economic agents and also the scarcity of a product in space and time. Indeed, consumer behavior may explain why the rise in price of a product is passed to that of a third-party product. For example, cereals (millet, sorghum, maize, and rice) consumed by households are, to some extent, used as substitutes. In response to price changes, households can move from consumption of millet to sorghum or corn. Therefore, a price change for a given product can impact the price of other products, especially substitutes. This can explain why some African commodities that are not traded internationally responded greatly to global food price

spikes. In fact, according to the World Bank (2012, 7 ), "The prices of maize, beans, and cowpeas, which are mainly traded locally and regionally, are more volatile, on average 20–30 percent above the price volatility of internationally traded commodities." The scarcity of a given product (shortage, poor harvest, locust invasion, and so forth) is also a factor that can lead households to change their consumption behavior. Under these conditions, economic agents will adapt their preference over available alternatives. Each of these situations can affect prices and therefore demand of products.

### 3. METHODOLOGICAL FRAMEWORK

In order to take into account interaction among geographical units, we formulate a spatial dynamic panel data (SDPD) model. Let  $Y_t^k$  be the vector of price for  $N$  locations at time  $t$  for commodity  $k$  and  $X_t$  stand for exogenous variables, which could be the price of other products or weather variables. The SDPD setup is:

$$Y_t^k = \tau Y_{t-1}^k + \rho W Y_t^k + \eta W Y_{t-1}^k + X_t \theta + W X_t \beta + \mu + \alpha_t l_N + V_t \quad (1)$$

where:

$W$  is an  $N \times N$  spatial weights matrix.

$\tau$  is the autoregressive time *home* effect.

$\rho$  is the contemporaneous endogenous interaction effects.

$\eta$  is the lagged endogenous interaction effects.

$\theta$  denotes the contemporaneous exogenous *home* effects.

$\beta$  denotes the contemporaneous exogenous interaction effects.

$\mu$  is a vector of individual fixed effects.

$\alpha_t$  vector of time fixed effects.

$l_N$  is a vector of ones.

$V_t$  is a vector i.i.d error terms.

This framework offers many advantages for price transmission analysis. Indeed, by eliminating all the terms associated to the weight matrix ( $W$ ), we obtain a time-series econometric model. This model is an example of a *VARX/VECMX* (VAR model with exogenous variables). Assuming  $\rho$  parameter is nonzero in the previous model, one explicitly integrates a spatial aspect in the modeling. The resulting model states that the price dynamics in a region depend on the price in other regions but on a different scales. In fact, the weight matrix discriminates the different regions based on some considerations, such as proximity or contiguity and existence of road infrastructure. If instead, the term  $\eta$  is introduced into the model, the assumption is that the price level of a product in a given area is related to the observed prices for the same product in surrounding areas during an earlier period. Another advantage of the model 1 is the presence of variable  $X$  (exogenous variables) that could be weather or other variables. When  $X$  represents the prices of other products, this model makes it possible to study price transmission across products, which we called *cross commodities price transmission*. For example, one can examine the transmission between rice and other cereal prices in a given country to substitute crops (for example, sorghum, rice and maize).

One issue that may arise with cross-products analysis is the problem of endogeneity between prices. In fact, rice price can affect the price of other cereals and vice versa. Therefore, it is relevant to treat this problem appropriately. One solution is use of the instrumental variables or generalized method of moments (IV/GMM) approach. However, Elhorst (2010) found that this method is severely biased in the context of model 1. Lee and Yu (2014) proposed a suited GMM estimator for model 1 which is only consistent when  $T$  is small relative to  $N$ . This is not the case for our empirical study. Another solution to the endogenous problem consists of estimating a system equation of model 1 where equations for all commodities must be estimated simultaneously. Such an approach is not well developed in the literature<sup>1</sup>.

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<sup>1</sup> Future work should pay more attention to those models.

In this paper, we addressed the endogeneity issue by using a moving average on lags of the prices of other cereals. We also used the average of the three, four, and five previous months<sup>2</sup>.

Based on the proprieties of model 1, it can be classified into three different cases. According to Lee and Yu (2010b), we have:

- a stable model if:  $\tau + \rho + n < 1$ ,
- a spatial cointegrated model if:  $\tau + \rho + n = 1$ , and
- an explosive case when  $\tau + \rho + n > 1$ .

To estimate model 1, we followed Yu et al. (2008), Lee and Yu (2010a; 2010b; 2010c), and Yu et al. (2012), who used a bias-corrected quasi-maximum likelihood (BC-QML) estimator. This method produces consistent parameter estimates when the model is stable. However, when this stability condition is not satisfied, a data transformation is needed to consistently estimate model 1 using BC-QML. In fact, if the stability condition is not satisfied, model 1 has two components: stable and unstable. The objective of the data transformation is to remove the possible unstable components. Lee and Yu (2010b) and Yu et al. (2012) propose the spatial first-difference transformation of model 1 using the matrix  $(I-W)$  where  $I$  denotes the  $N \times N$  identity matrix.

$$\begin{aligned} (I-W)Y_t^k &= \tau(I-W)Y_{t-1}^k + \rho W(I-W)Y_t^k + \eta W(I-W)Y_{t-1}^k + \\ & (I-W)X_t\theta + W(I-W)X_t\beta + (I-W)\mu + \alpha_t(I-W)l_N + (I-W)V_t \end{aligned} \quad (2)$$

It is worth noting that this transformation has three main effects on the model. First, it eliminates the time-fixed effect. Second, similar to time first-difference transformation, it reduces the cross-section dimension and therefore the number of observations. Third, it modifies the rank of the variance-covariance matrix, which is the number of nonzero eigenvalues of  $\Sigma = (I-W)(I-W)'$ . Let  $[F_n, H_n]$  be the orthonormal matrix of eigenvectors and  $\Lambda_n$  the diagonal matrix nonzero eigenvalues of  $\Sigma$  such that  $\Sigma F_n = F_n \Lambda_n$  and  $\Sigma H_n = 0$ . Note that the transformed weight matrix is  $W^* = \Lambda_n^{-1/2} F_n' W_n F_n \Lambda_n^{-1/2}$  which is  $(N-1) \times (N-1)$  dimension.

Model 2 can be written, when omitting  $k$  index for simplicity as

$$Y_t^* = \tau Y_{t-1}^* + \rho W^* Y_t^* + \eta W^* Y_{t-1}^* + X_t^* \theta + W^* X_t^* \beta + \mu^* + V_t^* \quad , \quad (3)$$

where  $Y_t^* = \Lambda_n^{-1/2} F_n' (I-W) Y_t$  and other variables are defined accordingly. This model is estimated using BC-QML.

### Direct and Indirect Effects

The coefficients of the equation 1 cannot be use directly to test the existence of spillover effects as that could lead to erroneous conclusions (LeSage and Pace 2009). One should instead estimate the partial derivatives.

Equation 1 is rewritten as

$$Y_t = [(I - \rho W)^{-1}(\tau I + \eta W)]Y_{t-1} + (I - \rho W)^{-1}[X_t\theta + W X_t\beta] + (I - \rho W)^{-1}[\mu l_N + \alpha_t l_n + V_t] \quad (4)$$

The short-term impacts of a change in the explanatory variable  $X_i$  on the dependent variable can be computed as:

$$\left[ \frac{\partial Y}{\partial X_i} \right] = [(I - \rho W)^{-1}(X_i\theta + W X_i\beta)] \quad (5)$$

---

<sup>2</sup> It means  $\frac{1}{n} \sum_{i=1}^n x_{t-i}$ , where  $n = 3, 4, \text{ or } 5$  and  $x$  the price of other commodities.

This partial derivative is an  $N \times N$  matrix. As noticed in Debarsy et al. (2012), diagonal elements of equation (3) are different for each cross section, and off-diagonal elements differ from zero and the matrix is nonsymmetric. This model is richer than the traditional linear model. Similarly, according to Elhorst (2014), the long-term effects can be depicted as

$$\left[ \frac{\partial Y}{\partial X_i} \right] = [(1 - \tau)I + (n - \rho)W]^{-1}[X_i\theta + WX_i\beta] \quad (6)$$

As the model is dynamic, one can also calculate convergence effects as

$$\left[ \frac{\partial Y}{\partial Y_{i-1}} \right] = [(I - \rho W)^{-1}(\tau I + nW)] \quad (7)$$

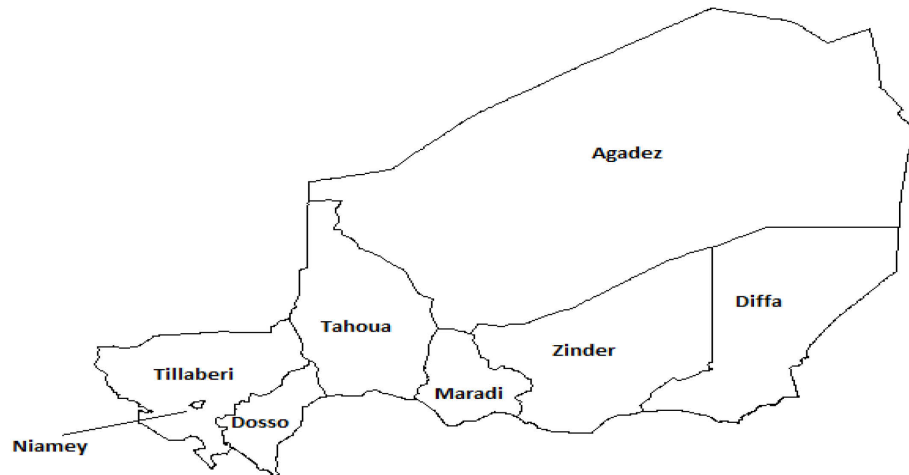
To summarize the information contained in the previous three matrices, LeSage and Pace (2009) proposed three scalar measures: direct effect, indirect effect, and total effect. The direct effect is obtained by the average of the  $N$ -diagonal elements while the indirect effect is the average of either the row sums or the column sums of the non-diagonal elements of these matrices. The total effect is the average of all elements of the respective matrix.

## 4. DATA

The data used in this study is drawn from the System of Agricultural Market Information (SIMA) monthly commodity price data for Niger from January 2000 to December 2012. Our sample includes the four most consumed cereals—millet, sorghum, maize, and rice—for the eight regions of Niger: Agadez, Diffa, Dosso, Maradi, Niamey, Tahoua, Tillaberi and Zinder (Figure 4.1).

Established in 1989, SIMA is a specialized service of the government of Niger, which is operated by the Ministry of Trade and Private Sector Promotion. The main mission of SIMA is to collect, process, and disseminate information about agricultural markets for better decision making by policy makers. By doing so, it contributes to a sustainable improvement of food security in Niger by providing better market transparency and a good knowledge of food trade, especially cereals. SIMA follows a sample of 74 agricultural markets, including 48 regular markets,<sup>3</sup> 18 sentinel markets,<sup>4</sup> and 8 cross-border markets<sup>5</sup>.

**Figure 4.1 Map of Niger's regions**



Source: DIVA-GIS (2013).

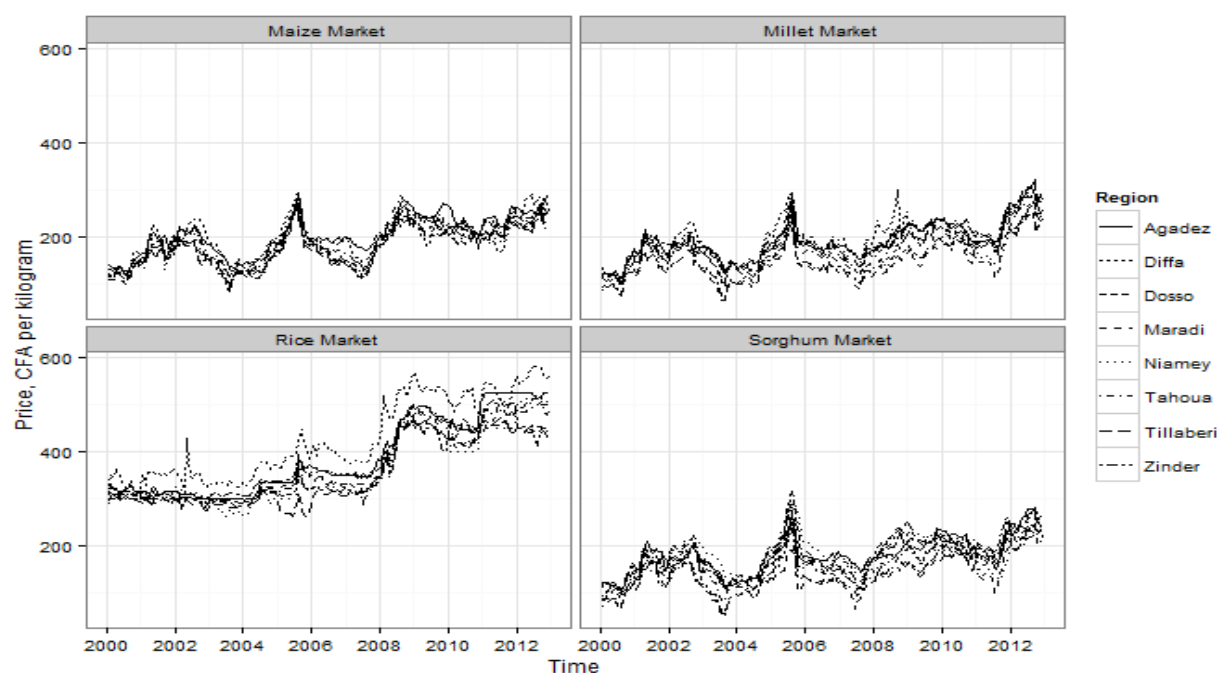
The dynamics of various cereals prices considered are depicted in Figure 4.2. As seen from this figure, for each cereal market all prices seem to follow a common trend. It can be noted that the trend shifted for rice markets after the 2007–2008 international food price crisis. For other cereals, which are mainly traded locally, their dynamics are quite similar. Summary statistics (average and standard deviation) of cereals prices are available in appendix.

<sup>3</sup> These e-markets are constituted of collection, aggregation, and consumption markets.

<sup>4</sup> They are selected as a result of an analysis on the vulnerability of areas. These markets are located in structurally vulnerable areas.

<sup>5</sup> These markets are located in foreign territory, but within the national borders.

**Figure 4.2 Trends in Niger cereals prices, 2000–2012**



Source: SIMA (2013).

Note: CFA = Communauté Financière Africaine (West African Economic Monetary Union currency unit).

In terms of the linkages between prices in different markets, a high correlation exists between the four commodities we studied (Table A.1 in the appendix). Correlation coefficients vary from 0.69 between rice and maize, to 0.99 between millet and sorghum. The results give a preliminary idea about the strong relationship of prices between different commodities. Further analysis will clarify if price transmission takes place between those commodities.

Table 4.1 describes distances between different regions of Niger. It is the great-circle distance between different regions from their centers. Pairwise distances between regions vary between 104 km and 1225 km with an average of 542 km and about 292 km as standard deviation. The average distance between a selected region and other regions is between 422 km (for Tahoua) and 845 km (for Diffa). The entire pairwise distance matrix between Niger's regions is available in the appendix.

**Table 4.1 Distance summary statistic between regions (km)**

Niger's regions	Minimum	Average	Standard deviation	Maximum
Agadez	367.72	565.50	178.40	763.12
Diffa	410.50	845.13	304.54	1,225.55
Dosso	127.87	489.34	314.32	1037.48
Maradi	210.74	435.86	163.25	616.01
Niamey	104.58	538.93	374.66	1152.19
Tahoua	251.69	422.89	187.69	825.82
Tillaberi	104.58	595.30	383.24	1,225.55
Zinder	210.74	514.35	220.09	815.15
<b>Overall</b>	<b>104.58</b>	<b>542.46</b>	<b>291.58</b>	<b>1,225.55</b>

Source: Authors calculations from SIMA data.

Following Elhorst et al. (2013), we use the weight matrix based on the inverse of the distance between regions with a defined threshold. In other words, we assume that there is a threshold distance beyond which the interaction between two regions is zero. This means that if the distance between two regions is lower than the threshold distance, the weight matrix is set to the inverse of that distance. However, if the distance is greater than the threshold, the corresponding matrix element is set to zero, which means there is no interaction). The best threshold is such that every region has at least one neighbor region and the estimated model shows the highest value of the log-likelihood function. Therefore, the candidate thresholds are between 500 and 1000 km. The selected threshold is 850 km.

## 5. APPLICATION TO NIGER'S MILLET MARKET

In this section, the model previously presented was applied to analyze price transmission of millet, the most consumed cereal in Niger. Two competing models were estimated; the first considered only spatial fixed effects, and the second examined spatial and time-fixed effects.<sup>6</sup> As in Elhorst et al. (2013), the model choice is made using a Fisher test. This Fisher tests null means that the model without time-fixed effect is preferred to the model with time-fixed effect. Another important characteristic of the selected model is its stability. If the selected model is not stable, further transformation is needed before interpreting findings. The stability condition is tested for the selected model using a Wald test.

Table 5.1 presents the results of price transmission analysis on Niger's millet market when accounting for other cereal prices. The results of the two competing models are presented in columns 1 and 2. The choice between those two models is made using a Fisher test with a null hypothesis that column 1 is preferred to column 2. According to the *p*-value of the Fisher test, the null hypothesis cannot be rejected if specification 1 is selected. Therefore, a model without time-fixed effect is the best model. However, before using this model, it is necessary to test if it is stable using a Wald test<sup>7</sup>. As the last three rows of the Table 5.1 show, model 1 is not stable.

**Table 5.1 Millet market integration results using dynamic spatial approach**

Independent variables	Spatial first-differences and effects estimates					
	No time dummies	Time dummies	Coefficient	Direct	Indirect	Total
	(1)	(2)	(3)	(4)	(5)	(6)
Millet (-1)	0.751	0.695	<b>0.688</b>	<b>0.676</b>	-0.002	<b>0.675</b>
	27.673	24.968	24.247	17.586	-0.493	16.657
W*Millet (-1)	-0.338	-0.233	<b>-0.229</b>			
	-10.853	-3.418	-3.269			
W*Millet	0.658	0.275	<b>0.281</b>			
	31.088	5.124	3.715			
Maize	0.051	0.028	0.017	0.020	0.000	0.020
	1.814	1.037	0.603	0.500	-0.056	0.482
Rice	0.064	0.046	0.047	0.051	-0.001	0.051
	1.661	1.119	1.152	1.037	-0.220	1.001
Sorghum	0.029	0.081	<b>0.091</b>	<b>0.097</b>	0.002	<b>0.099</b>
	2.290	3.774	3.965	2.635	0.791	2.570
W*Maize	-0.017	-0.082	-0.011			
	-0.338	-1.161	-0.343			
W*Rice	-0.052	-0.036	-0.024			
	-1.178	-0.526	-1.107			
W*Sorghum	-0.157	0.021	0.012			
	-4.600	0.394	0.498			
Observation	1208	1208	1057			
Fisher Stat		1.0765				
P-value Fisher test		0.2634				
tau + rho + eta	1.071	0.737	<b>0.791</b>			
Wald-test	15.876	15.591	<b>23.357</b>			
P-value Wald test	0.00	0.00	0.00			

Source: Authors' calculations.

Note: The numbers in (.) are the asymptotic t-statistic.

<sup>6</sup> For estimation, we use the Matlab routine of Jihai Yu available on Elhorst's homepage.

<sup>7</sup> The row named "tau+rho+eta" reported the sum of the first three parameters of the model (see the first three rows). This amount is tested to be equal to one using the Wald test.

As model 1 is unstable, a spatial first-difference model was estimated, as seen in column 3. This model is stable (“tau + rho + eta” equals 0.791, which is significantly different from 1). Therefore, model 3 has all the required features to be used for our analysis.

The first parameter of model 3 is significantly positive and equals 0.688, which implies that the previous observed price of millet had a positive and high impact on the current price. The second and third parameters (-0.229 and 0.281) are both significant. These parameters showed the existence of a spatial price transmission among various millet markets. It also showed that only sorghum price (0.091) had a positive and significant impact on millet’s price. As stated in the methodological section, none of the estimated parameters (significant or not) could not be directly interpreted. Only direct, indirect, and total effects are useful.

Columns 4 to 6 present the direct, indirect, and total effects associated with every explanatory variable. The *convergence* effect, the effect due to the temporal or spatial lag of the dependent variable, here the millet price, showed a positive and significant direct effect and a negative and insignificant indirect effect. The direct convergence effect is equal to 0.676. Meaning, an increase in the previous price of millet is transmitted to its current level for about 67.6 percent. This parameter is the price transmission elasticity of millet price from one period to the next.

Concerning the impact of the price of millet’s substitute commodities (maize, sorghum, and rice), we found that a change in the price of maize or rice in any region of Niger had no direct or indirect impact on the millet price. Price dynamics in maize and rice markets did not significantly affect the demand for millet. Conversely, an increase of the price of sorghum significantly increased the price of millet. In fact, the coefficient associated with sorghum (0.091) means that a change in the price of this commodity is transmitted for about 9 percent of the price of millet. This finding could be seen as evidence of the fact sorghum is a substitute for millet.

These results can be explained by the production structure of millet and sorghum. In fact, these commodities, are not only the most consumed cereals in Niger, but also the most produced. According to the figures of the Niger’s National Institute of Statistics (INS-Niger 2013), millet is produced in all regions of Niger. The major regions of production are Maradi, which contributed 22.58 percent of the national production in 2012; Tahoua (19.61 percent); Tillaberi (19.45 percent); Dosso (17.77 percent); and Zinder (17.76 percent). Millet, which is similar to sorghum, is produced in seven of the eight regions of Niger. The main regions of sorghum production are Maradi, which contributed 29.18 percent of the national production in 2012; Zinder (29.16 percent); and Tahoua (28.20 percent). Other cereals are marginally produced in Niger. In addition, according to the USDA database, in 2012 the local demands of millet and sorghum were mainly satisfied by the national production, in contrast to the demands for rice and maize. In fact, the import-consumption ratio for 2012 are 0 percent for millet, 2 percent for sorghum, 84 percent for rice and 90 percent for maize (USDA 2016).

This data sheds light on our findings, especially about the existence of price transmission between cereal markets in Niger. Even though each of the aforementioned cereals were natural substitutes, their availability on local markets and the associated prices would determine consumers’ choices. Millet and sorghum, which are locally produced and consumed, are likely to be the first choices of the population. Results also confirmed that Niger’s top cereal imports, rice and maize, are not substitutes for locally traded commodities such as millet and sorghum.

Consumption habits are likely an important factor in consumer choice. In fact, it is difficult to explain why the maize market does not have any influence on the millet market based on the price differential between millet and other cereals. Over the period of study, the average price differential between maize and millet was 10.58 CFA per kg, -9.16 CFA between sorghum and millet, and 198.92 CFA between rice and millet. Consequently, the inexistence of price transmission from maize to millet is likely due to availability and consumers behavior. For rice, this could be explained by the price gap—rice price is about 2 to 4 times the price of millet (SIMA 2013)— and the fact that in many West African countries, rice is considered a luxury good, and is generally only consumed during special events (FAO 2009).

Concerning the cross-regions price transmission, results showed that none are significant. Therefore, there is no spatial price transmission for the millet market. This means that a price change in any market (millet, maize, sorghum, or rice) had no effect on price level for other, adjacent (separated) markets. Therefore, price signals that originated from one region (for any cereals commodities) are not transmitted to others regions. Many reasons could be given to explain such situation. Among them, we found (1) high transportation cost, (2) malfunctioning transport service (lagged transmission), (3) imperfect substitution of goods, (4) lack of price information, and (5) installed infrastructures (Badiane and Shively 1998, Ghosh 2011, Rashid et al. 2008, Minot 2010).

Even though each of these factors could explain the inexistence of price transmission across regions, transport-related factors and infrastructure would be the most important factors in Africa, in general, and Niger specifically. Limited road infrastructure is available in Africa. Therefore, transport costs are high compared to other regions of the world (Macchi and Raballand 2009, Teravaninthorn and Rabelland 2009). Due to a lack of adequate infrastructure, the transportation of commodities took too much time. This situation could constitute a caveat for price transmission because traders cannot access readily available price information.

## 6. CONCLUSION AND POLICY IMPLICATIONS

Price transmission is an important research topic from a scientific and policy perspective. The recurring commodity price spikes, especially the recent food price crisis, have revived the debate on the issue of market integration and best policy response. Price transmission occurs from one period to another and between separate locations. This study is one of few that propose the use of a dynamic spatial econometrics framework for the analysis of price transmission and thus the integration of markets. Spatial econometrics approaches, especially its dynamic version, have some appealing features for price transmission analysis. As an application, the dynamic spatial model presented has been used to analyze the price transmission on the millet market and the linkage of this market with other cereals markets. Our results showed that price transmission is stable but not cointegrated. Past price shocks are highly transmitted to future prices for around 70 percent of the price variation. Cross commodities price transmission has been shown also between selected cereals, especially from the sorghum market to the millet market. A change in the price of sorghum was capable to be transmitted to millet price for around 10 percent. The prices of other cereals were found have no influence on the price of millet. These results revealed a relationship between locally traded commodities, such as millet and sorghum, but no linkage between locally, regionally, or internationally traded products, such as millet, rice, or maize). Conversely, our results did not reveal any spillover or diffusion effects between regions for the millet market. One interesting lesson from those findings is that our approach is able to decompose impacts of a price shock into direct effect (origin location self-impact), indirect effect (impact on other locations), and the total effect (cumulated impact). Traditional approaches don't allow such distinction. Therefore, results showed that only region specific self-transmission occurred for the millet market.

These findings have some policy implications. First, the absence of cross-regions price transmission reveals that a unique market-based price policy in Niger might not be effective in terms of mitigating food crisis impact. To be effective, the government has to design region-specific interventions. However, such options come with a high cost. Therefore, strategic investments are required to create conditions for price transmission between regions and ensure market integration. For example, investments in road infrastructures, which are essential in transport costs reduction, could be a good starting point. Second, as there is price transmission only between locally produced and consumed cereals (millet and sorghum), it would be interesting for the government to promote growth of their production, which may be a good resilience strategy for consumers. In fact, these cereals constitute the major portion of households' baskets and are mainly produced in Niger (less than 2 percent of their consumption are from imports). The country has a small connection with international market, and results showed that a price change for other cereals (rice and maize) is not transmitted to them. In addition, the government could promote efficient trading of agricultural commodities by providing storage facilities in order to reduce postharvest losses.

Even though, this study and its empirical application showed that spatial dynamics econometrics could be very useful in the analysis of price transmission and market integration, some aspects of this work could be improved for future works. First, the issue of price endogeneity needs a clear treatment. The use of a vector auto-regressive-like spatial model may be a good solution. Second, in this work, we only considered one lag for the model. In a future version of the model, it would be interesting to investigate the use of further lags. Third, it may be useful to test dynamic weights matrix, as interactions (trade and trade related infrastructures) between locations could change over time. When available, this matrix could be based on average trade costs or an index of road infrastructure quality between selected regions.

## APPENDIX: SUPPLEMENTARY TABLES

**Table A.1 Cross commodities correlation matrix**

Commodity	Rice	Maize	Millet	Sorghum
Rice	1			
Maize	0,77	1		
Millet	0,7	0,92	1	
Sorghum	0,69	0,95	0,99	1

Source: Authors' calculations from SIMA data (2013).

**Table A.2 Commodity prices per kg, in CFA**

Region	Millet	Maize	Sorghum	Rice
Agadez	190.69 (40.13)	205.22 (41.87)	181.4 (38.36)	388.23 (83.22)
Diffa	193.65 (42.06)	196.04 (40.77)	177.34 (40.63)	426.83 (85.82)
Dosso	174.66 (36.97)	178.69 (42.05)	176.18 (44.2)	358.32 (66.35)
Maradi	144.49 (39)	181.69 (44.49)	137.11 (38.56)	374.57 (78.62)
Niamey	188.98 (44.21)	180.63 (42.07)	185.58 (41.66)	361.15 (78.05)
Tahoua	177.44 (41.48)	196.85 (44.21)	160.29 (38.02)	371.59 (77.54)
Tillaberi	188.67 (45.02)	183.5 (41.94)	177.11 (41.23)	350.88 (71.27)
Zinder	155.98 (41.46)	176.58 (41.63)	146.22 (42.48)	374.37 (67.88)

Source: Authors' calculations from SIMA data (2013).

Note: The numbers in parentheses ( ) are the standard deviation.

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