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Transmission of International Food Price Changes to Mexican Markets

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Abstract

The spatial price relationship exposed by Enke (1951), Samuelson (1952), Takayama and Judge (1971), and the way of working with non-stationary variables moving together in the long run, established by Engle and Granger (1987) were the origins of the price transmission analysis. This investigation uses the method of Minot (2010) and proves the price relation of the selected grains -wheat, maize, sorghum and rice- from the international market to the Mexican domestic market. We use a vector error-correction model (ECM) to examine the relationship between world food prices and domestic food prices in México. There is strong evidence about the transmission process for the Mexican markets as in the long run the international prices affect the domestic prices. In contrast, in the short run there is no price transmission from the international market to the domestic.

Resumen

La relación espacial de precios propuesta por Enke (1951), Samuelson (1952), Takayama and Judge (1971), y el método para trabajar con variables no estacionarias moviéndose en conjunto en el largo plazo, establecida por Engle and Granger (1987), fueron los orígenes del análisis de transmisión de precios. Esta investigación utiliza la metodología de Minot (2010) y prueba la relación de precios para los granos seleccionados -trigo, maíz, sorgo y arroz- del mercado internacional al mercado mexicano. Se utiliza el modelo vector de corrección de errores (ECM) para examinar la relación entre los precios mundiales y mexicanos, de dichos cereales. Hay una fuerte evidencia del proceso de transmisión para los mercados mexicanos pues en el largo plazo los precios internacionales afectan a los precios domésticos. En contraste, en el corto plazo no hay transmisión de precios del mercado internacional al doméstico.

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1. INTRODUCTION

More than 60 years ago, Enke (1951), Samuelson (1952), and Takayama and Judge (1971) began the traditional analysis of spatial price relationships. Later, Engle and Granger (1987) established a way to deal with non-stationary variables, including prices, moving together in the long run. In all these cases, they were looking for an answer to the following questions: do changes in international prices move together with prices in a domestic market, and if so, to what degree?

First, we must understand a statement that clarifies the previous questions: a process of price transmission must occur if international food prices impact domestic prices. The purpose of this study consists in analyzing the effect, if it exists, of an increase in food prices in the international market, during the 2007-2008 and 2011 international crises, caused to the selected grains prices in the Mexican domestic market. This involves analyzing if there is empiric evidence about both types of prices moving together in the long run. Thereby, we use a time series analysis to deal with the problems of dynamic effects and non-stationarity.

Despite the effort over recent decades, the research community is still unraveling the causes, consequences and responses to price surges (Hajkowicz et al. 2012). This is why the price transmission analysis within crisis periods it is important because it might help enlighten the connection between them. Furthermore, with the analysis we would be able to develop appropriate policies that could help diminish the price spikes which are known to exacerbate the crises.

In the present paper, we will estimate short and long run elasticities of price transmission (domestic price with respect to the international prices), a coefficient that reflects the speed of adjustment, and a coefficient reflecting the effect of each change in the domestic price on the change in domestic price in the next period, by estimating an error-correction model. Minot (2010) establishes that by estimating the model it will be determined the existence of price transmission, and since prices in the model are expressed in logarithms the coefficients will establish the quantity of the proportional change in the international price that is transmitted to the domestic price in the short and long run. This investigation is an extension for the Mexican case, in specifics it follows the approach developed by Minot (2010). The results and evidence driven by this exercise will be the first, in its type, for Mexico even though the implications of the price transmission have been analyzed, as mentioned above, in other contexts.

We made a time series analysis for four Mexican staple grains: wheat, maize, sorghum and rice. The information was obtained monthly corresponding to the years 2005 to August 2012. For each pair of domestic and world prices: first, we test the price variables individually to see if they are integrated of degree one. Second, we use the Johansen test to determine whether the two series are co-integrated. Third, if the Johansen test indicated a long-run relationship between the two variables, the vector ECM is estimated. Specifically, we obtained monthly domestic and international prices of wheat, maize, sorghum, and rice, plus Mexican exchange rates, and the USA consumer price index (CPI). This information we retrieved it from the following sources: the Food and Agricultural Organization of the

United Nations (FAO), the National System of Markets' Information (SNIIM), the Mexican Central Bank (Banxico), and the U.S. Bureau of Labor Statistics.

Our motivation for doing this empiric investigation comes from the suspicion that there exists a price transmission from the international markets to the Mexican market. Principally, during the recent global crisis staple grains prices claimed up, dramatically (Keats et al. 2010). So, given our previous idea and the subject of study, we expect an increase (decrease) in prices of the domestic market when there is an increase (decrease) in the prices of the international market. Thus, the importance of this type of conclusions could be taken in count by the policy makers. For example, for the proposal of regional policies; to understand the impact of market distortions, costs adjustments, and government interventions; and to focus the attention on the markets which have less prices transmission or more distortions.

The results we obtained are positive and according to the analyzed evidence provided by Minot (2010). First, there is strong evidence about the transmission process for the Mexican markets as in the long run the international prices affect the domestic prices, most of the grains display elasticities in a range of 43.0 to 89.0%. On the other hand, the speed of adjustment parameters present low values which seem a slow adjustment of the deviations from the equilibrium; the parameters are in a range of 18.9 to 48.0%. In contrast, the short run relation and the autoregressive term are not statistically significant, in almost all cases. Only for the rice both parameters are significant; and the autoregressive parameter is significant just for the maize (white from Mexico and yellow from US).

We organized the present investigation it in four parts. In Section 2 we describe the background of the causes and consequences of the global crisis in food markets, and the progress of cereal grains prices in Mexico. In Section 3 we provide the literature review. In Section 4 we describe and present the time series analysis used in this study. In Section 5 we discuss the results, provide conclusions, and comment on some possible extensions of the analysis.

2. BACKGROUND

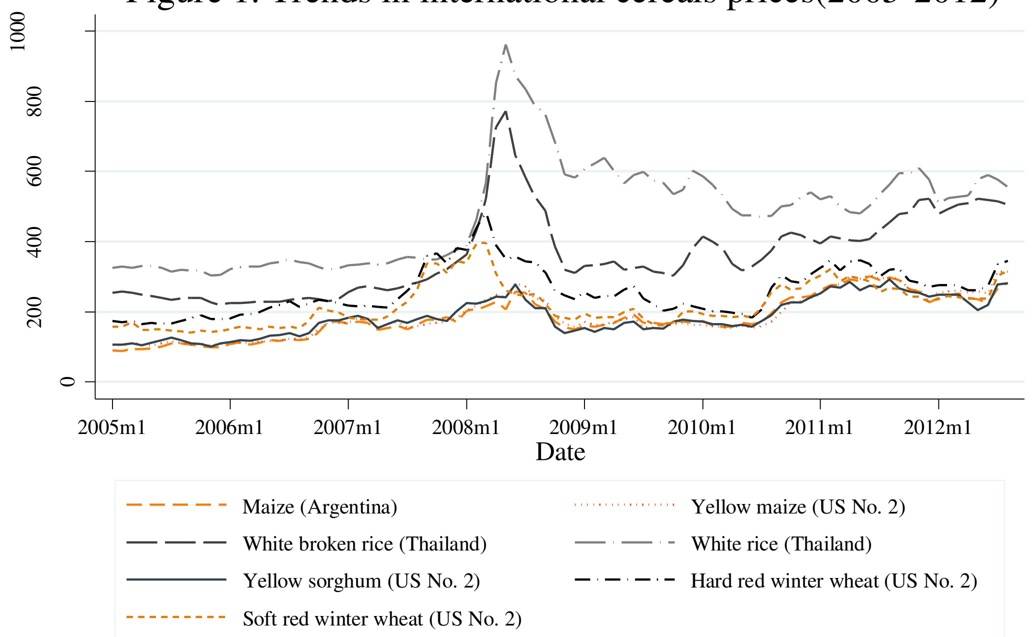
2.1. Trends in International markets

The international prices of cereals rose sharply in two occasions in 2007-2008 and in 2011. These spikes arise after six years of price increases, followed by one year during which prices fell before they started to rise again. The prices of maize (Argentina and US), sorghum, and wheat (hard and soft) reached a point where they more than doubled during the first crisis while the rice (A1 and B) prices tripled. In the 2011, prices of these staple grains more than doubled, but in this case they stayed at a new level (Figure 1).

The sharp increases in 2011, higher than in 2008, in food prices were catalyzed by various factors: low food stocks, export restrictions, drought, income growth, depreciation in the US dollar, urbanization, speculation on food commodity future markets and rises in oil prices. Other factors of special consideration are climate change and water scarcity which were significant to pressure upward food prices (Islam and Buckley 2009, and Hajkowicz et al. 2012).

In order to understand the behavior of international prices it is relevant to know its basic properties. There are four indicators of a price distribution-its mean, volatility, asymmetry and kurtosis. The importance here is to have a previous knowledge to identify if these movements vary over time (Table 1).

Figure 1. Trends in international cereals prices(2005-2012)



Source: FAO (2012)

Table 1. International cereals prices properties

Statistical	Maize (Argentina)	Yellow Maize (US)	Rice (A1)	Rice (B)	Sorghum	Wheat (Hard)	Wheat (Soft)
Mean	173.56	177.65	342.22	462.16	177.21	251.07	212.30
Volatility	59.12	61.66	118.36	147.25	53.79	68.12	62.10
Skewness	0.29	0.46	1.04	0.81	0.30	0.74	0.79
Kurtosis	-0.88	-0.94	1.10	0.61	-1.03	0.15	-0.06

Sources: Own calculations based on data from FAO (2012).

The mean of the prices focuses mainly on how price series evolve around their mean. The key issue is whether prices tend to be stationary and revert to their mean, or instead follow an unpredictable random walk. It is to highlight there is significant uncertainty regarding the presence of trends in cereal prices (Stigler 2011). Volatility refers to a high rate of persistence that leads to uncertainty in future price movements. A price increase implies a higher volatility. Agricultural markets are characterized by high price volatility.

The skewness coefficient informs about the asymmetry of a distribution. A value of cero will indicate a symmetric distribution while a positive (negative) value will indicate a distribution skewed to the right (left). For all of the cereal prices the skewness coefficient shows a positive value which indicates prices distributions are skewed to the right, meaning the values lie to the left of the mean. This goes according to the evidence on commodities which tend generally to exhibit positive skewness (Stigler 2011). A positive price asymmetry implies that one can be quite confident in establishing a minimum price level under which prices are unlikely to fall.

The kurtosis coefficient establishes the excess of a distribution which determines the thickness of its tails, the preponderance of extreme values. A positive (negative) excess kurtosis will imply a distribution that is fat (thin) tailed, while a value close to zero will indicate a distribution with tails similar to those of the normal distribution. In this case, wheat (hard) and rice (A1 and B) show a positive excess kurtosis that implies a fat tailed distribution and prices that are very concentrated around the mean. Sorghum and maize (US and Argentina) show a negative excess kurtosis that implies a thin tailed distribution and prices that are disperse around the mean. While wheat (soft) has a value near zero which implies a normal distribution.

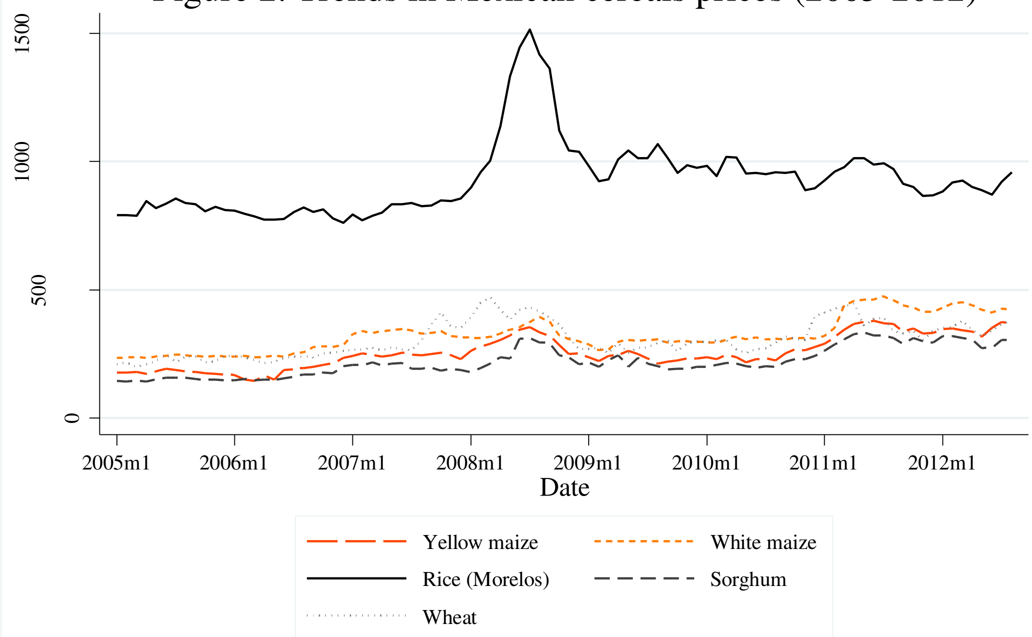
2.2. Trends in Mexican market

The idea of this study is to determine if the world prices affected the domestic (Mexican) prices and if this happened, in what degree they influenced them. In this part the trends of the Mexican prices will be described in order to have a first glance of how they behaved. The domestic prices in Mexico suffered from sharp increases in two food crises, first in 2007 - 2008, and second in 2011. Specifically, the prices of maize (yellow) and sorghum in both crises more than doubled, and after the second the prices of both grains stayed up in those levels. The prices of wheat increased at levels of 90% in the first, and 80% in the second, keeping prices in a new level approximately 50% up. The levels of rice just increased more than 80% in the first crisis, but in the second they did not rise dramatically. The maize (white) increased more than a 50% in the first, but in the second one the rise was for more than a 90%, and stayed up approximately a 70%. A relevant aspect to notice for analyzing the transmission of prices is that the Mexican prices reached their maximum level few months after the international prices had their own spikes (Figure 2).

To understand the behavior of the local prices it is appropriate to know its properties in means of the four indicators of a price distribution -mean, volatility, asymmetry and kurtosis (Table 2). The mean of the prices focuses mainly on how price series evolve around their means. As mentioned before, the issue is whether prices tend to be stationary and revert to their mean, or instead follow an unpredictable random walk. Volatility is the high rate of persistence that is difficult to distinguish from a random-walk, leading to uncertainty in future price movements. High price volatility characterizes agricultural Mexican markets.

Skewness, its coefficient, informs about the asymmetry of a distribution. In this case, the cereal Mexican prices skewness coefficients show a positive value that indicates that all prices distributions are skewed to the right. Similarly to the international prices, with a positive skewness coefficient implies that domestic prices of cereals lie to the left of the mean and that there are few high values.

Figure 2. Trends in Mexican cereals prices (2005-2012)



Source: SNIIM and FAO (2012)

Table 2. Mexican cereals prices properties

Statisticals	White Maize	Yellow Maize	Rice	Sorghum	Wheat
Mean	316.59	247.71	919.93	212.55	298.63
Volatility	68.16	63.99	147.56	57.02	69.04
Skewness	0.65	0.35	1.96	0.51	0.52
Kurtosis	-0.53	-0.89	4.85	-0.92	-0.77

Source: Own calculations based on data from SNIIM (2012).

The kurtosis coefficient, establishes the excess of a distribution, the thickness of its tails and the preponderance of extreme values. In this case, rice shows a positive excess kurtosis which implies a fat tailed distribution and that their prices do not change much around its mean. Sorghum, maize (yellow and white), and wheat show a negative excess kurtosis coefficient meaning that their distribution is thin trailed and that their prices are disperse from their mean.

2.3. Transmission of world prices to Mexican markets

The principal objective of this paper is to define if there is a pass-through from world prices to Mexican prices, and if there is, to measure the degree. In order to establish if there is a price transmission it is necessary to know the conditions under which world prices influence domestic markets. This material will be useful for interpreting the results retrieved from the analysis of price transmission.

Price transmission or the pass-through refers to the effect of prices in one market on prices in another market. It is measured using the transmission elasticity, defined as the percentage change in the price in one market given a 1% change in the price in another market. This paper focuses on the case of markets for the same commodity in two locations. When the markets are perfectly competitive: the product is homogeneous; traders are numerous and small so that none of them has market power; traders have perfect information; trading occurs instantly; there are no trade taxes or other policy barriers to trade, and there are no transportation or transaction costs (Minot 2012).

In this case, spatial arbitrage would ensure that the price of a commodity is the same in all markets. If the price in market A exceeded the price in market B, it would be lucrative to ship the product from market B to market A, until prices are equal again. Price transmission would be perfect if any price change in a market is quickly reflected in an equivalent change in other markets, the transmission elasticity would be 1.0. Actually, these assumptions do not often hold which reduces the pass-through from one market to another.

3. LITERATURE REVIEW

One of the most substantial questions in the field of price theory is to what degree, if so, changes in the international prices modify the prices in a domestic market. The price transmission represents, if markets are efficient and policies do not intervene, changes in the world price of any given commodity similarly reflected in changes in domestic prices (Keats et al. 2010). There is a great variety of studies trying to give a first glance of the effects on domestic markets caused by the changes in international prices (Enke 1951, Samuelson 1952, and Takayama and Judge 1971). Others like Abdulai (2000), Rashid (2004), Kuiper et al. (2003), Negassa and Meyers (2007), Van Campenhout (2007), Meyers (2008), and Moser et al. (2009) focused in emerging countries to examine the degree of price transmission between markets within a country.

According to the advances in the understanding of the implications of price transmission other models were developed with deeper implications. Mundlack and Larson (1992) had an early approach by estimating the transmission using simple correlation coefficients to measure the co-movement of prices. Ravallion (1986) and Timmer (1987) considering the criticism on assuming instantaneous responses in a market, due to changes in other markets, included lagged world prices as explanatory variables in their regression analysis. While in 1980s other researches became aware of the problem of non-stationarity (Granger and Newbold 1974, and Phillips 1987). Further, considering the problems described above, two non-stationary variables might be related to each other, by a long-term relationship, even if they diverge in the short-run. If two non-stationary variables move together in the long run, they are said to be co-integrated. In this case, the ECM is appropriate to deal with the problems of dynamic effects and non-stationarity (Engle and Granger 1987).

Precisely, there is literature that treats the food price transmission in the world markets. Keats et al. (2010) analyzed the rising of international cereal prices and domestic markets. They studied, given the 2007/08 crisis, how valid are the assumptions about price transmission from international to domestic markets. They state that the price transmission was uneven, but when the world cereal prices spiked in 2007-2008 there were corresponding rises on domestic markets across much of the developing world. While, Wiggings et al. (2010) tried to untangled what caused the food price spike of 2007-2008 also from the cereals market perspective. They state that the combination of multiple causes created an unusual event in which it is difficult to judge the weight of any given cause, were maize, rice and wheat responded differently to the factors.

The intentions of the government count, which is why the relation between price transmission and government objectives is important. Quiroz and Soto (1995) studied the extent to which international price movements of agricultural goods are transmitted to domestic prices. They state that a widespread intervention in local agricultural markets imply an increased international price instability, which in turn may induce governments to intervene with increasing trade distortion in order to isolate domestic prices from world market fluctuations. The way in which international price signals are allowed to affect (or not) domestic prices, might reveal some of the underlying objective of government intervention in agriculture. On the other hand, Mundlak and Larson (1992) showed that most of the variations in world agricultural prices are transmitted and they constitute the dominant component in the variations of domestic prices. Robles (2011) also examined the price transmission from international agricultural commodity markets to domestic food prices focusing on Asia and Latin American Countries. He established the extent to which the increases in international commodity prices are transmitted to domestic food prices has major implications for the poor and the overall welfare of developing nations.

Moreover, studies focused on the asymmetrical price transmission between markets. The price transmission process has rigidities that might result in an asymmetrical adjustment process. An example are Jalonja, Liu and Pietola (2006), they estimated the market integration between the Finish and German pork and beef markets with an econometric ECM that allows for threshold effects and asymmetric price response to be estimated. The threshold effects are significant and the price adjustment process is asymmetric, but slow in all regimes. De-Graft and Onumah (2010) worked with a comparison of two different approaches, retail and wholesale, to detect asymmetry in price transmission. They work out this problem by making a comparison of static and dynamic results, their results suggest that different methods of testing for asymmetry may lead to different conclusion given the same market data, but they do not answer if the asymmetric behavior exists in other agricultural markets.

Fiess and Lederman (2004) measure the price relation for maize in Mexico and the US; they found that prices in Mexico and the US are co-integrated. Other authors such as Araujo-Enciso (2008) and Motamed et al. (2008) have found that the estimated VECM are weak to assert for market integration, both focusing on testing whether US maize prices have an impact on the Mexican maize prices. And more recently, the analysis of Araujo (2009) approaches price transmission by establishing that it is a non-linear process. He tests whether US maize prices have an impact on the Mexican maize prices, and studies of this impact using time series econometric techniques. The model suggests that Mexican prices adjust at changes in US prices, there is strong evidence that maize market in Mexico and the US are integrated, and that prices share a common relationship.

Meyer and Von Cramon-Taubadel (2004) made a survey on studies about asymmetric price transmission because they noticed the problem of a wide variety of often conflicting theories and empirical tests for asymmetry. They mention that there is little progress toward a unified theory or set of testing procedures; proposing to new studies a comparison of results with those attained using older methods. Years after, Amikuzuno and Ogundari (2012) made a recount of the contribution of agricultural economics to the price transmission analysis. They emphasize the importance of the price transmission studies because of their application in assessing the impact of market reform policies. They made a meta-database obtained from 43 price transmission studies that estimated price transmission coefficient and identify asymmetric price transmission.

Cudjoe et al. (2008), with another type of investigation, considers the impact of price transmission on people´s welfare, by analyzing food´s price transmission from world markets to regional markets, in Ghana, and the impacts of local food price´s increases to households. They found that prices for domestic staples within all regional markets are highly correlated with imported rice price. Also, they show the importance of seasonality, in the determination of market integration, for the price transmission. While, Minot (2010) examined the impact of the global food crisis on sub-Saharan Africa countries by analyzing the degree to which changes in the international prices of staples foods are transmitted to their domestic markets and the impact of the households. The effects on African markets are usually swamped by the dominant effect of weather-related domestic supply shocks.

Through this paper we evaluate the possibility of a price transmission process from international prices to Mexican prices. With this, we try to establish the degree of transmission of a price change. This evidence will be the first in type for Mexico because there are few studies considering the recent crisis for the cereals markets. Therefore, the analysis employed in this empiric exercise extends the evidence for Mexico because it uses a statistical method with official international and domestic prices. In order to accomplish the above, we followed the methodology based on Minot (2010) whose specification is described below.

4. TIME SERIES ANALYSIS

The time series analysis is related with the dynamic effects of events over time (Hamilton 1994). When we are talking about time series, we refer to an empirical data sequence ordered in time. There are two kinds of time series data: stochastic, unpredictable because randomness elements are present, and deterministic, predictable. Nevertheless, most of the existent time series are stochastic by nature. Thus, in practice, the econometric theory studies this kind of data through models that include an error term (Montenegro 2001).

In order to develop this analysis and accomplish the objective of this work, mentioned above, we used prices of four grains (maize, rice, sorghum, and wheat) in domestic (Mexican) and international markets. These grains are from different origins and kinds. Prices from Mexico come from the National System of Information and Integration of Markets (SNIIM), and prices from international markets are from the international commodity prices database of the Food and Agriculture Organization of the United Nations (FAO). The database that we created is monthly and covers the 2005 - 2012 (August) periods. All prices are in 2008 US dollars per ton. In the international market case, prices are free on board (FOB), and grains are from different kinds and countries.

The Mexican maize is white and yellow, white maize is local, while yellow maize is both local and imported. Sorghum and wheat are local and imported, too. Rice is Morelos kind, and it is local. The international maize is Up River from Argentina, and yellow from US Gulf No. 2. Rice is white broken Thai A1 super, and white rice Thai 100% B second grade, both from Bangkok. Sorghum kind is yellow from US Gulf No. 2. Wheat is hard red winter, and soft red winter from US Gulf No. 2.

4.1. Cointegration analysis

A time series can be defined as a stochastic process in which each observation is a random variable. The underlying assumption of this process is called, stationarity, meaning that the series will tend to return to their mean. Nevertheless, most of the series in economics are not stationary; their mean will change over time. If the stationarity assumption is not fulfilled there are possibilities that the regression's results be spurious, i.e. invalid and meaningless (Granger and Newbold 1974). This is why before modeling and estimating the price transmission it is necessary to analyze if variables are stationary, or not.

A stochastic process is stationary if the joint and conditional probability distributions do not change over time i.e. the means and the variances of the process are constant over time, and the covariance between two periods depends only on the gap between the periods, not of the actual time in which it is considered (Charemza and Deadman 2003). The nonstationarity problem arises when a series has unit root. One well known model of a unit root series is the random walk, that is, if we have a stochastic process behaved as a random walk (Gujarati 2004):

$$Y_t = \rho Y_{t-1} + u_t \qquad -1 \leq \rho \leq 1$$

If $\rho = 1$ it has a unit root problem meaning, nonstationarity. However, if $|\rho| < 1$ it is a possible prove that the series is stationary.

One of the elementary steps in time series analysis is to show the behavior of the variables' observations over time through graphs. Before proceeding with the formal test, and in order to give us initial evidence about the nature of these time series, we show several graphs for prices in domestic and international markets for each grain and their respective graphs in logarithms (See Annex).

It is usual to prove, if the time series are stationary, through the Dickey-Fuller test, which proves the null hypothesis ($\delta = 0$) of the presence of unit root and therefore, if the series are nonstationary:

$$\Delta Y_t = \beta_0 + \beta_1 T + \delta Y_{t-1} + \varepsilon_t$$

Where β_0 is the drift, T is the time (or trend), $\delta = (\rho - 1)$, and Δ is the first difference operator. Nevertheless, this proof takes the assumption that the error term is not correlated, so this test is used when it does not matter if the error term is correlated. Due to this, we use the Augmented Dickey-Fuller (ADF) test, which is conducted increasing the lagged values of the dependent variable ΔY_t:

$$\Delta Y_t = \beta_0 + \beta_1 T + \delta Y_{t-1} + \sum_{i=1}^{m} \alpha_i \Delta Y_{t-i} + \varepsilon_t$$

Where ε_t is white noise (the error term), and $\Delta Y_{t-1} = (Y_{t-1} - Y_{t-2})$, $\Delta Y_{t-2} = (Y_{t-2} - Y_{t-3})$, etc. The number of lagged difference terms is determined according to the situation, and it includes enough lags so that the error term is serially uncorrelated (Gujarati 2004).

Results of the ADF test are shown in Table 3, where the presence of unit root in all series is evident, the null hypothesis is not rejected so, the series are not stationary. To correct the nonstationarity it is necessary to obtain the first differences of the series, to avoid the unit root problem, and finally, have a stationary series:

$$\Delta Y_t = (Y_t - Y_{t-1})$$

Once we obtain the first differences, the series are tested again through the ADF test. This time, the results show that the null hypothesis of unit root presence is rejected so, the series are stationary (Table 4). Thus, the series are integrated of order one, denoted as $I(1)$. This is because when a nonstationary series has to be differenced d times to make it stationary, that series is called integrated of order d, denoted as $Y_t \sim I(d)$ (Gujarati 2004).

We express the model of price transmission as:

$$DP_t = \beta_0 + \beta_1 IP_t + u$$

Where DP_t is the domestic price, IP_t is the international price, and u is the error term. In this case, both series are $I(1)$, which means series have a unit root and are nonstationary. But, we cannot estimate this model because according to Granger and Newbold (1974), the regression of one nonstationary variable over another one cause a spurious regression. However, if we re-express the above model as:

$$u_t = DP_t - \beta_0 - \beta_1 IP_t$$

Where $u_t \sim I(0)$ is the linear combination that represents the joint movement of the variables in long run. As result, the linear combination cancels out the stochastic trends in the two series. In consequence, the variables are cointegrated because there is a long run, or equilibrium relation among them, and the residuals are stationary (Engle and Granger 1987).

Table 3. Unit root test (ADF)

Variable	z(t)	Critical values			p - value*
		1%	5%	10%	
Domestic					
Yellow maize	-2.738	-4.066	-3.462	-3.157	0.2205
White maize	-2.563	-4.066	-3.462	-3.157	0.2973
Sorghum	-3.65	-4.066	-3.462	-3.157	0.0258
Rice	-2.957	-4.066	-3.462	-3.157	0.1444
Wheat	-2.332	-4.066	-3.462	-3.157	0.4165
International					
Yellow maize (US)	-2.652	-4.066	-3.462	-3.157	0.2566
Up River maize (Argentina)	-2.752	-4.066	-3.462	-3.157	0.215
Yellow sorghum (US)	-2.532	-4.066	-3.462	-3.157	0.3121
White broken rice (Thailand)	-2.904	-4.066	-3.462	-3.157	0.161
White rice (Thailand)	-2.245	-4.066	-3.462	-3.157	0.4646
Hard red winter wheat (US)	-2.182	-4.066	-3.462	-3.157	0.4999
Soft red winter wheat (US)	-2.144	-4.066	-3.462	-3.157	0.5212

Note: Mackinnon approximate p-value for z(t).

Table 4. Unit root test (ADF) for variables in first differences

Variable	z(t)	Critical values			p - value*
		1%	5%	10%	
Domestic					
Yellow maize	-4.328	-3.528	-2.9	-2.585	0.0004
White maize	-3.881	-3.528	-2.9	-2.585	0.0022
Sorghum	-4.639	-3.528	-2.9	-2.585	0.0001
Rice	-4.126	-3.528	-2.9	-2.585	0.0009
Wheat	-4.77	-3.528	-2.9	-2.585	0.0001
International					
Yellow maize (US)	-3.637	-3.528	-2.9	-2.585	0.0051
Up River maize (Argentina)	-4.651	-3.528	-2.9	-2.585	0.0001
Yellow sorghum (US)	-4.317	-3.528	-2.9	-2.585	0.0004
White broken rice (Thailand)	-4.413	-3.528	-2.9	-2.585	0.0003
White rice	-4.754	-3.528	-2.9	-2.585	0.0001
Hard red winter wheat (US)	-4.164	-3.528	-2.9	-2.585	0.0008
Soft red winter wheat (US)	-4.347	-3.528	-2.9	-2.585	0.0004

Note: Mackinnon approximate p-value for z(t).

Source: Own calculations.

As Charemza and Deadman (2003) suggest, we can intuit a linear combination (cointegration) of variables watching the variables' graphs (see Annex) but, it is necessary to prove if the residuals (u_t) are stationary or not. Thus, to prove the presence of cointegration in each series, and for each type of grain, we follow the Engle and Granger (1987) two-step procedure which consists in:

1. It is necessary to determine the order of integration of the variables.[4]

1.1. As the variables are integrated of same order, we can continue with the long run relationship estimation through ordinary least squares (OLS). Results of the price transmission model estimation show possible evidence of a spurious regression because the parameters are significant and the value of the adjusted r-squared is high (Table 5).

2. Then, we must prove that each regression residuals are stationary [$u_t \sim I(0)$] which was done through the ADF test. Results show that almost all the variables are cointegrated, except the relation between Mexican rice and white broken rice from Thailand, where there is not long-term relationship, i.e. variables are not cointegrated (Table 6).

2.1. Once we know which variables are cointegrated, it is possible to use the equilibrium regressions residuals to estimate the error correction model (ECM), and analyze the short and long run effects of the variables.

[4] This step has already conducted and the results have already been discussed.

According to Engle and Granger (1987), an error correction mechanism helps to avoid the issues of a spurious regression. This mechanism introduces long run imbalances that exist between variables, therefore, it includes one lag in the imbalances, which are introduced in the model as exogenous variables, tying the short run behavior with its long run value:

$$\Delta DP_t = \alpha_0 + \alpha_1 \Delta IP_t + \alpha_2 u_{t-1} + \varepsilon_t$$

Where Δ is the first difference operator, ε_t is the error term, and $u_{t-1} = DP_{t-1} - \beta_0 - \beta_1 IP_{t-1}$, is a one period lagged value of the residuals of the cointegration regression. In this case, the domestic prices (*DP*) depend on the international prices (*IP*), and on the equilibrium or error term (u_{t-1}) whose value, if different of zero, indicates that the model is not in equilibrium. If *DP* is above its equilibrium value, in the next period it begins to decline in order to correct the error in the equilibrium and vice versa. Therefore, $|\alpha_2|$ determines the rate at which equilibrium is restored.

Table 5. Results of the long run relationship (OLS)

Variable	Coefficient	z	Adjusted R^2	Prob > F	No. Observations
Yellow maize (Mexico)					
Yellow maize (US)	0.7380	35.32	0.9320	0.0000	92
Constant	1.6893	15.58			
Yellow maize (Mexico)					
Up River maize (Argentina)	0.7019	24.96	0.8724	0.0000	92
Constant	1.8929	13.03			
White maize (Mexico)					
Yellow maize (US)	0.5668	21.68	0.8376	0.0000	92
Constant	2.8216	20.8			
White maize (Mexico)					
Up River maize (Argentina)	0.5451	19.22	0.8019	0.0000	92
Constant	2.9467	20.11			
Rice (Mexico)					
White broken rice (Thailand)	0.3243	9.42	0.4910	0.0000	92
Constant	4.9318	24.52			
Rice (Mexico)					
White rice (Thailand)	0.4159	16.19	0.7415	0.0000	92
Constant	4.2722	27.07			
Sorghum (Mexico)					
Yellow sorghum (US)	0.7661	18.5	0.7894	0.0000	92
Constant	1.3930	6.49			
Wheat (Mexico)					
Hard red winter wheat (US)	0.7766	18.79	0.7947	0.0000	92
Constant	1.4079	6.16			
Wheat (Mexico)					
Soft red winter wheat (US)	0.7163	17.01	0.7602	0.0000	92
Constant	1.8613	8.24			

Source: Own calculations.

Table 6. Unit root test (ADF) for residuals

Variable	z(t)	Critical values			p - value*
		1%	5%	10%	
Residuals 1	-4.9830	-3.5230	-2.8970	-2.5840	0.0000
Residuals 2	-3.6660	-3.5230	-2.8970	-2.5840	0.0046
Residuals 3	-3.1260	-3.5230	-2.8970	-2.5840	0.0247
Residuals 4	-2.9590	-3.5230	-2.8970	-2.5840	0.0389
Residuals 5	-1.9920	-3.5230	-2.8970	-2.5840	0.2902
Residuals 6	-3.0920	-3.5230	-2.8970	-2.5840	0.0271
Residuals 7	-2.9960	-3.5230	-2.8970	-2.5840	0.0352
Residuals 8	-4.5970	-3.5230	-2.8970	-2.5840	0.0001
Residuals 9	-4.3300	-3.5230	-2.8970	-2.5840	0.0004

Note: Mackinnon approximate p-value for z(t).

Source: Own calculations.

Results of the ECM estimation through OLS show that the equilibrium mechanisms are different from zero, negative, and significant in all grain kinds thus, markets are not in equilibrium. Also, in all cases, β_2 presents the expected results ($-1 < \beta_2 < 0$), and β_1 shows that there are positive effects of international prices in the domestic prices for almost all grains in the short run. Only in white maize the short run effect is not significant. The yellow maize is the grain whose deviation from the equilibrium will be corrected faster because of a greater absolute value of β_2, at 45.2% per month, followed by both kinds of wheat, soft and hard red winter, at 40.2% and 38.5% per month, respectively. Contrary to the yellow maize, the white kind will return to the equilibrium slowly at around 18.9% per month. Similarly, the international prices affect more to the yellow maize and wheat (hard red winter kind) in the short run because of a greater value of β_1 (Table 7).

Additional to the OLS method, there is another commonly used approach in time series analysis; the vector autoregression (VAR). The VAR is used to model situations where relationships are described by systems of equations. In this model K variables are specified as linear functions of p of their own lags; p lags of the order K - 1 variables, and with the possibility to add exogenous variables.

$$y_t = v + A_1 y_{t-1} + A_2 y_{t-2} + \dots + A_p y_{t-p} + \epsilon_t$$

Where y_t is a K x 1 vector of variables, v is a K x 1 vector of parameters, A_1-A_p are K x K matrices of parameters, and ϵ_t is the error term.

However, as in OLS, if the time series are cointegrated by a common factor (are not stationary) it is not possible to use the standard approach. It is necessary to consider this relation, and to introduce the error correction mechanism in order to obtain proper results i.e. not spurious. In this way, the vector error correction (VEC) model which is, a special VAR case, can be rewritten as:

[illegible]

Where □ is the difference operator (□y_t = y_t - y_{t-1}), v is the vector of parameters that describe the trend factor, □ is an K x 1 matrix of parameters that describe the long run relationship and the error correction adjustment(□ □ ∑ □ □ □), □ is the is a set of K x K matrices of parameters that describe the short run relationship between variables (□ □ □ ∑ □), and □$_t$ is a K x 1 vector of error terms.

Table 7. Results of the error corretcion model (OLS)

Variable	Coefficient	z	Adjusted R^2	Prob > F	No. Observations
□*Yellow maize (Mexico)*					
□Yellow maize (US)	0.3311	4.770	0.4000	0.0000	91
Resid$_{(t-1)}$	-0.4522	-6.070			
□Yellow maize (Mexico)					
□Up River maize (Argentina)	0.2913	3.920	0.2671	0.0000	91
Resid$_{(t-1)}$	-0.2607	-4.330			
□White maize (Mexico)					
□Yellow maize (US)	0.1539	2.560	0.2020	0.0000	91
Resid$_{(t-1)}$	-0.2141	-4.150			
□White maize (Mexico)					
□Up River maize (Argentina)	0.1110	1.870	0.1638	0.0000	91
Resid$_{(t-1)}$	-0.1890	-3.960			
□Rice (Mexico)					
□White rice (Thailand)	0.2132	3.310	0.1899	0.0000	91
Resid$_{(t-1)}$	-0.2024	-3.360			
□Sorghum (Mexico)					
□Yellow sorghum (US)	0.2617	3.440	0.3287	0.0000	91
Resid$_{(t-1)}$	-0.2561	-4.980			
□Wheat (Mexico)					
□Hard red winter wheat (US)	0.3332	3.470	0.2916	0.0000	91
Resid$_{(t-1)}$	-0.3851	-5.150			
□Wheat (Mexico)					
□Soft red winter wheat (US)	0.2183	2.530	0.3349	0.0000	91
Resid$_{(t-1)}$	-0.4017	-5.910			

Source: Own calculations.

Engle and Granger (1987) showed that if the y_t variables are $I(1)$, the matrix □ has rank $0 \leq r < K$ where r is the number of linearly independent cointegrating vectors. So, if the variables cointegrate, a VAR in first differences is misspecified because it omits the lagged term □y_{t-1}. In contrast with the Engle and Granger (1987) two-step estimation procedure in OLS, the estimation is based in the maximum likelihood framework developed by Johansen (1988). The maximum likelihood estimators elude the use of two-step estimators, avoiding the possibility of introducing errors from the first to the second step, also they can estimate and test for the presence of multiple cointegrating vectors.

In this way, if a set of variables are found to have one or more cointegrating vectors, the VECM is an appropriate model to estimate both short and long run relations, and the equilibrium condition. Thus, this model tests the effects among variables, in this case, the effect of international prices on domestic prices, and vice versa.

The model that we estimate can be simplified as follows:

[illegible]

Where DP_t is the logarithm of domestic prices, IP_t is the logarithm of international prices of the same commodity, and [illegible] is the difference operator, v is an estimated parameter, [illegible] is the error correction coefficient, and represents the speed of adjustment, [illegible] is the cointegration factor and represents the long run relation (elasticity) of the domestic prices with respect to the international prices, [illegible] is the short run relation (elasticity) if the domestic prices relative to the international prices, and [illegible] is the autoregressive term that reflects the effect of changes in the domestic prices on the changes of the domestic prices in the next period. Finally, [illegible]$_t$ is the error term.

We look for the presence of unit roots in the series through the Johansen (1988) test which is a multivariate generalization of the ADF test. Results show presence of unit roots in the relation between domestic and international prices, for almost all types of grains except between rice and white broken rice, from Mexico and Thailand, respectively (Table 8). Thus, once we know that variables are cointegrated, we can proceed to estimate the short and long run relationships, as well as the equilibrium conditions.

Table 8. Johansen test of cointegrating vectors

Variables	Rank	Trace	Critical value (5%)
Yellow maize (Mexico) Yellow maize (US)	1	2.8446	3.76
Yellow maize (Mexico) Up river maize (Argentina)	1	2.1417	3.76
White maize (Mexico) Yellow maize (US)	1	1.9855	3.76
White maize (Mexico) Up river maize (Argentina)	1	2.2349	3.76
Rice (Mexico) White rice (Thailand)	1	4.7912	6.65*
Sorghum (Mexico) Yellow sorghum (US)	1	3.0603	3.76
Wheat (Mexico) Hard red winter wheat (US)	1	2.4904	3.76
Wheat (Mexico) Soft red winter (US)	1	2.6173	3.76

Note: *Critical value at 1%.

Source: Own calculations.

In general, results from the VECM estimation show that both parameters, speed of adjustment and long run relation, in the cointegration equation, are significant for all grains. The long run elasticity of the price transmission from international to domestic prices for all grains show that changes in the international prices will be transmitted, in the long term, to the domestic prices. The rice presents the smallest price transmission effect (43.5%) opposite to the sorghum which presents the greatest effect (88.6%). The rest of the grains indicate a high price transmission effect, since most of them display elasticities in a range of 60 to 80%. On the other hand, the speed of adjustment parameters present low values which seem a slow adjustment of the deviations from the equilibrium. The relation between prices of white maize (Mexico), and of up river maize (Argentina) presents the lowest adjustment with 18.8%; and the faster adjustment is presented by the relation between prices of yellow maize (from Mexico, and US) with 47.9%. The rest of the parameters are in a range of 20 to 40%. In contrast, the short run relation and the autoregressive term are not statistically significant, in almost all cases. Only for the rice both parameters are significant; and the autoregressive parameter is significant just for the maize (white from Mexico and yellow from US). So, changes in international prices do not affect the domestic prices in the short run (Table 9).

Table 9. Vector error correction model results

Variables	Speed of adjustment (□)	Long-run relation(□)	Short-run relation (□)	Autoregressive (□)
Yellow maize (Mexico)	-0.4789	-0.7680		
Yellow maize (US)	*(-4.82)*	*(-22.68)*		
Yellow maize (Mexico)	-0.2541	-0.7716		
Up river maize (Argentina)	*(-4.05)*	*(-12.49)*		
White maize (Mexico)	-0.2399	-0.5932		0.3905
Yellow maize (US)	*(-4.46)*	*(-11.43)*		*(-4.16)*
White maize (Mexico)	-0.1878	-0.6126		
Up river maize (Argentina)	*(-4.01)*	*(-8.98)*		
Rice (Mexico)	-0.2175	-0.4348	0.1508	0.3708
White rice (Thailand)	*(-3.69)*	*(-7.71)*	*(-2.28)*	*(-3.84)*
Sorghum (Mexico)	-0.3112	-0.8864		
Yellow sorghum (US)	*(-5.28)*	*(-12.77)*		
Wheat (Mexico)	-0.3834	-0.8205		
Hard red winter wheat (US)	*(-4.86)*	*(-10.76)*		
Wheat (Mexico)	-0.4285	-0.7746		
Soft red winter (US)	*(-6.29)*	*(-11.96)*		

Note: z statistics in parenthesis (significant at 5%).

Source: Own calculations.

4.2. Causality

Other kind of analysis, proper when working with time series is the Granger causality, in order to know if variables cause one another, and if so in which direction, meaning if there is a feedback between them. In order to determine the causality direction between two related variables we use the causality test developed by Granger (1969). This test estimates the bivariate regression:

$$□_□ □ \sum_{□□□}^{□} □_□ □_{□□□} □ \sum_{□□□}^{□} □_□ □_{□□□} □ □_□$$

$$□_□ □ \sum_{□□□}^{□} □_□ □_{□□□} □ \sum_{□□□}^{□} □_□ □_{□□□} □ □_□$$

Where $□_t$ and $□_t$ are white noise, while the definition of causality given by equations implies that x_t is causing y_t if a_j is not zero. Similarly, y_t is causing x_t if d_j is not zero. Although, if both phenomena occur, we can say there is a feedback relation between variables.

Before the causality relations through the Granger (1969) procedure, we plot some scatter plots by type of grains in order to understand the relation between them (See annex). They show there is a positive linear relationship between domestic and international prices for each type of grain. Afterwards, we estimate the following bivariate regressions for all possible pairs of (x, y) series in the group i.e. each kind of grain:

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \cdots + \alpha_l y_{t-l} + \beta_1 x_{t-1} + \cdots + \beta_l x_{t-l} + \epsilon_t$$
$$x_t = \alpha_0 + \alpha_1 x_{t-1} + \cdots + \alpha_l x_{t-l} + \beta_1 y_{t-1} + \cdots + \beta_l y_{t-l} + u_t$$

And test the null hypothesis that x does not cause y, and y does not cause x through the joint hypothesis:

$$\beta_1 = \beta_2 = \cdots = \beta_l = 0$$

Results indicate that the Granger causality is bidirectional in half of the cases: yellow maize (from Mexico and US); yellow maize (Mexico) and up river maize (Argentina); white and yellow maize (Mexico and US, respectively); and sorghum (Mexico and US). In the other cases, the null hypothesis which states that domestic prices do not cause international prices cannot be rejected. In this sense, the direction of price transmission is from international to domestic, for: white maize (from Mexico) and up river maize (from Argentina); rice (Mexico and Thailand); wheat (Mexico) and hard red winter wheat (US); and wheat (Mexico), and soft red winter wheat (US) (Table 10).

Nevertheless, these results could be spurious due to the series nonstationarity. In this sense, it is necessary to decompose the series into trend, seasonal, cyclical, and irregular components. According to the unobservable components hypothesis, a time series is the result of the combination of an inertial movement that represents the long-run behavior, the regular periodic movements, a seasonal component derivative of economic or other phenomena, and random or stochastic elements:

$$y_t = \mu_t + \gamma_t + \psi_t + r_t + \sum_{i=1}^{p} \phi_i y_{t-i} + \sum_{j=1}^{m} \beta_j x_{jt} + \epsilon_t$$

Where y_t represents the series to be model with the respective autoregressive and explanatory regression terms. The μ_t, γ_t, and ψ_t are the trend, seasonal, and cyclical components, respectively, r_t is an autoregressive component, and ϵ_t is the irregular component, and all are assumed unobservable.

Thereby, before we estimate the Granger causality test, it is necessary to decompose the series. Usually this is done by using filters, there are diverse procedures, but the best and the most used is the Hodrick-Prescott (1997) filter. This filter assumes that the time series y_t is the sum of a growth component g_t, and a cyclical component c_t, i.e. $y_t = g_t + c_t$ for $t = 1, \ldots, T$. So, in this way, the filter separates the components, removing the trend from the series by solving the minimization problem:

$$\min_{\{\tau_t\}_{t=1}^{T}} \left\{ \sum_{t=1}^{T} (y_t - \tau_t)^2 + \lambda \sum_{t=2}^{T-1} [(\tau_{t+1} - \tau_t) - (\tau_t - \tau_{t-1})]^2 \right\}$$

The parameter λ is a positive number (predetermined) that penalizes variability in the growth component so the larger value of λ causes a smoother fluctuation.

Table 10. Granger causality test (OLS)

Y variable	X variable	Null hypothesis	Prob > F
Yellow maize (Mexico)	Yellow maize (US)	International prices does not cause domestic prices	0.0000
Yellow maize (US)	Yellow maize (Mexico)	Domestic prices does not cause international prices	0.0055
Yellow maize (Mexico)	Up River maize (Argentina)	International prices does not cause domestic prices	0.0031
Up River maize (Argentina)	Yellow maize (Mexico)	Domestic prices does not cause international prices	0.0185
White maize (Mexico)	Yellow maize (US)	International prices does not cause domestic prices	0.0007
Yellow maize (US)	White maize (Mexico)	Domestic prices does not cause international prices	0.0782
White maize (Mexico)	Up River maize (Argentina)	International prices does not cause domestic prices	0.0012
Up River maize (Argentina)	White maize (Mexico)	Domestic prices does not cause international prices	0.1894
Rice (Mexico)	White rice (Thailand)	International prices does not cause domestic prices	0.0001
White rice (Thailand)	Rice (Mexico)	Domestic prices does not cause international prices	0.7797
Sorghum (Mexico)	Yellow sorghum (US)	International prices does not cause domestic prices	0.0000
Yellow sorghum (US)	Sorghum (Mexico)	Domestic prices does not cause international prices	0.0000
Wheat (Mexico)	Hard red winter wheat (US)	International prices does not cause domestic prices	0.0001
Hard red winter wheat (US)	Wheat (Mexico)	Domestic prices does not cause international prices	0.6508
Wheat (Mexico)	Soft red winter (US)	International prices does not cause domestic prices	0.0000
Soft red winter (US)	Wheat (Mexico)	Domestic prices does not cause international prices	0.7666

Source: Own calculations.

Once the series were filtered, we estimate again the Granger causality test, but using only the cycles' series. Results are very similar to the mentioned above. The only difference, in this case, is that the white maize (from Mexico), and the up river maize (from Argentina) present bidirectional causality. Here, five cases have a bidirectional causality relation, and three have a causal relation of price transmission, from international to domestic (Table 11). In conclusion, taking into account both results, with and without filtering, we can say that in most of the cases there is a price transmission from international to domestic ones, and vice versa. This could indicate the Mexican market, in the selected grains, has an important role in the international prices, and it also could explain the aforementioned cointegrating relationship.

Table 11. Granger causality test (OLS) using the Hodrick - Prescott filter

Y variable	X variable	Null hypothesis	Prob > F
Yellow maize (Mexico)	Yellow maize (US)	International prices does not cause domestic prices	0.0000
Yellow maize (US)	Yellow maize (Mexico)	Domestic prices does not cause international prices	0.0005
Yellow maize (Mexico)	Up River maize (Argentina)	International prices does not cause domestic prices	0.002
Up River maize (Argentina)	Yellow maize (Mexico)	Domestic prices does not cause international prices	0.0022
White maize (Mexico)	Yellow maize (US)	International prices does not cause domestic prices	0.0006
Yellow maize (US)	White maize (Mexico)	Domestic prices does not cause international prices	0.0336
White maize (Mexico)	Up River maize (Argentina)	International prices does not cause domestic prices	0.0007
Up River maize (Argentina)	White maize (Mexico)	Domestic prices does not cause international prices	0.0457
Rice (Mexico)	White rice (Thailand)	International prices does not cause domestic prices	0.0000
White rice (Thailand)	Rice (Mexico)	Domestic prices does not cause international prices	0.1152
Sorghum (Mexico)	Yellow sorghum (US)	International prices does not cause domestic prices	0.0000
Yellow sorghum (US)	Sorghum (Mexico)	Domestic prices does not cause international prices	0.0113
Wheat (Mexico)	Hard red winter wheat (US)	International prices does not cause domestic prices	0.0000
Hard red winter wheat (US)	Wheat (Mexico)	Domestic prices does not cause international prices	0.7373
Wheat (Mexico)	Soft red winter (US)	International prices does not cause domestic prices	0.0000
Soft red winter (US)	Wheat (Mexico)	Domestic prices does not cause international prices	0.3861

Note: This test was just performed to the variable cycles obtained through the Hodrick - Prescott filter.

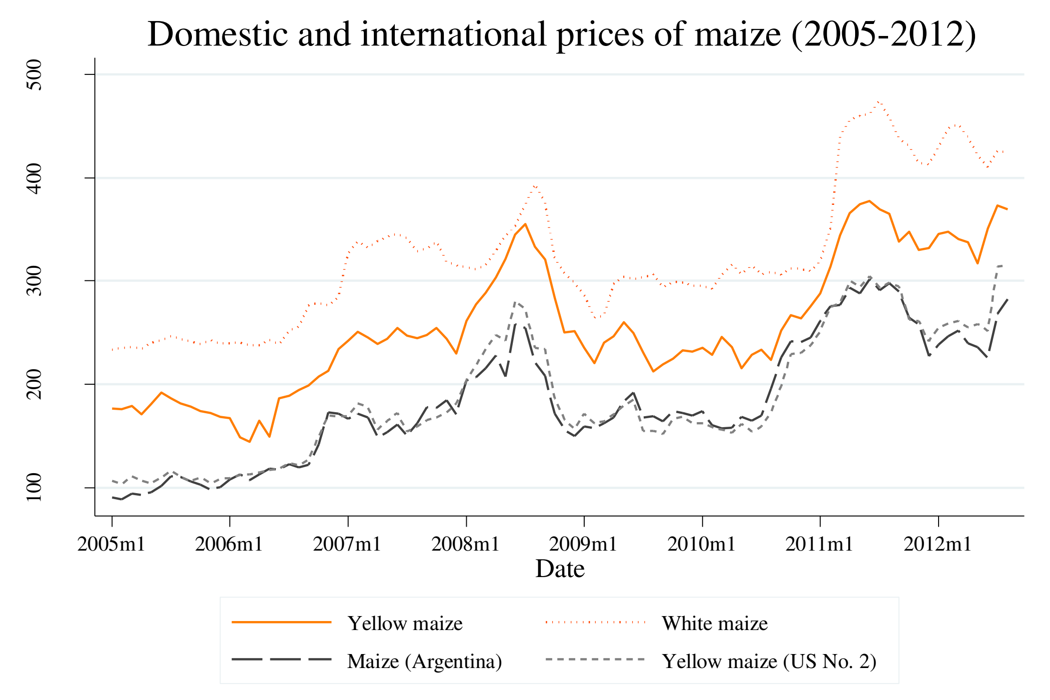
Source: Own calculations.

5. CONCLUSIONS

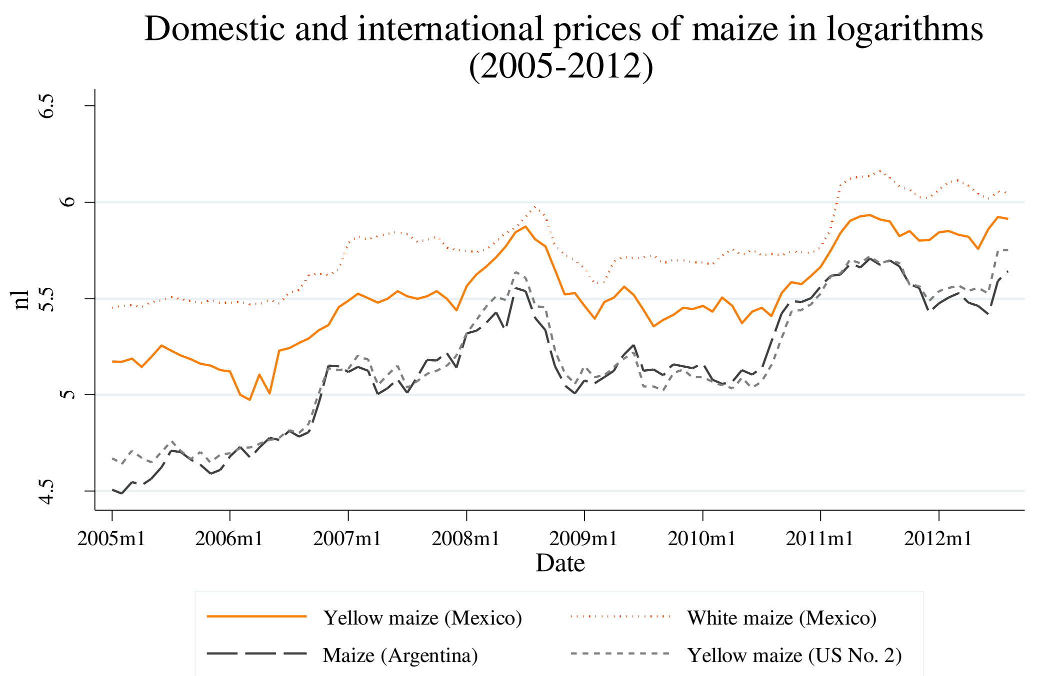
In summary, the questions we previously raised were solved, for the markets of selected Mexican grains: do changes in international prices move together with prices in a domestic market, and if so, to what degree? We showed that changes in the international prices will affect the domestic prices, in the long run, but to what degree will depend on the type of the cereal. The smallest price transmission effect is on rice, and the greatest on sorghum. The latter case could be supported by the important position the Mexican sorghum has on the world's production. On the other hand, the speed of adjustment reveals the stretch relationship between the Mexican and US as the price transmission of their yellow maize has the fastest adjustment. In contrast, the short run relation and the autoregressive term are not statistically significant, in most of the cases, indicating that changes in international prices do not affect domestic prices in the short run. Additionally, through the Granger causality test we can establish, in most cases, there is a price transmission from international to domestic, and vice versa.

6. ANNEX

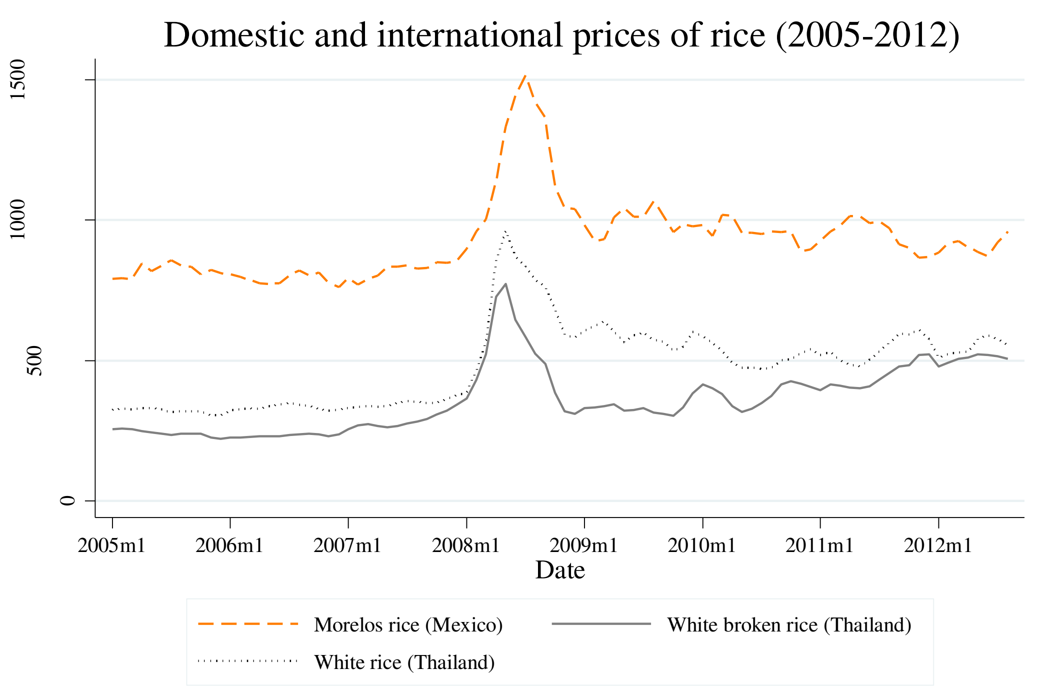
6.1 Prices in domestic and international markets by type of grain



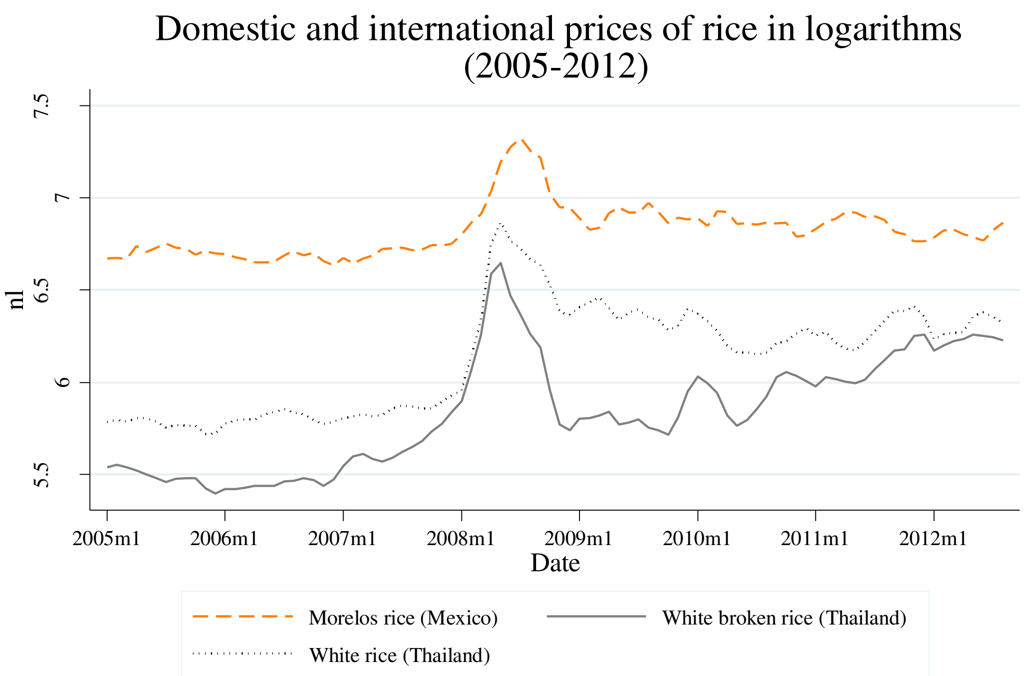
Source: SNIIM and FAO (2012)



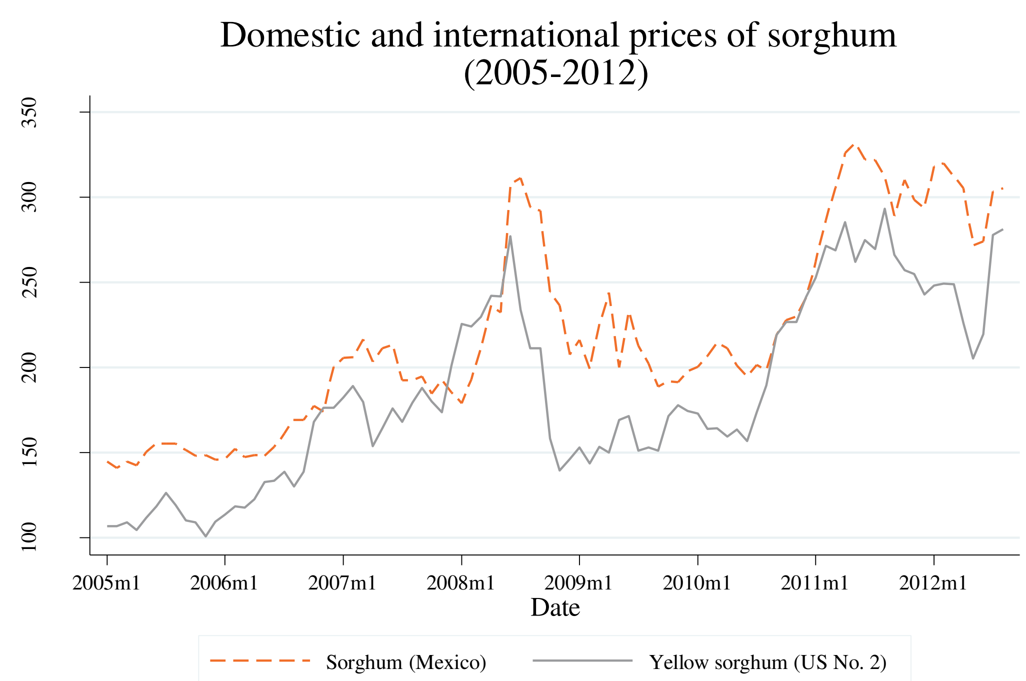
Source: Own calculations based on SNIIM and FAO (2012)



Source: SNIIM and FAO (2012)

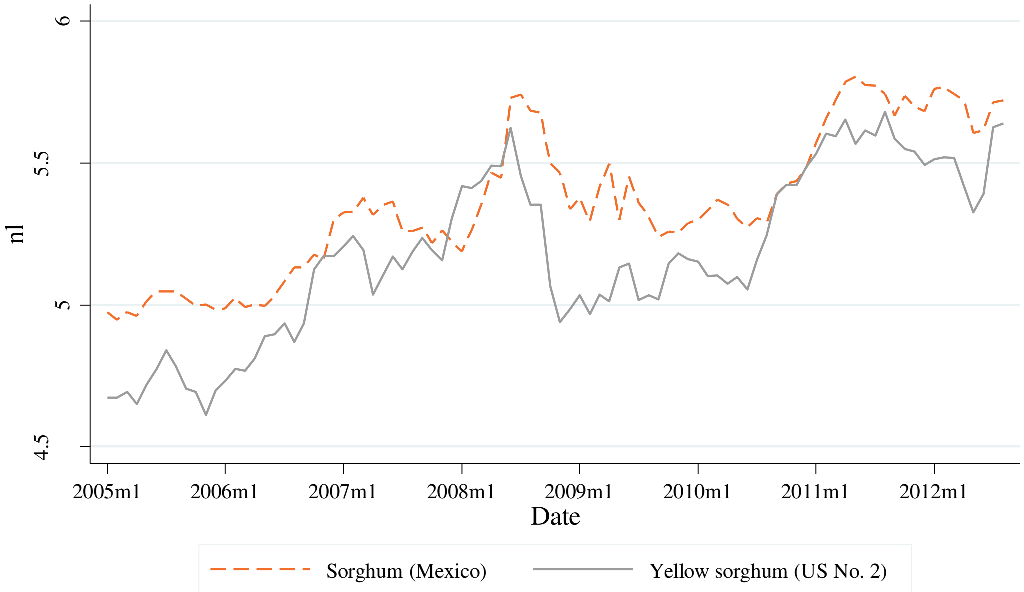


Source: Own calculations based on SNIIM and FAO (2012)



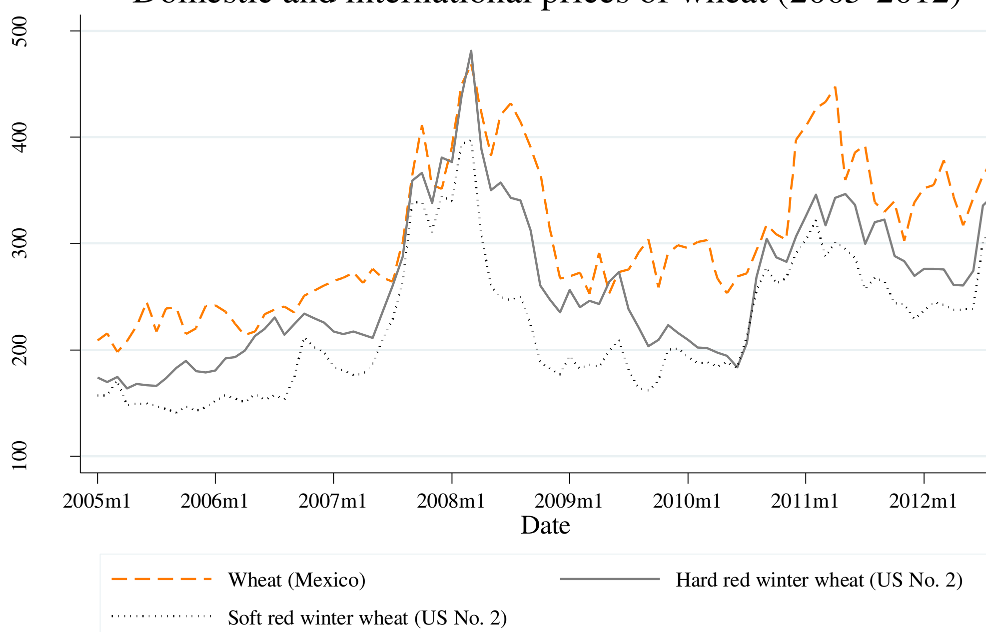
Source: SNIIM and FAO (2012)

Domestic and international prices of sorghum in logarithms (2005-2012)

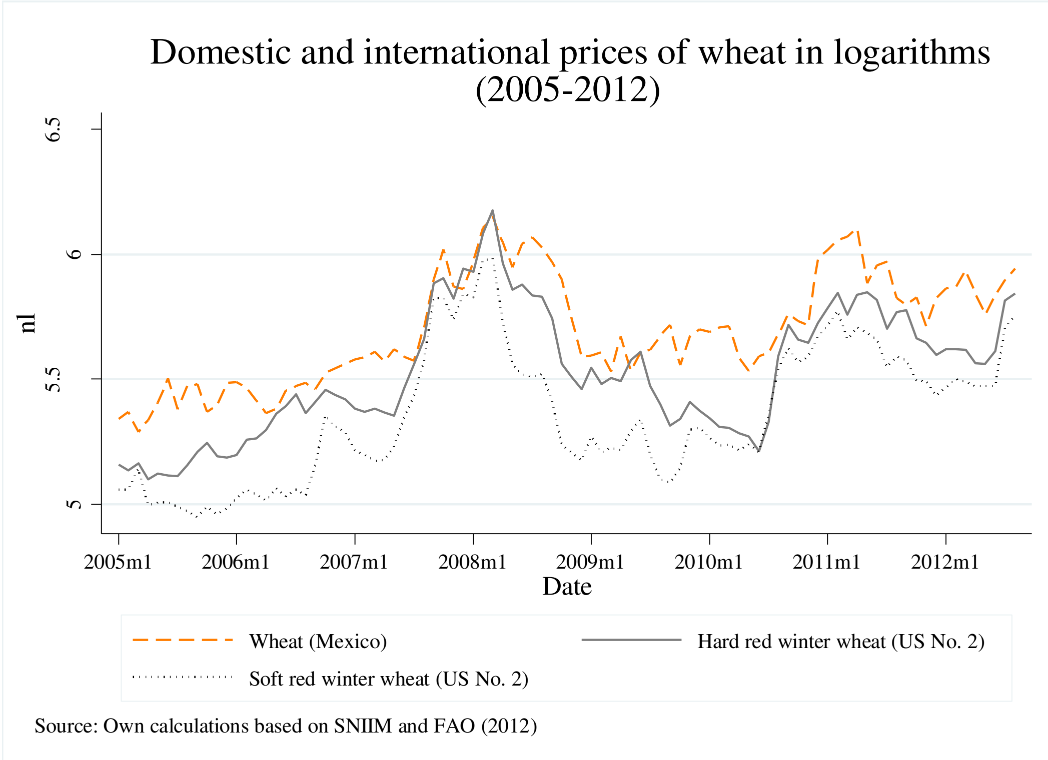


Source: Own calculations based on SNIIM and FAO (2012)

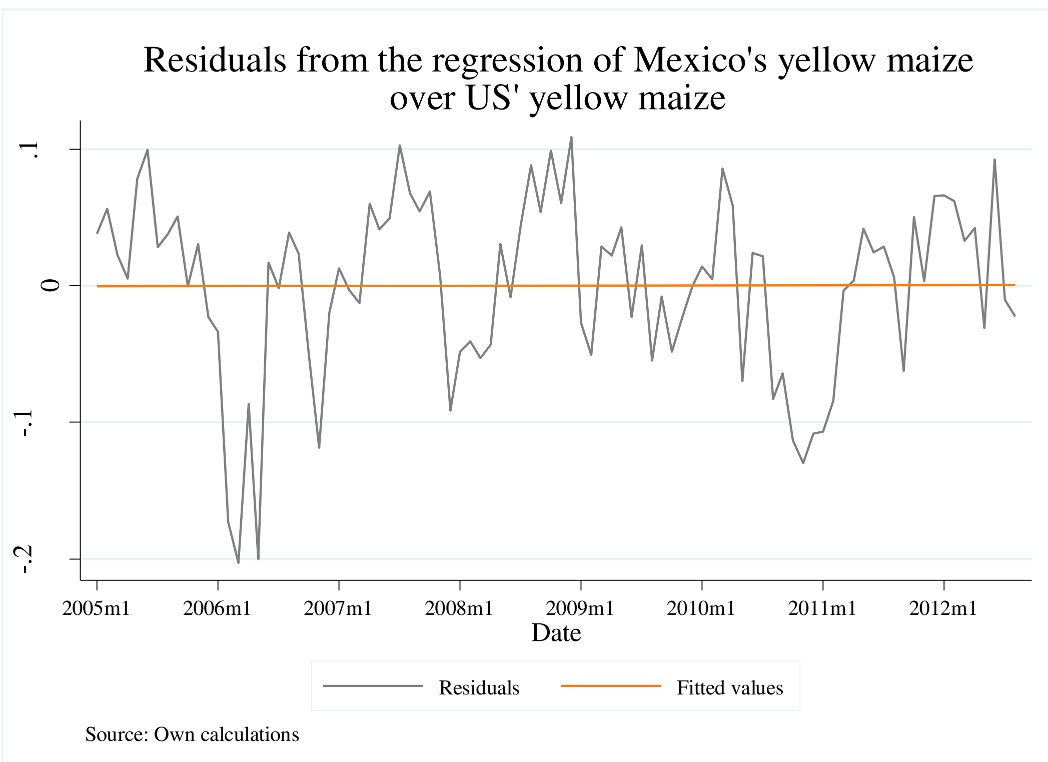
Domestic and international prices of wheat (2005-2012)

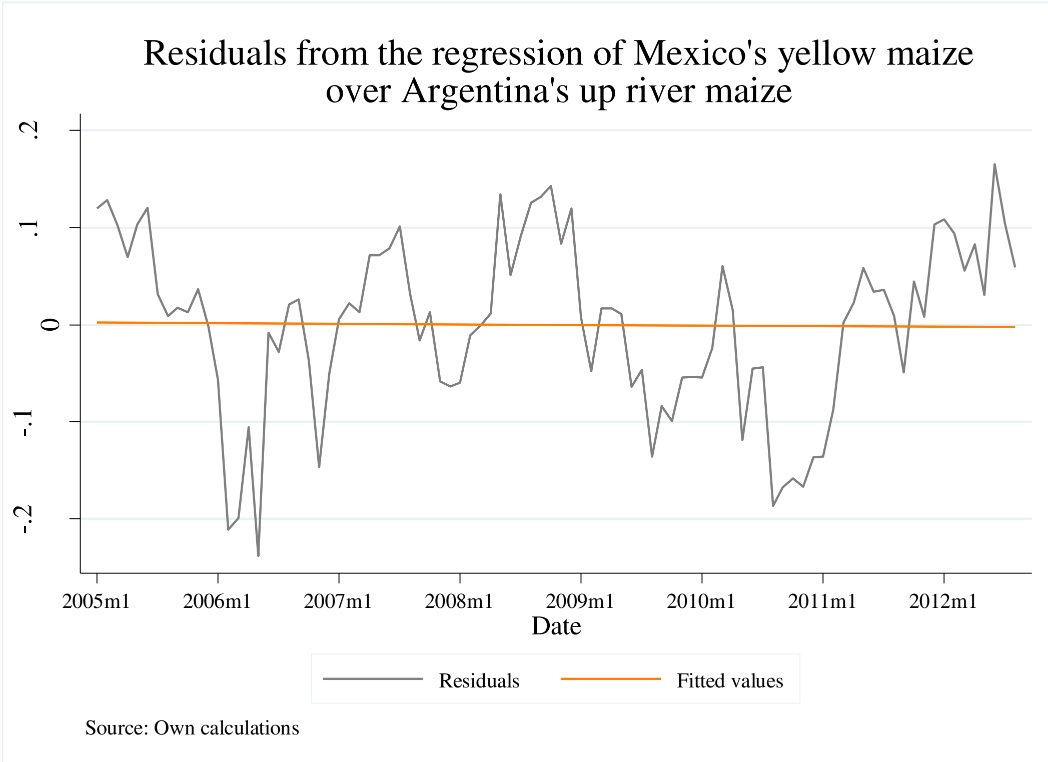


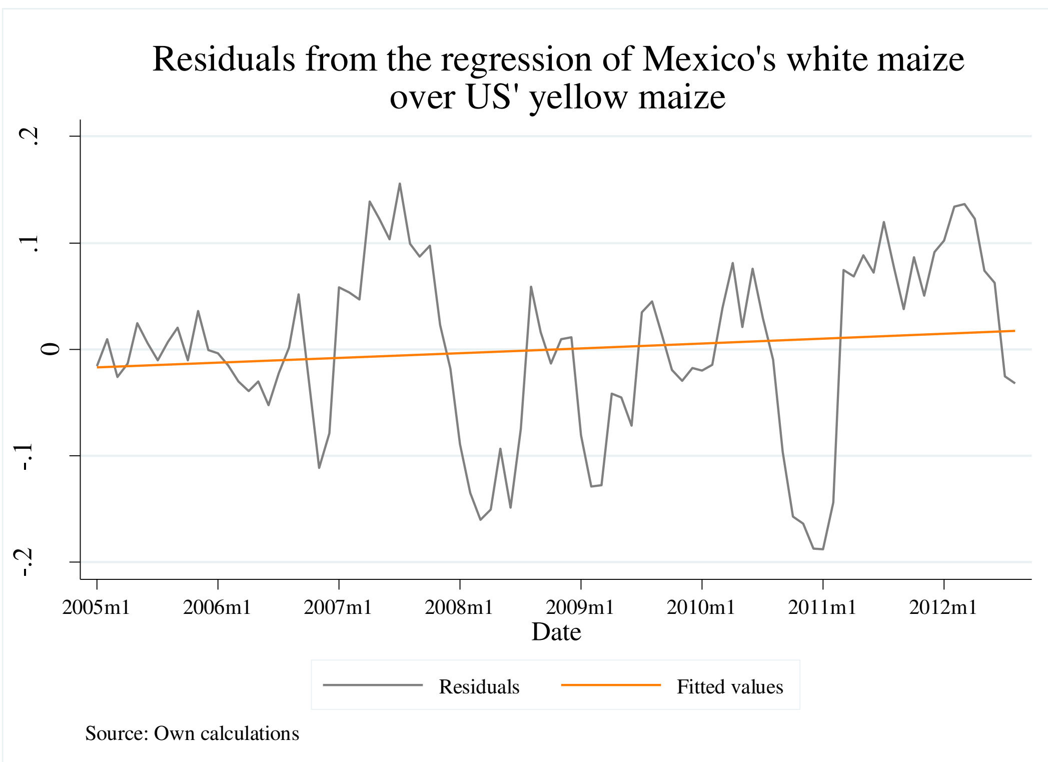
Source: SNIIM and FAO (2012)

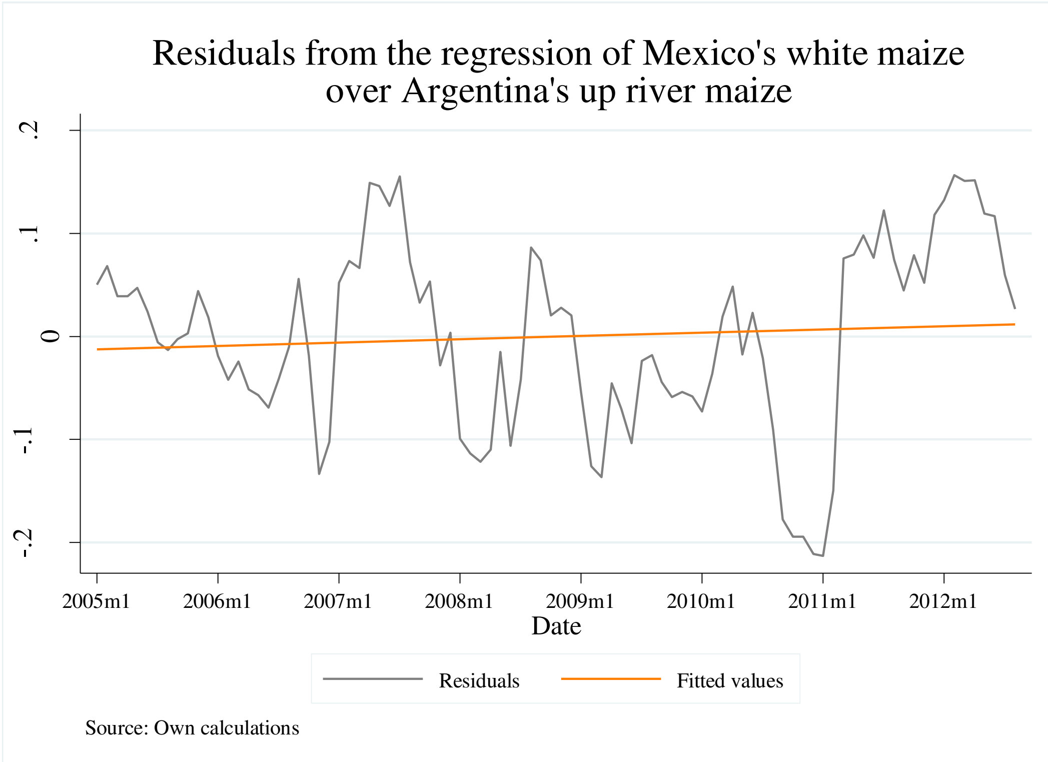


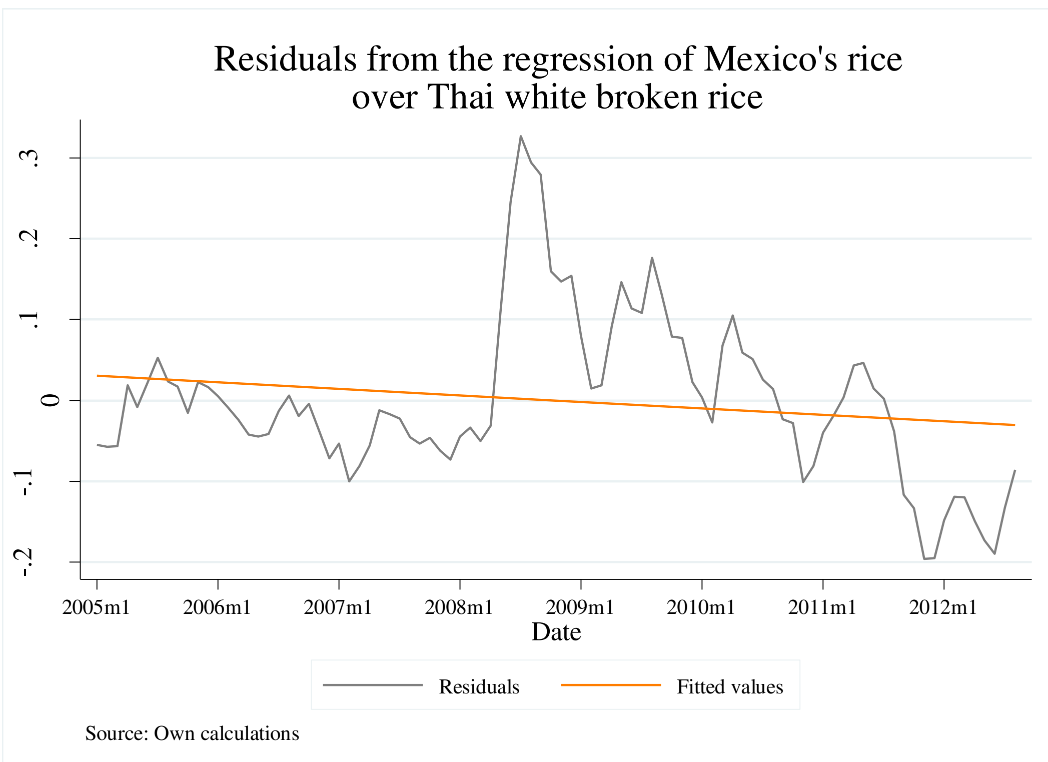
6.2 Residuals' regressions by type of grain



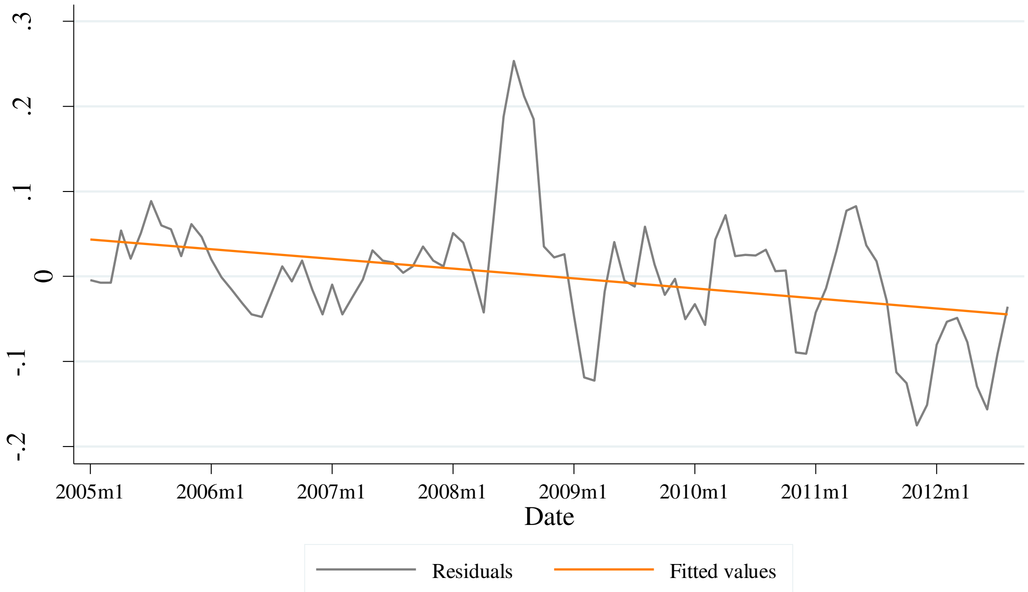

Residuals from the regression of Mexico's yellow maize over Argentina's up river maize
.2
.1
0
-.1
-.2
2005m1
2006m1
2007m1
2008m1
2009m1
2010m1
2011m1
2012m1
Date
Residuals
Fitted values
Source: Own calculations


Residuals from the regression of Mexico's white maize over US' yellow maize
.2
.1
0
-.1
-.2
2005m1
2006m1
2007m1
2008m1
2009m1
2010m1
2011m1
2012m1
Date
Residuals
Fitted values
Source: Own calculations


Residuals from the regression of Mexico's white maize
over Argentina's up river maize
.2
.1
0
-.1
-.2
2005m1
2006m1
2007m1
2008m1
2009m1
2010m1
2011m1
2012m1
Date
Residuals
Fitted values
Source: Own calculations

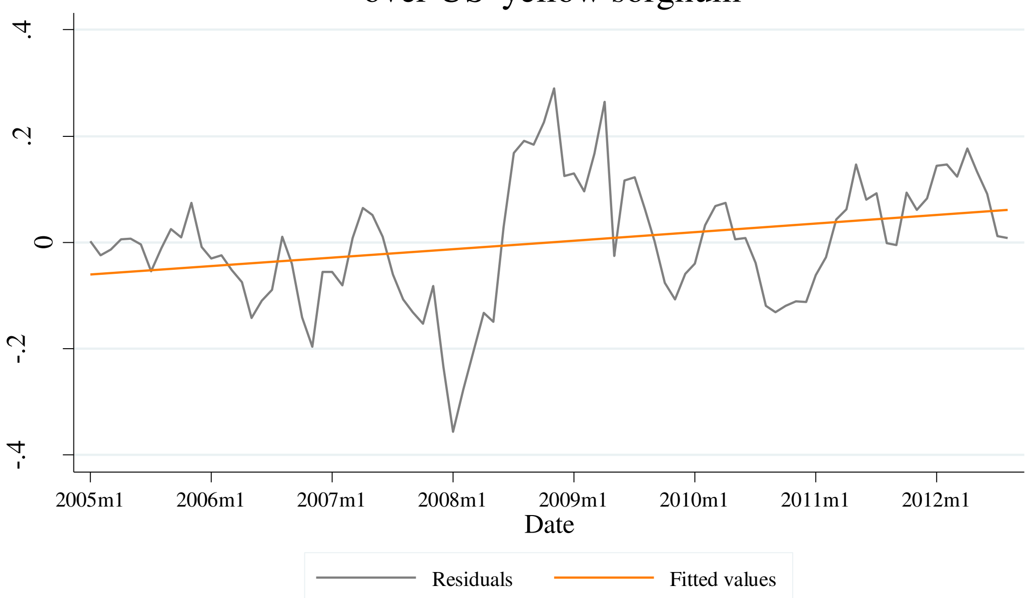

Residuals from the regression of Mexico's rice
over Thai white broken rice
.3
.2
.1
0
-.1
-.2
2005m1
2006m1
2007m1
2008m1
2009m1
2010m1
2011m1
2012m1
Date
Residuals
Fitted values
Source: Own calculations

Residuals from the regression of Mexico's rice over Thai white rice

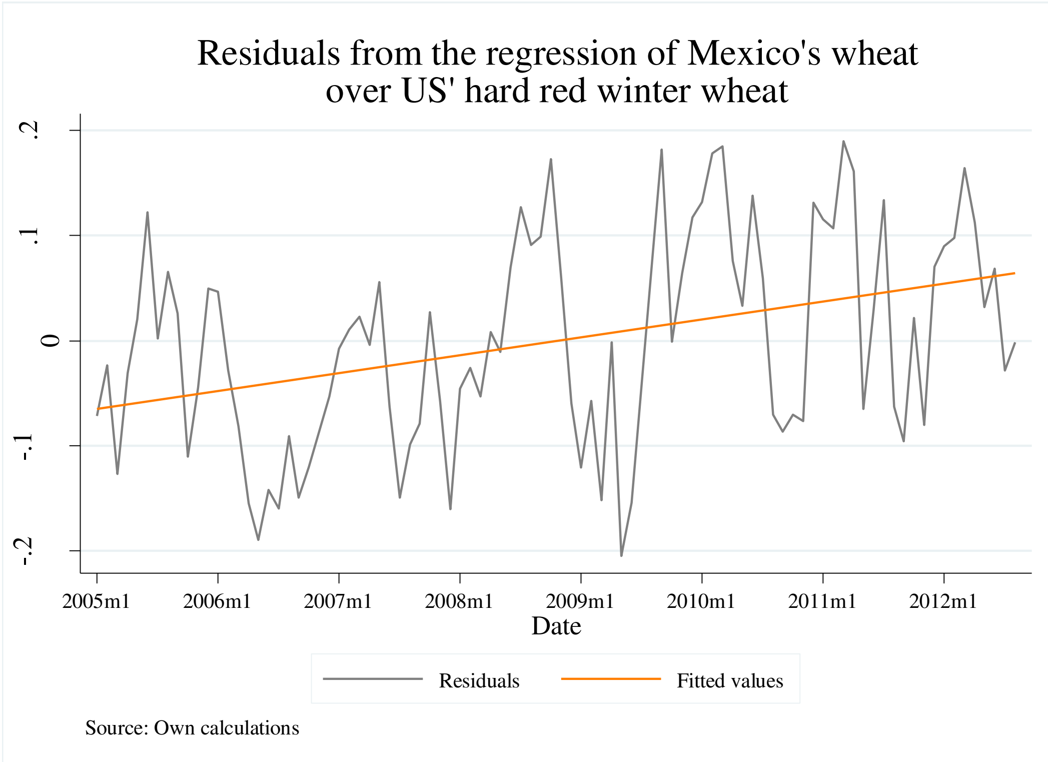


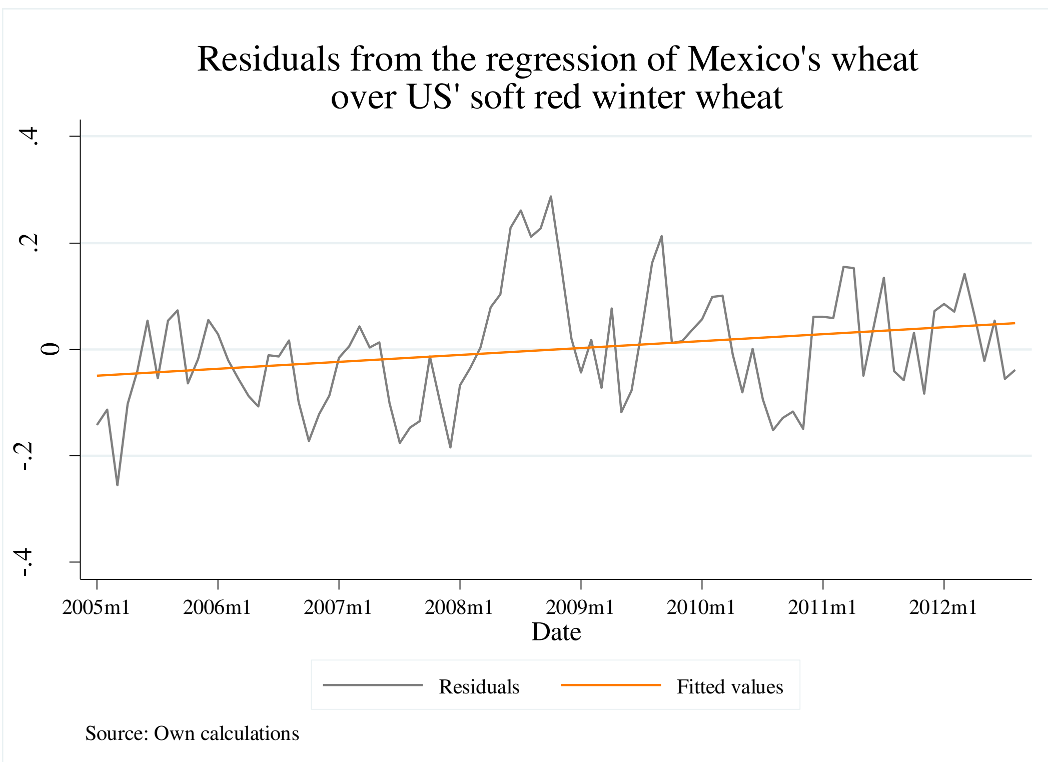
Source: Own calculations

Residuals from the regression of Mexico's sorghum over US' yellow sorghum

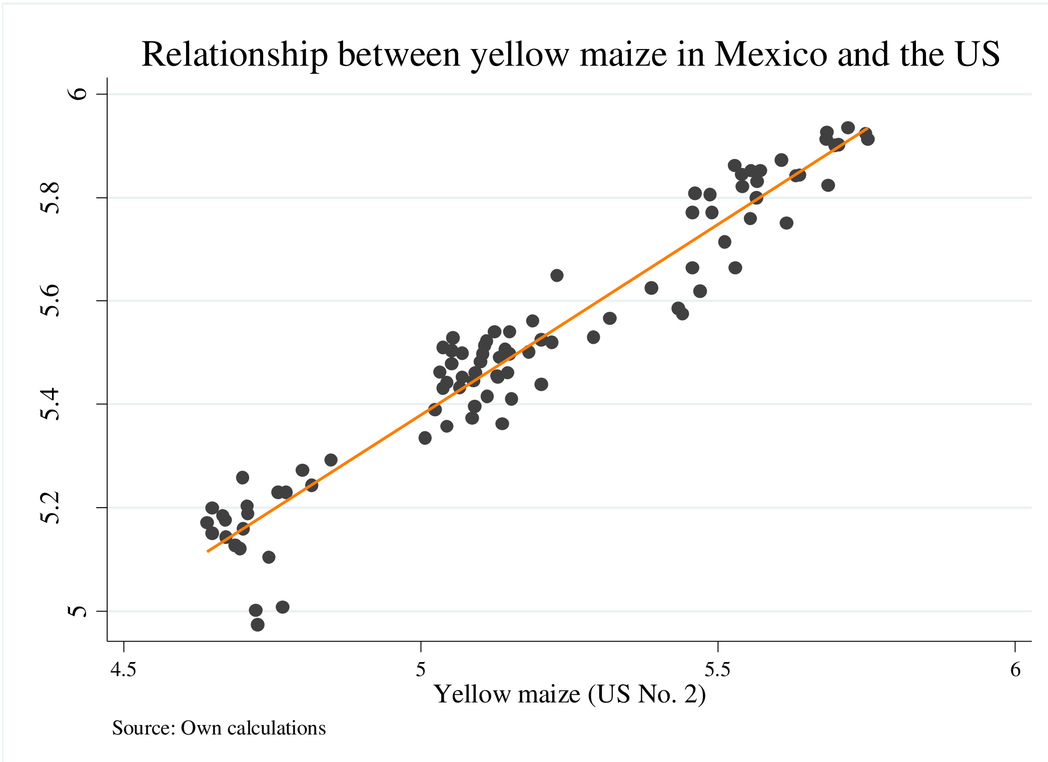


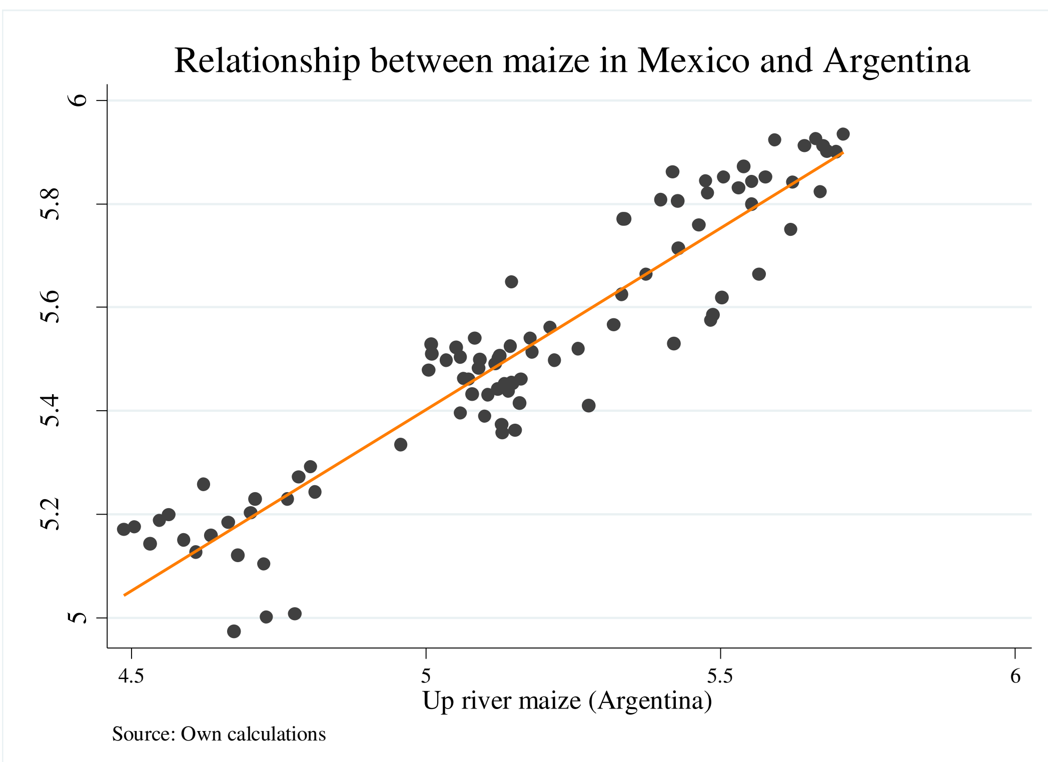
Source: Own calculations

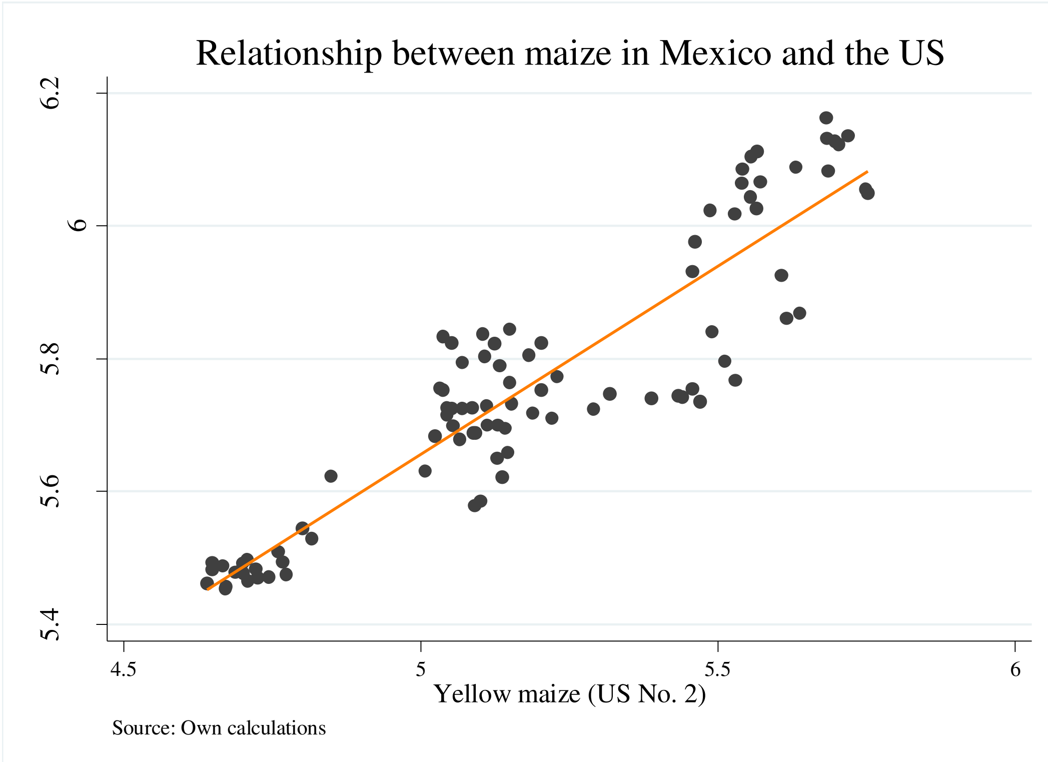

Residuals from the regression of Mexico's wheat
over US' hard red winter wheat
-.2
-.1
0
.1
.2
2005m1
2006m1
2007m1
2008m1
2009m1
2010m1
2011m1
2012m1
Date
Residuals
Fitted values
Source: Own calculations

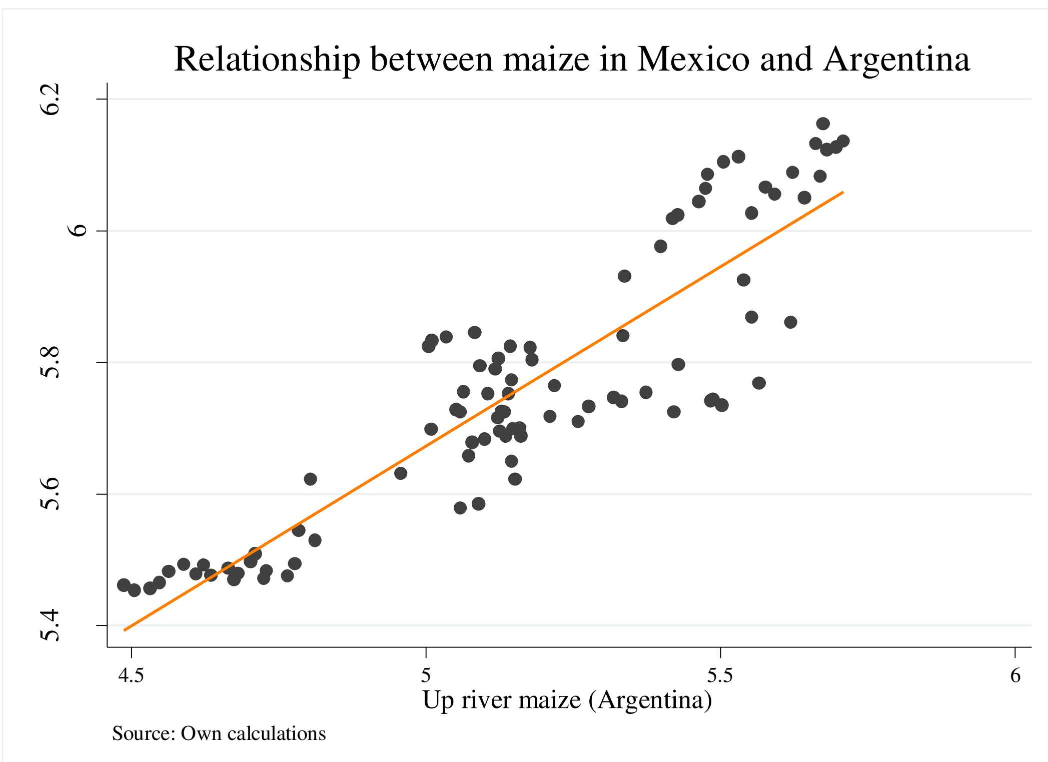

Residuals from the regression of Mexico's wheat
over US' soft red winter wheat
-.4
-.2
0
.2
.4
2005m1
2006m1
2007m1
2008m1
2009m1
2010m1
2011m1
2012m1
Date
Residuals
Fitted values
Source: Own calculations

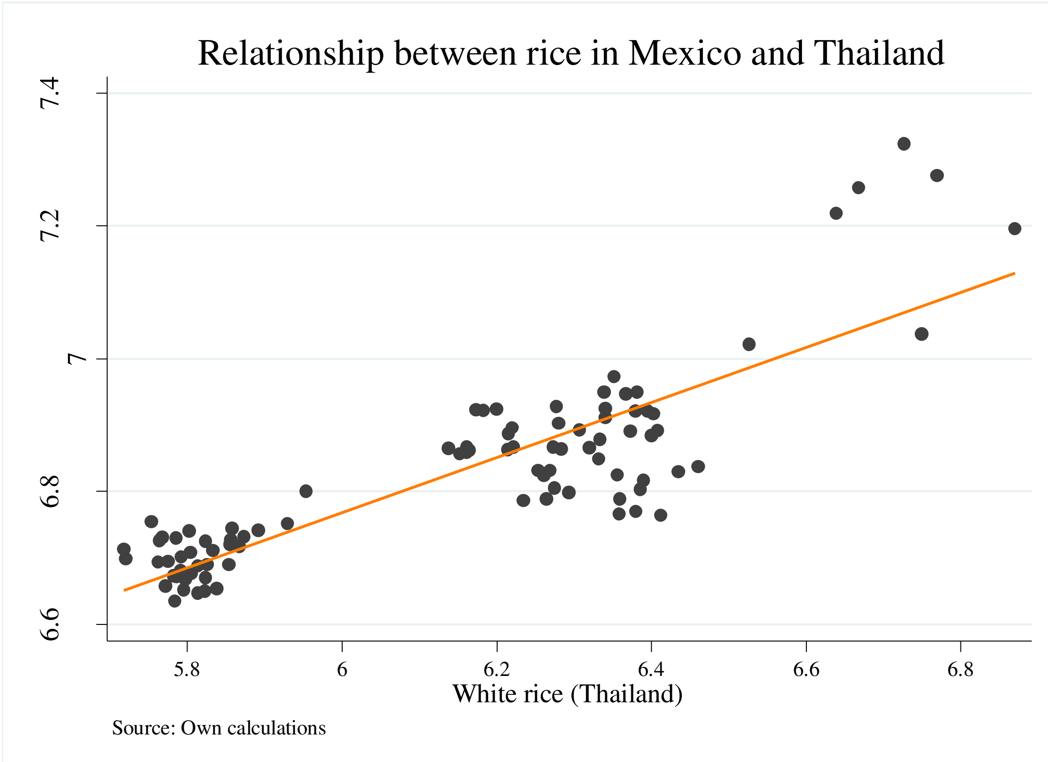
6.3 Relation between variables by type of grains

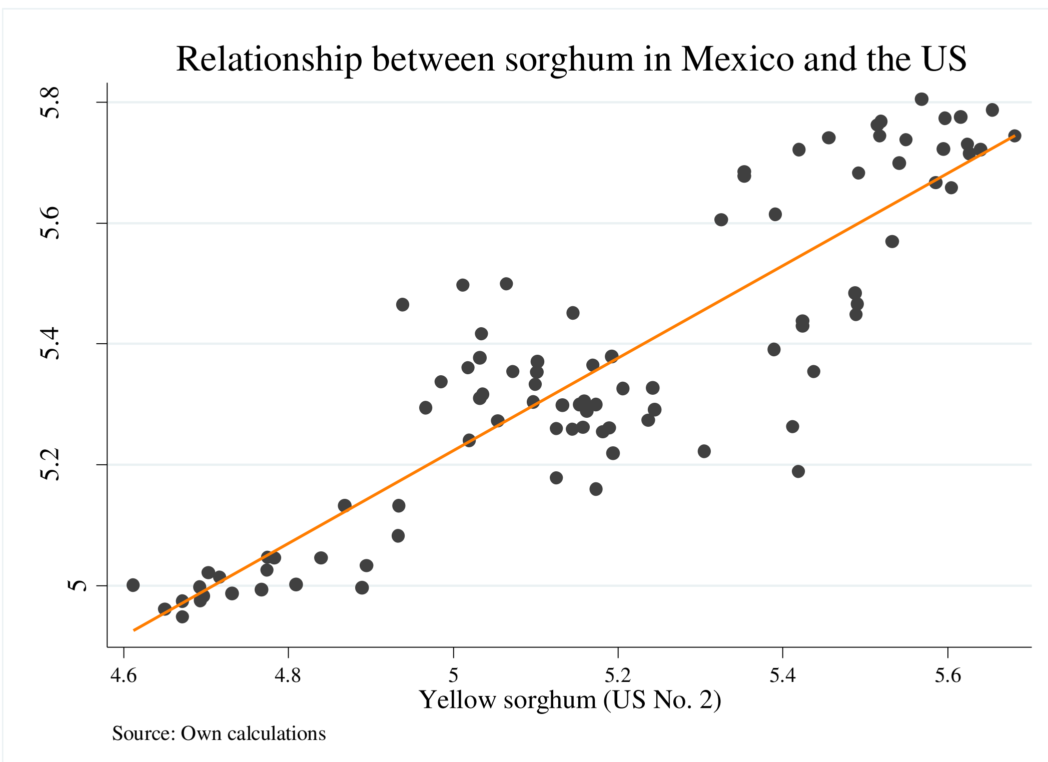


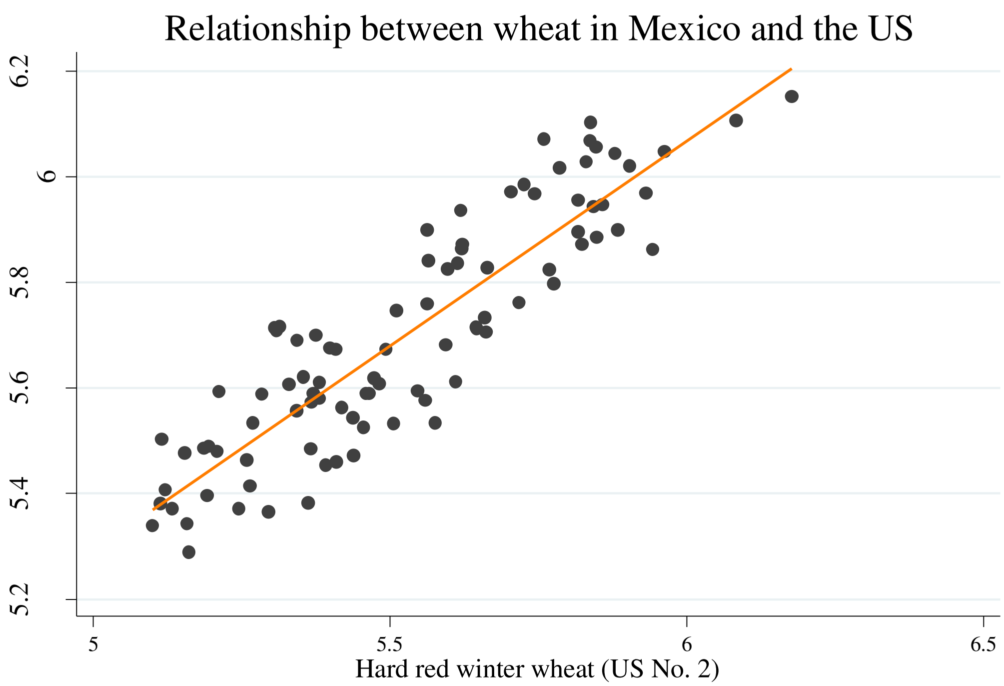



Relationship between maize in Mexico and the US
5.4
5.6
5.8
6
6.2
4.5
5
5.5
6
Yellow maize (US No. 2)
Source: Own calculations

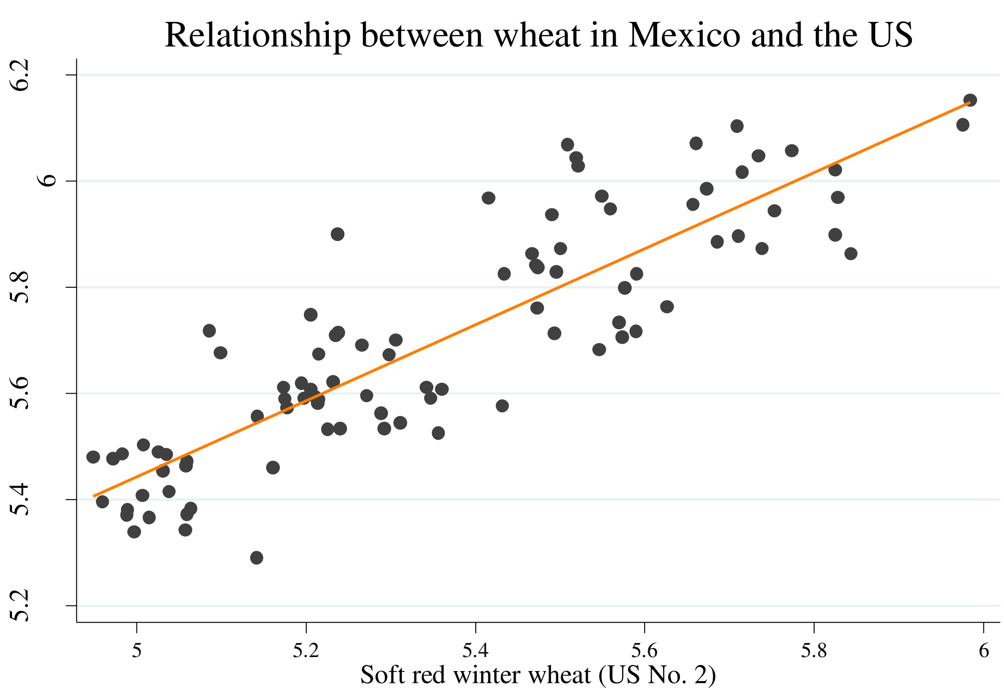

Relationship between maize in Mexico and Argentina
5.4
5.6
5.8
6
6.2
4.5
5
5.5
6
Up river maize (Argentina)
Source: Own calculations


Relationship between rice in Mexico and Thailand
7.4
7.2
7
6.8
6.6
5.8
6
6.2
6.4
6.6
6.8
White rice (Thailand)
Source: Own calculations


Relationship between sorghum in Mexico and the US
5.8
5.6
5.4
5.2
5
4.6
4.8
5
5.2
5.4
5.6
Yellow sorghum (US No. 2)
Source: Own calculations



Source: Own calculations



Source: Own calculations

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