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abstract

We analyze wholesale maize prices in 12 Mexican markets from 1998 to 2010, a period when markets became more open to inter- and intranational trade. We ask how the influence of global and local forces on Mexican maize prices changed during this period. We also explore how the strength of global and local forces varies across maize-producing regions. In general, we expect the influence of global forces to increase and local forces to decrease as markets become more open. We find that the influence of global forces does vary over the study period and, counter to expectation, is the highest at the beginning and middle of the period rather than at the end. This result suggests that even under less open market conditions, buyers and sellers were still following global price signals. In contrast, the influence of local forces follows expectation and decreases over time. However, the estimated pattern of response is not uniform across various maize-producing regions. Taken together, our results suggest that opening agricultural markets can result in regionally distinct outcomes and counterintuitive price behavior.

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Prior research suggests that the impact of open markets on domestic agricultural prices results from a balance between local crop loss and global prices (Johnson 1975; Giovanni and Levchenko 2009; Jacks, O'Rourke, and Williamson 2011). In a closed market, where the transmission of goods and information to and from other markets is difficult, local factors, such as unexpected crop loss, should dominate domestic price behavior. In an open market, we expect that buyers and sellers will also respond to global price signals and thus reduce the influence of local factors on domestic market prices. Some argue that greater integration with global markets can reduce domestic price movements by stabilizing the influence of local shocks (Johnson 1975). For example, under an open market, a local crop loss should not have a significant effect on total supply because the supply loss can be compensated with imports. There is also evidence that greater intranational market integration can mitigate the influence of a local shock (Burgess and Donaldson 2010)[1]. However, global market integration can also cause domestic prices to become more volatile: the prices are now subject to supply and demand shocks from much larger countries producing the same product (Giovanni and Levchenko 2009).

In this article we investigate how opening markets change the influence that local crop loss and global prices have on regional price behavior. Most prior research on this topic focuses on determining whether opening markets increase or decrease price levels and volatility (Jacks et al. 2011; Giovanni and Levchenko 2009). Missing from much of this work is an analysis that explicitly addresses how factors known to influence prices might change under open markets. We expand on this research by examining specific mechanisms—global prices and local crop loss—that are known to influence agricultural price movements. We analyze how the magnitude of that influence varies over a period of increasing market openness. We also examine how these forces vary spatially because, for a variety of reasons that we discuss below, not all regions respond to market openness in the same way (Barret and Mutambatsere 2005; Baffes and Gardner 2003). Our analysis focuses on Mexico because that country is highly dependent on a globally traded

[1] Burgess and Donaldson (2010) find that increasing market connectivity through railroad lines reduced the likelihood of weather-induced famine in early twentieth-century India.

commodity: maize. Mexico is the world's fourth largest maize producer but also a net importer. Mexico is a large geographically diverse country, and the maize-growing regions within vary with respect to modes of production, transport infrastructure, and institutional support. Mexico also recently entered into a free-trade agreement (North American Free Trade Agreement [NAFTA]) with the United States: the world's largest producer and exporter of maize.

The importance of maize in the United States and Mexico made it a contentious topic during NAFTA negotiations (Zahniser and Coyle 2004). NAFTA was ratified in 1994, but maize trade between the United States and Mexico was not fully open until January 2008, when all Mexican import barriers were removed. This study examines the movement and stability of Mexican maize prices from 1998 to the end of 2010. We want to know if and how the influence of local and global determinants of Mexican maize prices changed during various stages of maize market openness leading up to and following January 2008—a period when all maize trade barriers with the United States were removed. We might expect that under a closed economic system, maize prices in Mexico will respond more to local influences, such as crop loss, and less to global influences such as the US maize price. The reverse should apply in the NAFTA post-2008 period. However, prior analyses of how Mexican maize prices move with respect to US prices have produced mixed results.

A recent study examining Mexican maize markets and US prices over the period 1998–2005 did not find evidence of maize price integration between the two countries (Motamed et al. 2008). However, other researchers present contradictory results (Fiess and Lederman 2004; McMillan, Zwane, and Ashraf 2007; Araujo-Enciso 2009). In a synthesis of prior work, Fiess and Lederman (2004) found that the Mexican national price had historically followed US prices and that pre-NAFTA price policies had kept prices artificially high. The most recent study also found evidence of US prices influencing Mexico prices, but not the other way around (Araujo-Enciso 2009). Why do these studies have conflicting results? The only study that rejects the hypothesis that Mexican maize prices are integrated with US prices (Motamed, Foster, and Tyner 2008) is the one that analyzes prices in specific markets, not just the national price. This suggests a finding similar to those in cross-country studies (discussed in 'Data') that not all regions have the same capacity to integrate with global markets, and not all regions are open to the same degree or in the same way. However, the analysis in Motamed et al. (2008) stops in 2005, before the maize trade with the United States was officially *open*, and none of the studies listed above explore the influence of local supply shocks.

We build on these studies by analyzing the *influences* on price movements, not just the movements of the prices themselves. We use state and time-varying fixed effects to control for the influence of state–year-specific factors such as changes in policy and technology. We also include state and season-specific crop production data to gauge the degree of influence that local factors have had on prices. We estimate the influence of local and global forces on Mexican prices and try to determine whether the magnitude of those influences changed over time and across regional markets.

We examine prices in individual markets rather than the national price. By examining specific states in varying agroclimatic areas, we aim to identify whether price behavior in different regions responds to market integration in different ways. The diversity of production modes (irrigated vs. nonirrigated, traditional vs. nontraditional) provides variation that allows us to analyze how trade openness and different policy regimes impact various types of farmers. The broad aim of this study is to provide insight into future analyses of agricultural policies and trade openness in a variety of countries.

We find that the influence of global forces does vary over the study period, and counter to expectation, is the highest at the beginning and middle of the period rather than at the end. This suggests that even under less open market conditions, buyers and sellers were still following global price signals. Our estimates of the influence of local forces on maize prices do follow expectation and decrease over time, but also exhibited more regional variation in the response. Taken together, our results suggest that it is difficult to generalize exactly how market openness might change the response of domestic prices to local and global influences. Regional differences in physical geography, production regimes, and infrastructure can all lead to heterogeneous outcomes at the subnational level. This finding is broadly in agreement with the mixed results found in other global and cross-county studies (see 'Data').

The article proceeds as follows: The next section provides pertinent background information on the Mexican maize supply chain, agricultural policies, and NAFTA. We follow with a discussion of our conceptual framework, key covariates, and empirical models used to answer our main questions. The final two sections present the results and interpretation of our analysis.

Maize in Mexico

Maize is a pan-American plant and in the pre-Columbian era was grown from southern Chile to central Canada. The most likely origin of the plant is in the Yucatan region of modern-day Mexico and Guatemala since this is the location of corn's only known wild relative: *teosinte*. Today approximately 120 countries grow maize, with Asia (particularly China) experiencing the fastest growth in both harvested area and production (Ransom et al. 2004; Food and Agriculture Organization [FAO] 2010). The United States is the world's biggest maize producer, with China a close second. The other major producers are Brazil, Mexico, Argentina, France, India, Indonesia, Italy, and South Africa (FAO 2010). As mentioned above, despite being a major maize producer, Mexico remains a net importer and the United States is the primary supplier of imported maize.

Mexican maize production[2] is generally classed into two sectors: rain-fed and irrigated. Rain-fed production includes most small- (less than 5 hectares) and medium- (5 to 20 hectares) scale farmers who plant and harvest during the spring growing season (March–September), mostly in the center and southern regions. The irrigated sector is dominated by larger farmers, primarily in the northwest, who farm plots of 20 or more hectares (though the center also has rain-fed plots of 20 or more hectares). Farmers working on irrigated land also plant and harvest in the fall (October–February). The majority of fall production occurs in the northwestern state of Sinaloa, and as of 2010, the northwest region produced roughly 50 percent of all irrigated maize in Mexico (Keleman and Rano 2011; Sweeney et al. 2013). The total volume at harvest time changes through the growing season, generally shrinking due to exogenous factors such as pests and weather. Freeze, floods, drought, and other weather shocks have the largest impacts on total volume harvested relative to the number of crops planted.

However, because of storage and cross-state trading, maize transactions occur at all times in almost all states. The amount of maize available on the market is either stored

[2] For general background and historic information, see de Janvry et al. (1995), Appendini (2008), and Smith, Betrn, and Runge (2004).

or consumed. Medium- to large-scale farmers sell their harvested grain to millers at large wholesale grain markets known as *abastos*. Although no specific data on transaction volume exists, it is estimated that roughly 20–30 percent of all maize grown in Mexico passes through the *abastos* and that *abastos* prices are correlated with the direct contract prices used by the largest producers (Eakin, Bausch, and Sweeney 2014a). The prices recorded at various *abastos* around Mexico are what we analyze in this article. These regional markets consist of buyers and sellers, both of whom have storage capacity. Buyers are (or represent) grain millers; sellers are (or represent) grain farmers. Millers process the grain to flour then sell the flour to tortilla manufactures (some manufactures also own mills). Keleman, Ra, and Hellin (2009) note that buyer concentration has increased since the 1990s and that as of 2004 the majority of maize for tortilla production was purchased by five different milling companies and that the net effect is depressed farm gate prices for small and medium producers. Buyers and sellers both use storage to take advantage of market timing to mitigate against unexpected supply or demand shocks. When prices are low, buyers will purchase more and sellers will allocate more volume to storage. Total market supply in a given state is determined by production in that state, neighboring states, and sometimes the state of Sinaloa. Larger-scale producers can substitute between maize and other grains (sorghum); smaller-scale producers cannot substitute crops.

Our study focuses on the period of most direct changes in maize policy—1998–2008; however, there is a vast literature focused on the effects of long-term changes in agricultural development policy on the Mexican countryside. As noted by Arizpe (1981), the general policy shift toward agricultural intensification and irrigation started as early as the 1940s. Even prior to the market-liberalizing reforms under the Salinas and Zedilllo administrations (1988♀2000), complex changes initiated by overall modernization and development of the Mexican economy were impacting rural livelihoods. Although the social structure and economic organization of rural communities have been strained, maize farming has persisted as part of a multifaceted livelihood strategy (de Janvry, Sadoulet, and de Anda 1995; Eakin et al. 2014b; Wiggins et al. 2002). Thus, the context for the relatively brief period in which we can observe market price adjustments is in relation to complex, long-run changes in rural livelihoods that remain intimately tied to maize.

Beginning in the early 1990s, Mexico began a series of structural reforms aimed at liberalizing agricultural prices. After the signing of NAFTA in 1994 but prior to full maize liberalization in 2008, maize trade between the United States and Mexico was regulated by a duty-free tariff-rate quota system. The quota was set at 2.5 million metric tons in 1994 and increased by 3 percent each year until January 1, 2008, when it was removed. Once the quota was met in a given year, the Mexican government could choose to sell quota expansions to the United States. The over-quota expansions were sold in most years but primarily for yellow feed corn, not white corn used for tortillas (Zahniser and Coyle 2004).

White maize prices arguably did not begin to start following genuine market forces until 1998, when the state grain-purchasing agency, CONASUPO, was completely dismantled (Yunez-Naude 2003). However, there were still a number of domestic price supports[3] for maize following 1998. During most of the period from 1999 to 2008, price supports benefited producers, and the main result was the creation of a price floor. Figure 1 shows the various price support programs active during our study period. The specifics of these policies are described in Table 1. Following the data in Figure 1

[3] Agricultural price supports subsidize either inputs (fertilizer, tractors, seeds, etc.) or outputs (price floors/ceilings, direct payment programs). Output supports can be directed at either producers or consumers.

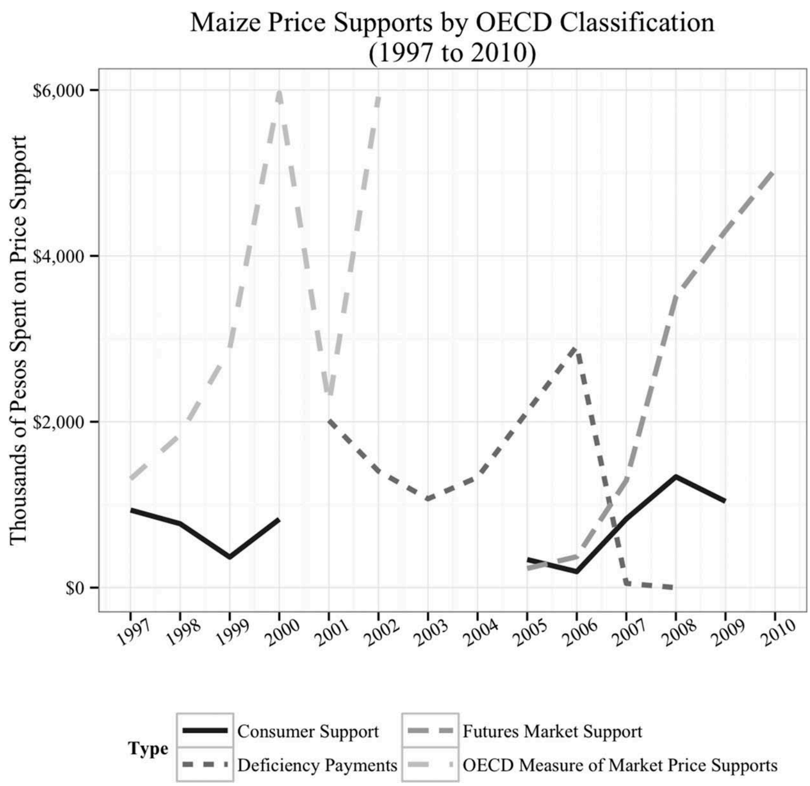

Figure 1. Price supports over time by program.
Source: OECD.
Notes: Market price supports are an OECD measure of policies used to make up the difference between the world and domestic price. Futures supports are payments made to farmers that try to reduce the transaction costs (transport and storage) associated with creating futures contracts. Consumer supports are payments given to millers and other wholesale buyers to facilitate purchase of domestic maize products. Deficiency payments are made to farmers and based on the per-ton output. The payments are based on the difference between a guaranteed minimum price and the estimated market price at the beginning of the growing season.

and prior research (Keleman and Rano 2011; Appendini 2014), we can divide the period 1998–2010 into the following price support periods:

1. 1998–2000: National market price supports intended to make up for the difference between world and domestic prices. These supports were supposed to benefit both consumers and producers and did not vary nationally.
2. 2001–2002: A period of combined market price supports and per-ton deficiency payments made directly to producers.
3. 2003–2006: The removal of market price supports and an increase in per-ton deficiency payments to producers.
4. 2007–2010: The removal of deficiency payments and a shift to consumer and producer supports for engaging the futures market (transport, storage, contracts, etc.).

The timeline of these policy periods coincides with the January 2008 NAFTA deadline of complete free maize trade with the United States. During that period,

Table 1

Description of Price Support Programs

Support Type	Program Name	Major Time Interval	Description
Output	Ingreso Objectivo (Deficiency Payment)	2001–2006 (peaks in 2001 and 2006)	Intended to cover the difference between market prices and a set price determined by cost of living in farmers regions. Payments are made per ton of output. Covers the difference between international price and cost of transport/storage to place of sale (Mexico).
Input	Compras Anticipadas (Futures Market)	2005–2010 (dramatic rise from 2007 to 2008)	Intended to assist farmers and buyers in engaging in the futures market. Participants receive assistance with transport, storage, and insurance. Payments are made on a per ton basis.
Consumer support	Cobetura de Precios	1997–2000; 2007–2009	Primarily a payment to wholesale buyers (millers, manufacturers) to offset the difference between domestic and international prices.
Output	Market Price Support	1997–2003	This is not a specific policy but an Organization for Economic Cooperation and Development (OECD) metric that measures total government transfers from consumers/taxpayers to producers. This measure is based on differences between the domestic producer price and the reference world market price. For an exact definition see OECD (2010a).

Source: Adapted from material in OECD (2010a, 2010b).

the Mexican government began rolling back various forms of price supports and producer payments. Government spending on *Ingreso Objectivo*, a producer support (see Table 1), peaked in 2006 and steadily declined until 2008 when it stopped entirely (see Figure 1). Spending on the *Coberta de Precios* program (see Table 1), intended to support wholesale buyers by offsetting the difference between domestic and international prices, was completely phased out by the beginning of 2009. However, the government also implemented support programs to cushion the perceived impact that NAFTA would have on domestic farmers. The *Compras Anticipadas* program includes subsidies aimed at supporting buyer and seller participation in a nascent futures market (Avalos Sartorio 2006; Yunez-Naude and Paredes 2004). Spending on this program dramatically increased from 235,000 pesos in 2005 to nearly 5 million pesos in 2010. In the next section, we discuss how this transition from a closed to an open market system, both in Mexico and with respect to the United States, might impact the speed and magnitude with which prices respond to local and global influences.

Conceptual Framework

Our goal in this article is to estimate how the magnitude of global and local influences on Mexican maize prices changes over time. The conceptual model is simple: if Mexican maize markets become more open, price levels should respond more to global forces outside the country and less to those inside the country. Before presenting the conceptual model below, we place it in a broader context by reviewing similar empirical work from global studies and countries other than Mexico.

Other authors who study market openness and commodity prices both globally and in specific countries have produced mixed results. Recent empirical work examining commodity prices from 1700 to 2000 found that commodity prices do stabilize during periods of greater market integration (Jacks et al. 2011). However, an earlier article in the same journal (Giovanni and Levchenko 2009) found that trade openness tends to increase volatility in developing countries and that the effect of trade openness on volatility varies considerably by country. Country-specific analyses of how prices react to market openness also produce varying results. Baffes and Gardner (2003) study transmission from world prices to national prices before and after market liberalization (late 1970s through the early 1990s) for several countries and commodities. In general, they found that following periods of policy reform, agricultural commodity prices in Chile, Mexico, and Argentina respond to global prices, but prices in Ghana, Madagascar, Egypt, Indonesia, and Columbia do not (Baffes and Gardner 2003). One explanation for these cross-country discrepancies is simply that differences in physical geography (soils, terrain, climate) and infrastructure (transportation, irrigation) imply that even after the removal of trade barriers and price supports, certain domestic markets remain isolated from global influences. Another explanation for cross-country differences is that not all markets open in the same way or to the same degree. For example, some countries completely remove import protections although others ease them or simply replace them with stronger domestic price supports. In summary, there are at least two possible explanations for the country-varying degree of price integration following market openness: (1) that differences in physical geography and infrastructure make some regions more integrated than others and (2) that not all countries reform in the same way. In other words, variation in physical conditions, infrastructure, and policy implementation implies that the response of domestic prices to local and global influences under market openness can follow a number of different patterns.

We illustrate two of these patterns in Figure 2. If the opening were sudden and unknown we expect the resulting change in influence of global and local shocks to be abrupt (dashed line in Figure 2). If the opening is a known event that occurs in stages, we expect the change to be smooth (solid line in Figure 2). In the case of NAFTA and Mexican maize prices, it is reasonable to assume that change in global and local influences would be smooth. Although the official switch to fully open trade occurring on January 2008 was technically abrupt, it was a known and well-publicized event negotiated years in advance. As described above, there were also a series of phased policy changes in Mexico that were implemented to both make markets more open and make farmers better able to cope with the new trade regime. However, not all states have the same production and storage capacity, and anecdotal evidence suggests that not all received the same degree of policy *treatments*. Thus, we expect the magnitude of these influences to vary across states as well as time. Finally the growing role of Sinaloa as a major producer could also have simultaneously reduced the impact of global and local influences as Sinaloa itself became more of a *global* influence in Mexico. In the next section we describe in more detail the growing role of Sinaloa as well as the variables we use to measure local and global influences.

Data

In this section we present our dependent variables and key covariates. Our models and data are indexed over states, years, seasons, months, and weeks. To mitigate potential confusion, Table 2 contains a list of the various symbols and subscripts used in this section.

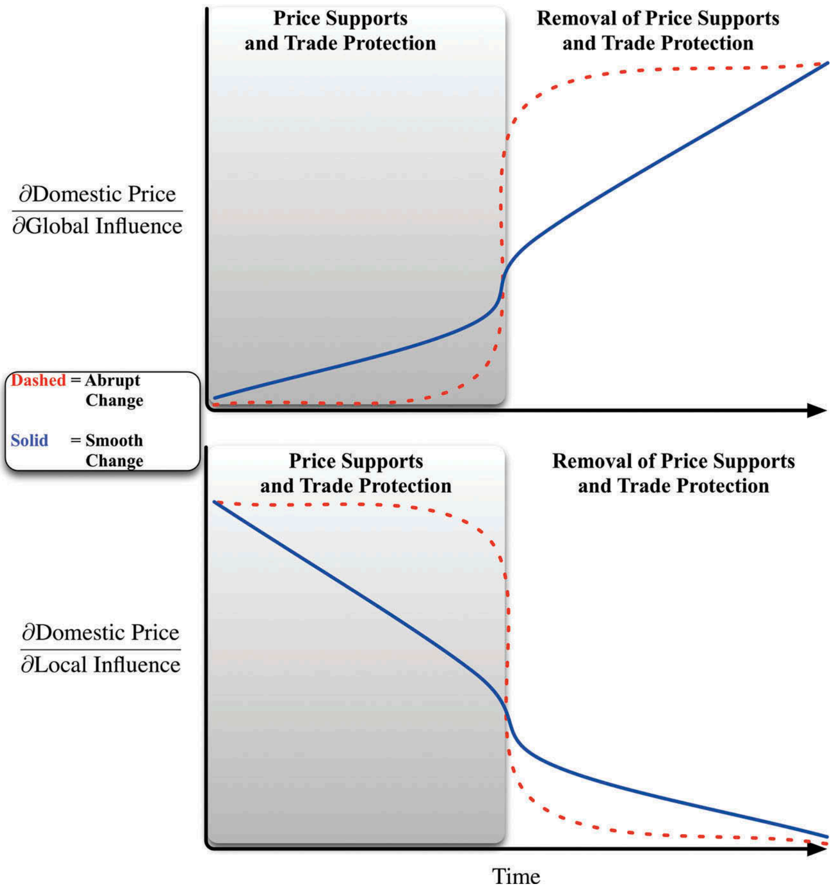

Figure 2. Conceptual model of how the influence of local and global influences might change under two different market opening scenarios.

Notes: The dotted line indicates an abrupt change and the solid line indicates a smooth change. We anticipate that Mexican maize prices will follow a smooth change because the opening event (January 2008) was known well in advance. In addition there were also a number of policy actions taken to avoid an abrupt change. This figure is intended as a conceptual overview of two different scenarios and not a deterministic prescription of all potential responses. There could be a variety of responses among these two extremes.

Table 2

Definitions and Notation

Notation	Description
t	The time unit in our panel data is the **calendar month** with $t = 1, \ldots, 135$ covering October 1998 through December 2010.
s	There are two growing seasons—fall (October to February) and spring (March to September). The subscript *s* indexes growing seasons in specific years, starting with the spring of 1998 through to the fall of 2010. The **loss** variable (*L*) defined in the main text is only available at the time scale of season (not month) each year. Thus $L_{i,s-1}$ indicates loss in the prior season for state *i*.
g	Since the fall season spans the calendar year, we define the **crop growing periods** as March to February, with indexing $g = 1, \ldots, 6$ periods we analyze in our model. There are 6 periods because we group the growing years into two year groups (e.g., 2001–2002, 2003–2004, etc.). We do this to have sufficient variation when exploring how the seasonal crop loss term varies over time. We also group 1998 with 1999 and 2000 because our complete price series does not begin until October of 1998.

Maize Price Data

The data are a weekly series of real[4] prices (pesos per kilo) recorded at wholesale grain markets in various Mexican states from January 1998 to December 2010[5]. Every week, the Mexican Economics Ministry records the minimum, maximum, and mode of white maize prices sold in a given location. The ministry also records the state in which the maize was grown.

We restrict our analysis to states that have a minimum of one data point (transaction) per month for the entire study period. These include major maize-producing states (*Sinaloa, Jalisco, Chiapas, Mexico, Michoacan, Coahuila*), population centers (*Distrito Federal, Nuevo Leon, Veracruz*), and states transitioning away from maize production (*Oaxaca*). Figure 3 shows the states, major regions, and major maize production areas in each state.

Figure 4 provides an overview of both prices and trade among the states of interest. We see from Figure 4 that maize prices across Mexico tend to follow similar trends over time. Figure 4 shows that all regions experienced a rise in prices during 2006–2008, a period that coincides with a global rise in cereal prices (Piesse and Thirtle 2009). Overall, similarity in regional price behavior likely stems from the high sourcing of maize from neighboring states and the state of Sinaloa. Figure 4 shows that the majority of maize in a given market comes from one of three locations: (1) the state itself, (2) neighboring states, or (3) *Sinaloa*. This reflects the fact that maize used for commercial milling is generally considered to be homogeneous, and there are no overwhelming preferences for maize from specific regions (Sweeney et al. 2013). Turning back to Figure 4, *Sinaloa*-grown maize tends to dominate in recent years, especially in the states of *Mexico, Distrito Federal, Guanjuato*, and *Oaxaca*. However, *Michoacan, Jalisco*, and *Chiapas* consume virtually no externally grown maize.

At first glance, Figure 4 also shows an increasing diversity of participants (by state of origin) in most (but not all) markets over time. This is also known as market thickening (McLaren 2003). A simple measure of market thickness follows:

$$\text{Thickness} = \frac{\sum_i \sum_j B_{ij}}{(N(\mathrm{N}-1))}$$
$$\text{where } \; N = \text{total \# of markets and,} \qquad (1)$$
$$B_{ij} = \begin{cases} 1 \text{ if tradeoccurs between status } i \text{ and } j \\ \qquad 0 \text{ if not} \end{cases}$$

Figure 5 shows this measure over time, with and without Sinaloa. When Sinaloa is removed from the calculation, the measure of thickness decreases over time. Thus, although markets appeared to be getting thicker, the increased thickness measure is really more reflective of Sinaloa's rising dominance as a producer rather than an increased trade activity among all the producers and buyers. Eakin et al. (2014a) credit Sinaloa's dominance with a combination of rapid technological adoption by Sinaloan farmers and the fact that Sinaloa was the prime beneficiary of agricultural development policies during the early to mid-1990s. This adds a third component[6] to the

[4] Authors deflated prices using the Consumer Price Index published by the Bank of Mexico http://www.banxico.org.mx/portal-inflacion/inflation.html. January 1998 is used as the base price.

[5] The data is published by the Economy Ministry via the System for National Information Integration (SNIIM), http://www.economia-sniim.gob.mx/nuevo/.

[6] The first two components are global (US prices) and local (crop loss).

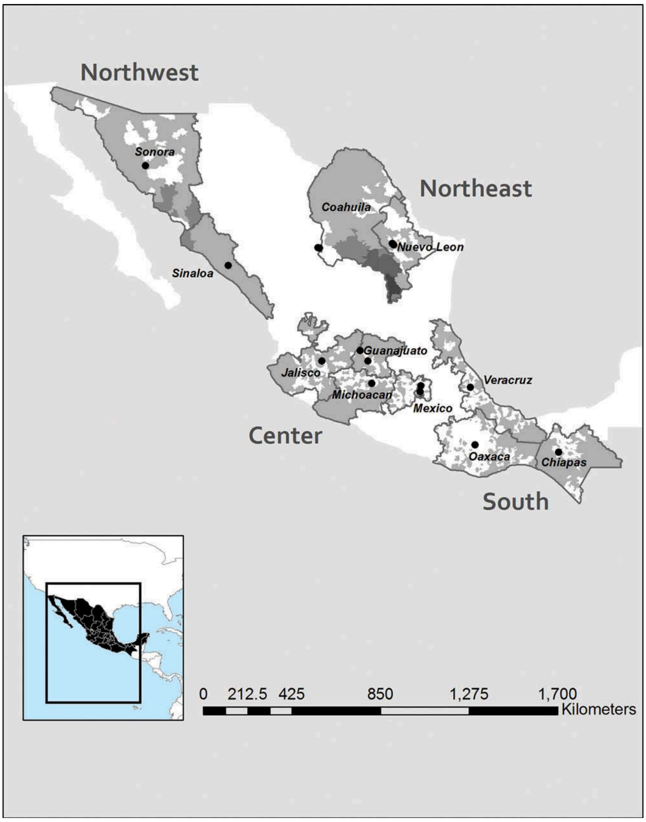

Figure 3. Mexican states studied in this article.
Source: Original data collected by the Mexican National Institute of Statistics and Geography (INEGI) and Agricultural and Fishery Information Service (SIAP).
Notes: Regions are labeled in larger gray font and states are labeled in smaller black font. Points indicate market locations. Areas highlighted in states are municipalities that grow maize. Municipalities are highlighted if ≥ 0.1 percent of the total maize planted in the state is planted in that municipality. Darker areas indicate higher percentages.

responsiveness of maize prices to shocks over time: the increasing importance of Sinaloa in the Mexican maize system. We include the influence of Sinaloa because that state's total share of national production has risen dramatically in the past ten years and thus has the potential to be as important as the United States in domestic Mexican maize markets (Sweeney et al. 2013).

Crop Loss

We use hectares lost prior to harvest for our measure of crop loss because we expect prices to reflect local supply. Output volume is the natural measure of supply, but volume can also be endogenous with price. Loss, on the other hand, represents an unknown component, primarily a function of exogenous factors related to weather. Finally loss tends to be realized and observed at the end of the season, just prior to when the next price series will be observed.

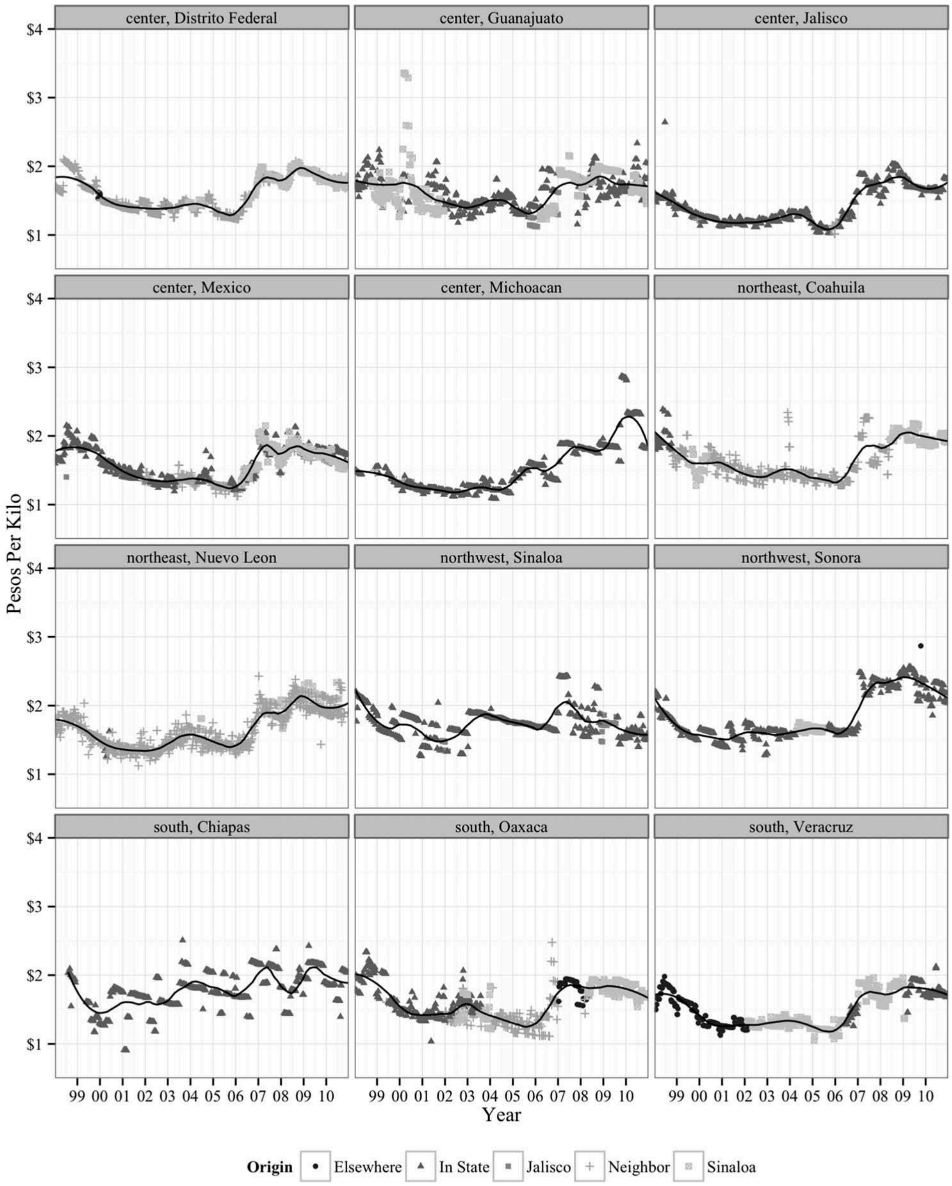

Figure 4. Maize price series comparing states where sold, colored by origin state.

The Mexican agricultural survey reports area planted and lost prior to harvest for each state season and growing year. Our measure of crop loss is simply area lost (prior to harvest) divided by the total area planted.

To account for aggregate supply shocks from neighboring states and because weather and pest-related crop failure tends to be spatially correlated, our crop-loss term represents the sum of loss in state *i* and all neighboring states, divided by the sum of area planted in state *i* and all neighboring states. As a robustness check, we also report results for models that separate out the crop-loss and region-loss terms. Finally because the

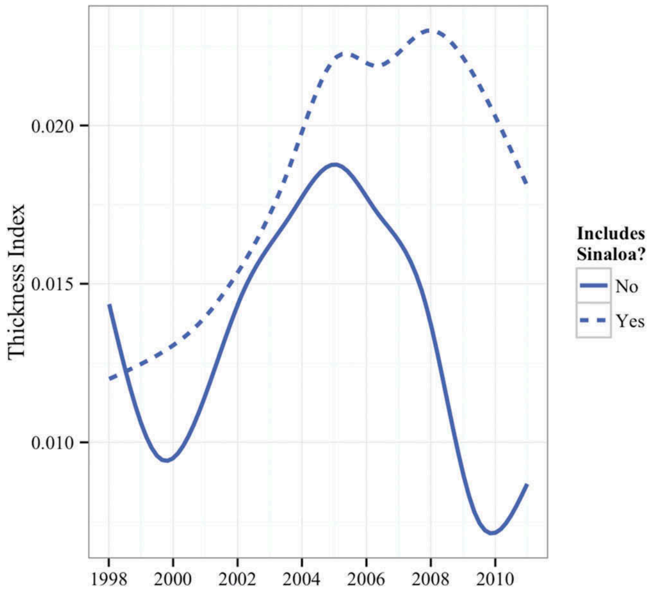

Figure 5. Market thickness over time for all states.
Notes: The solid line shows the same measure but with the state of Sinaloa excluded from the calculation. The figure demonstrates the rising dominance of Sinaloa as a provider of maize to other states.

state of Sinaloa is the dominant national producer (see Figures 4 and 5), we include a separate term for crop loss in Sinaloa.

US Maize Prices

Mexico's northern neighbor and principal trading partner, the United States, is the world's largest producer of maize. World maize supply is mostly set by US exports, and maize trade with Mexico is predominantly one way (Zahniser and Coyle 2004). Thus, to measure the impact of global influences, we include the monthly freight on board price of yellow maize recorded at the Gulf of Mexico Louisiana grain elevator[7]. Because exchange rates can influence trade (Sarker and Villanueva 2007), we convert the nominal dollar prices to pesos and then deflate them the same way we do the Mexican maize prices.

Empirical Model

The objective of our empirical analysis is to estimate the time-varying influence of global and local shocks on Mexican maize price levels. We use US maize prices to measure global shocks and state-level crop loss data to measure local shocks. We want to test the hypothesis that the influence of US prices increases although the influence of crop loss decreases (see Figure 2) during a period when markets are opening. A straightforward but naive approach would be to fit a model that integrates the crop loss and US price terms with a dummy variable for the post-2007 period. However, as discussed above, we expect the widely publicized and phased implementation of NAFTA to result in a smooth rather than an abrupt transition to market openness.

[7] Yellow and white maize prices in the United States are highly correlated (Zahniser and Coyle 2004).

Hence, we allow the effect of NAFTA to differ over each of the six growing periods defined in 'Data.' If we let s index the growing season (fall or spring of a specific year) to which month t belongs, and let g index the growing period (see Table 2) to which month t belongs, then for the monthly price of maize in state i our model is

$$P_{i,t} = \mu_{i,t} + \alpha_g P_{US,t-1} + \gamma_g L_{i,s} - 1 + U_{i,t} \quad (2)$$

where P_{US} measures the US maize price, L measures crop loss, $\mu_{i,t}$ is a vector of controls defined below, and $U_{i,t}$ captures unmodeled influences on prices. We lag the US maize price by one month and the crop loss by one season to reflect the timing of information in regional markets.

The vector of controls is

$$\mu_{i,t} = \beta_0 + \beta_1 L_{\text{Sinaloa,t}-1} \cdot I_{\text{Sinaloa}} + \beta_2 \cdot I_s + \beta_3 \cdot I_g + \beta_4 \cdot I_i + \beta_5 \cdot I_i \cdot I_g$$

 where *I* Sinaloa is an indicator variable that takes the value 1 if state i is not Sinaloa, *Is* is an indicator for growing season, *Ig* is an indicator for growing period, and *Ii* is an indicator for state. Thus, we directly model the effect of both crop loss in Sinaloa, reflecting the importance of Sinaloa to the national maize market, and the effect of the irrigated fall growing season on state maize prices. We also indirectly model the effect of other forces, among them government policies that vary over states and through time in a flexible way with the remaining controls[8].

To capture potential geographic variation, we also estimate Equation (2) for each of the regions (Figure 3) separately. In each model the parameters of interest are the six pairs of coefficients (αg, $\gamma g, g$ = 1 to 6). We use the monthly variation in the US price in a growing period to identify αg. Likewise, we use the variation of crop loss in growing period g and across states i to identify γg. In each case, the estimation is performed with an interaction between the variable of interest and the growing period indicator *Ig*. A time series comparison of the estimated coefficients reveals how the effect of global and local shocks evolved over the period of market opening.

Results

We estimate the model with ordinary least squares (OLS) and construct fixed effects estimates for our coefficients. We do not report random effects estimates because we do not believe that the strict exogeneity requirement of the random effects model holds for this study. Our data exhibit spatial, serial, and spatial–serial correlation, which under standard OLS assumptions will downward bias the standard error estimates. We use Driscoll and Kraay (1998) standard errors to correct this bias[9].

[8] In addition to government policies, the state and year fixed effects are meant to capture the other forces potentially influencing prices. These include grain storage capacity, the substitution of other crops (particularly sorghum), changes in the prices of land, labor, and other inputs, and the influence of remittances on production costs.

[9] They apply Newey–West standard errors to time series consisting of the cross-sectional averages of orthogonality conditions $h_t\ (\theta) = \frac{1}{N}\sum_{i=1}^{N} h_{it}(\theta)$ where $h_{it}\ (\theta)$ is measured using the covariance of the regressors and the residuals in each cross section. This approach is dependent on a moderately large time series ($T > 30$) with no constraints on the size of the cross section (N). We use this approach with a time lag of six months.

Table 3

Marginal Effects of US Prices α and Crop Loss γ over Time

	All	Center	Northeast	Northwest	South
US prices 1998–2000	1.14*	1.2*	0.89*	0.74*	1.23*
	(0.15)	(0.14)	(0.16)	(0.29)	(0.46)
US prices 2001–2002	0.07	−0.17	0.17	0	0.36
	(0.15)	(0.12)	(0.29)	(0.44)	(0.32)
US prices 2003–2004	0.03	0.05	0.16	−0.07	−0.05
	(0.08)	(0.08)	(0.16)	(0.08)	(0.15)
US prices 2005–2006	1.23*	1.21*	1.22*	1.01*	1.35*
	(0.16)	(0.15)	(0.21)	(0.43)	(0.08)
US prices 2007–2008	−0.02	0.13	0.07	−0.34	−0.26
	(0.14)	(0.08)	(0.2)	(0.21)	(0.25)
US prices 2009–2010	0.24*	−0.06	0.3*	0.68*	0.38*
	(0.04)	(0.11)	(0.07)	(0.17)	(0.14)
Crop loss 1998–2000	0.16*	0.17*	−0.02	0.5*	0.35
	(0.06)	(0.08)	(0.1)	(0.28)	(0.27)
Crop loss 2001–2002	0.03	0.25*	0.04	0.19	0
	(0.05)	(0.15)	(0.1)	(0.27)	(0.09)
Crop loss 2003–2004	0.02	0.28*	−0.22	0.32	−0.08
	(0.05)	(0.12)	(0.71)	(0.29)	(0.06)
Crop loss 2005–2006	−0.02	0	0.1	0.22	−0.06
	(0.03)	(0.06)	(0.18)	(0.25)	(0.07)
Crop loss 2007–2008	0.18	0.21	0.26	0.11	0.04
	(0.13)	(0.15)	(0.19)	(0.45)	(0.14)
Crop loss 2009–2010	0.04	0.04	0.04	0.36	0.05
	(0.04)	(0.07)	(0.07)	(0.27)	(0.08)

Note: The point estimates and standard errors correspond to Figures 6 (US prices) and 7 (crop loss) (see Appendix A). Standard Errors reported here are robust to heteroskedasticity, spatial correlation, and serial correlation. See Driscoll and Kraay (1998).

The purpose of the empirical model is to answer our principle question: *How did the influence of US prices and crop loss vary during a period of policy change and market openness?* To answer this question we compare the marginal effects of US prices and crop loss over time and test against the standard null. Our primary results are listed in Table 3 and presented graphically in Figures 6 (US prices) and 7 (crop loss). All price and loss variables have been normalized by region (converted to *Z*-scores) to allow for direct comparison of coefficients across regions.

Our results were not entirely in line with our expectations. We expected the estimated effect of US prices to increase over time, and instead we find that the effect size peaks in the 1998–2000 and 2005–2006 periods. Likewise, we also expected the crop loss variable to decrease over time. In this case, we do find that the crop loss effect tended to be both smaller and not statistically significant in the later periods. The next two sections discuss the results for US prices and crop loss in more detail.

Marginal Effect of US Prices on Mexican Maize Prices over Time

The dotted line in Figure A1 is the estimated influence of US prices on Mexican maize prices over time. As we mentioned above, the estimated trend for the US price variable runs counter to expectation. Rather than becoming larger over time, the effect size peaks in the 1998–2000 and 2005–2006 periods. The estimates for specific regions all yield broadly similar results across time periods. However, the northwest region that contains the state of Sinaloa had the smallest estimated effect of all models in all periods except the final (2009–2010). This is evident when one examines the first row of Table 3 in which we see that in the 1998–2000 period, a one standard deviation change in the

US maize price corresponds to a three-quarters standard deviation (α*northwest* = 0.74*) change in maize prices in the northwest region. Contrast this with models containing all, center, and southern states in which the respective effects are 1.14*, 1.20*, and 1.23*. The point estimate for the northwest region in this period also falls outside the 95 percent confidence interval of the point estimates in the all (1.14* ± 0.15) and center (1.20* ± 0.14) models. This pattern of smaller effects in the northwest holds in all but the last two periods.

Marginal Effect of Crop Loss on Mexican Maize Prices over Time

The models run on all states and the center region had estimates of crop loss that were larger in the first period than in the final period. In addition, the coefficients estimates in the all, center, and northwest models were not statistically significant from zero in the final period (but are in the first period), suggesting that crop loss was not influencing prices in those regions during the post-NAFTA era. The small effect size relative to the standard errors makes it difficult to see this trend in Figure A2, so again we focus on Table 3, this time considering the first two columns on the bottom half of the table below the dashed line. Crop loss tended to have the largest influence in the center region, and this is also the only region in which the coefficients are significantly different from zero for the first three periods.

Robustness Checks

Here we present results from specification tests and alternate models in order to explore the robustness of our results.

Model Specification and Panel Unit Root Tests

Table 4 shows F-tests indicating the significance of the US price × period and crop loss × period interaction terms. We also test for the presence of a unit root, which would indicate a nonstationary series. Table 5 shows the results of panel unit root tests that allow for cross-sectional correlation (Pesaran 2007). We test for a panel unit root in the presence and absence of both trend and drift terms and in all cases reject the null hypothesis of a nonstationary series.

Table 4

F-Tests for Model Run on All States

	Df	*F*	Pr(> *F*)
Season	1	12.22	0.0005
State	11	29.83	0.0000
Year	5	215.88	0.0000
US price	1	108.99	0.0000
Loss	1	5.38	0.0205
Loss(*Sinaloa*)	1	0.81	0.3676
US price × year *ye*Year	5	56.00	0.0000
loss × year	5	3.71	0.0024
State × year	55	19.82	0.0000
Residuals	1642		

Notes: Each row corresponds to a test comparing a model that excludes the one listed in that row with a model that includes all other variables. Main effects are also excluded for tests on interaction terms.

Table 5

Panel Unit Root Tests Using Cross-sectionally Augmented Dickey Fuller Regressions as Described in Pesaran (2007)

Test Statistic	Lag Order	Type	*p*-dF
−4.06	3	trend	0.01
−3.56	3	drift	0.01
−3.57	3	none	0.01

Note: In each case the alternative hypothesis indicates a stationary series. The tests are calculated using the cipstest() function from the **plm** package (Croissant and Millo 2008).

Alternate Models

To check the robustness of our results, we fit several alternate models and examine the resulting changes in the estimated coefficients for US prices and crop loss. Table A1 (see Appendix B) summarizes the robustness checks and the resulting impacts on the two covariates of interest[10].

In the first alternate model we replace the year groups with individual years to check whether the two-year groups hide significant year-to-year variation. In the second alternate model, we replace the spring–fall growing season dummy variable with dummy variables for each calendar month. In this case, the goal is to see whether there are unobserved calendar-month-specific supply or demand influences beyond what is accounted for by growing season. Other alternate specifications include replacing the US price with a global cereal price index and various alternative measures of crop loss. In each model, we examine how the alternate specification influences the trend, effect sizes, and significance against the baseline results seen in Figures 6 and 7. In general, the US prices variable is the most robust to the model specification changes. The pattern and effect size over time remain similar in most model specifications. When we substitute the US price variable for another measure of global influence, the FAO Cereal Price Index, the pattern still remains, but the effect size becomes noticeably bigger, suggesting that domestic Mexican maize prices might also be responding to movements of other global grains. The crop loss variable is less robust than the US prices variable, especially among the regional models, but the overall patterns remain the same. In general the alternate specifications shrank the crop loss coefficient and induced some changes in the significance of crop loss, especially during the later years of the study period and in the southern region. None of the alternate specifications change the overall interpretation of the results presented above.

Discussion

Our objective in this study is to examine how the response of maize price levels to global and local influences changed over periods of increasing market openness. In an ideal experiment, there would be no state varying policy treatments, production regimes would be clearly separated by state, and markets would become uniformly open on a fixed date. As is often the case, the data did not lend itself to a clean experimental design. However, we can observe markets in varying states and production regimes

[10] Graphs showing the results of each robustness check (similar to Figures 6 and 7) are available from the authors.

(traditional to commercial, irrigated and nonirrigated), and we are able to control for unequal policy treatments through state-year fixed effects. Thus, some key results do emerge.

At first glance, the standard story of open trade increasing the influence of global forces over time is not obvious here. Our results indicate that even during the *closed* period, the US maize price was still having a strong influence on Mexican prices. The marginal effect of US prices on Mexican prices is the largest in the 1998–2000 and 2005–2006 periods. One explanation for this result is that 1998 marked the end of the Mexican government grain purchasing program, CONASUPO, and the beginning of *real* (not state-controlled) maize prices in Mexico. However, this period, 1998–2000, is also when market price supports were at their *highest* (see Figure 1 and Table 1). We *speculate* that, despite market price supports, import quotas, and the rise of Sinaloan production, the absence of CONASUPO caused buyers and sellers to assume US prices were the clearest guide to domestic prices. The influence of US prices also rose dramatically in 2005–2006. This period immediately precedes an international rise in commodity prices and the Mexican tortilla crisis—so called because of the rapid rise in tortilla prices. Overall, the evidence suggests that during our study period, the removal of trade barriers and even the increasing dominance of Sinaloa had little influence on a market that was already following US price signals.

The influence of crop loss on prices over time did appear to follow theory. The effect shrank over time in the model run on all regions. However, the nature of the response did vary across regions. The results were the strongest and most persistent in the center. Several facts about the center region shed light on this result. The center region is the largest producer outside of the northwest and is the largest producer of rain-fed maize, making it the most susceptible to weather shocks (Sweeney et al. 2013). Also, as seen in Figure 4 the states in the center consume virtually no maize grown outside that region. In contrast, the south was not responsive at all to crop loss. Although the south is also dependent on rain-fed maize, it produces less than the center and, with the exception of Chiapas, most maize consumed in that region comes from other states. These different results from two different regions illustrate how the impacts of market opening may not be homogeneous across regions. A potential future research topic is to explore the extent that remittances sent by emigrants might also contribute to regional variation in the response of prices to crop loss[11].

Taken together the results suggest that under a *closed* market, domestic prices may still be responsive to global signals and that a market opening may not have one uniform impact on all regions in a country. Geographic differences, intranational trade, and state-specific policy treatments might all generate regionally specific outcomes. Policies designed to cushion impacts of trade liberalization should ideally take these factors into account. But even in an open market, there are other factors (the dominance of a national producer, isolation because of poor transport/communication infrastructure) that can spatially vary the impact of global or local forces. We suggest that attempts to forecast or summarize the results of a market opening should be done in the context of the country, product, and government response, with special attention paid to how these factors vary over regions.

[11] We thank an anonymous reviewer for highlighting this point.

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Appendix A. Figures

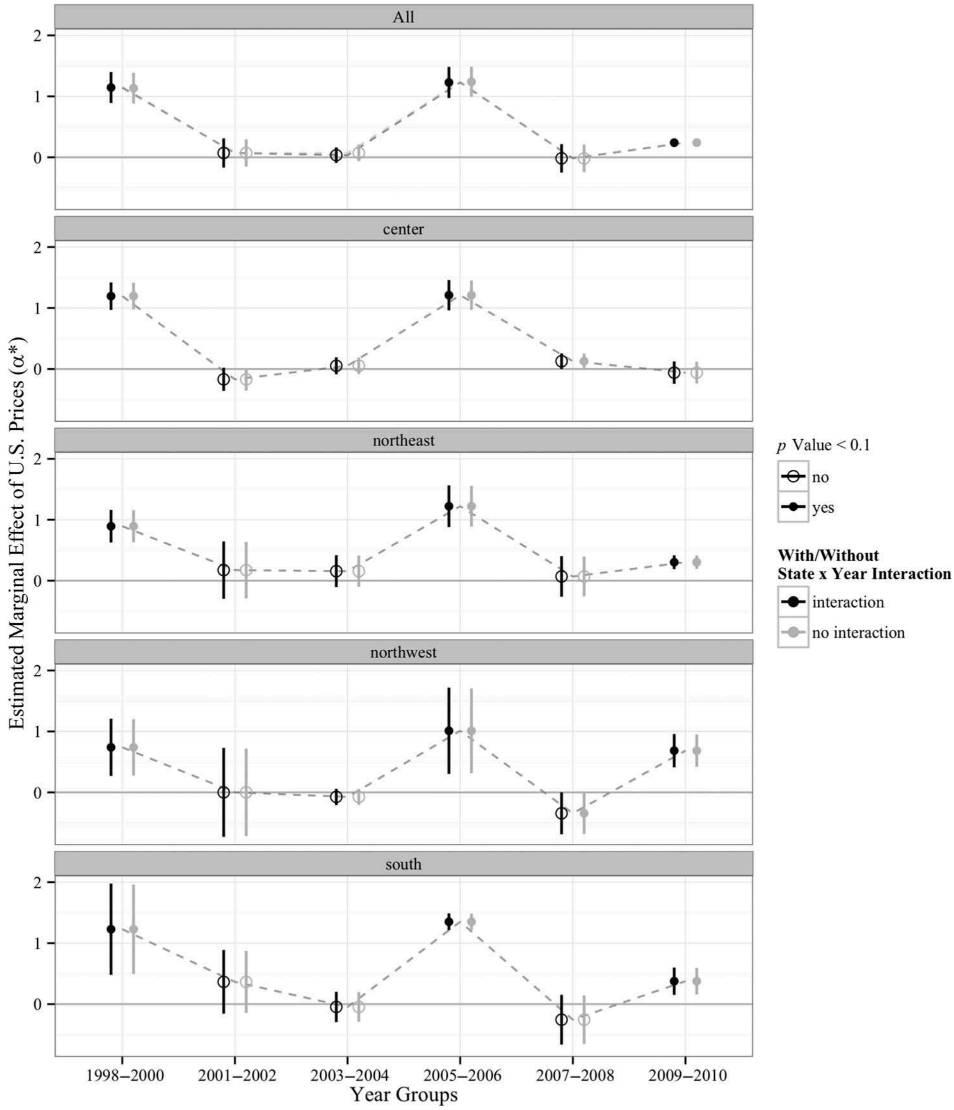

Figure A1. Estimates of α^* (US prices).
Notes: This figure presents the marginal effects of the Year × US Prices interaction term: α. Each panel in the figure corresponds to a model fit to a specific region (the top panel is the model fit to all regions). The y-axis corresponds to the effect size of the estimated coefficients and the x-axis corresponds to the different year groups over which the coefficients vary. Point estimates and 90 percent confidence intervals for two models are presented side by side in each region panel. Results from the model, which includes the State × Year interaction term, are in black and on the left side of each x-axis interval. Significant coefficients are shown with closed circles and insignificant coefficients are shown with open circles.

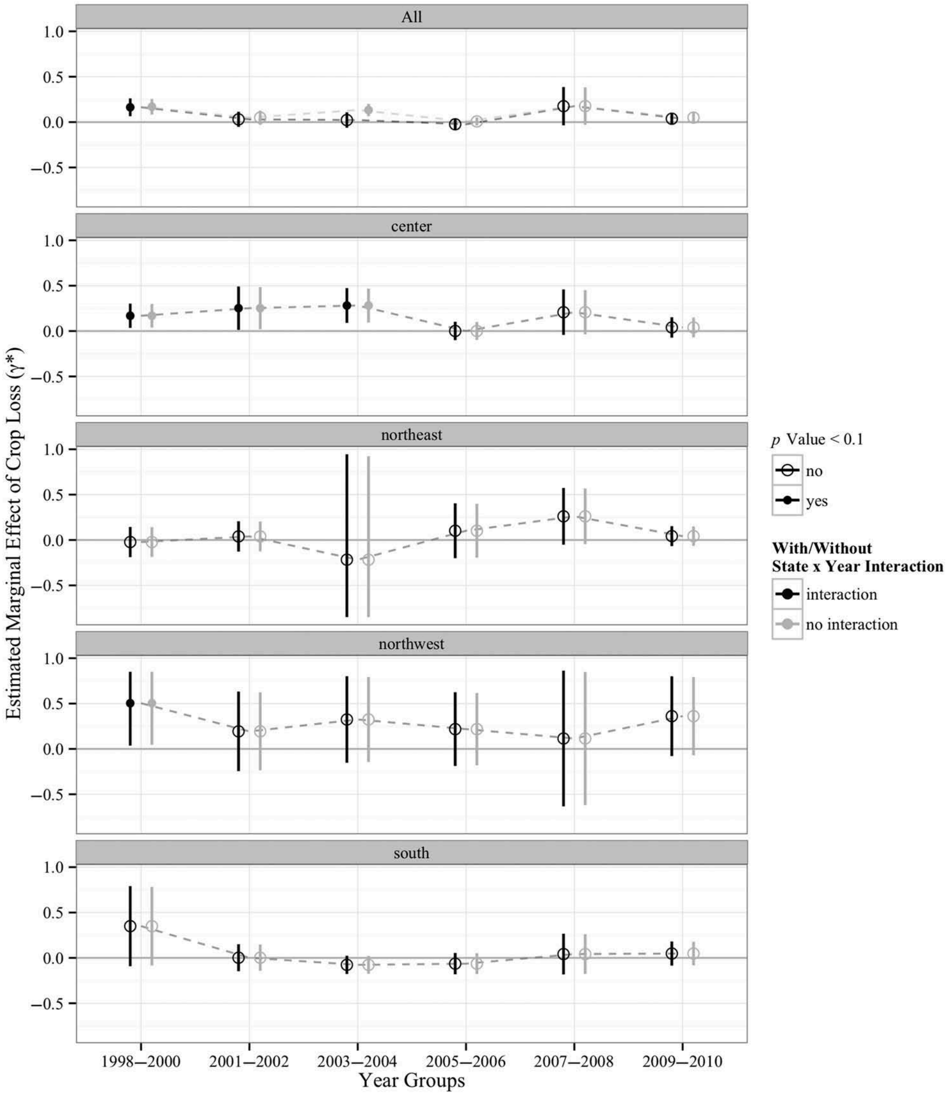

Figure A2. Estimates of γ^* crop loss.
Notes: This figure presents the marginal effects of the Year × Crop Loss interaction term: γ. Each panel in the figure corresponds to a model fit to a specific region (the top panel is the model fit to all regions). The y-axis corresponds to the effect size of the estimated coefficients and the x-axis corresponds to the different year groups over which the coefficients vary. Point estimates and 90 percent confidence intervals for two models are presented side by side in each region panel. Results from the model, which includes the State × Year interaction term, are in black and on the left side of each x-axis interval. Significant coefficients are shown with closed circles and insignificant coefficients are shown with open circles.

Appendix B. Tables

Table A1

Results from Price-Levels Model

	All	AllSY	Center	$Center^{SY}$	Northeast	$Northeast^{SY}$	Northwest	$Northwest^{SY}$	South	$South^{SY}$
(Intercept)	0.37*	0.62*	0.61*	0.65*	0.24*	0.46*	−0.17	0.09	0.46*	−0.04
	(0.11)	(0.22)	(0.08)	(0.18)	(0.08)	(0.10)	(0.20)	(0.21)	(0.21)	(0.21)
Season (spring)	0.10*	0.10*	0.13*	0.13*	0.08	0.08	0.22*	0.22*	0.06	0.06
	(0.04)	(0.05)	(0.07)	(0.07)	(0.09)	(0.09)	(0.11)	(0.11)	(0.07)	(0.08)
Year 2001–2002	−1.13*	−1.47*	−1.56*	−1.65*	−1.04*	−1.10*	−0.68	−0.95*	−0.81*	−0.33
	(0.14)	(0.26)	(0.10)	(0.20)	(0.24)	(0.27)	(0.47)	(0.57)	(0.31)	(0.31)
Year 2003–2004	−0.85*	−1.35*	−1.23*	−1.27*	−1.03	−1.39*	−0.04	0.23	−0.92*	0.28
	(0.08)	(0.24)	(0.10)	(0.19)	(0.75)	(0.74)	(0.19)	(0.24)	(0.20)	(0.29)
Year 2005–2006	−0.24*	−0.75*	−0.61*	−0.79*	−0.23	−0.64*	0.46	0.44	−0.20	0.87*
	(0.14)	(0.27)	(0.14)	(0.22)	(0.16)	(0.17)	(0.38)	(0.44)	(0.22)	(0.26)
Year 2007–2008	0.73*	0.68*	0.30*	0.41*	0.79*	0.49	1.47*	0.85*	0.85*	0.88*
	(0.17)	(0.26)	(0.13)	(0.21)	(0.34)	(0.44)	(0.24)	(0.39)	(0.27)	(0.38)
Year 2009–2910	0.25*	0.09	0.36*	0.36	0.67*	0.44*	−0.21	−1.38*	0.05	0.32
	(0.08)	(0.22)	(0.11)	(0.23)	(0.15)	(0.16)	(0.26)	(0.32)	(0.27)	(0.40)
US prices	1.13*	1.14*	1.20*	1.20*	0.89*	0.89*	0.74*	0.74*	1.23*	1.23*
	(0.15)	(0.15)	(0.13)	(0.14)	(0.16)	(0.16)	(0.28)	(0.29)	(0.45)	(0.46)
Crop loss	0.17*	0.16*	0.17*	0.17*	−0.02	−0.02	0.50*	0.50*	0.35	0.35
	(0.05)	(0.06)	(0.08)	(0.08)	(0.10)	(0.10)	(0.28)	(0.28)	(0.26)	(0.27)
Sinaloa (Sin) crop loss	0.01	0.02	−0.04	−0.04	0.02	0.02	−0.29	−0.29	0.12*	0.12
	(0.03)	(0.04)	(0.07)	(0.07)	(0.04)	(0.04)	(0.26)	(0.27)	(0.07)	(0.07)
US prices 2001–2002	−1.06*	−1.07*	−1.37*	−1.37*	−0.72*	−0.72*	−0.74	−0.74	−0.86	−0.86
	(0.21)	(0.22)	(0.15)	(0.16)	(0.32)	(0.33)	(0.53)	(0.54)	(0.55)	(0.56)
US prices 2003–2004	−1.06*	−1.11*	−1.14*	−1.14*	−0.74*	−0.74*	−0.81*	−0.81*	−1.27*	−1.27*
	(0.17)	(0.17)	(0.16)	(0.17)	(0.22)	(0.23)	(0.29)	(0.29)	(0.48)	(0.49)
US prices 2005–2006	0.11	0.08	0.02	0.02	0.33	0.33	0.27	0.27	0.12	0.12
	(0.22)	(0.23)	(0.20)	(0.20)	(0.26)	(0.26)	(0.51)	(0.52)	(0.46)	(0.47)
US prices 2007–2008	−1.15*	−1.16*	−1.07*	−1.07*	−0.82*	−0.82*	−1.08*	−1.08*	−1.48*	−1.48*
	(0.20)	(0.21)	(0.15)	(0.16)	(0.26)	(0.26)	(0.35)	(0.35)	(0.51)	(0.52)
US prices 2009–2010	−0.89*	−0.90*	−1.25*	−1.25*	−0.59*	−0.59*	−0.05	−0.05	−0.85*	−0.85*
	(0.16)	(0.16)	(0.17)	(0.18)	(0.18)	(0.18)	(0.32)	(0.33)	(0.48)	(0.49)
Crop loss 2001–2002	−0.12*	−0.13*	0.08	0.08	0.06	0.06	−0.31*	−0.31*	−0.35	−0.35
	(0.06)	(0.06)	(0.15)	(0.15)	(0.13)	(0.14)	(0.15)	(0.16)	(0.27)	(0.27)
Crop loss 2003–2004	−0.04	−0.14*	0.11	0.11	−0.19	−0.19	−0.18	−0.18	−0.43*	−0.43*
	(0.06)	(0.06)	(0.09)	(0.09)	(0.70)	(0.71)	(0.14)	(0.14)	(0.25)	(0.25)
Crop loss 2005–2006	−0.16*	−0.19*	−0.17*	−0.17*	0.12	0.12	−0.29*	−0.29*	−0.41*	−0.41*
	(0.05)	(0.05)	(0.06)	(0.06)	(0.23)	(0.24)	(0.12)	(0.12)	(0.24)	(0.24)

(*continued*)

Table A1
(*Continued*)

	All	AllSY	Center	$Center^{SY}$	Northeast	$Northeast^{SY}$	Northwest	$Northwest^{SY}$	South	$South^{SY}$
Crop loss 2007–2008	0.01	0.01	0.04	0.04	0.28	0.28	−0.39	−0.39	−0.31	−0.31
	(0.14)	(0.14)	(0.15)	(0.15)	(0.21)	(0.22)	(0.37)	(0.37)	(0.29)	(0.29)
Crop loss 2009–2010	−0.12*	−0.13*	−0.13*	−0.13*	0.07	0.07	−0.14	−0.14	−0.30	−0.30
	(0.05)	(0.05)	(0.05)	(0.06)	(0.10)	(0.10)	(0.11)	(0.11)	(0.23)	(0.23)
N	1728	1728	720	720	288	288	288	288	432	432
R2	0.60	0.74	0.68	0.78	0.82	0.84	0.45	0.65	0.58	0.70
adj. R^2	0.59	0.72	0.67	0.77	0.80	0.82	0.41	0.62	0.55	0.68
Resid. sd	0.64	0.53	0.57	0.48	0.44	0.42	0.77	0.62	0.67	0.57

Notes: Coefficient estimates from models on all states (All) and various Regions. Standard Errors reported here are robust to heteroskedasticity, spatial, and serial correlation (see Driscoll and Kraay 1998). Note that in this table, we show main effects and interactions but not the combination of the two (as shown in Table 3).
Driscoll and Kraay (1998) standard errors in parentheses.
SY indicates results from the model that includes a state-year interaction.
*indicates significance at $p < 0.1$.

Table A2

Summary of Results from Robustness Checks

Change	Reason	Effect on US Prices	Effect on Crop Loss
Replace two growing-year groups with individual growing years	Determine if the two-year groupings hide significant year-to-year variation	Overall trend is the same but the effect size shrinks, and there is more movement, especially in the South where the effect size increases in the first period and there are negative terms in 2000 and 2001	Trend is the same but effect size for the South contains more year-to-year variation, and some estimates are negative. Standard errors are bigger, likely due to decreased crop loss variation in the one-year period
Replace growing sea son dummy variable with calendar month dummy variable	Determine if there are calendar-specific demand or supply influences beyond what is accounted for by growing seasons	No change	Trend is the same, effect size increases slightly.
Replace US price with FAO Global Cereal Price Index	An alternative measure of global influence. To test the extent that domestic white maize prices also respond to prices for competing grains	Trend is the same, effect size decreases slightly in the first period.	Trend is the same, levels increase slightly in the center region, indicating that these areas are more responsive to competing grain prices.
Replace the regional loss term with a loss term specific to that state	Alternative model specification —assumes that prices do not respond to loss in neighboring states	No change	Trend is the same but there are more negative signs. Northwest now has significant differences in the two models, and a significantly negative sign in the last period. A possible explanation is that not accounting for regional loss can potentially shift the sign if loss in state *i* implies an influx of grain from neighboring state *j*.
Include Region Loss as separate covariate	Alternative model specification —assumes that in- state loss and neighboring-state loss have different effects	No change	Trend is the same and effect sizes shrink or become negative, likely due to colinearity between state loss and region loss coefficients.
Use hectares failed without controlling for area planted	Alternative measure of loss, does not account for area planted	No change	Trend is the same, but effect size increases in the Northeast, making the 2003–2004 and 2005–2006 periods significant. Effect size shrinks for the Northwest and the period 2007–2008 become negative. Not controlling for area planted implies that states with smaller acreage (Sonora in the Northwest, Nuevo Leon in the Northeast) become bigger outliers and exert more influence on the model.