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Trade policies and the transmission of international to domestic prices

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Abstract
We look for evidence that countries increasingly insulate their domestic markets for staple grains from global markets when international prices increase. Previous studies have demonstrated that the transmission of international to domestic prices for these products is less than perfect, which reduces the ability of the global trading system to buffer shocks. However, past studies generally assume that relationships between international and domestic prices are constant, and hence that a country's degree of insulation does not vary over time. To relax this assumption, we use a smooth-transition model, a modified version of the error correction model (ECM). We estimate elasticities of transmission from international to domestic wholesale and retail prices for a comprehensive set of countries for wheat, yellow and white maize, and rice. We find that price transmission from international to domestic prices weakens in many countries and on average when international prices peak, in other words that the insulation of domestic from international prices increases during high-price episodes (such as in 2007/08 and 2022). We also find that this increased insulation cannot be attributed exclusively to changes in border measures such as export restrictions or import tariffs. This suggests that countries are also using measures such as price controls or the release of stocks to insulate their domestic markets for staple grains.

JEL Codes: Q17, F13, Q11

1. Introduction

Many countries use policy interventions to stabilise domestic food prices when international prices peak. The Covid-19 pandemic and Russia's war in Ukraine disrupted food supply chains and triggered rapid increases in food prices in international markets. Governments responded with different measures to insulate their domestic markets from these price peaks. These measures included export restrictions, which proliferated following the onset of Russia's aggression. Other border measures such as reductions in import tariffs can also be used to insulate domestic markets, as can domestic market measures such as reductions in sales taxes and various types of domestic price control.

These policy responses may appear rational to individual implementing governments as they endeavour to insulate their domestic consumers from high and volatile prices. However, these policies create a collective action problem, fuelling a vicious circle of further increases in international price levels and volatility, additional policy responses and, ultimately, increased food insecurity, especially in low-income importing countries. In essence, policy responses to high and volatile food prices in both exporting and importing countries can reduce the capacity of the global trading system to buffer shocks precisely when this capacity is most needed.

The objective of this study is to empirically analyse how the transmission of international to domestic food prices changes during episodes of increasing international prices. We look for evidence that countries insulate their domestic markets for staple grains when international prices increase. A point of departure for our analysis is a recent paper by Martin and Minot (2022) who study how measures implemented by countries to insulate their domestic prices from international prices amplify the volatility of these international prices. Martin and Minot (2022) estimate error correction models (ECMs) and find that domestic wheat prices in most countries for which data are available are linked to international wheat prices in the long run. However, they find that long-run transmission from international to domestic prices is less than 100% in most cases. They interpret this as evidence that many governments implement policy measures designed to dampen the transmission of international to domestic prices and thus insulate their domestic markets.

A possible weakness in Martin and Minot's (2022) approach is the implicit assumption that the relationships between international and individual domestic prices are constant over the 2004-2022 sample period that they analyse. In other words, they assume that each government implements policies that result in a constant, time-invariant degree of insulation of domestic from international markets. We relax this assumption and look for evidence that governments respond to increasing international prices by implementing measures that reduce price transmission and increase insulation. If countries are indeed responding to increasing international prices by increasing insulation, then we can expect to see corresponding changes in the parameters of ECMs that describe the relationships between international and individual domestic prices. We also study whether any increases in domestic market insulation that we identify are due to changes in border measures such as export restrictions or import tariffs, or whether there is evidence that other policy measures (such as domestic price controls or the purchase and release of stocks) are being used to insulate domestic markets.

2. Theoretical framework and empirical methods

We use a simple model that describes the relationship between a domestic price of a commodity, such as wheat, and its corresponding international price to show how policy changes and other factors affect this relationship. Based on this we then describe a price transmission model that we use to look for empirical evidence that government policies and, hence, relationships between domestic and international prices change when international prices increase strongly.

2.1 Theoretical framework

Consider a country importing a food commodity that applies a combination of *ad valorem* (v) and specific (s) tariffs. The domestic price in this country (p^D) will equal:

$$p^D = p^I(1+v) + s + TC + OTC \tag{1}$$

where p^I is the international price, and TC measures transport costs between the locations at which p^I and p^D are reported. OTC are trade costs other than transport costs. The first two terms on the right-hand-side of equation (1) ($p^I(1+v)+s$) capture the effects of border policies in the importing country. TC captures the physical costs and OTC covers other costs of trade as well as traders' margins.[1]

Under these conditions the elasticity of international to domestic price transmission (ε) equals

$$\varepsilon = \frac{p^I(1+v)}{p^I(1+v)+s+TC+OTC} \tag{2}$$

It is immediately apparent that $0 < \varepsilon \leq 1$, with $\varepsilon = 1$ when $s = TC = OTC = 0$.

Equation (2) can be used to derive the following results:

$$\frac{\partial \varepsilon}{\partial p^I} = \frac{\varepsilon}{p^I}(1-\varepsilon) > 0, \tag{3}$$

$$\frac{\partial \varepsilon}{\partial v} = \frac{\varepsilon}{(1+v)}(1-\varepsilon) > 0, \text{ and} \tag{4}$$

$$\frac{\partial \varepsilon}{\partial s} = \frac{\partial \varepsilon}{\partial TC} = \frac{\partial \varepsilon}{\partial OTC} = \frac{-\varepsilon}{p^I(1+v)+s+TC+OTC} < 0. \tag{5}$$

Equation (3) shows that the elasticity of international to domestic price transmission (ε) is an increasing function of the international price. This is because as p^I increases, the price difference $p^D - p^I$ that is due to a given s, TC and OTC becomes smaller relative to the price level and ε asymptotically approaches 1. Equation (4) shows that if the importing country reduces its *ad valorem* tariff v, ε will decrease and insulation will increase. However, if $\varepsilon = 1$, then changes in p^I and v in equations (3) and (4) have no effect on ε. Finally, equation (5)

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[1] In the case of an exporting country, TC can be negative, as will v and s if export taxes are applied. If the price in a major exporting country is used to measure p^I, then v, s, TC and OTC will measure relative border measures and trade costs for the exporting country vis-à-vis the major exporter. This has no effect on the following derivations.

shows that if a country increases its specific tariff s, or if its trade costs TC and OTC increase, ε will decrease and insulation will increase.

Equations (3), (4) and (5) describe partial changes to elasticities driven by p^I, v, s, TC and OTC. In reality, *ceteris paribus* condition will rarely hold, as changes in p^I, v, s, TC and OTC will be contemporaneous and interrelated. Indeed, the hypothesis underlying our analysis is that changes in p^I cause countries to adjust policies such as tariffs, in other words that v and s are functions of p^I. In addition, since energy costs are an important component of TC, and agricultural and energy commodity prices co-move (Pindyck and Rotemberg, 1990; Baffes and Haniotis, 2016), $\partial TC/\partial p^I \neq 0$. If we assume, for illustration, that p^I and TC increase by the same amount ($dp^I = dTC = x$), then we can derive the total derivative:

$$d\varepsilon = \left[\frac{\varepsilon}{p^I(1+v)}\left(1 + v - \varepsilon(2+v)\right)\right] x \qquad (6)$$

which will be negative or positive depending on the relative magnitudes of v and ε. In reality, p^I and TC will likely change by different amounts, and these changes might trigger changes in v and s. When p^I, v, s, TC and OTC change simultaneously, the resulting total change in the elasticity of international to domestic price transmission will be a different, more complex combination of the reactions in equations (3), (4) and (5).

Governments can use other policy tools in addition to border measures to influence their domestic prices. These tools include price and margin controls, sales and value added taxes, subsidies, manipulation of exchange rates and public stockholding. The effects of some but not all of these policy tools can be expressed as tariff equivalents. Depending on how and when such policy tools are implemented, ε might even appear to be negative over a period. If, for example, in response to increasing international prices the government of an importing country releases public stocks on its domestic market, or the government of an exporting country imposes an export ban, then international and domestic prices might move in opposite directions for a period, leading to $\varepsilon < 0$.

Finally, the relationship between international and domestic prices can also be influenced by the exercise of market power by traders and other businesses along the supply chain, such as harbour facilities and other critical infrastructure, logistics, or testing and certification procedures. Such businesses might, for example, attempt to take advantage of the uncertainty and confusion created by a sudden agricultural price peak to inflate their prices and margins. In this case, domestic prices might increase more rapidly than the international price over a period. If p^D is not a border price but rather measured further along the supply chain (for example, at the retail level), OTC will include additional marketing-costs. This will render the price transmission mechanism more complex and, depending on market structure in processing and retailing, will increase the scope for non-competitive pricing. It is therefore conceivable that increasing trade costs and non-competitive pricing behaviour could cause domestic prices to grow faster than international prices, in which case we might observe $\varepsilon > 1$ over a period.

Considering all of these factors, it is difficult to predict *a priori* how the relationship between international and a domestic price for an agricultural commodity will change when international prices increase rapidly. While we can be quite certain that this relationship will change, the nature of this change will depend on a wide range of country- and product-specific factors. It is reasonable to expect that when international prices increase sharply, most governments will attempt to insulate domestic markets for political reasons, thus reducing ε, and perhaps even making it negative over certain periods. However, increases in marketing costs, and non-competitive pricing behaviour in the value chain, could cause domestic prices to grow more than international prices, leading to periods in which $\varepsilon > 1$.

To analyse the varying relationships between domestic and international prices econometrically, we use a simple specification of the long-run relationship between prices:

$$p_t^D = \beta_0 + \beta_1 p_t^I + \beta_2 TC_t + u_t \qquad (7)$$

where the subscript t indexes time and u is a stochastic error. In equation (7), β_1 captures the term $(1 + v)$ in equation (1), β_0 captures $s + OTC$, and the elasticity of international to domestic price transmission is given by:

$$\varepsilon = \frac{\beta_1 p^I}{\beta_1 p^I + \beta_0 + \beta_2 TC_t} \qquad (8)$$

A country seeking to insulate its domestic market from a surge in international prices would typically take steps that aim at reducing β_1 (for example by reducing its ad valorem tariff v). At the same time, if trade costs increase, say, because of a raise in fuel prices (which often co-move with agricultural prices), $\beta_2 TC_t$ will increase (unless compensated by reductions in any specific tariff s). The combined effect of decreasing β_1 and increasing $\beta_2 TC_t$ would be to reduce ε in equation (8), but since increasing international prices (p_t^I) have the opposite effect, the total effect on ε is ambiguous.

Moving from comparative statics to econometrics, if v, s, TC and/or OTC are changing over time, then equation (7) is mis-specified and estimates of β_0, β_1 and ε will be biased. This omitted-variable bias in purely price-based estimates of price transmission relationships is discussed in many studies (e.g., Barrett, 1996; Kinnucan, 2022). Given complete information on the evolution of v, s, TC and/or OTC over time, the ideal solution to this problem would be to specify a structural model of the relationship between p^D and p^I. Since complete information on all of these factors (especially *OTC*) is rarely available, an alternative solution is to estimate a flexible form of equation (7) that allows β_0 and β_1 to vary over time. Many such flexible models that allow for structural breaks, threshold effects, asymmetry, non-parametric variation and other non-linearities have been proposed and applied in the price transmission literature (Vollmer et al., 2019). This solution is less than ideal because it is unlikely that a chosen flexible model will exactly mimic the changes in unobserved factors that cause β_0 and β_1 to vary over time. Nonetheless, models with varying parameters allow us to look for plausible patterns in price data and accumulate evidence, if not rigorously test hypotheses.

The ECM has been the dominant model in price transmission analysis since the mid-1990s.[2] The ECM combines estimation of the long-run relationship between two variables with estimation of the short-run dynamic reaction to shocks that ensure that this relationship is restored when disturbed and thus holds in the long run. The ECM for the relationship between a domestic price and an international price is:

$$\Delta p_t^D = \alpha(p_{t-1}^D - \beta_0 - \beta_1 p_{t-1}^I - \beta_2 TC_{t-1}) + \sum_{i=1}^{k} \delta_i \Delta p_{t-i}^D + \sum_{j=1}^{l} \varphi_j \Delta p_{t-j}^I + u_t \qquad (9)$$

In equation (9), the first term on the right-hand-side $(p_t^D - \beta_0 - \beta_1 p_t^I - \beta_2 TC_t)$ measures deviations from the long-run relationship between p^D and p^I in equation (7). α is the so-called adjustment parameter that describes the speed at which deviations from this long-run

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[2] Von Cramon-Taubadel and Goodwin (2021) is a recent survey of the price transmission literature.

relationship ('errors') are corrected by changes in the domestic price (hence the term 'error correction model'). The δ and the φ are parameters that capture short-run dynamic responses in the system. The ECM is an appropriate specification for variables that are non-stationary (the technical term is 'integrated') but co-move so that the deviations from their long-run relationship are stationary (this co-movement is referred to as 'cointegration'). Hence, prior to estimating an ECM, one first tests whether the variables are integrated (which is often the case with price series), and whether they are cointegrated. Variables that are not cointegrated do not share a common long-run relationship, in which case there can be no error correction process that restores such a relationship and, hence, no ECM. In our setting, lack of cointegration (i.e., lack of a long-run relationship) between a domestic and the corresponding international price suggests complete insulation of the domestic market.[3] Otherwise, if the domestic price is cointegrated with the international price, we expect to see the parameters of the long-run relationship change in a manner consistent with increasing insulation, as outlined above, when international prices increase sharply.

Martin and Minot (2022) estimate the ECM in equation (9) for 46 domestic wheat price series, using US No. 2 SRW fob Gulf as a representative international price.[4] They find evidence for cointegration between 37 of these domestic price series and the international price. For those 37 series they estimate an average elasticity of price transmission of 0.765. Since complete price transmission would be reflected in cointegration with an elasticity close to 1, Martin and Minot (2022) interpret their results (the lack of cointegration in some cases, and elasticities of price transmission lower than 1 in others) as evidence that countries are, to varying degrees, insulating their domestic market from international markets. In the second step of their analysis, Martin and Minot (2022) proceed to model the effects of this insulation on how international prices respond to shocks.

As outlined above, we hypothesise that countries will respond to increasing international prices with policy changes that, depending on previous policies, either introduce or increase pre-existing insulation. If this hypothesis is true, β_0 and β_1 in equation (7) will vary over time. To test this hypothesis, we use a smooth-transition version of the ECM in equation (9).

2.3. The smooth transition model

The modification of the ECM that we use is a so-called smooth-transition (ST) model. ST models assume that the relationship between two or more variables switches smoothly between two regimes depending on the value of a transition function. The transition function is bounded between 0 and 1: for values of 0 the relationship between the variables being modelled follows one regime entirely; for values of 1 it follows the second regime entirely; for values between 0 and 1 it follows a correspondingly weighted mixture of the two regimes.

Several ST models have been proposed and implemented in the literature. We use a specification proposed by Saikkonen and Choi (2004) and implemented in agricultural price

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[3] As we discuss below, we might fail to find that two prices are cointegrated because we do not use an appropriately specified test that accounts for possible non-linear relationship between them.

[4] Of the 46 domestic prices analysed by Martin and Minot (2022), 17 are for wheat grain, 18 for wheat flour, and 11 for bread. Domestic flour and bread prices are not only spatially separated from the international wheat price by TC and OTC in equation (1), they are also vertically separated in the food chain because they include varying degrees of processing. All other things equal, elasticities of transmission from international to processed domestic prices will be lower than elasticities of transmission from international to unprocessed prices. Hence, estimates of wheat-to-flour and wheat-to-bread price transmission are not directly comparable with estimates of wheat-to-wheat price transmission. To avoid this additional complication, we only analyse prices for unprocessed grains.

transmission for example by Götz et al. (2016). This specification allows for smooth transition in the long-run relationship between a domestic and the international price:

$$p_t^D = \beta_0^L + \beta_1^L p_t^I + (\beta_0^H + \beta_1^H p_t^I) * g(p_t^I) + \beta_2 TC_t + u_t \tag{10}$$

where the superscripts L and H refer to low- and high-price regimes, respectively, and

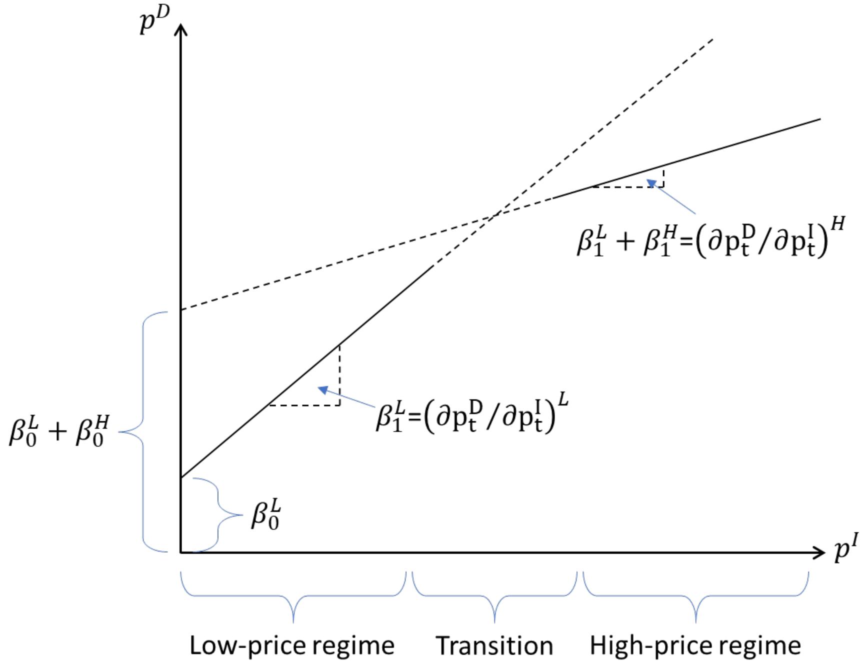
$$g(p_t^I) = \left(1 + e^{\left(-\gamma(p_t^I - c)\right)}\right)^{-1} \tag{11}$$

In equation (10), the function $g(\cdot)$ ranges from 0 for low values of p_t^I to 1 for high values. When $g(\cdot)$ = 0, the long-run relationship between p_t^I and p_t^D in equation (10) reduces to $p_t^D = \beta_0^L + \beta_1^L p_t^I$, which we refer to as the low-price regime. When $g(\cdot)$ = 1, the long-run relationship becomes $p_t^D = (\beta_0^L + \beta_0^H) + (\beta_1^L + \beta_1^H) p_t^I$, which we refer to as the high-price regime. The coefficient c marks the mid-point of the transition between the regimes where $g(\cdot)$ = 0.5, and the relationship between p_t^I and p_t^D is an equally-weighted mixture of the low- and the high-price regimes. The coefficient γ determines the speed with which $g(\cdot)$ transitions from 0 to 1 as $\mathrm{p}_{\mathrm{t}}^{\mathrm{I}}$ increases. As $\gamma \rightarrow \infty$ the transition function $g(\cdot)$ approaches a step function and the transition from the low- to the high-price regime becomes increasingly abrupt at $p_t^I = c$. This ST model is estimated using maximum likelihood techniques.

Based on the theoretical framework outlined above we derive two expectations for the results of estimating the ST model. First, the specification of $g(\cdot)$ in equation (11) assumes that the transition between regimes is driven by the level of the international price (hence the terms 'low-price' and 'high-price' regime). We expect that the transition from the low- to the high-price regime will take place when international prices reach what are perceived to be critical levels. These critical levels will vary by commodity and differ among countries depending, *inter alia*, on their trade exposure (especially import dependence), and food (in)security and fiscal situations. International wheat prices, for example, have typically ranged between 150 and 200 \$/t in recent decades, interrupted by peaks such as in 2007/08 and 2022, when they increased rapidly to over 300 \$/t. Hence, we expect that many countries will implement policy changes and thus trigger the transition from the low-price to the high-price regime for wheat when international wheat prices climb above 200 \$/t and reach levels of 250 \$/t and above.

Second, if countries are indeed responding to increasing international prices by increasing the insulation of their domestic markets, then the high-price regime will be characterised by a higher degree of insulation than the low-price regime. Figure 1 depicts what we might expect for a typical importing country. For low international prices, the low-price regime $p_t^D = \beta_0^L - \beta_1^L p_t^I$ holds. The coefficients β_0^L and $\beta_1^L = (\partial p_t^D / \partial p_t^I)^L$ will vary among countries depending on their trade costs (e.g., whether they are landlocked, the efficiency of port infrastructure) and the policy measures that they implement (e.g., their import tariffs, internal price controls, etc.). For high international prices the high-price regime holds, and we expect that increased insulation in this regime will be reflected a reduction in the responsiveness of domestic to international prices, i.e. $(\beta_1^L + \beta_1^H) = (\partial p_t^D / \partial p_t^I)^H < (\partial p_t^D / \partial p_t^I)^L = \beta_1^L$, and therefore $\beta_1^H < 0$. In addition, we expect that $(\beta_0^L + \beta_0^H) > \beta_0^L$ and therefore $\beta_0^H > 0$. As discussed above, an importing country might respond to increasing international prices by reducing specific tariffs, which would shift the price relationship downward, implying that $\beta_0^H < 0$ and $(\beta_0^L + \beta_0^H) < \beta_0^L$. However, the constant term β_0 also includes the costs of trade and especially transport (fuel) costs which typically increase when agricultural prices and commodity price in general increase.

Figure 1: The relationship between international and domestic prices in the low- and high-price regimes



As discussed above, the combined effect of these changes will typically be to reduce the elasticity of international to domestic price transmission. Some countries might even be able to implement measures that drive domestic prices down when international prices reach critical levels. In this case the high-price regime would be downward sloping and the elasticity of international to domestic price transmission would become negative. However, we cannot rule out that this elasticity increases for specific countries and commodities.

3. Data

We use monthly prices for wheat, maize and rice obtained from the Food and Agriculture Organization's Global Information and Early Warning System (GIEWS, FAO, 2023) and US AID's Famine Early Warning Systems Network (FEWS NET, US AID, 2023). Depending on availability we use price series beginning as early as January 2004 and no later than January 2011, and ending in June 2023. As international reference prices we use US No. 2 SRW fob Gulf for wheat, US No. 2 Yellow for yellow maize, South Africa Randfontein white for white maize, and Thailand Bangkok Thai 100 B for rice.[5]

We only consider domestic price series with no more than 5% missing values. For all series that satisfy this condition, missing values were replaced using Kalman smoothing with an ARIMA model (Moritz and Bartz-Beielstein, 2017). Whenever both wholesale and retail prices are available for a domestic market location, we only analyse the wholesale prices because the marketing step from wholesale to retail can further modify prices depending on market structure, competition, retailer pricing strategies, and domestic price regulation (see footnote 4). Often, however, only retail prices are available, and we also compare results for wholesale and retail prices below. As a proxy for transport costs, we use the Baltic Dry Index, which is a weighted average for transport costs of bulk goods measured in US-Dollar per day and ship.

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[5] Jamora and von Cramon-Taubadel (2017) discuss the choice of an international reference prices for rice.

After applying these criteria, we are left with: 33 price series from 26 countries for wheat (three series for durum wheat in EU member states were not included in the analysis); 45 prices from 22 countries for yellow maize; 58 price series from 18 countries for white maize; and 126 prices from 48 countries for rice. For each individual price we estimated a simple auxiliary regression with monthly dummy variables, and used the results to generate de-seasonalised price series. We estimate the ST models in equations (10) using these de-seasonalised prices.[6]

4. Results

We test the price series for stationarity using the ADF (Dickey and Fuller, 1979) and KPSS (Kwiatkowski et al., 1992) tests. The former tests the null hypothesis that the series in question has a unit root, and the latter tests the null hypothesis of stationarity. The ADF test is carried out for the price series in levels and in first differences. The results indicate that for the great majority of price series the ADF test does not reject the null hypothesis of a unit root for levels but does reject that null hypothesis for first differences. The KPSS test corroborates these results for most series by failing to reject the null hypothesis of stationarity.

Table 1 shows for wheat, maize and rice the numbers of domestic price series that are non-stationary, and the numbers that are cointegrated with their respective international reference prices. We do not use the standard Johansen (1991) test for linear cointegration between p_t^D and p_t^I because this test does not perform well in the presence of non-linearities such as structural breaks (Campos et al., 1996). As discussed above, we might to find that two prices are cointegrated because we do not use an appropriately specified test that accounts for the actual, non-linear relationship between them. Hence, it could be the case that a price pair that is not cointegrated according to the Johansen test for linear cointegration is in fact ST cointegrated. We therefore test for ST cointegration using a residual-based KPSS test.[7] Of course, failure to find evidence of ST cointegration between two prices does not rule out the possibility that they are cointegrated in some other, more complex non-linear manner. We propose that even if some such complex non-linear relationship holds between a domestic and an international price, the effective result is that the domestic price is highly insulated from international price movements.

For wheat, there is evidence that 43 series are ST cointegrated with the international reference price. Of these, ten produce implausible results (β_1 values that are either negative or greater than 10 in the low-price regime or smaller than -10 or bigger than 10 in the high-price regime), leaving 33 prices that we include in the following estimation of ST models. The 23 of 56 domestic wheat price series that are not included in the ST estimation (because they are either not cointegrated with the international reference price, or produce implausible results) are: a Brazilian price, two of four Chinese prices, all three Ethiopian prices, all four Indian prices, one of two French prices, the Italian and the Latvian prices, the Somalian price, the Spanish price, and eight of eleven Sudanese prices (see Table 2 below). The results of applying similar criteria to prices for yellow maize (45 prices included in ST estimation), white maize (58 prices included) and rice (126 prices included) are summarized in Table 1.

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[6] We also estimated the ST models using original (not de-seasonalised) price series. As most of the price series that we analyse display no or only weak seasonality, this has no major effect on our results.

[7] We carry out the KPSS test for each international-domestic price pair using the full residual series of the estimated ST model in equation (10). Choi and Saikkonen (2010) compare the performance of the full-residual KPSS test with a subresidual-based test that they develop and find that the full-residual test has more power but at the cost of higher size distortions.

Table 1: Summary results of unit root and cointegration tests

	Wheat	Yellow maize	White maize	Rice
Number of price series analysed (of which retail)	56 (5)	78 (26)	152 (100)	217 (103)
Number of countries for which prices available	33	30	24	58
Number of non-stationary price series *	35	54	107	182
Number of price series cointegrated with international price (of which retail) **	43 (4)	57 (19)	75 (56)	150 (73)
Cointegrated but implausible results***	10	10	16	23
Number of price series not included in estimation	23	33	94	91
Number of price series included in estimation (of which retail)	33 (4)	45 (16)	58 (40)	126 (59)
Number of countries included in estimation	26	22	18	48

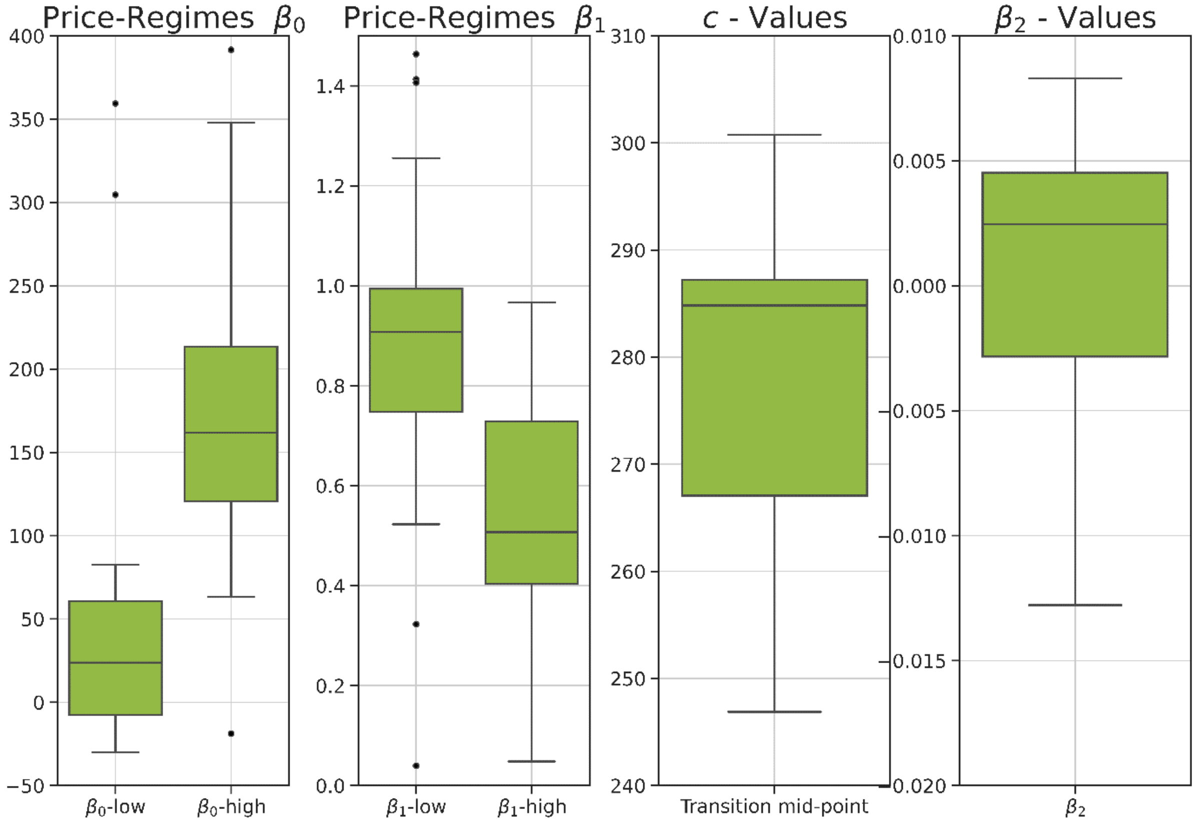
** Based on ADF and KPSS test results. ** KPSS test of full residuals of the estimated ST model in equation (10). *** We consider results implausible when* β_1 *does not fall between 0 and 10 in the low-price regime, and between -10 and 10 in the high-price regime.*

In the following we first present the results of the ST model estimations for those domestic prices that are ST cointegrated with the corresponding international price and produce plausible estimates of β_1. Sections 4.1 through 4.4 present results for wheat, yellow maize, white maize and rice, respectively. In section 4.5 we compare results for wholesale and retail prices, and in section 4.6 we discuss the prices (summarised in Table 2) that are not considered in the ST estimation for the reasons outlined above.

4.1. Wheat

For the 33 wheat price series that we analyse, Figure 2 presents boxplots of the estimated β_0 and β_1 values in the low- and in the high-price regimes, as well as a boxplot of the estimated transition mid-point *c* and β_2, the parameter that resizes our proxy for *TC* (the Baltic Dry Index). As expected, β_0 increases from the low- to the high-price regime, while β_1 falls. The β_1 estimates are clustered around 0.9 in the low-price regime, but fall to values around 0.5 in the high-price regime, indicating that domestic prices become less responsive to changes in international prices. These results are consistent with the hypothesis that countries increase the insulation of their domestic markets when international prices increase strongly.

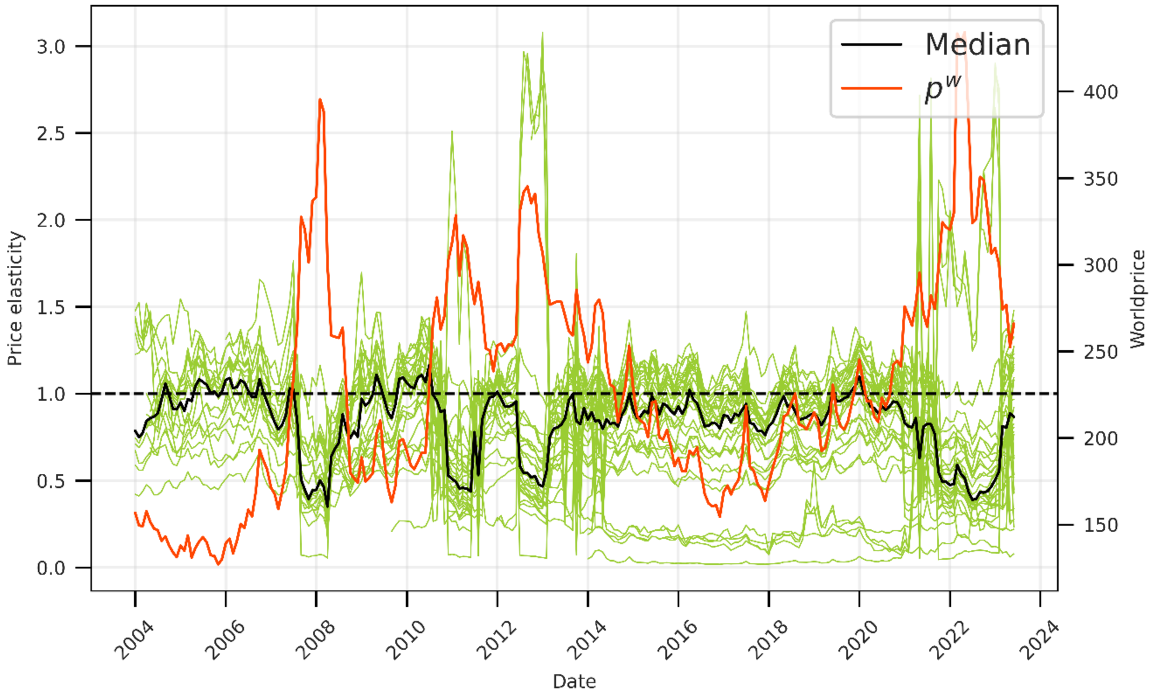
Figure 2: Smooth transition model for wheat - estimated β_0 and β_1 values in the low- and high-price regimes, and estimated transition mid-point c



In Figure 2 we also see that the mid-point of the transition from the low- to the high-price regimes (c) lies between 250 and 300 $/t for most countries, which is in line with our expectations for wheat. Additional results (not shown) indicate that the parameter γ is large for most of the analysed price series. The transition from the low- to the high-price regime is therefore relatively abrupt, in most cases taking place over a range of less than ± 5 $/t around the estimated value of c. We find similar abrupt transitions from the low- to the high-price regime for the great majority of the maize and rice price series that we analyse (see below).

We use the estimated ST parameters (β_0 and β_1 in the low-price and in the high-price regimes) to calculate the evolution of the elasticities of transmission from international to domestic wheat prices (ε, see equation 8) over time. The results presented in Figure 3 show that ε falls for most countries and on average during episodes of high international wheat prices such as in 2007/08 and 2022/23.

Figure 3: Smooth transition model for wheat - estimated elasticities of transmission from international to domestic prices over time

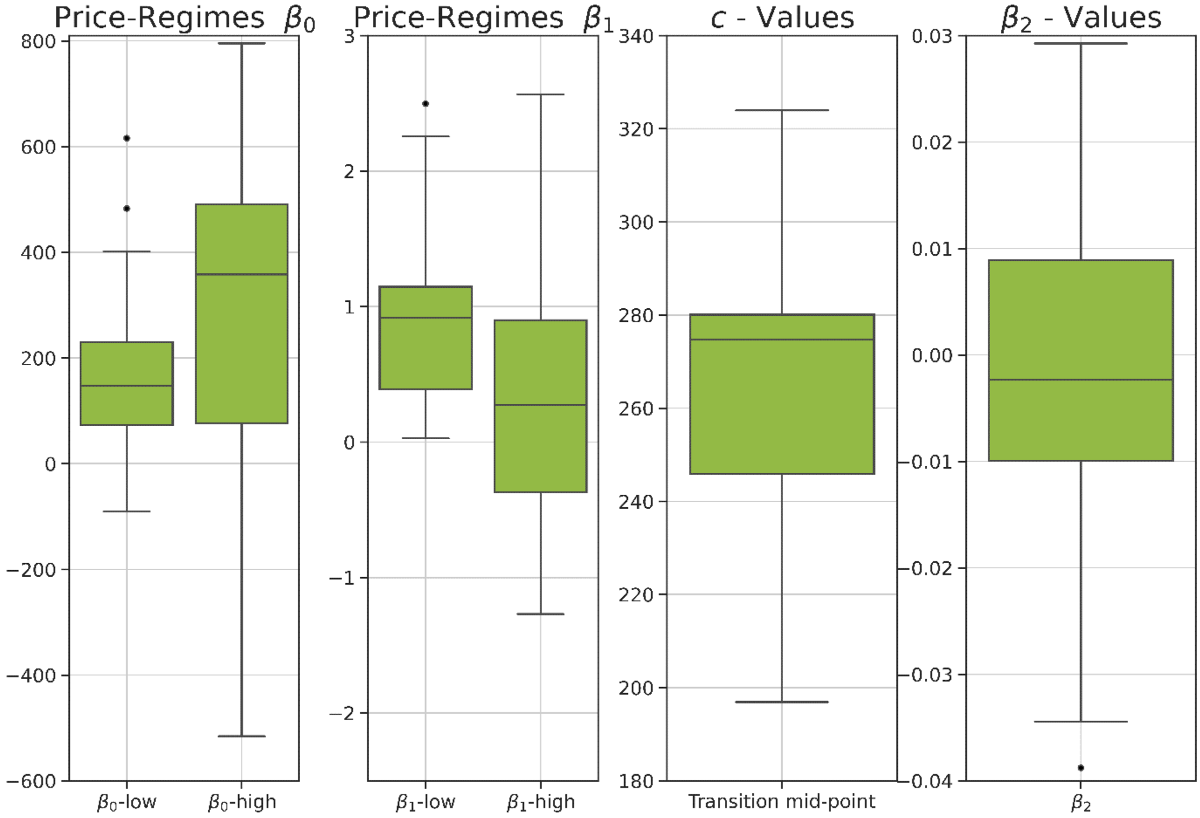


International price in red, individual elasticities in green, median elasticity in ***black****.*

4.2. Yellow maize

For yellow maize, as was the case for wheat, we see that β_0 increases from the low- to the high-price regime, while β_1 falls (Figure 4). The mid-point of the transition from the low- to the high-price regimes for yellow maize lies between roughly 270 and 280 \$/t for most countries, which corresponds to the major price peaks experienced in the last two decades. However, compared with wheat there is more overlap between the low- and the high-price values of the β_0 and β_1, and more variation among the estimated values for different domestic prices. While most low-price regime estimates of β_1, for example, range from 0.85 to 0.95 for wheat, they range from 0.4 to 1.2 for maize. In the high-price regime, the estimated β_1 values are on average lower, indicating that domestic prices become less responsive to international prices for yellow maize. However, the high-price regime estimates of β_1 vary considerably, and in some cases are close to 0 or even negative, suggesting a strong degree of decoupling from the international price. We see that the estimated values of β_0 increase and also become considerably more variable from the low- to the high-price regime.

Figure 4: Smooth transition model for yellow maize - estimated β_0 and β_1 values in the low- and high-price regimes, and estimated transition mid-point c



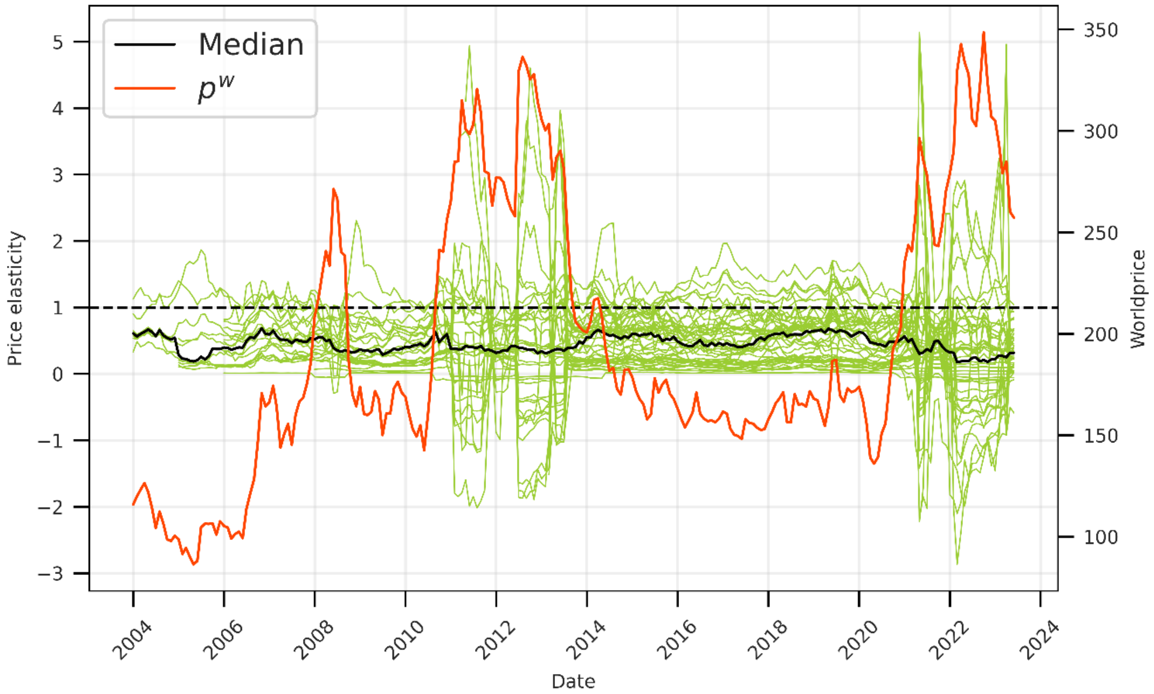
The elasticities of international to domestic price transmission (ε) corresponding to these β_0 and β_1 values are presented in Figure 5. These elasticities are lower than for wheat on average; the median ε mostly moves in a range between 0.3 and 0.5 when international prices are low, and falls to roughly 0.2 when international prices peak. Again, we see considerably more heterogeneity than was the case for wheat (compare with Figure 3). Some elasticities drop sharply in the high-price regime and become negative, while others increase.

Overall, these results confirm for yellow maize that countries tend to increase the insulation of their domestic markets when international prices peak. However, these results also indicate that on average domestic markets for yellow maize are more insulated from international price movements than is the case for wheat. Moreover, compared with wheat there is a greater range of price relationships within the low-price and within the high-price regime, and a greater range of changes when price relationships switch between these regimes.

4.3. White maize

The results of the ST model for white maize are similar to those for wheat and yellow maize: β_0 increases from the low- to the high-price regime, while β_1 falls (Figure 6). These changes are quite strong. β_0 roughly triples on average, and β_1 falls from values between roughly 0.5 and 0.8 in the low-price regime to values clustered around and below 0 in the high-price regime, which suggests that in some countries, domestic price decrease when international price increase in the high-price regime. In most countries the transition between the low- and the high-price regimes takes place when international prices reach a level between 260 and 265 $/t, which is somewhat lower than the transition trigger for yellow maize.

Figure 5: Smooth transition model for yellow maize - estimated elasticities of transmission from international to domestic prices over time



International price in red, individual elasticities in green, median elasticity in ***black****.*

The elasticities of international to domestic price transmission corresponding to these β_0 and β_1 values are presented in Figure 7. The median ε mostly moves in a range between 0.3 and 0.5 but falls sharply to negative values when international prices increase (for example in 2011/12, 2016 and 2022). Note that we only analyse 11 white maize price series, of which six are prices from different market locations in Togo. Hence, the results for white maize are far from representative. The price series for which ε in Figure 9 is higher rather than lower in the high-price regime is a retail price from Maputo in Mozambique.

4.4. Rice

The results of the ST model for rice once again show that β_0 increases from the low- to the high-price regime, while β_1 falls (Figure 8). We analyse 126 different domestic rice prices, and hence we see more variation than was the case for wheat and (especially white) maize. Most β_0 values lie between roughly 100 and 500 \$/t in the low-price regime; this range shifts upward to between roughly 250 and 1000 \$/t in the high-price regime. β_1 falls from values between roughly 0.6 and 1.8 in the low-price regime to values between 0 and 0.7 in the high-price regime, with values in a number of countries becoming negative. The mid-point of the transition between the low- and the high-price regimes is around 550 \$/t on average.

Figure 6: Smooth transition model for white maize - estimated β_0 and β_1 values in the low- and high-price regimes, and estimated transition mid-point *c*

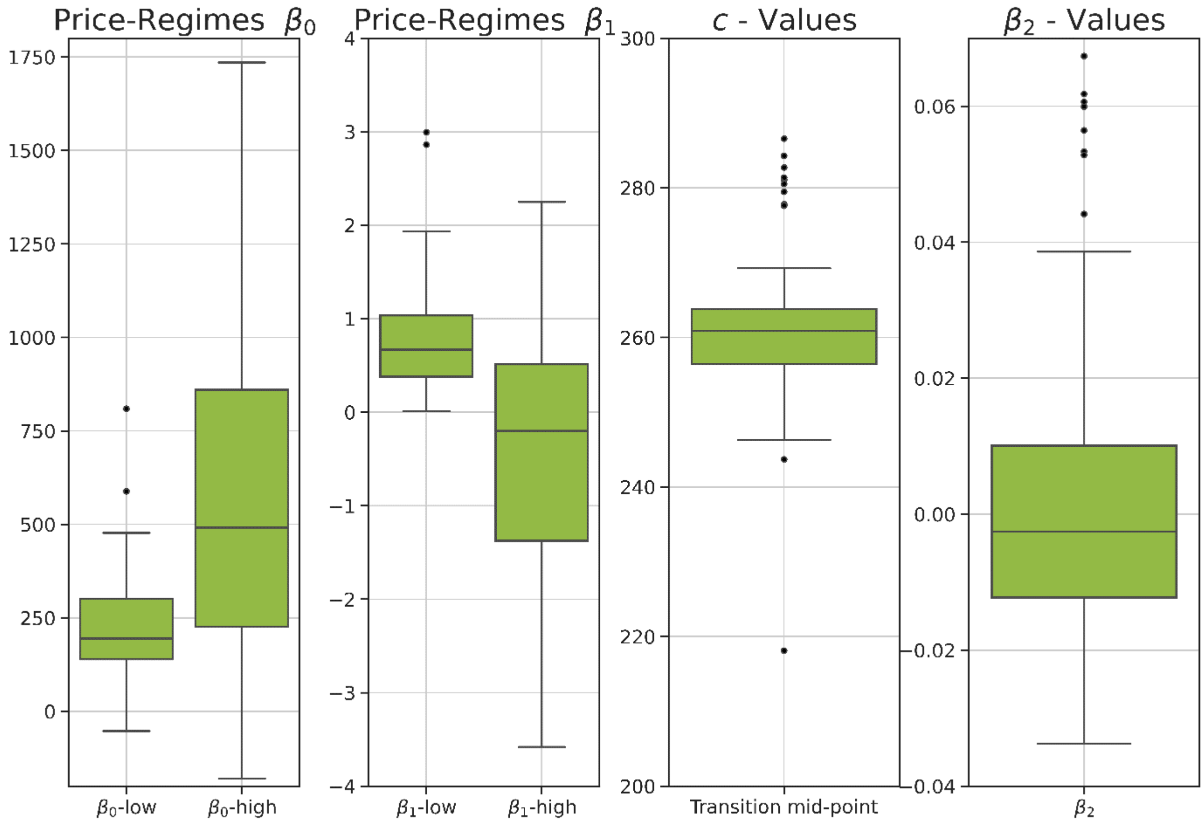
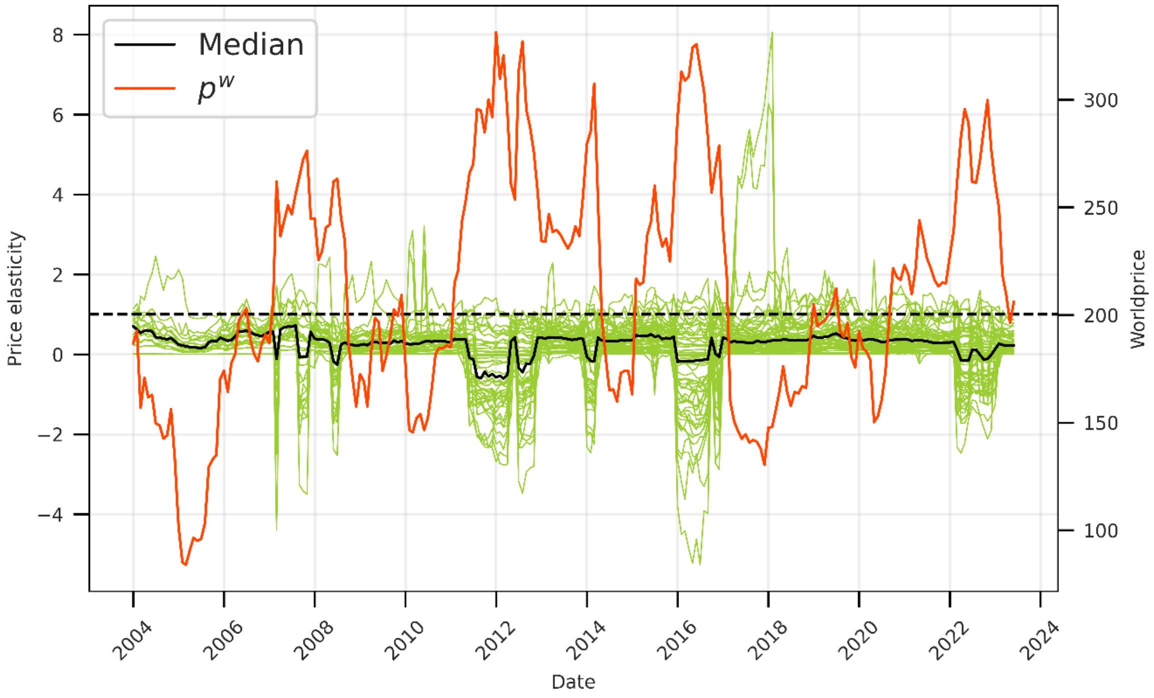


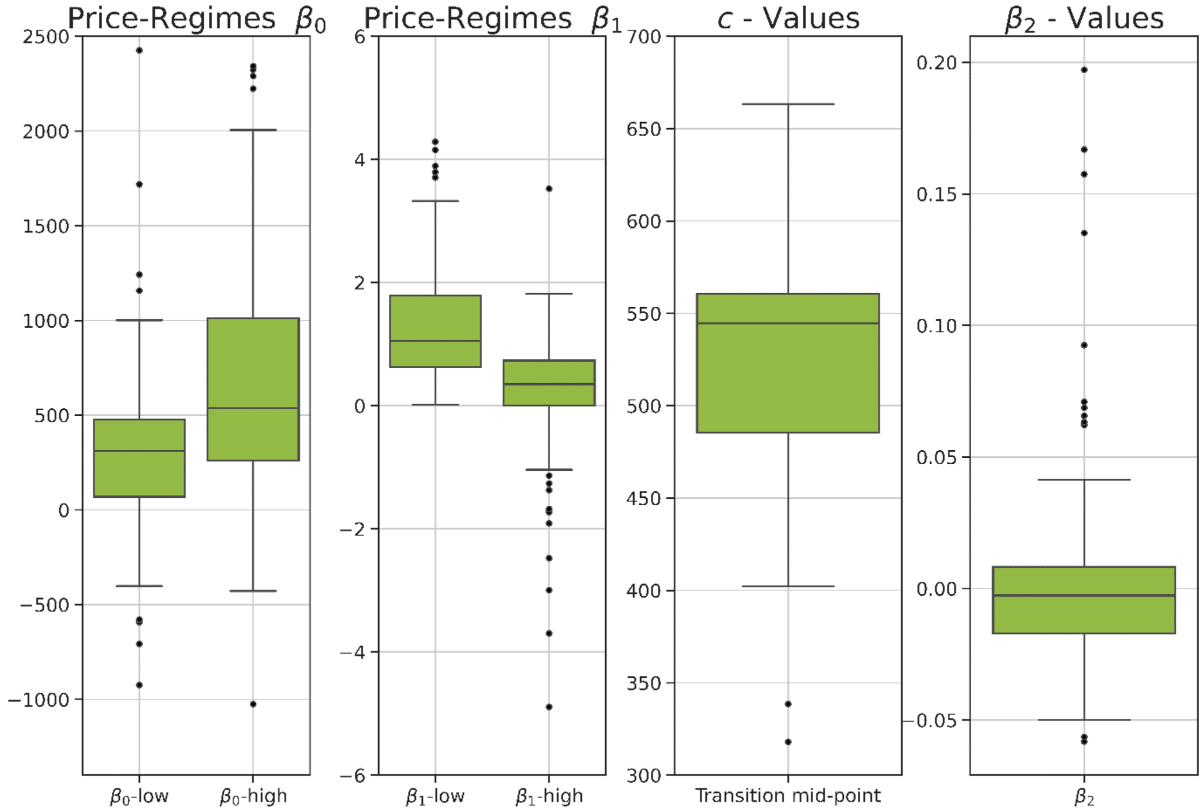
Figure 7: Smooth transition model for white maize - estimated elasticities of transmission from international to domestic prices over time



International price in red, individual elasticities in green, median elasticity in ***black***.

The evolution of the elasticities of transmission from international to domestic rice prices (ε) based on the ST estimates are presented in Figure 9. The median ε is generally higher for rice than for maize (compare Figures 6 and 9) and typically equals 0.5 and more. However, when international rice prices increase the median ε falls to as low as 0.25. We see this effect in 2008 and again in 2011/12 as well as briefly in 2020 and early 2021. As rice prices did not peak as strongly as wheat and maize prices in 2022, we see no evidence of increased insulation for this important staple following Russia's attack on Ukraine.

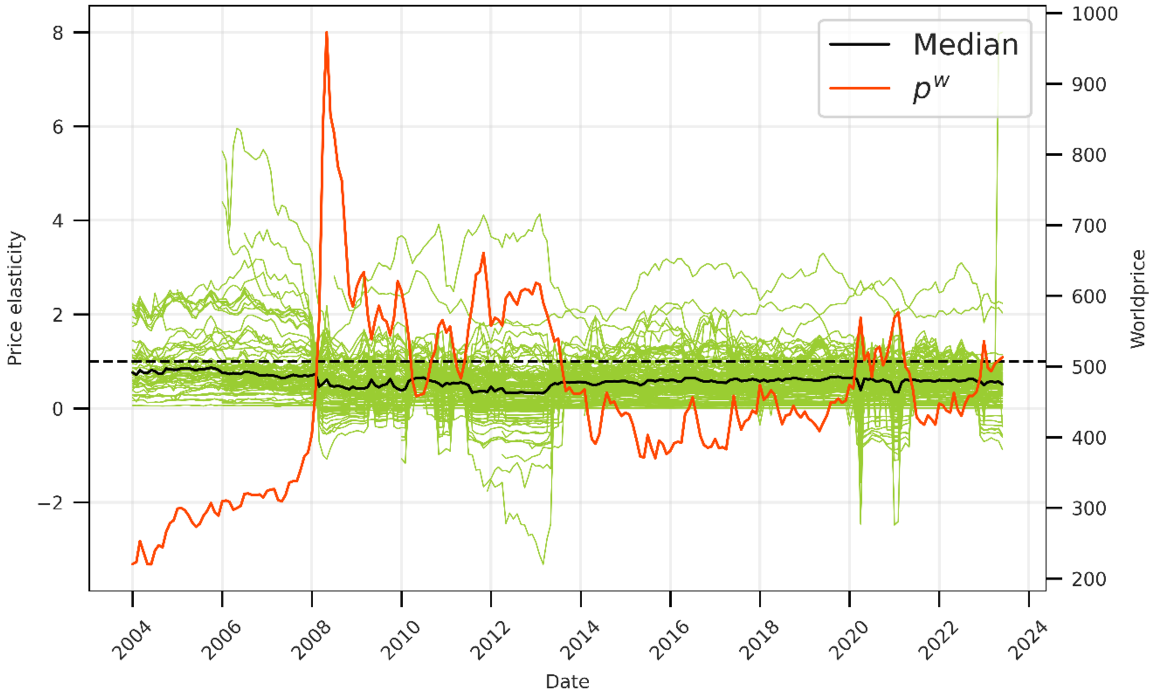
Figure 8: Smooth transition model for rice - estimated β_0 and β_1 values in the low- and high-price regimes, and estimated transition mid-point c



4.5. Comparing results for wholesale and retail prices

In this section we compare the results for wholesale and retail domestic prices. When p^D is measured at the retail rather than the wholesale level, the other trade costs (OTC in equation 1) will include additional marketing-cost components such as transport and packaging that are incurred as the product in question is moved to the retail market. As a result, we expect β_0 in equation (7) to be higher for retail than for wholesale prices. We also expect that it will increase more for retail than for wholesale prices when the price relationship transitions from the low- to the high-price regime in the ST model. Given the common stickiness of retail food prices (Schnepf, 2015), we might also expect β_1 to be lower for retail than for wholesale prices. However, in many countries, the food retail sector is concentrated, which can give rise to non-competitive pricing. This clouds the picture, as imperfect competition in the food chain can have a wide variety of effects on price transmission depending on market structure and strategic behaviour (Weldegebriel, 2004).

Figure 9: Smooth transition model for rice - estimated elasticities of transmission from international to domestic prices over time



*International price in red, individual elasticities in green, median elasticity in **black**.*

In the following we present results for yellow maize, white maize and rice (Figures 10, 11 and 12 respectively). For wheat only four of 33 analysed prices are recorded at the retail level (see Table 1 above), which does not provide a sufficient basis for meaningful comparison. For yellow maize 16 of 45 prices are recorded at the retail level, for white maize 40 of 58 prices, and for rice 59 of 126 prices.

For yellow maize in Figure 10 we see that β_0 in equation (7) is indeed higher for retail than for wholesale prices, and that it increases more for retail than for wholesale prices between the low- and the high-price regime. Hence, retail margins are higher than wholesale margins, and increase strongly when international prices increase. We also see that β_1 is lower for retail than for wholesale prices especially in the high-price regime, where it is close to 0 or negative for most of the analysed price series. This might be evidence that in addition to border measures, governments are using domestic interventions such as price and margin controls to additionally insulate retail prices when international prices peak. In Figure 10 we also see that the transition mid-point (270-280 \$/t) does not differ much between wholesale and retail prices for yellow maize. The results for white maize in Figure 11 are similar.

For rice in Figure 12 we again see the expected result that β_0 tends to be higher for retail than for wholesale prices, and that it increased more between the low- and the high-price regime for retail than for wholesale prices. However, there are no striking differences in the β_1-values for wholesale and for retail prices; for both types of prices β_1 falls from the low-price to the high-price regime from similar levels by similar amounts. As was the case for both yellow and white maize, the transition from the low- to the high-price regime takes place over roughly the same range of international prices (500-550 \$/t) for most wholesale and retail rice prices.

Figure 10: Smooth transition model for wholesale and retail yellow maize - estimated β_0 and β_1 values in the low- and high-price regimes, and estimated transition mid-point c

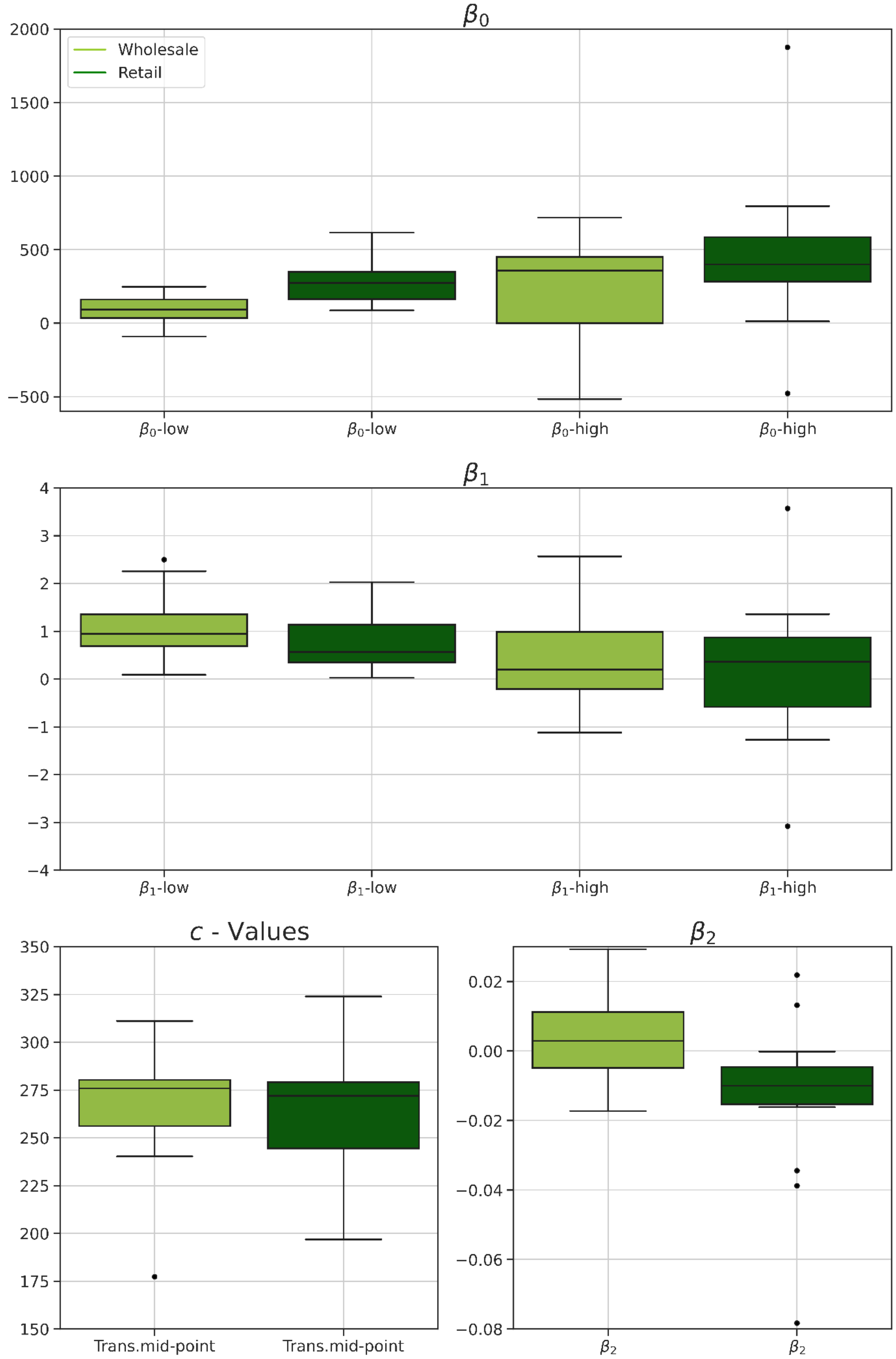


Figure 11: Smooth transition model for wholesale and retail white maize - estimated β_0 and β_1 values in the low- and high-price regimes, and estimated transition mid-point c

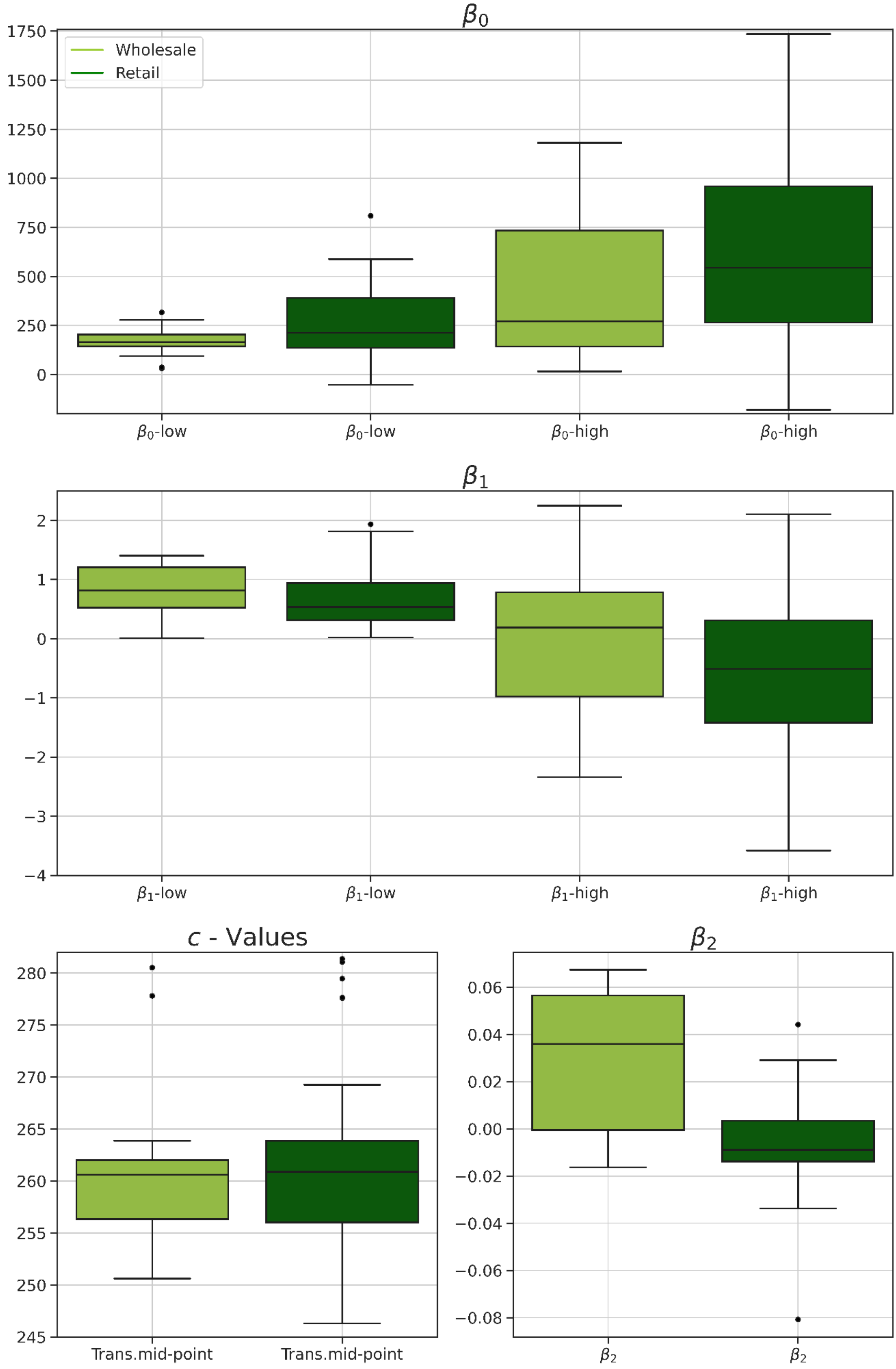
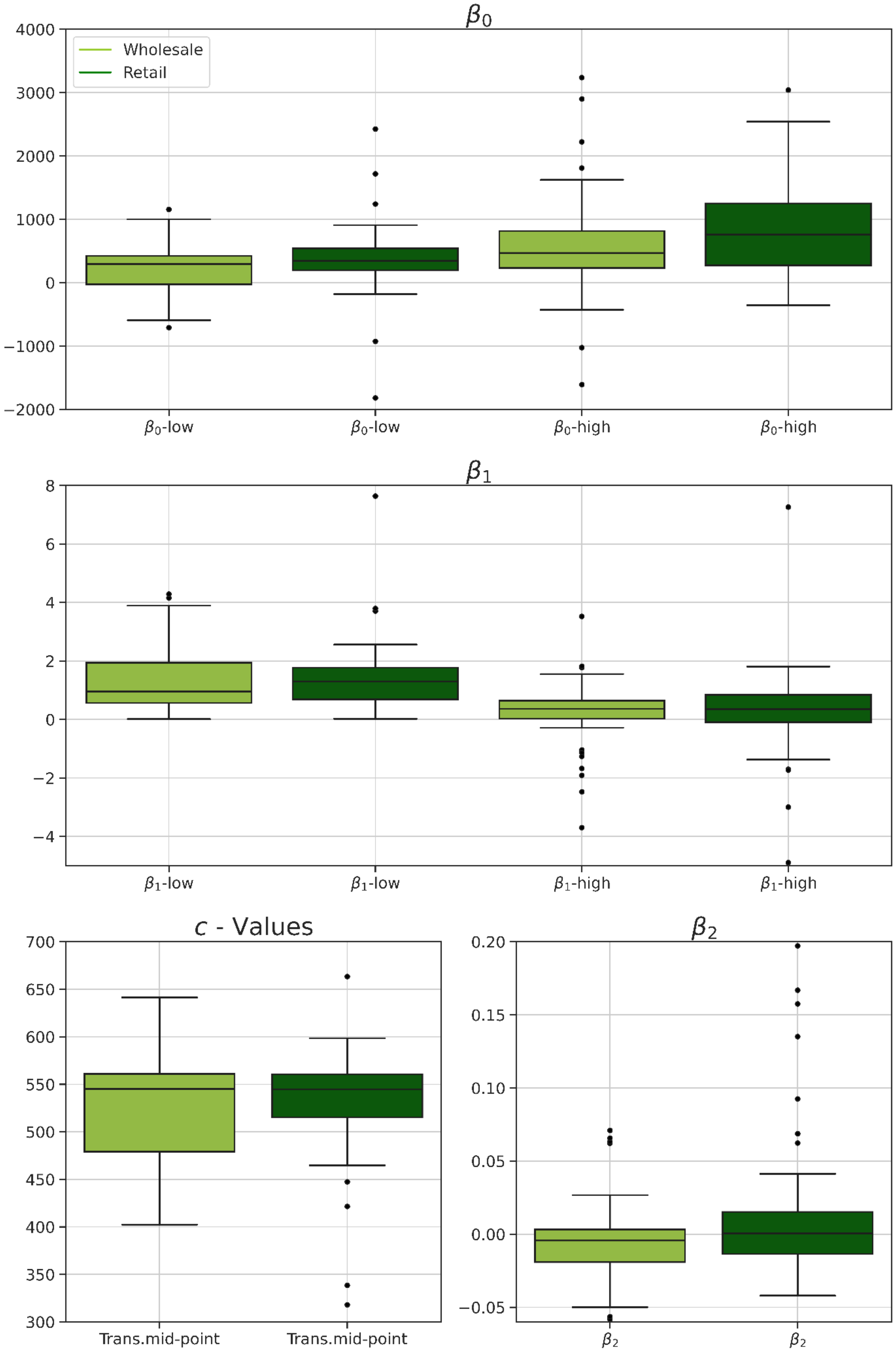


Figure 12: Smooth transition model for wholesale and retail rice - estimated β_0 and β_1 values in the low- and high-price regimes, and estimated transition mid-point c



4.6 Prices that are not included in the estimation

Table 2 lists all of the domestic price series for wheat, yellow and white maize and rice that were not used to estimate ST models. In all of these cases, the domestic price in question is either not smooth transition cointegrated with the corresponding international reference price, or the estimated long-run relationship between the domestic and the international price is implausible. In these cases, we do not find that insulation changes when international prices increase sharply; instead, insulation appears to be high over the entire period that we analyse.

Several countries stand out in Table 3. For example, 11 of 18 prices from the Philippines are excluded, as are the majority of the prices from Bolivia, Ethiopia, Guatemala, Laos, Mexico, Somalia and Zimbabwe. Most of these countries are individually small, but in sum the insulation of their domestic markets from international price fluctuations can reduce the buffering capacity of the global trade system (Martin and Minot, 2022). Furthermore, not all of these countries are small – several prices from India and China were omitted from the econometric analysis above because they are not cointegrated with the corresponding international price.

Table 2: List of the domestic price series omitted from further analysis

Wheat	Rice	Yellow maize	White maize
Brazil (1 of 1)	India (1 of 5)	Argentina (1 of 2)	Burundi (2 of 2)
China (2 of 4)	Israel (1 of 1)	Bolivia (2 of 4)	Cape Verde (2 of 2)
Ethiopia (3 of 3)	Japan (1 of 2)	Cameroon (1 of 5)	Chad (3 of 9)
France (1 of 2)	Laos (5 of 6)	Cape Verde (4 of 6)	Costa Rica (1 of 2)
India (4 of 4)	Lebanon (1 of 1)	C. Afric. Rep. (1 of 1)	El Salvador (13 of 14)
Italy (1 of 1)	Lesotho (1 of 4)	Chad (1 of 3)	Guatemala (1 of 2)
Latvia (1 of 1)	Mali (1 of 12)	Colombia (1 of 2)	Honduras (4 of 4)
Somalia (1 of 1)	Mauritius (1 of 1)	Dominican Rep. (2 of 2)	Kenya (19 of 27)
Spain (1 of 1)	Mexico (1 of 3)	Ecuador (2 of 3)	Malawi (2 of 11)
Sudan (8 of 11)	Mongolia (1 of 1)	Ethiopia (2 of 3)	Mexico (4 of 5)
Rice	Namibia (5 of 8)	Ghana (1 of 4)	Mozambique (1 of 2)
Bolivia (6 of 10)	Niger (3 of 9)	Guatemala (1 of 1)	Nicaragua (2 of 2)
Botswana (1 of 1)	Nigeria (2 of 7)	Haiti (3 of 5)	Nigeria (2 of 12)
Burkina Faso (5 of 8)	Pakistan (4 of 10)	Israel (1 of 1)	Philippines (2 of 2)
Cambodia (1 of 4)	Palestine (4 of 4)	Nigeria (2 of 8)	Somalia (30 of 31)
Cameroon (1 of 5)	Philippines (7 of 14)	Panama (2 of 2)	South Sudan (1 of 5)
Cape Verde (1 of 4)	Saudi Arabia (1 of 2)	Peru (1 of 1)	Zimbabwe (5 of 5)
China (8 of 9)	Somalia (5 of 12)	Philippines (2 of 2)	
Colombia (9 of 16)	Syria (2 of 2)	Tanzania (1 of 3)	
Ecuador (2 of 3)	Togo (2 of 6)	Thailand (1 of 1)	
Eswatini (1 of 4)	Tunisia (1 of 1)	Uganda (1 of 4)	
Ghana (3 of 5)	Uruguay (1 of 1)		
Guatemala (2 of 2)			

4.7 Are increases in insulation due to trade policy changes?

A common assumption is that border measures such as export restriction and changes in import tariffs are the primary cause of increased insulation of domestic markets and the resulting additional increases in international price levels and volatility during agricultural price ‘crises’ (see, for example, Pangestu and Van Trostenberg, 2022). However, many other policy tools can be used to insulate domestic markets. These tools include price controls, stockholding, changes in domestic sales and value-added taxes, and exchange rate manipulation.

To analyse the contribution of border measures to increases in insulation, we turn to the Global Trade Alert database (2024). For each switch from the low- to the high-price regime that we estimate using the ST model[8], we consult this database to determine whether any changes in border measures took place for the product and country in question within up to three months prior to the switch. We consider liberalising trade policy changes such as tariff reductions in cases in which an importing country switched from the low- to the high-price regime, and restrictive trade policy changes such as an export tax or ban in cases in which an exporting country switched.

The results are summarised in Table 3. We see that in importing countries, changes in border measures preceded increases in insulation in only a small share of all cases. For example, in the case of yellow maize, only 5 of 82 instances of increasing insulation in importing countries were preceded within 3 months by changes in border measures. For wheat and yellow maize exporters, changes in border measures preceded increases in insulation in a somewhat higher share of all cases, but even here the evidence is not overwhelming. For example, in the case of wheat, 13 of 55 episodes of increasing insulation in exporting countries were preceded by restrictive border measures. These results suggest that while changes in border measures are playing a role, in the great majority of cases other policy tools are being used by governments to increase the insulation of their domestic grain markets from international price surges.

We acknowledge that this conclusion might be biased by missing data in the Global Trade Alert database. While the database likely includes all policy changes that are notified to the WTO, some countries might not always fulfil their obligations to make such notifications. Hence, border measures might account for a larger share of the increases in insulation that we observe than suggested by the results in Table 3. In addition, the distinction between ‘border’ measures and ‘other’ policy measures that might be used to insulate a domestic market is not always clear. For example, in some countries state trading agencies manage and control imports or exports. When international prices peak, a state-controlled importer might be instructed by the government to sell imported grain to domestic users at a price that is below the import price, in other words to operate at a loss. This might be considered to be an example of an insulating border measure, and it is equivalent to a negative import tariff or an import subsidy. But it will not be reflected in the Global Trade Alert database. Other domestic measures such as a retail price control or the release of domestic stocks (as futile as that might prove in the longer run) are clearly not ‘border’ measures.

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[8] We consider that a switch from the low-price to the high-price regime has taken place when the international price increases to above the mid-point (*c*) value and remains higher for at least three months.

Table 3: Episodes of increased domestic price insulation and correspondence with trade policy changes.

	Wheat		**Yellow maize**		**White maize**		**Rice**	
	Importer	Exporter	Importer	Exporter	Importer	Exporter	Importer	Exporter
# of estimated switches from low- to high-price regime	39	55	82	28	148	27	206	38
# of trade policy changes within 3 months prior to a switch *	1 (3%)	13 (24%)	5 (6%)	5 (18%)	1 (1%)	0 (0%)	8 (4%)	3 (8%)

* We count liberalising trade policy changes for importers, and restrictive trade policy changes for exporters.
Source: Own calculations with Global Trade Alert database (2024).

Table 3 only considers those country-product prices that are ST cointegrated with the corresponding international prices. Table 2 lists a large number of prices for which this is not the case, either because they are not ST cointegrated with international prices, or because the ST model produces implausible results. Taking a broader view, we can group all of the available prices into three categories:

1. Highly insulated markets, including those listed in Table 2 (no or implausible ST cointegration) and those for which the estimated β_1 in the ST model is smaller than 0.5 in both the low-price and the high-price regimes.
2. Moderately insulated markets for which β_1 is larger than 0.5 in the low-price regime, and otherwise smaller.
3. The least insulated markets for which β_1 is larger than 0.5 in both regimes.

Table 4 presents information on import tariff rates in 2018 for wheat, maize and rice, for all of the prices in our database and for each of the individual insulation categories defined above. We have chosen 2018 as a 'normal' year on grain markets that was not characterised by any major crisis. For wheat and white maize, we find that the average tariff was higher for the highly insulated markets. However, this was not the case for yellow maize and rice, for which the markets with the highest insulation had, on average, the lowest import tariffs. Hence, there is no clear correlation between insulation and tariff levels. These results also suggest that insulation is not exclusively achieved using border measures such as import tariffs, and that other types of policy also play an important role.

5. Conclusions

The results of our analysis suggest that the insulation of domestic from international markets for staple grains increases when international prices increase sharply as was the case in 2007/08 and more recently in 2022. Our results and the available data also suggest that border measures such as import tariffs and export restriction are not the sole or even the main cause of increases in insulation – governments must also be making use of other policy tools when international prices surge. Future research could study what tools are being used. This would a detailed exploration of market structures and policy interventions on a case-by-case basis for individual countries and grains. Ultimately, a better understanding of whether and how countries insulate their domestic markets from international price movements can inform efforts to make the global food trading system better able to buffer shocks.

Table 4: Tariff rates 2018 (in %) by international integration of markets

		All markets	**Highly insulated markets**	**Moderately insulated markets**	**Least insulated markets**
wheat	Number of markets	56	25	14	17
	Mean tariff rate	13.2	23.7	4.1	5.4
	Standard deviation of tariff rates	17.7	18.8	13.8	9.7
	Range of tariff rates	0 - 55	0 - 55	0 - 50	0 - 25
yellow maize	Number of markets	78	42	20	16
	Mean tariff rate	12.9	10.8	15.1	15.5
	Standard deviation of tariff rates	12.8	11.2	15.9	12.5
	Range of tariff rates	0 - 40.1	0 - 40.1	0 - 40.1	0 - 40.1
white maize	Number of markets	152	113	27	12
	Mean tariff rate	13.2	15.5	7.2	8.7
	Standard deviation of tariff rates	13.6	14.3	9.7	11.2
	Range of tariff rates	0 - 40.1	0 - 40.1	0 - 30	0 - 32.17
rice	Number of markets	217	110	67	40
	Mean tariff rate	13.6	12.7	14.9	13.6
	Standard deviation of tariff rates	15.3	14.7	16.0	15.6
	Range of tariff rates	0 - 75	0 - 47.4	0 - 75	0 - 51.3

Source: UNCTAD-TRAINS (2024)

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