Analysis of Price Shock Transmission: Case of the Wheat-Bread Market Value Chain in Ethiopia

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Abstract

This study assesses the degree of vertical price transmission along the wheat-bread value chain in Ethiopia. This is pursued by applying a vector error correction model (VECM) and an impulse response analysis using monthly price data for the period 2000 –2015. The empirical findings indicate that significant cointegration exists across prices of the different stages along the value chain. In particular, there is a strong price shock transmission for the price pair international–local wholesale wheat prices. This suggests that international wheat price shocks could have significant consequences for the Ethiopian economy, given that the country is not only a net importer of wheat but it also imports a sizable amount vis-à-vis the domestic production. Although price shocks are transmitted along the value chain to a different extent, the speed of adjustment is quite slow. For instance, less than 6% of the disequilibrium in bread prices is eliminated in one month, implying that it takes longer that one year for bread price to virtually restore to its long-run equilibrium value after a shock. The results also reveal that causal relationships exist between prices at different market stages. To this end, the impulse response analysis shows diverse responses to shocks, with some shocks producing weak and temporary adjustments while others producing stronger and persistent changes. We found that producer and wholesale market levels play a dominant role in the wheat value chain, implying that policies may give particular attention to these markets.

Keywords: *Value chain, price transmission, impulse response, wheat, Ethiopia*

JEL codes: *Q02, Q11, Q13, L11, M31*

1. Introduction

Wheat is an important staple food in the diets of many Ethiopians, providing about 15% of the caloric intake for the country's over 90 million population (FAO 2015). Not only is wheat one of the most widely produced cereal in the country—accounting for 20% of the domestic cereal production in 2013/14—it is also the most important staple food crop that the government imports from abroad. Imported wheat has contributed a significant share of the marketable wheat in the country. Wheat import has been as high as 40% of the locally produced wheat over the last decade. This large import dependency exposes the domestic wheat market to international shocks and price volatility. This is especially true in situations of food price spikes, such as during the global food price crisis in 2007/08 and in 2011, when grain prices in Ethiopia showed dramatic increases. Nominal wheat price, for instance, surged by 60% in four months between April and August 2008 and the prices of domestic wheat flour and wheat bread increased too by about 30% and 40% respectively during the same period (CSA, 2015). As a consequence, the Ethiopian government took several administrative measures on the domestic market including the most direct intervention of controlling prices for selected staples including bread (Admassie, 2013).

Several studies argue that the price changes in Ethiopia are not significantly affected by international prices (Admassie, 2013; Minot, 2010). This may be true for the general inflation in the country and for agricultural crops (such as sorghum and teff) for which Ethiopia has a negligible net trade with the rest of the world. This could, however, be different in the case of some crops such as wheat. As roughly 80% of the domestic wheat production is used for own consumption (Gebreselassie et al., forthcoming), imported wheat contributes a much higher share to marketed wheat than to produced wheat. Following the 2007/08 food crisis, for instance, imported wheat contributed more than twice of the domestic market surplus (Rashid and Lemma, 2014). Because imported wheat is distributed at government administered prices, this may moderate the domestic market exposure to shocks in the international market. Moreover, wheat is just one of inputs for higher-value products such as bread and this may further dilute shock transmission from international wheat markets. The higher is the value added to a raw material, the lower is the share of the raw material costs in the total costs. Consequently, price shocks in the raw commodity may have a lower impact on the price of processed consumer products like flour or bread.

Against this background, the objective of the present study is to investigate price transmission along the wheat-bread value supply chain in Ethiopia using monthly prices over the period 2000 to 2015. We explicitly examine the degree of transmission of price shocks from international wheat markets to domestic producer, domestic wholesale and retail wheat markets, as well as to wheat flour and bread markets in the country. To this end, we consider the various linkages and causalities between different processing steps and actors in the wheat value chain by estimating a system of response functions to exogenous shocks. Indeed, in well-functioning (integrated) markets[1], price shocks in any market level are virtually transmitted to other market levels. While primary producers benefit from price increases at the wholesale and the retail market levels, final consumers benefit from upstream cost reductions. The efficiency of wheat supply chain is, therefore, crucial to maintain a sustainable distribution of value addition and benefits among farmers, processors, wholesalers, retailers and consumers.

This study provides several contributions to the extant literature. It explicitly examines price transmission along the wheat-bread value chain in Ethiopia and the degree of shocks transmission from international wheat prices to domestic prices. To our knowledge, an analysis on the system of inter-linked market channels that interact and influence each other along the wheat value chain is still missing. In addition, we provide information about the size and speed of price shock transmission. This study analyses the direction of causal relationships across market price levels. The focus on price transmission and its interlinkages along the wheat-bread value chain is important. It allows analysis of changes in the value between the intermediaries; helps explain their negotiation power; identifies sales margins at different levels of the chain; and discovers market inefficiencies. Furthermore, the direction of causality is useful to know whether there is any single market level with a dominant price leadership role so that policy interventions can be targeted.

2. Price shock transmission along the wheat-bread value chain

Transmission of price shocks can happen in horizontally or vertically related markets. Horizontal price or shock transmission, as discussed in the above section, occurs between similar products traded in different geographical locations. Vertical price transmission, on the other hand, relates to shock innovations between different stages of the supply chain. Given that price is the primary mechanism that interconnects various market stages, the extent of adjustment and the speed at which price shocks are transmitted into producer, wholesale, and retail markets shows the actions of participants at the various market levels (Goodwin & Harper, 2000). The degree of shock transmission depends on the stage of the product in the value chain. Theoretically, the value addition increases when we move from the raw commodity market (e.g., wheat grain) to processed products (e.g., wheat bread) along the value chain. As a result, we expect the exposure of agents to grain price volatility to decrease along the value chain. For instance, we expect that a

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[1] Market integration refers to a condition in which there exists flow of goods and information across place, time and form. Market integration thus implies a reduced localised price volatility, high specialisation and efficiency.

shock at the international wheat market transmits to domestic producer and wholesale prices at a reasonable size and speed, whereas the transmission will be limited at further stages of the value chain, such as at the consumption end.

The Ethiopian wheat value chain consists of multiple actors and channels. A range of actors that include smallholder farmers, wholesalers, retailers, part-time farmer-traders, brokers, processors, cooperatives, the government and parastatal organizations, and private consumers take part in the wheat value chain. Previous studies indicated that the wheat supply chain in Ethiopia consists of as much as seven to ten marketing channels or outlets (Urgessa, 2011; Woldehanna et al., 2010). In general, wheat trade involves a large number of transactions of small value and quantity. Small traders and brokers play a significant role in the supply chain. The size of transactions is largely governed by subsistence domestic production and traditional transport system. The subsistence nature of domestic wheat growers and the big role the government plays through the Ethiopian grain trade enterprise (EGTE), a parastatal organization, in the wheat market affect the efficiency and effectiveness of the value chain. The length and complexity of the value chain, number of actors involved, and the level of transparency among actors have nontrivial implications for the distributional gains and losses among wheat producers and consumers.

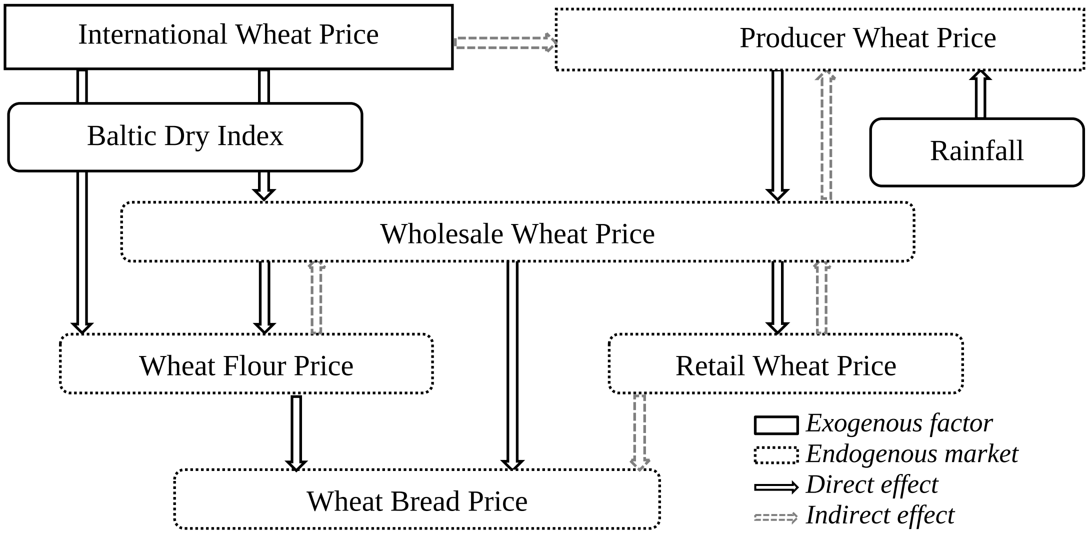

Figure 1. Shock transmission along the wheat supply chain in Ethiopia

Figure 1 illustrates different stages of the wheat market that we consider in our analyses. The boxes in solid lines denote markets or factors that are largely exogenous to the effects of changes in the domestic market. Because Ethiopia is a net importer of wheat and it is a “small country”, its demand (import) does not affect world wheat price. We therefore expect shock transmission from international market prices to wheat and wheat product prices in the domestic markets, but not vice versa. Besides shocks in the international wheat prices, changes in shipment costs, which we proxy by the Baltic dry index (BDI), can also affect domestic prices. The solid line arrows in figure 1 therefore show our expectation of a direct impact from one market level to the other, whereas the dotted arrows reflect indirect effects. This figure will guide our time series analyses in subsequent sections. Figure 1 does not exclude shock transmission, for instance, from international wheat market to domestic bread markets. Nevertheless, it hints that as the value chain gets longer, the degree of shock transmission form the international market is expected to get weaker.

3. Empirical Analysis

3.1. Data

Monthly data for the period January 2000 to February 2015 are used for our empirical analysis. While data on domestic prices are taken from the Ethiopian central statistical agency (CSA)[2], data on international wheat price are obtained from the World Bank price database, the Baltic Dry Index from Bloomberg, and monthly rainfall from the Ethiopian meteorological agency.[3] Table 1 presents the descriptive statistics of these variables along with their descriptions.

Table 1. Descriptive statistics of time series variables, January 2000- February 2015

Variable name	Description	Mean	SD	Min.	Max.
INT_P	International wheat Price, Birr/kg	1.06	0.21	0.63	1.86
PROD_P	Domestic producer price, Birr/kg	1.18	0.26	0.46	1.94
WHOL_P	Domestic wholesale price, Birr/kg	1.57	0.25	1.10	2.61
RET_P	Retail price in Addis Ababa, Birr/kg	1.84	0.26	1.28	2.70
FLOUR_P	Flour price in Addis Ababa, Birr/kg	2.68	0.38	1.75	3.74
BREAD_P	Bread price in Addis Ababa, Birr/kg	3.13	0.73	1.88	6.39
BDI	Baltic Dry Index (Birr)	14.21	10.95	1.75	48.30
EX-RATE	Exchange rate, Birr/USD	12.22	4.49	8.14	20.82
PRE	Precipitation, mm	69.25	47.05	1.10	217.50
PRE_DEV	Precipitation deviation from long-run mean, mm	0.00	20.36	-54.87	114.33

Notes: Prices are in real 2000 Ethiopian Birr deflated by CPI.

We converted the International wheat price and BDI values into Ethiopian Birr using the official exchange rate. All price series are in real 2000 Ethiopian Birr values deflated by the general consumer price index (CPI) of the country. As it is expected for an importing country, the international price is below the domestic producer wheat prices. Prices increase as we go downstream along the wheat value chain, reflecting other costs gaining more importance in the

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[2] We consider retail, flour, and bread prices in Addis Ababa since grain markets in Ethiopia have a radial structure with the capital city of Addis Ababa being the central location.

[3] We construct a rainfall shock variable as a deviation of current month precipitation value from the long-run average value for that particular month.

final product compared to wheat grain itself. Indeed, the average international wheat price (in local currency) is 1.06 Birr/kg and the average wheat bread price is 3.13 Birr/kg. This is equivalent to about a 200 percent relative price increase from the top to the bottom of the value chain. Figure 2 shows a general declining trend of real wheat flour and bread prices but an increasing trend of all the other price series, with frequent volatility overtime. The period 2007/08 exhibits a more pronounced increase of all real prices. The Baltic dry index has been rising until it reached at its peak value in 2007/08 when it has started to decline.

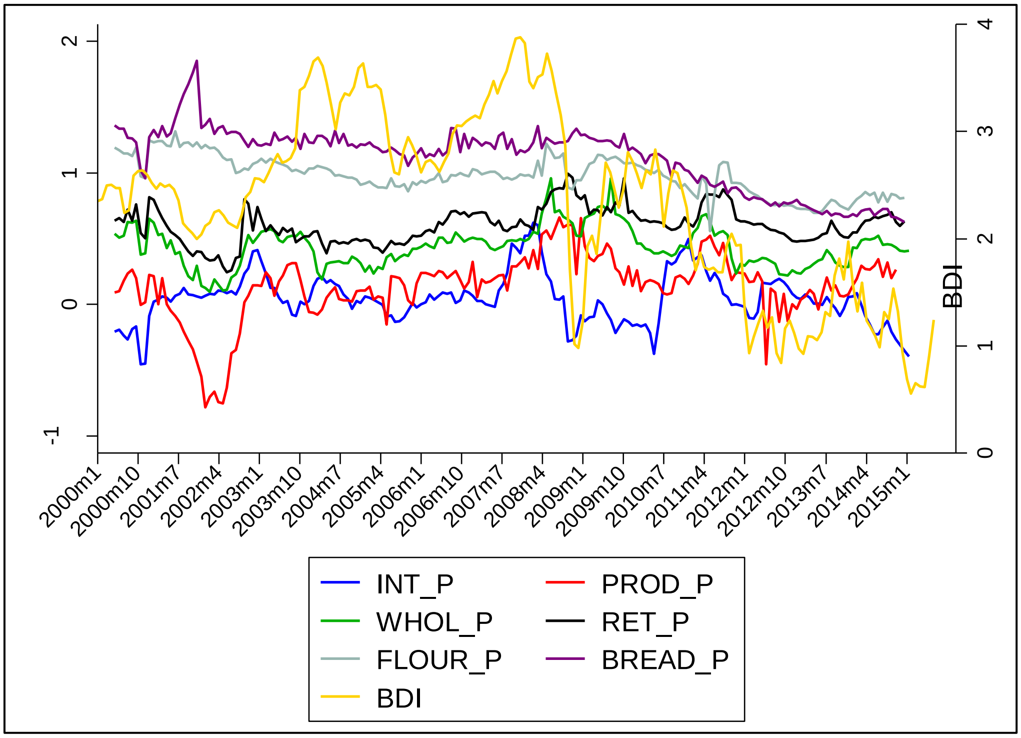

Figure 2. Monthly real international and domestic wheat and wheat product prices

3.2. *Econometric framework*

As a preliminary step of our time series analysis, we test all variables for the presence of unit root with the Augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP) tests. The results of these tests show that most of the variable series exhibit non-stationarity, with the exception of the precipitation variables. A contrasting result between the ADF and PP tests is recorded for retail price, which is stationary according to the PP test and non-stationary following the ADF test. We follow the ADF test which, according to the literature, is more accurate. Thus, we conclude that all price variables and the Baltic Dry Index are integrated of order one $I(1)$ in levels and become stationary by first differencing. The outcomes of the tests are summarized in table 2.

Given non-stationary variable series—except the rainfall variables that enter as exogenous variables in our time series analysis—we test if the price series are cointegrated. We follow the Johansen-Juselius procedure to determine whether the series are cointegrated and to identify the number of cointegrating equations (Johansen & Juselius, 1990). We allow the series to have a constant in the VAR model and a linear trend in the cointegrating equations.[4] The lag length is determined based on the Akaike Information Criterion (AIC) and the Schwartz-Bayesian Information Criterion (SBIC).

Table 2. Unit root test results

Variables	Test on level variables				Test on first differenced variables			
	ADF test statistics		PP test statistics		ADF test statistics		PP test statistics	
	Constant	Trend	constant	trend	constant	trend	Constant	Trend
INT_P	-2.99**	-3.04	-2.85	-2.89		-7.35**	-11.65**	-11.70**
PROD_P	-2.14	-2.52	-2.73	-3.12	-7.85**	-7.84**	-19.05**	-19.01**
WHOL_P	-2.71	-2.73	-2.98**	-2.99	-8.74**	-8.72**		-13.78**
RET_P	-2.83	-3.19	-3.36**	-3.63**	-6.50**	-6.51**		
FLOUR_P	-1.81	-2.76	-2.59	-4.40	-8.84**	-8.81**	-18.10**	-18.04**
BREAD_P	-0.70	-2.63	-1.26	-3.30	-7.88**	-7.93**	-18.46**	-18.46**
BDI	-1.13	-2.12	-1.17	-2.14	-6.77**	-6.85**	-10.22**	-10.26**
PRE	-10.41**	-10.66**	-6.90**	-6.92**				
PRE_DEV	-12.98**	-13.31**	-12.48**	-13.06**				

Notes: AIC and BIC are used to determine appropriate lag lengths. The critical values are **-2.885** and **-3.439** for the 5% significance level, corresponding to the specifications using a constant (but not trend) and a trend, respectively. ** indicates rejection of the null hypothesis at the 5% level.

Under the Johansen-Juselius procedure, the trace and the maximum eigenvalue tests have been implemented to determine the number of cointegrating vectors. The critical values are those computed by Osterwald-Lenum (Osterwald-Lenum, 1992). The two tests deliver different results (table 3). There are two cointegrating equations according to the trace test, as the null hypotheses of $r = 0$ and $r \leq 1$ (against the alternatives $r > 0$ and $r > 1$ respectively) are rejected at conventional significance levels, whereas the null of $r=2$ cannot be rejected. There is, however, just one cointegrating equation following the maximum eigenvalue test. We rely on results from the trace test because it tends to have superior power performance in empirical works (Lütkepohl et al., 2001) and since the computed λ_{max} value—when the null hypothesis is $r=1$—is very close to the 95% critical value. We therefore estimate a vector error correction model (VECM) with two cointegrating relationships, whereby two lags of the precipitation deviation and two lags of first-differenced Baltic dry index are included as exogenous variables.

Table 3. Johansen cointegration tests: Adjusted Sample: Apr 2000 to Feb 2015

H_0	**H_1**		**95% Critical value**
λ_{trace} test		***λ_{trace} value***	
$r = 0$	$r > 0$	141.90**	114.90
$r \leq 1$	$r > 1$	93.93**	87.31
$r \leq 2$	$r > 2$	56.77	62.99
$r \leq 3$	$r > 3$	37.24	42.44

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[4] This is determined based on the Pantula test (Pantula, 1989).

r ≤ 4	r > 4	19.75	25.32
λ_{max} ***test***		λ_{max} ***value***	
r = 0	r = 1	47.65**	43.97
r = 1	r = 2	37.16	37.52
r = 2	r = 3	19.52	31.46
r = 3	r = 4	17.49	25.54
r = 4	r = 5	12.10	18.96

Note: ** denotes rejection of the null for the 5% significance levels critical values from Osterwald-Lenum (1992)

3.3. Vector autoregressive and error correction model analysis

A VECM is a restricted vector autoregressive (VAR) model that can be applied to analyse nonstationary data series that are found to be cointegrated. The VECM modelling procedure can be written by defining an unrestricted VAR of order *k* as follows:

$$\boldsymbol{P_t = c + A_1 P_{t-1} + \cdots + A_k P_{t-k} + B_0 X_t + B_1 X_{t-1} + \cdots + B_s X_{t-s} + v_t} \qquad (1)$$

where c is constant and P_t is a $(6x1)$ vector of all endogenous variables defined in the model, namely international wheat price, domestic producer, wholesale, and retail wheat prices, as well as wheat flour and bread prices.

X_t is a $(2x1)$ vector comprising all exogenous variables; the precipitation deviation variable, to account for weather conditions, and the BDI variable to allow for changes in shipping costs that could affect the margin between domestic prices and international wheat prices.

$\boldsymbol{A_1}, \ldots, \boldsymbol{A_k}$ and $\boldsymbol{B_0}, \ldots, \boldsymbol{B_s}$ are matrices containing the coefficients to be estimated; $\boldsymbol{v_t}$ is a $(6x1)$ vector of *i.i.d* normal disturbances with mean 0 and covariance matrix $\boldsymbol{\Sigma}$.

Equation 1 can be adjusted in form of vector autoregressive in differences and error correction components:

$$\boldsymbol{\Delta P_t = \sum_{i=1}^{k-1} \Gamma_i \Delta P_{t-i} + \Pi P_{t-1} + \sum_{j=0}^{s} B_j X_{t-j} + v_t} \qquad (2)$$

Equation 2 is the classical VECM (Engle & Granger, 1987) obtained from the level VAR from (1) by subtracting $\boldsymbol{P_{t-1}}$ from both sides and rearranging terms. Here $\boldsymbol{\Gamma_i = -(A_{i+1} + A_{i+2} + \ldots + A_k)}$ and $\boldsymbol{\Pi = -(I - A_1 - A_2 - \cdots - A_k)}$ for $i = 1,2, \ldots k - 1$, where I is the identity matrix. More specifically, $\boldsymbol{\Gamma_i}$ is the (6x6) matrix of parameters for an $\boldsymbol{i}$ order lag process that capture short-run dynamics. $\boldsymbol{\Pi}$ is the (6x6) matrix that contains information regarding the long-run relationship. We can decompose $\boldsymbol{\Pi = \alpha\beta'}$ where $\boldsymbol{\alpha}$ includes the speed of adjustment coefficients to equilibrium (or error correction term ECT) and $\boldsymbol{\beta'}$ is the long-run matrix of coefficients, i.e., the cointegrating vector in the long-run. In formal terms:

$$\boldsymbol{\Delta P_t = \sum_{i=1}^{k-1} \Gamma_i \Delta P_{t-i} + \alpha\beta' P_{t-1} + \sum_{j=0}^{s} B_j X_{t-j} + v_t} \qquad (3)$$

The adjustment coefficients $\boldsymbol{\alpha}$, the long-run coefficients entering $\boldsymbol{\beta}'$ (the cointegrating equation), the short-run coefficients contained in $\boldsymbol{\Gamma_i}$ (in the VAR model), and the coefficients on the exogenous variables are estimated based on the Johansen maximum likelihood framework (Johansen, 1988; Johansen & Juselius, 1990). All the variable series (except the rainfall deviation) are transformed to their natural logarithms in our empirical analysis, coefficients can therefore be interpreted as elasticity transmissions.

4. Results and Discussions

4.1. Granger causality analysis

Although the variables in our data are cointegrated, this is not sufficient to determine the lead-lag relationship between the variable series. We follow the Toda and Yamamoto (1995) procedure to test for Granger causality among our variables. We set up a VAR model in the levels of the log-transformed variables in our data. Because the unit root test results indicate that the maximum order of integration among our variables is one, we add one additional lag of each of the (non-stationary) price variables, precipitation deviation and BDI as exogenous variables into each of the equations in the VAR model. According to Toda and Yamamoto (1995), the Wald test statistics are asymptotically chi-square distributed under the null hypothesis of Granger non-causality. The results are reported in table 4.

According to table 4, we have reasonable evidence of no Granger causality from or to the price of the final product in the wheat value chain, which is, bread. Neither individually nor jointly do the variables in our VAR model Granger cause bread price in the Addis Ababa market. An obvious explanation is the importance of other costs (which may include labour, electricity, packaging, house rent, among others) besides the price of the raw material (wheat grain). The value added to wheat grain at this stage may be of more relevance in determining the price of bread. Considering the price of wheat flour, we find that Granger causality runs both from and to producer and wholesale prices. Although millers in Addis Ababa obtain a significant share of their wheat grain from imported wheat, it is the government that imports and resells wheat to millers at a subsidized price. This may explain why we do not find Granger causality from international wheat price to domestic wheat flour prices. We control for a proxy to transportation cost of importing wheat (two lags of BDI) as an exogenous variable and it turns out to be a statistically significant factor for wheat flour price. We may therefore conclude that the effect of international wheat price to domestic wheat flour prices is mainly transmitted though the cost of shipping wheat to the country.

Table 4. Granger Causality Wald test Results

Dependent Variable	Excluded	chi2	df	Prob>chi2
PROD_P	INT_P	9.57	2	0.008
	WHOL_P	9.30	2	0.010
	RET_P	1.25	2	0.535

	FLOUR_P	6.38	2	0.041
	BREAD_P	1.36	2	0.507
	All	25.25	10	0.005
WHOL_P	INT_P	1.89	2	0.389
	WHOL_P	14.96	2	0.001
	RET_P	5.07	2	0.079
	FLOUR_P	5.97	2	0.051
	BREAD_P	0.26	2	0.879
	All	26.11	10	0.004
RET_P	INT_P	5.66	2	0.059
	WHOL_P	5.10	2	0.078
	RET_P	12.47	2	0.002
	FLOUR_P	0.91	2	0.633
	BREAD_P	2.54	2	0.282
	All	41.13	10	0.000
FLOUR_P	INT_P	1.04	2	0.593
	WHOL_P	6.64	2	0.036
	RET_P	6.10	2	0.047
	FLOUR_P	1.23	2	0.542
	BREAD_P	3.19	2	0.203
	All	16.38	10	0.089
BREAD_P	INT_P	3.81	2	0.149
	WHOL_P	0.15	2	0.930
	RET_P	0.84	2	0.656
	FLOUR_P	0.57	2	0.750
	BREAD_P	0.78	2	0.677
	All	9.04	10	0.529

Notes: We add only two lags as endogenous variables in the VAR system; there are more exogenous variables that do not count in the degree of freedom. This is an appropriate procedure to conduct Granger causality because it does not depend on a pre-test for cointegration (Toda & Yamamoto, 1995)

There is a two-way Granger causality between wholesale and retail prices, whereas there is Granger causality from only producer price to retail price, but not *vice versa.* Similarly, the Wald test results show a strong Granger causality from domestic wholesale price to producer prices, and vice versa. On the other end of the wheat value chain, we have reasonable evidence of Granger causality from international wheat price to domestic producer and retail prices of wheat, but (as expected) not *vice versa.*

4.2. Results of the VEC model

The results of the cointegrating equations are reported in tables 5 and 6. In particular, the long-run equilibrium relationships between the price variables are reported in table 5, while the short-run dynamics are displayed in table 6.

The two cointegrating equations— in which we have normalized by coefficients of bread and flour price (the bottom of the chain) to one—can be interpreted as two stationary bread and flour price setting long-run relations. All wheat prices, with the exception of domestic wholesale and international prices, are above their equilibrium values as the respective price coefficients in the cointegrating equation are positive (table 5). Domestic wholesale and international wheat prices instead are currently below the long-run equilibrium. This implies that the latter wheat prices should adjust upwards to remain in the long-run equilibrium, while all the other prices need to adjust downwards. To this end, the short-run adjustments coefficients—that is, the coefficients of the ECTs in table 6— help to restore these deviations toward the equilibrium.

All the statistically significant estimated coefficients of the *ECT* have expected signs, that is, negative when the deviation in the long-run relation is positive, and vice versa. For instance, when the average international wheat price is too low, it slowly adjusts upward while at the same time the other prices fall back towards their equilibrium values. Adjustments towards the equilibrium are generally slow, however. For instance, about 6% of the disequilibrium in bread prices is eliminated in 1 month, which means it takes above 16 months to restore the equilibrium after a shock. The speed that markets adjust to shocks is determined by the actions of market agents who are involved in the transactions that link different market levels. Our results indicate that price signals pass across agents with some delays, that is, increases or decreases in one end of the chain are not transmitted instantaneously but instead are distributed over time. This may indicate that adjustment is costly or it is subject to constraints, such as very high transaction costs.

Table 5. Long-run relationship between prices

Variable	**CointEq1**	**CointEq2**
BREAD_P (t-1)	1	0
FLOUR_P (t-1)	0	1
RET_P (t-1)	2.936***	0.108
	(0.664)	(0.189)
WHOL_P (t-1)	-3.404***	-1.282***
	(0.632)	(0.180)
PROD_P (t-1)	0.305	0.577***
	(0.355)	(0.101)
INT_P (t-1)	-0.674***	-0.156**
	(0.243)	(0.069)
Intercept	-1.390	-0.549

Notes: *, **, and *** denote statistical significance at the 10%, 5% and 1% levels, respectively. Standard errors in parentheses.

Table 6. VECM short-run estimates and adjustment parameters

Variables	***ΔBREAD_P***	***ΔFLOUR_P***	***ΔRET_P***	***ΔWHOL_P***	***ΔPROD_P***	***ΔINT_P***
ECT_{t-1}	-0.058**	0.052***	-0.091***	-0.005	0.039	0.075***
	(0.029)	(0.025)	(0.026)	(0.029)	(0.048)	(0.032)
ECT_{t-2}	0.065	-0.326***	0.011	0.050	-0.443***	-0.152
	(0.095)	(0.080)	(0.085)	(0.094)	(0.156)	(0.106)
$\Delta BREAD\_P_{t-1}$	-0.269***	-0.072	-0.049	-0.070	0.050	-0.118

	(0.081)	(0.068)	(0.073)	(0.080)	(0.133)	(0.090)
$\Delta BREAD\_P_{t-2}$	-0.063	0.049	0.024	-0.039	-0.112	-0.077
	(0.082)	(0.069)	(0.074)	(0.081)	(0.135)	(0.092)
$\Delta FLOUR\_P_{t-1}$	-0.011	-0.114	0.024	0.068	0.339**	-0.190*
	(0.095)	(0.080)	(0.086)	(0.094)	(0.156)	(0.106)
$\Delta FLOUR\_P_{t-2}$	-0.032	-0.182**	-0.030	-0.189**	-0.006	-0.130
	(0.098)	(0.082)	(0.088)	(0.096)	(0.160)	(0.109)
ΔRET_P_{t-1}	0.100	-0.164**	-0.202**	-0.017	0.015	-0.150
	(0.088)	(0.074)	(0.079)	(0.087)	(0.144)	(0.098)
ΔRET_P_{t-2}	0.026	-0.064	-0.119	-0.149*	-0.207	-0.141
	(0.085)	(0.072)	(0.077)	(0.084)	(0.140)	(0.095)
$\Delta WHOL\_P_{t-1}$	-0.180**	-0.007	0.034	-0.085	-0.086	0.125
	(0.090)	(0.076)	(0.081)	(0.089)	(0.147)	(0.100)
$\Delta WHOL\_P_{t-2}$	-0.191**	-0.125*	-0.088	0.028	-0.100	0.006
	(0.090)	(0.076)	(0.081)	(0.089)	(0.148)	(0.101)
$\Delta PROD\_P_{t-1}$	-0.003	0.125***	0.090**	0.132***	-0.214***	-0.011
	(0.050)	(0.042)	(0.044)	(0.049)	(0.081)	(0.055)
$\Delta PROD\_P_{t-2}$	-0.010	-0.008	0.011	0.031	-0.094	0.020
	(0.051)	(0.043)	(0.045)	(0.050)	(0.083)	(0.056)
ΔINT_P_{t-1}	0.077	0.031	0.074	-0.073	-0.310**	0.316***
	(0.074)	(0.062)	(0.066)	(0.073)	(0.121)	(0.082)
ΔINT_P_{t-2}	-0.159**	-0.082	-0.165**	0.072	0.246**	-0.128
	(0.075)	(0.063)	(0.067)	(0.074)	(0.123)	(0.083)
PRE_DEV_{t-1}	8.28E-5	1.11E-4	-4.43E-5	-1.04E-5	-0.001*	0
	(0.0003)	(0.0002)	(0.0002)	(0.0003)	(0.0003)	(0.0003)
PRE_DEV_{t-2}	-3.38E-4	-4.97E-5	-2.13E-4	-1.35E-4	1.60E-4	0
	(0.0003)	(0.0002)	(0.0002)	(0.0003)	(0.0004)	(0.0003)
$\Delta LRBDI_{t-1}$	0.002	0.039**	-0.005	0.035	-0.034	-0.022
	(0.028)	(0.020)	(0.025)	(0.028)	(0.046)	(0.032)
$\Delta LRBDI_{t-2}$	0.017	0.008	-0.015	-0.006	0.041	0.041
	(0.028)	(0.023)	(0.025)	(0.027)	(0.045)	(0.031)
Intercept	0.060	0.255***	0.168***	-0.069	0.399***	0.070
	(0.062)	(0.052)	(0.056)	(0.061)	(0.102)	(0.069)
N	179					
R-Squared	0.174	0.282	0.312	0.132	0.258	0.193
F-statistics, p-value	0.017	0.000	0.005	0.199	0.011	0.154

Notes: *, **, and *** denote statistical significance at the 10%, 5% and 1% levels, respectively. Standard errors in parentheses.

Nearly all short-run own-price elasticities are statistically significant and negative, indicating that a higher rate of price in the previous month is followed by a lower rate in the current month. The only exception is that of the international wheat price, which has a positive sign. This implies that while, domestic prices are mean reverting, that is, a shock in one period is not persistent as the price converges back to its equilibrium level, the opposite applies to international wheat price. Another interesting result is that a change in domestic producer price triggers a short-run response in wholesale, retail, and flour prices, whereas domestic producer price is influenced by international wheat and domestic wheat flour prices. More specifically, a 10% increase in the rate of domestic producer price in the previous month triggers a short-run decline of about 2.1% in its own price but an increase of about 1.2% in flour price, 1.3% in wholesale, and slightly less than 1% in wheat retail prices. As expected, rainfall deviation in the previous month results to a lower rate of producer prices in the current month. The positive and statistically significant effect of changes in BDI on the rate of flour prices is because domestic millers typically obtain a significant share of their wheat grain from imports (Gebreselassie et al, forthcoming). One expects the government to adjust the price at which it sells imported wheat to millers depending on changes in shipment costs.

The VEC model is fairly well specified: there is no serial correlation in the disturbances (table 7) and the stability conditions needed to compute impulse response functions are satisfied (figure 3). However, we fail to reject non-normality of the disturbance term, which indicates that our parameter estimates are not efficient, but consistent.

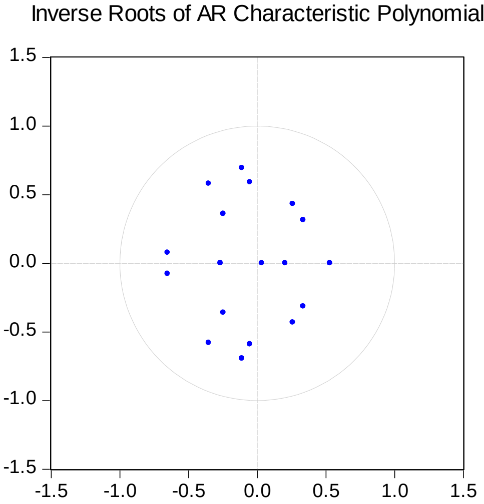

Figure 3. Stability of the VAR model specification

Table 7. Lagrange-multiplier test for autocorrelation

Lags	**LM-Stat**	**Prob**
1	34.635	0.534
2	43.228	0.190
3	34.783	0.526
4	60.633	0.006
5	21.574	0.973
6	33.793	0.574

H0: No autocorrelation at given lag order

4.3. Alternative specifications of the VEC model

We also estimate a similar VECM for a subset of the price variables in our data. In particular, we want to analyse the relations among prices at the downstream and upstream of the wheat value chain. The first specification investigates the relationship between international wheat price, wholesale price, wheat flour and bread prices, while constraining the long-run coefficients on producer and retail prices to zero. The long-run equilibrium relationship estimates of these price variables are reported in table 8, while the coefficients on short-run dynamics are displayed in table 9.[5]

The two cointegrating equations—which we have normalized by coefficients of bread and flour price (variables at the downstream of the value chain) to one—can be interpreted as two stationary bread and flour price setting long-run relations. In relation to the normalized prices,

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[5] For the sake of brevity, the parameters estimates on ECT terms and on own price variables are reported. The remaining results—which can be available on request—are qualitatively similar to our previous estimates.

domestic flour price (CointEq1) and wholesale price (CointEq2) and international wheat prices are currently below the long-run equilibrium. Thus, these prices need to adjust upwards to restore to their long-run equilibrium values, whereas the normalized prices should adjust downwards. As expected the estimated coefficients of the *ECT* on the normalized prices—wheat bread in the first and flour in the second cointegration equations—are negative and statistically significant at the 1 percent level. According to the estimated coefficients, when the average wheat bread price is too high, it adjusts downwards by about 9% in one month alone, whereas wheat flour price adjusts upward by a slightly faster speed (21%). The other short-run adjustments coefficients on the unconstrained price variables have expected signs; however, all except the one on international prices are not statistically significant. These findings are qualitatively consistent to our earlier estimates that do not impose the additional constraints.

Table 8. Long-run relationship between prices, with specific constraints

Variable	**CointEq1**	**CointEq2**
WHBREAD_P(t-1)	1	0
WHFLOUR_P(t-1)	-1.990***	1
	(0.323)	
WHRET_P(t-1)	0	0
WHWHOL_P(t-1)	0	-0.493***
		(0.109)
WHPROD_P(t-1)	0	0
INT_P(t-1)	-0.432**	-0.215**
	(0.178)	(0.100)
Intercept	0.762	-0.748

Notes: *, **, and *** denote statistical significance at the 10%, 5% and 1% levels, respectively. Standard errors in parentheses.

In line with our previous findings, all but international wheat own-price elasticities are statistically significant and negative, indicating that a higher rate of price in the previous month is followed by a lower rate in the current month. This confirms our conclusion that domestic prices are mean reverting, whereas a higher international price in the previous month is reinforced in the current month.

Table 9. VECM short-run estimates and adjustment parameters, with specific constraints

Variables	***ΔBREAD_P***	***ΔFLOUR_P***	***ΔRET_P***	***ΔWHOL_P***	***ΔPROD_P***	***ΔINT_P***
ECT_{t-1}	-0.092**	0.050	-0.017	0.052	-0.036	0.131***
	(0.040)	(0.034)	(0.038)	(0.038)	(0.067)	(0.044)
ECT_{t-2}	-0.151**	-0.208***	-0.135**	-0.053	-0.165	0.096
	(0.064)	(0.054)	(0.060)	(0.061)	(0.108)	(0.070)
$\Delta(\text{Own price})_{t-1}$	-0.253***	-0.078	-0.339***	-0.168**	-0.383***	0.306***
	(0.083)	(0.090)	(0.082)	(0.090)	(0.084)	(0.079)
$\Delta(\text{Own price})_{t-2}$	-0.068	-0.151*	-0.185**	0.006	-0.207**	-0.076
	(0.081)	(0.086)	(0.081)	(0.088)	(0.085)	(0.081)

Intercept	0.032*	0.034**	0.025	0.003	0.026	-0.001
	(0.017)	(0.014)	(0.016)	(0.016)	(0.028)	(0.018)
N	178					
R-squared	0.184	0.281	0.235	0.174	0.208	0.206
F-statistic	2.122	3.671	2.884	1.978	2.476	2.445

Notes: *, **, and *** denote statistical significance at the 10%, 5% and 1% levels, respectively. Standard errors in parentheses.

The second alternative specification considers the relationship of prices at the upstream of the domestic wheat market chain. In particular, we analyse the relationship between domestic producer, wholesale, and retail prices with a single cointegration equation.[6] The long-run equilibrium relationship estimates and selected coefficients on short-run dynamics of this model are reported in tables 10 and 11.

Table 10. Long-run relationship between prices, upstream

Variables	**CointEq1**
RET_P(t-1)	1
WHOL_P(t-1)	-0.638***
	(0.120)
PROD_P(t-1)	-0.176**
	(0.072)
Intercept	-0.296

Notes: *, **, and *** denote statistical significance at the 10%, 5% and 1% levels, respectively. Standard errors in parentheses.

The coefficients on both domestic wholesale and producer wheat prices in the cointegrating equation are statistically significant, as is the adjustment parameter for retail price. When the predictions from the cointegrating equation are positive, retail price is above its equilibrium value, whereas wholesale and producer prices are below their equilibrium values—since the respective coefficient in the cointegrating equation is positive for retail price but negative for the latter two. The estimate of the adjustment parameter for retail price is -0.42 and it is statistically significant at the 1% level. Thus, when the average retail price is above its equilibrium value, it quickly falls back towards the wholesale and producer price levels. Indeed, it takes less than a quarter of a year for the retail price to attain its equilibrium value.

Table 11. VECM short-run estimates and adjustment parameters, upstream

Variables	***ΔRET_P***	***ΔWHOL_P***	***ΔPROD_P***
ECT_{t-1}	-0.421***	-0.021	0.090
	(0.080)	(0.088)	(0.153)
Δ(Own price)t-1	-0.105	-0.130	-0.399***
	(0.090)	(0.100)	(0.084)
Δ(Own price)t-2	-0.075	-0.013	-0.163**

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[6] The number of cointegration equations is again determined based on the Johansen-Juselius procedure.

	(0.077)	(0.093)	(0.084)
Intercept	0.034**	0.001	-0.024
	(0.017)	(0.018)	(0.032)
N	179		
R-squared	0.281	0.084	0.147
F-statistic	6.580	1.549	2.900

Notes: *, **, and *** denote statistical significance at the 10%, 5% and 1% levels, respectively. Standard errors in parentheses.

4.4. Impulse response functions and variance decomposition

The discussion in this section refers to variance decomposition and impulse response functions (IRF) based on our estimates from the baseline specification (tables 5 and 6).[7] We provide the impulse response functions based on the Cholesky decomposition method (figure 4) and the variance decomposition based on Monte Carlo repetitions (table 12) to evaluate how shocks impact the wheat-to-bread value chain. In particular, the IRFs give information on how innovations to one variable trigger changes in other variables after a certain number of periods, whereas the variance decomposition provides information about the relative importance of factors in explaining the variation of each price series.

The four graphs in the first column of figure 4 display the impacts of international wheat price shock on domestic price dynamics. It emerges that the effect of a shock in the international wheat price dies out within three to four months. A shock of one standard deviation in the international price triggers a positive response from all domestic price series in the current month. This shock leads to a decline in all domestic prices in subsequent months before they bounce back to positive after one month in the case of producer prices but after three months for the other domestic prices. The other four graphs in the second and third columns of this figure show the impacts of impulses in producer and wholesale prices on the remaining domestic prices. A one standard deviation shock in both producer and wholesale prices leads to a persistent increase in retail prices. Increases in wholesale prices also generate long-lasting upsurges in both producer and wheat flour prices. Note also that the response of producer price to the initial impulse in producer price itself, as well as, the response of wholesale price to the initial wholesale price impulse are persistent, suggesting a high degree of inertia in both prices. This implies that increases in producer and wholesale prices are difficult to eradicate. Retail price shocks—fourth column in figure 4—have a negligible effect on all prices except a quite delayed one on bread price and one that exponentially vanishes on subsequent own prices. The graphs in the last two columns of figure 4 show that flour and bread price shocks have a contained influence on other price dynamics, but have a persistent effect on their own respective prices. The bottom panel of figure 4 depicts that current shocks in the Baltic dry index triggers a transitory but positive change in domestic wheat flour and producer prices, which occurs after one month for the former price but after two months for the latter.

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[7] The variance decomposition and IRFs from the alternative specification are available upon request.

The cumulative responses also show that impacts of international wheat prices remain positive in the case of producer but become negligible for wheat flour and bread prices (figure A.1). This implies that positive shocks in international wheat prices may have long-run benefits to domestic producers but they negatively affect consumers in the short-run. Shocks in producer prices do also trigger contemporaneous positive responses in wholesale, retail and wheat bread prices, as do wholesale price shocks trigger positive changes in producer, retail and flour prices. In general, upstream price shocks are stronger and more persistent. This conclusion is also supported by the IRFs from the alternative specifications.[8]

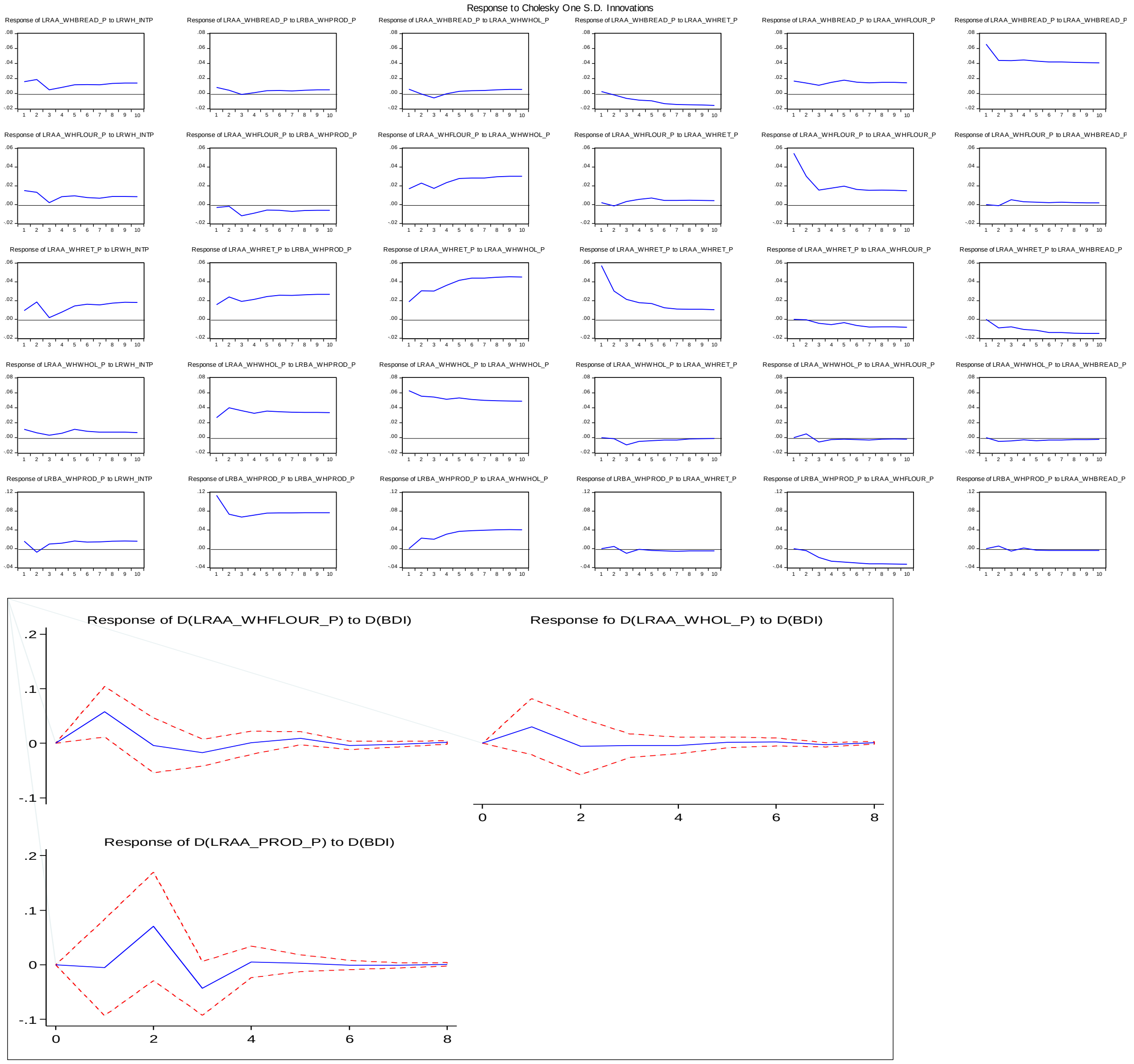

Figure 4. Selected Impulse response functions

The variance decomposition indicates the percentage of domestic price changes explained by their own shocks and by shocks on other variables in the system. The results show that a

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[8] These results are available upon request.

substantial part of all price variations are explained by own-price shocks, though this diminishes in latter periods. Considering variances of wheat flour prices, for instance, above half of the variation is explained by current shocks in flour prices itself for about the subsequent 6 months. However, shocks in other prices—in particular, wholesale prices—become more important in explaining variations in flour price in latter months. Shocks in wholesale prices also explain a sizable share of the variability in retail prices. In fact, four to five months delayed changes in retail prices are better explained by contemporaneous shocks in wholesale prices than shocks in retail prices themselves. Shocks in domestic producer price are also important in explaining changes in retail and wholesale prices, explaining above a fifth of the variability in the latter price starting from the second month horizon. The variances of the downstream prices along the wheat value chain—bread, flour, and retail wheat prices—are largely explained by own shocks. These conclusions remain unchanged when we consider corresponding variance decomposition results from the alternative specifications.[9]

Table 12. Variance decomposition of domestic price series

Variance Decomposition of ΔBREAD_P:							
Period	S.E.	ΔBREAD_P	ΔFLOUR_P	ΔRET_P	ΔWHOL_P	ΔPROD_P	ΔINT_P
1	0.070	87.195	5.596	0.140	0.672	1.361	5.036
2	0.086	83.904	6.387	0.129	0.450	1.171	7.959
3	0.098	85.179	6.228	0.528	0.699	0.920	6.447
4	0.110	85.060	6.855	1.060	0.562	0.748	5.715
5	0.120	83.626	7.895	1.516	0.525	0.724	5.714
6	0.130	82.432	8.185	2.358	0.538	0.722	5.765
7	0.139	81.523	8.273	3.167	0.554	0.700	5.782
8	0.147	80.461	8.381	3.843	0.614	0.714	5.987
9	0.155	79.463	8.462	4.432	0.681	0.744	6.219
10	0.162	78.645	8.482	4.968	0.732	0.767	6.406
Variance Decomposition of ΔFLOUR_P:							
Period	S.E.	ΔBREAD_P	ΔFLOUR_P	ΔRET_P	ΔWHOL_P	ΔPROD_P	ΔINT_P
1	0.059	0.000	85.217	0.141	7.989	0.275	6.378
2	0.072	0.032	76.062	0.136	15.805	0.250	7.714
3	0.077	0.499	70.698	0.306	18.986	2.688	6.824
4	0.083	0.548	64.383	0.726	24.037	3.508	6.798
5	0.091	0.535	58.623	1.191	29.531	3.360	6.759
6	0.097	0.515	54.025	1.241	34.370	3.345	6.505
7	0.103	0.520	50.282	1.300	38.204	3.465	6.229
8	0.109	0.502	46.950	1.353	41.574	3.440	6.181
9	0.115	0.482	44.140	1.378	44.460	3.378	6.162
10	0.120	0.465	41.784	1.379	46.909	3.342	6.122
Variance Decomposition of ΔRET_P:							
Period	S.E.	ΔBREAD_P	ΔFLOUR_P	ΔRET_P	ΔWHOL_P	ΔPROD_P	ΔINT_P
1	0.063	0.000	0.000	82.829	8.752	6.242	2.178
2	0.082	1.251	0.003	61.716	18.768	11.965	6.298
3	0.093	1.725	0.197	53.892	25.441	13.739	5.006
4	0.104	2.410	0.443	45.460	32.202	14.991	4.494

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[9] These results are not reported for the sake of brevity.

5	0.118	2.898	0.439	37.792	37.845	16.029	4.996
6	0.131	3.481	0.604	31.510	41.972	16.864	5.569
7	0.143	3.915	0.835	27.124	44.888	17.370	5.868
8	0.154	4.262	0.988	23.717	46.989	17.760	6.284
9	0.165	4.526	1.088	21.092	48.516	18.092	6.686
10	0.175	4.744	1.191	19.057	49.656	18.356	6.996
Variance Decomposition of ΔWHOL_P:							
Period	S.E.	ΔBREAD_P	ΔFLOUR_P	ΔRET_P	ΔWHOL_P	ΔPROD_P	ΔINT_P
1	0.069	0.000	0.000	0.000	82.346	15.028	2.627
2	0.098	0.248	0.280	0.021	73.425	24.259	1.767
3	0.118	0.299	0.423	0.659	71.361	25.973	1.285
4	0.133	0.279	0.369	0.653	71.065	26.414	1.220
5	0.148	0.301	0.317	0.599	70.168	27.051	1.563
6	0.161	0.295	0.295	0.547	69.632	27.621	1.610
7	0.172	0.290	0.291	0.509	69.256	28.060	1.594
8	0.183	0.277	0.272	0.461	68.986	28.423	1.581
9	0.192	0.266	0.254	0.421	68.744	28.739	1.577
10	0.201	0.255	0.240	0.387	68.566	28.999	1.553
Variance Decomposition of ΔPROD_P:							
Period	S.E.	ΔBREAD_P	ΔFLOUR_P	ΔRET_P	ΔWHOL_P	ΔPROD_P	ΔINT_P
1	0.115	0.000	0.000	0.000	0.000	98.069	1.931
2	0.139	0.175	0.093	0.114	2.588	95.394	1.636
3	0.157	0.241	1.495	0.493	3.642	92.451	1.678
4	0.178	0.194	3.396	0.391	5.854	88.431	1.733
5	0.200	0.184	4.713	0.342	8.106	84.609	2.047
6	0.220	0.177	5.808	0.331	9.739	81.852	2.093
7	0.239	0.173	6.752	0.333	10.990	79.605	2.146
8	0.256	0.170	7.430	0.322	11.970	77.867	2.240
9	0.273	0.170	7.979	0.315	12.739	76.466	2.331
10	0.289	0.170	8.444	0.308	13.328	75.363	2.387
Cholesky Ordering: ΔINT_P, ΔPROD_P, ΔWHOL_P, ΔRET_P, ΔFLOUR_P, ΔBREAD_P							

In summary, the variance decomposition findings are in agreement with the implications of the IRFs, suggesting that stronger shock transmission happens from upstream to downstream of the wheat value chain than vice versa. Not only does this support the major findings of the granger causality analysis, this is also in line with our prior expectations (figure 1). These results appear robust, qualitatively, across alternative specifications as well the use of alternative analysis.

5. Conclusions

The empirical analysis of this paper emphasizes inter-linkages in the wheat value chain in Ethiopia and its exposure to international price shocks. The wholesale market has been identified as an important market as it Granger-causes every other domestic market (except bread prices). Similar to wholesale prices, producer prices Granger-cause all other domestic markets except bread. Both findings indicate that prices and expectations are formed at the upstream of the wheat-bread value chain—particularly at the wholesale market— and that prices are determined largely by supply side shocks. In general, our alternative time series analyses suggest that stronger shock transmission happens from upstream to downstream of the wheat value chain than vice versa. This is in line with our prior expectations as the items at the upstream of the local value chain serve as inputs in production of items downstream—and thus contribute to the cost of production.

The VECM analysis has shown that international prices explain an important share of the variance of domestic prices at the downstream of the wheat value chain—retail, flour, and bread prices. This implies that when price shocks occur in the worldwide wheat market, Ethiopia is not insulated from such price shocks. This could be due the fact that Ethiopia relies strongly on wheat imports. It should be noted that the speed of adjustment through the supply chain to market shocks is slow and this points to the fact that the adjustment may be subject to high transaction costs, the presence of market power, and information asymmetries.

Value chain development has been advocated as a key strategy to promote growth, to improve market structure, and to reduce exposure to volatility from raw materials (ILO, 2012). While our empirical analysis reveals that higher stages of the wheat value chain indeed depend less on the domestic production stage, exposure to international price volatility is not entirely mitigated. Yet, we found that producer and wholesale market levels play a dominant role in the wheat value chain, implying that policies may give particular attention to these markets.

Appendix

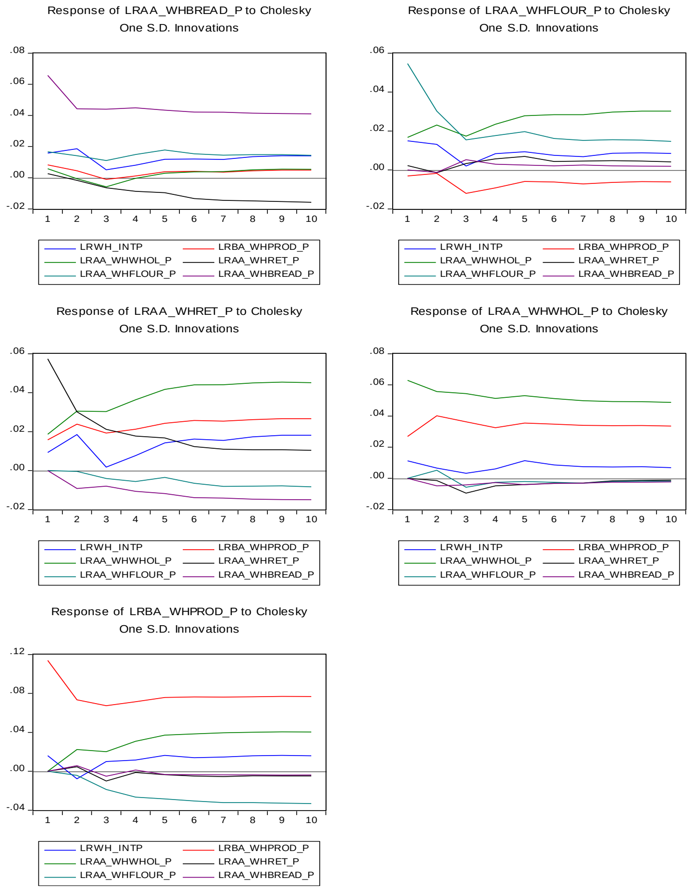

Figure A. 1. Impulse response functions for the baseline specification

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