Policy and Institutional Reforms to Improve Horticulture Markets in Pakistan
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Vertical Integration and Cross-Country Price Transmission in Pakistan's Agriculture Market.

Hayat Khan*
Assistant Professor
College of Business, Alfaisal University, Riyadh, Saudi Arabia
hakhan@alfaisal.edu

Sisira Jayasuriya
Director
Centre of Development Economics and Sustainability, Monash University
sisira.jayasuriya@monash.edu

Abstract
This paper reports on a component of studies on marketing efficiency and commodity market modelling of the horticulture sector in Pakistan. It presents preliminary results of an analysis of price transmission across spatially dispersed markets between monthly wholesale and retail prices of a variety of food crops in Pakistan, including tomato, onions, other fruits and vegetables, as well as rice, wheat, pulses and milk. It uses a novel methodology that takes into account the complex interactions between agricultural consumer goods. The approach mainly relies on variance-covariance structure of prices and use latent factors. The analysis (i) separates vertical price movements from fluctuations caused by country-wide shocks which affects all commodities with variable impact on individual commodities; (ii) quantifies the impact of price fluctuations in selected commodities in India on retail prices in Pakistan, and (iii) investigates if there are asymmetric responses to increases and decreases of prices. We also use data from India to assess the degree to which price shocks are transmitted across the two countries – a politically sensitive issue in both countries, particularly in the case of crops such as onions and potatoes. While these initial results must be treated primarily as illustrative, given the preliminary nature of the analysis, it is interesting to note that vertical transmission of shocks is important only in some markets but not in others, price transmission is asymmetric to positive versus negative shocks in many instances, and that there appears to be significant spatial price transmission in potato prices between India and Pakistan, though not in onions or tomatoes.

Keywords
Horticulture, Price Transmission, Vertical Integration, Pakistan

**Corresponding author*

1. Introduction

According to the 2016-17 Economic Survey of Pakistan, agriculture accounts for around [a] fifth of the country's GDP and employs over 40% of the country's labour force. Among agricultural products, the demand for high-value perishable horticulture and dairy products such as fruits, vegetables, dairy and meat is expected to increase particularly rapidly in response to population growth, rising incomes and ongoing urbanisation. Horticulture industries face both huge opportunities and new competitive threats from the development of the China Pakistan Economic Corridor (CPEC). On the one hand, CPEC is expected to open a huge demand window, which will provide the local industry profitable opportunities as China has one of world's fastest growing market for horticulture commodities. On the other hand, it poses a challenge in terms of opening a competition window with relatively more productive and cost-efficient competitors (China in particular).[1] This presents a multi-dimensional policy challenge to the government to identify and address weaknesses of the sector and create opportunities for the local sector to grow and compete without any market intervention. Whereas the immediate focus of the government seems to be on improving productivity, quality and building supply chain infrastructure marketing chain and efficiency of price transmission is critical to the successful transition of the horticulture sector to achieve its full potential.

The country's agriculture sector is currently operating below potential due to low productivity, inferior quality, high wastage, and low exports. The marketing system is widely considered to be one of the main factors constraining the industry's modernisation and development. According to Serra and Goodwin (2003) and Acosta and Valdes (2014), price is the instrument by which different levels of markets are integrated. In a perfect world with no market imperfections, market transfers information to the farm-gate level through the transmission of changes in prices. This facilitates efficient production and consumption decisions, as well as, rewards improvements in quality when markets are integrated and quality-premia are transferred down the marketing chain to the producer.

According to a USAID (2012) report, Pakistan's agriculture sector has a number of weaknesses, which creates market, as well as, marketing system inefficiencies. These include (i) exclusive public sector control of wholesale markets' operation and management, (ii) lack of accountability of the market committee, which is created through a political process to oversee the market, (iii) monopoly of the market committee over marketing of agriculture produce through a licensing system, and (vi) lack of provision for alternative marketing

[1] See Huang and Cui (2018) and Ali, Huang and Xie (2018)

channels such as farmers markets, consumer markets, direct marketing which limits scope for the development of value chain systems. These inefficiencies are agued to limit the range of opportunities available to market participants with (v) absence of appropriate standards (hygiene, grading, optimal space utilization, food safety and labelling), (vi) ability of the limited number of dealers to distort price related information, and (vii) giving the dealers the power to manipulate the system to make farmers reliant on them for their financing needs which expose them to permanent exploitation. Moreover, the system allows the marketing committee to receive a fee without providing commensurate services. The USAID report also adds that these inefficiencies result in unjustified levels of profit margins expropriated from the growers as well as paid by consumers. The median wholesale mark-up, including commissions, is estimated to be more than 18 per cent of the value of the produce. The inefficiencies in the marketing system are further passed on to consumers resulting in prices being inflated from 30 per cent to 50 per cent (USAID (2012). Pakistan's agriculture sector, horticulture in particular, is dominated by smallholders with strong participation of women who remain trapped in inefficient marketing systems. The marketing system does not incentivise producers to produce what is in demand in the market or to transmit quality-price premia to upstream producers (USAID 2012).

This paper is part of a project, funded by the Australian Centre for International Agricultural Research (ACIAR), which is in the process of assessing existing marketing arrangements to identify main problems in the marketing chain to formulate appropriate marketing policy reforms. Whereas the marketing system has a number of nodes with multiple players, there is a paucity of data that can be used to quantify how efficient the overall price system is. Some recent research by USAID projects, such as the one referred to above, indicates that the price system is inefficient and market players in the middle of the marketing chain either distort the price information or use their monopoly power to create information asymmetry and, or use their status to stop trickling down of favourable price movements to the farm-gate level. This paper focuses on the down stream components of the market. The main objective of this paper is to quantify the degree of vertical price transmission between the retail and wholesale markets across the marketing chain for high-value perishable horticulture and dairy products. We do so by modelling interaction between different commodities in the agriculture market. We also quantify spatial price transmission between India and Pakistan in the retail market for selected commodities.

It is important to understand whether changes in prices are driven by demand or supply from a policy perspective. [2] In integrated markets prices converge over time; the value of price differentials and the rate at which prices converge are both important issues. Such integration takes place via arbitrage and related trade. Once these mechanisms operate to produce price convergence, prices of homogenous goods across markets will differ only by transport cost.

There is a large literature on market integration of agricultural commodities, including those in developing countries, particularly following Ravalllion's (1986) paper on market integration.[3] Most previous studies of market integration use co-integration analysis and Granger-causality. This type of analysis requires a long and reliable time series data, which is a scarce resource in developing and under developed countries. Moreover, most previous studies either focus on aggregate outcomes or study individual markets in isolation.[4] Previous analyses of spatial market integration of rice, onions and mango in Pakistan have found that markets are integrated in the long run.

Building on Dungey's (2000) work on exchange rate fluctuations, this paper uses a novel approach to study interactions between WPI and CPI of selected agriculture commodities taking into account complex interactions between a variety of agriculture commodities. The approach mainly relies on variance-covariance structure of prices and use latent factors to (i) separate vertical price movements from fluctuations caused by country-wide shocks which affects all commodities with variable impact on individual commodities; and (ii) quantify the impact of price fluctuations in selected commodities in India on retail prices in Pakistan. Moreover, (iii) the paper also look for asymmetry in the transmission of shocks to assess if there are any differences in the degree of vertical and spatial price transmission when prices increase or decrease. Our approach differs significantly from previous studies in that the methodology permits a richer set of interactions between both spatially and vertically linked markets for the same commodity as well as interactions between different agricultural

[2] Note that if consumer prices are determined by supply coming into the wholesale markets with little or no feed back from consumer prices to upstream supply, then wholesale prices (WPI) will Granger cause consumer prices (CPI), in contrast to the conclusion of Shabaz et. al. (2012) that CPI Granger causes WPI, implying that the prices changes are demand driven.

[3] See, for example, Abdulai (2000), Baquedano and Liefert (2014), Barrett and Li (2002), Goodwin and Pigott (2001), Sekhar 92012), Silvapulle and Jayasuriya (1994). There is also some literature on Pakistan (e,g. Ahmed and Gjølberg (2015); Lohano and Mari, 2006; Mukhtar and Javed, 2008; Ghaffor, et. al. ,2009), which found that domestic markets are spatially integrated in the long run, though there are issues about the pattern and speed of price adjustments.

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[4] We will elaborate further in future versions of the paper on the reasons for choosing this approach,while recognizing that our approach can be treated as complementary to some others.

commodity markets, while empirically taking into consideration interactions with the Indian market.

We model the country-wide shocks so as to permit either have a fixed impact or a variable impact on individual markets. In the time-series analysis jargon, this is equivalent to having a non-stationary series to have a constant and a trend respectively. The "trend" in our model is richer in the sense that we assume the trend to be a latent shock rather than a time-variable which admits a complex set of movements which may cause changes in vertical and spatial prices. More importantly, time series analysis looks for the constant and trend in data generating process of a series which requires a reasonably long time series whereas we identify these aspects using movements in prices with reference to the market as a whole, which does not necessarily need a longer time series. The estimation technique extracts this information from the interaction of commodities in the market.

The rest of the paper is organized as follows. Section 2 provides an overview of the latent factor model. Section 3 explains how the model is used to quantify the degree of vertical and spatial market integration. Section 4 outlines the estimation technique, followed by section 5, which provides a stylized simple example to simplify the exposition of the somewhat complex model. Section 6 provides details of the actual model estimated and presents some detailed results.

2. The Model

Let $wpi_{i,t}$ be the period to period change in wholesale producer prices of a commodity (or a group of commodities) *i* at time t and $cpi_{ji,t}$ be the corresponding changes in consumer prices of commodity j in the group with n commodities. Similarly, $cpi_{ij,t,IND}$ is the change in CPI of commodity j, belonging to WPI in group i, in India. We model prices as follows.

$$wpi_{i,t} = \theta F_{tWOR} + \alpha_{0,P} F_{t,P} + \alpha_{i,P} T_{t,P} + \sum_{j}^{n} \beta_{w,ij} V_{j,t} + \omega_i \varepsilon_{W,i,t} \quad (1)$$

$$cpi_{ij,t} = \theta F_{tWOR} + \alpha_{0,P} F_{t,P} + \alpha_{ij,P} T_{t,P} + \beta_{ij} V_{j,t} + \gamma_{ij,P} S_{ij,t} + \omega_{ij} \varepsilon_{C,ij,t} \quad (2)$$

$$cpi_{ij,t,IND} = \theta F_{tWOR} + \alpha_{0,IND} F_{t,IND} + \alpha_{ij,IND} T_{t,IND} + \gamma_{ij,IND} S_{ij,t} + \omega_{ij,IND} \varepsilon_{C,j,t} \quad (3)$$

Equations (1) to (3) postulates that fluctuations in prices are caused by time varying

i. $F_{t,WOR}$ *:* world common shocks which has a fixed impact on world's prices (Pakistan and India in this case) as evident from the fixed loading θ.

ii. $F_{t,p}/F_{t,IND}$: domestic shocks (Pakistan and India respectively) which has a fixed impact on domestic prices. This impact may differ across the two countries as the corresponding loadings differ across the two countries.

iii. $T_{t,P}/T_{t,IND}$: shocks in Pakistan/India, independent of each other, which has a variable effect on different commodities. The corresponding loadings change across commodities within each country.

iv. $V_{j,t}$: shocks in CPI which are transmitted to CPI and vice versa referred to as vertical shocks,

v. $S_{j,t}$: shocks in the Indian CPI which are transmitted to Pakistani CPI and vice versa referred to as spatial shocks, and

vi. ε : shocks caused by idiosyncratic factors, factors specific to a market for a specific commodity.

$F_{t,WOR}$, $F_{t,p}$, $F_{t,IND}$, $T_{,t,P}$, V_j, $S_{j,IND}$ and ε s are independent latent factors distributed with constant means and finite variance and αs and βs, γs and ωs are the corresponding loading parameters. Given the loading parameters, we can normalize these distributions to have 0 mean and unit variance, without loss of generality.

It is important to note that common variation does not mean one variable is causing the other. It may also mean that a common variable causes (drives) both variables to change in the same manner. The common factors with fixed and variable loadings are meant to identify such factors. In time-series analysis, this is equivalent to checking for stationarity with a constant and a trend respectively. The first two terms on the right hand side of equations 1, 2 and 3 represent the constants and the third term represents the trend. As should be obvious, the "trend" in our model is richer in the sense that we assume the trend to be a latent shock rather than a time-variable which admits a complex set of movements which may cause co-movements in the vertical prices. This could be the result of monetary policy, a simple time trend or changing macroeconomic conditions.

The loadings on $V_{j,t}$ give us our measure of vertical price integration. We later show that it is not possible to estimate $\beta_{i,j}$ and $\beta_{w,i,j}$ at the same time. When $\beta_{i,j}$ =1, a product of the two coefficients measures the response of WPI to a vertical shock in CPI and vice versa when $\beta_{w,i,j}$ =1. The product is therefore our measure of the degree of vertical integration. Similarly, the loading on $S_{j,t}$ are used to quantify cross-country spatial integration in the retail market in the same way βs give us vertical price integration at the domestic level.

Finally, the last set of terms. capturing the effect of idiosyncratic shocks, are essentially the residual fluctuations in prices which are not explained by other factors explicitly modelled here

(Common factors with fixed and variable impact, vertical shocks and cross-country spatial shocks in our case).

3. Measuring Market Integration

The factors on the right hand side of equations 1 to 3 are latent factors which are not observable. We therefore cannot estimate the model using standard regression analysis. We can however estimate the loadings with the help of moment conditions. Our objective is to calculate the contribution of each factor to price volatility. Given that the latent factors are independent of each other with zero mean and unit variance, it is straight forward to show that the variance, *var*(.), of each equation is equal to

$$\text{var}\left(wpi_{i,t}\right) = \theta^2 + \alpha_{0,P}^2 + \alpha_{i,p}^2 + \sum_j^n \beta_{w,ij}^2 + \omega_i^2 \qquad (4)$$

$$\text{var}\left(cpi_{ij,t}\right) = \theta^2 + \alpha_{0,P}^2 + \alpha_{ij,P}^2 + \beta_{ij}^2 + \gamma_{ij,j,P}^2 + \omega_{i,j}^2 \qquad (5)$$

$$\text{var}\left(cpi_{ij,t,IND}\right) = \theta^2 + \alpha_{0,IND}^2 + \alpha_{ij,IND}^2 + \gamma_{ij,IND}^2 + \omega_{ij,IND}^2 \qquad (6)$$

We can rewrite the above as follows,

$$1 = \frac{\theta^2}{\text{var}\left(wpi_{i,t}\right)} + \frac{\alpha_{0,P}^2}{\text{var}\left(wpi_{i,t}\right)} + \frac{\alpha_{i,p}^2}{\text{var}\left(wpi_{i,t}\right)} + \sum_j^n \frac{\beta_{w,ij}^2}{\text{var}\left(wpi_{i,t}\right)} + \frac{\omega_i^2}{\text{var}\left(wpi_{i,t}\right)} \qquad (7)$$

The first term on the right side of equation 7 quantifies uniform or fixed contribution of the world shock to total price volatility whereas the second term quantifies the contribution of common domestic factor with fixed effect. The third term quantifies the contribution of domestic common factors with variable impact on WPI of a commodity. The last factor quantifies the contribution of residual idiosyncratic factors to price volatility. The second last term quantifies volatility in WPI of group *i* to due to changes in CPI of commodity j in the same group, which measures the intensity of vertical price integration. i.e.

$$\text{Contribution of CPI shocks to WPI volatility} = 100\frac{\beta_{w,ij}^2}{\text{var}\left(wpi_{i,t}\right)} \qquad (8)$$

Similarly, using equations 5 and 6, we can show that

$$1 = \frac{\theta^2}{\text{var}\left(cpi_{ij,t}\right)} + \frac{\alpha_{0,P}^2}{\text{var}\left(cpi_{ij,t}\right)} + \frac{\alpha_{ij,P}^2}{\text{var}\left(cpi_{ij,t}\right)} + \frac{\beta_{ij}^2}{\text{var}\left(cpi_{ij,t}\right)} + \frac{\gamma_{ij,j,P}^2}{\text{var}\left(cpi_{ij,t}\right)} + \frac{\omega_{i,j}^2}{\text{var}\left(cpi_{ij,t}\right)} \qquad (9)$$

$$1=\frac{\theta^2}{\text{var}\left(cpi_{ij,t,IND}\right)}+\frac{\alpha_{0,IND}^2}{\text{var}\left(cpi_{ij,t,IND}\right)}+\frac{\alpha_{ij,IND}^2}{\text{var}\left(cpi_{ij,t,IND}\right)}+\frac{\gamma_{ij,IND}^2}{\text{var}\left(cpi_{ij,t,IND}\right)}+\frac{\omega_{ij,IND}^2}{\text{var}\left(cpi_{ij,t,IND}\right)} \quad (10)$$

The first three terms and the last term in both equations has the same interpretation as discussed in the context of equation 7. Furthermore,

$$\text{Contribution of WPI shocks to CPI Volatility} = 100\frac{\beta_{w,ij}^2}{\text{var}\left(cpi_{i,t}\right)} \quad (11)$$

$$\text{Contribution of CPI}_{\text{India}} \text{ shocks to CPI}_{\text{Pakistan}} \text{ Volatility} = 100\frac{\gamma_{ij,j,P}^2}{\text{var}\left(cpi_{i,t}\right)} \quad (12)$$

$$\text{Contribution of CPI}_{\text{Pakstan}} \text{ shocks to CPI}_{\text{India}} \text{ Volatility} = 100\frac{\gamma_{ij,IND}^2}{\text{var}\left(cpi_{i,t,IND}\right)} \quad (13)$$

Equations (8) and (11) are vertical measures of price integration whereas as (12) and (13) quantifies cross-country spatial market integration. While estimating our model, we standardized the data to convert it to the same units and reconcile differences in base years. This means the variance of each series is equal to one and each parameter is a direct estimate of the contribution of each factor to volatility in prices.

4. Estimation procedure

As mentioned earlier, the model parameters cannot be estimated using standard regression analysis. We can however use the variance and covariance moment conditions to estimate these parameters. The variance of each commodity is given by equations 1, 2 and 3. The covariance, for all *i*s and *j*s, are given below.

$$\left.\begin{aligned}
&\text{Covar}\left(wpi_{i,t}, wpi_{k,t}\right)=\theta^2+\alpha_{0,P}^2+\alpha_{i,P}\alpha_{k,P}\\
&\text{Covar}\left(wpi_{i,t}, cpi_{ij,t}\right)=\theta^2+\alpha_{0,P}^2+\alpha_{i,P}\alpha_{ij,P}+\beta_{w,ij}\beta_{ij}\\
&\text{Covar}\left(wpi_{i,t}, cpi_{ij,t,IND}\right)=\theta^2\\
&\text{Covar}\left(cpi_{ij,t}, cpi_{ik,t}\right)=\theta^2+\alpha_{0,P}^2+\alpha_{ij,P}\alpha_{ik,P}\\
&\text{Covar}\left(cpi_{ij,t}, cpi_{ij,t,IND}\right)=\theta^2+\gamma_{ij,P}\gamma_{ij,P,IND}\\
&\text{Covar}\left(cpi_{ij,t,IND}, cpi_{ik,t,IND}\right)=\theta^2+\alpha_{0,IND}^2+\alpha_{ij,IND}\alpha_{ik,IND}
\end{aligned}\right\} \quad (14)$$

Notice that the moment conditions listed in (14) are independent of the idiosyncratic parameters. Thus, we can use (14) to estimate all parameters except ωs which can be calculated as residuals from the variance equations. The exact number of parameters that we need to

estimate depends upon the number of commodities in the wholesale market, the number of commodities that underlie the WPI and the number of CPI goods from India included the model. The estimation requires that the number of moment conditions must be greater than or equal to the number of parameters that we need to estimate[5]. It is however not possible to estimate $\beta_{i,j}$ and $\beta_{w,i,j}$ separately at the same time. The is because these parameters appear only in one moment condition for each combination. The system of equations is therefore locally under-identified. We can however get an estimate of the product of the two parameters which appears in *Covar* $(wpi_{i,t}, cpi_{ij,t})$ for all *i* and *j*. The product can however be interpreted as the degree of vertical market integration which is more than enough for our purpose.

As $\beta_i\beta_{wi}|_{\beta_{wi}=1} = \beta_i$ the product can be interpreted as the response CPI to a 100% shock in WPI. This is equivalent to regressing CPI on WPI as a 100% shock means that all fluctuations in the commodity prices are due to change in the wholesale market. This however does not mean that the common and idiosyncratic factors do not exist and the market is operating in isolation. This simply means that the common and idiosyncratic shocks cancel each other out for this commodity. The market however still interacts with the rest of the commodities. Similarly, $\beta_i\beta_{wi}|_{\beta_i=1} = \beta_{wi}$ means that the product can also be interpreted as the response of the wholesale prices to a full-fledged shock in the retail market. The product, in general therefore give us an estimate of the degree of market integration.

Similarly, we can only get estimates of $\gamma_{ij,P}$ and $\gamma_{ij,IND}$ and the individual γs cannot be recovered from the estimation for the same reasons as above. Again, the product however gives us the degree of spatial market integration in the retail market across Pakistan and India which serves our purpose.

5. Estimation of the Model

In the model that is estimated here, we consider fluctuations in prices of the following retail and wholesale commodities comprising of 9 WPI and 14 CPI goods from the Pakistan agriculture market and 4 CPI goods from India. These commodities and groups are summarized in Table 1.

[5] In general, with *n* commodities in the model, we have *n(n-1)/2* covariance based moment conditions and we can estimate a maximum of *n(n-1)/2* parameters. However, the number of moment conditions increases faster than the number of parameters as we add more commodities.

We use the variance-covariance moments of our selected variables to estimate the model. The parameters reported in Table 1 can be estimated either using GMM, Indirect Least Squares or Non-linear Least Squares estimation techniques. We use Stata's nonlinear least squared function evaluator program. The program solves a system of nonlinear equations by minimizing nonlinear least squares. It is important to note that we add CPI_{Milk} in our estimation twice, which means that we have a total of 28 commodities which give us a total of 28*(28-1)/2=378 covariance moments to estimate a total of 50 parameters. This includes two $\alpha_{VM,IND}$ and two $g_{MM,P}$. An advantage of Stata's function evaluator procedure is that that perfect multi-collinearity does not create a problem. Proper convergence of the Stata iterations must return exactly the same value for the repeated parameters which is true in our case. This is an important accuracy check in our case as there are many moment conditions and parameters and it is hard to keep track of redundant relationships or detect cases of local under identification as pointed out earlier. In our case, for example, if instead of asking the moment evaluator program to estimate product of the market integration parameters, we ask Stata to give us individual values of the parameters; Stata will have convergence issues and the repeater parameters will never be the same, at least when we change the starting values.

Table 1: List of commodities and factor loadings in the estimated model.

			Type of shocks and associated parameters		
	Variables		Common	Vertical	Spatial
World	Common shocks with fixed effect		θ		
Pakistan	Domestic common shocks with fixed effect		$\alpha_{0,P}$		
	Vegetables (V)	WPI_V	$\alpha_{V,P}$	*	**
		CPI_{Tomato}	$\alpha_{VT,P}$	$\beta_{V,VT}$	$\gamma_{VT,P}$
		CPI_{Potato}	$\alpha_{VP,P}$	$\beta_{V,VP}$	$\gamma_{VP,P}$
		CPI_{Onion}	$\alpha_{VO,P}$	$\beta_{V,VO}$	$\gamma_{VO,P}$
		$CPI_{Fresh\ Vegetable}$	$\alpha_{V,FV,P}$	$\beta_{V,VFV}$	
	Fresh Fruits (F)	WPI_F	$\alpha_{F,P}$	*	
		CPI_F	$\alpha_{FF,P}$	$\beta_{F,FF}$	
	Dry Fruits (D)	WPI_D	$\alpha_{D,P}$	*	
		CPI_D	$\alpha_{DD,P}$	$\beta_{D,DD}$	
	Chicken (C)	WPI_C	$\alpha_{C,P}$	*	
		CPI_C	$\alpha_{CC,P}$	$\beta_{C,CC}$	
	Milk (M)	WPI_M	$\alpha_{M,P}$	*	**
		CPI_M	$\alpha_{MM,P}$	$\beta_{M,MM}$	$\gamma_{MM,P}$
	Eggs (E)	WPI_E	$\alpha_{E,P}$	*	
		CPI_E	$\alpha_{EE,P}$	$\beta_{E,EE}$	
	Wheat (W)	WPI_W	$\alpha_{W,P}$	*	
		CPI_W	$\alpha_{WW,P}$	$\beta_{W,WW}$	
	Rice (C)	WPI_{Rice}	$\alpha_{R,P}$	*	
		CPI_{Rice}	$\alpha_{RR,P}$	$\beta_{F,FF}$	
	Pulses (P)	WPI_P	$\alpha_{P,P}$	*	
		CPI_{Masoor}	$\alpha_{P,MA,P}$	$\beta_{P,PM}$	
		CPI_{Moong}	$\alpha_{P,MO,P}$	$\beta_{P,P,MO}$	
		CPI_{Gram}	$\alpha_{PG,P}$	$\beta_{P,PG}$	
India	Domestic common shocks with fixed effect		$\alpha_{0,IND}$		
	Indian retail market	CPI_{Tomato}	$\alpha_{VT,IND}$		
		CPI_{Potato}	$\alpha_{VP,IND}$		
		CPI_{Onion}	$\alpha_{VO,IND}$		
		CPI_{Milk}	$\alpha_{VM,IND}$		

* In our estimation we report the vertical integration against CPI commodities only for convenience as if WPI is causing changes in CPI. The opposite is however true as well as discussed in the text. ** Similarly, we report spatial integration parameters against Pakistani CPIs as if shocks in Indian CPI causes shocks in Pakistani CPIs. The opposite is also true.

6. Data, Results and Discussion

6.1. Data

The data for used in this research is compiled from the Pakistan Bureau of Statistics (PBS) monthly reports from December 2013 to October 2018. Both CPI and WPI data are collected on monthly basis. The CPI data used in this paper is collected by PBS on the 11-14th of each month and the WPI data is collected from the 12th to 15th of each month. The data on India's CPI is extracted from the Indian Department of Consumers Affairs.

6.2.Vertical integration

Table 2 reports results of our base case model reported in table 1. Table 3 translates estimated values of the coefficients in Table 2 to the contribution of each factor to total fluctuations in the price of each commodity. For example, θ=0.181 (significant at 1% level of significance), which captures the fixed effect of world common shocks on prices in Pakistan and India. Common world shocks are therefore responsible for 3.3% (=0.181^2) of fluctuations in all prices in Pakistan and India. Similarly, $\alpha_{0,IND}$=0.453, significant at 1%, implies that around 21% of the variations in all prices in India are caused by common factors with a uniform impact on all prices. Such factors however play no role in Pakistan. In a sense, these parameter captures arbitrage opportunities signifying easy access to alternative markets. It is not surprising to see that this is playing an important role in India and no role in Pakistan as our sample picks a somewhat homogeneous markets (vegetable retail market in particular) which might be served by players who may have the privilege of having trade opportunities in alternative commodities. The selected sample for Pakistan, on the other hand, includes a variety of commodities from both the wholesale and retail markets which reduces the probability of having common shocks as arbitrage opportunities are limited.

Results of the "trend" factors, common factors with variable impacts on each commodity, suggest that these factors tend to play an important role in the wholesale and retail market for wheat; somewhat important role in the market for fresh fruits; and a reasonable role in the market for eggs. There is evidence of some heterogeneity in the market for Milk as the wholesale market is unaffected by these factors whereas around 1/4rth of the fluctuations in the retail market prices of milk are caused by factors common to the agriculture sector of Pakistan. These factors seem to be important in India as well, however it is hard to tell if there is any heterogeneity in terms of the contribution of these factors to the prices of Milk in the retail market relative to the wholesale market as we do not include wholesale prices for India.

Table 2: Estimation results for the base case model.

Variables			Type of shocks		
			Common	**Vertical**	**Spatial**
World	World common shocks with fixed effect		0.181***		
Pakistan	Domestic common shocks with fixed effect		0.000		
	Vegetables (V)	WPI_V	-0.086		
		CPI_{Tomato}	-0.270***	0.543***	0.037
		CPI_{Potato}	0.024	0.326*	0.746***
		CPI_{Onion}	-0.321***	0.527***	0.205
		$CPI_{Fresh\ Vegetable}$	-0.039	0.848***	
	Fresh Fruits (F)	WPI_F	0.533***		
		CPI_F	0.619***	0.467**	
	Dry Fruits (D)	WPI_D	0.225**		
		CPI_D	0.170*	0.178	
	Chicken (C)	WPI_C	0.178*		
		CPI_C	0.312***	0.779***	
	Milk (M)	WPI_M	0.109		
		CPI_M	0.487***	0.397**	0.323
	Eggs (E)	WPI_E	-0.402***		
		CPI_E	-0.476***	0.760***	
	Wheat (W)	WPI_W	-0.762***		
		CPI_W	-0.782***	0.316	
	Rice	Rice	0.076		
		Rice	-0.088	0.810***	
	Pulses (P)	WPI_P	0.261**		
		CPI_{Masoor}	0.229**	0.661***	
		CPI_{Moong}	0.494***	0.265	
		CPI_{Gram}	-0.024	0.359***	
India	Domestic common shocks with fixed effect		0.453***		
	Indian retail market	CPI_{Tomato}	-0.019		
		CPI_{Potato}	-0.168***		
		CPI_{Onion}	-0.147		
		CPI_{Milk}	0.874		
Adjusted R-squared		47.1%			
RMSE		0.177			

Notes: (a) '***', '**' and '*' represent significance at 1%, 5% and 10% respectively

(b) In our estimation we report the vertical integration against CPI commodities only for convenience as if WPI is causing changes in CPI. The opposite is true as well.

(c) ** Similarly, we report spatial integration parameters against Pakistani CPIs as if shocks in Indian CPI causes shocks in Pakistani CPIs. The opposite is also true.

Table 3: Contribution of each type of shock to volatility and market integration.

Variables			Type of shocks		
			Common	**Vertical (b)**	**Spatial (c)**
World	World common shocks with fixed effect		3.3%***		
Pakistan	Domestic common shocks with fixed effect		0.0%		
	Vegetables (V)	WPI_V	0.7%		
		CPI_{Tomato}	7.3%***	29.5%***	0.1%
		CPI_{Potato}	0.1%	10.7%*	55.7%***
		CPI_{Onion}	10.3%***	27.7%***	4.2%
		$CPI_{Fresh\ Vegetable}$	0.2%	71.9%***	
	Fresh Fruits (F)	WPI_F	28.4%***		
		CPI_F	38.3%***	21.8%**	
	Dry Fruits (D)	WPI_D	5.0%**		
		CPI_D	2.9%*	3.2%	
	Chicken (C)	WPI_C	3.2%*		
		CPI_C	9.7%***	60.7%***	
	Milk (M)	WPI_M	1.2%		
		CPI_M	23.8%***	15.8%**	5.4%
	Eggs (E)	WPI_E	16.2%***		
		CPI_E	22.7%***	57.8%***	
	Wheat (W)	WPI_W	58.1%***		
		CPI_W	61.1%***	10.0%	
	Rice	Rice	0.6%		
		Rice	0.8%	65.6%***	
	Pulses (P)	WPI_P	6.8%**		
		CPI_{Masoor}	5.2%**	43.7%***	
		CPI_{Moong}	24.4%***	7.0%	
		CPI_{Gram}	0.1%	12.9%**	
India	Domestic common shocks with fixed effect		20.5%***		
	Indian retail market	CPI_{Tomato}	0.0%		
		CPI_{Potato}	2.8%***		
		CPI_{Onion}	2.2%		
		CPI_{Milk}	76.5%		

Notes: (a) '***', '**' and '*' represent significance at 1%, 5% and 10% respectively

(b) In our estimation we report the vertical integration against CPI commodities only for convenience as if WPI is causing changes in CPI. The opposite is true as well.

(c) ** Similarly, we report spatial integration parameters against Pakistani CPIs as if shocks in Indian CPI causes shocks in Pakistani CPIs. The opposite is also true.

Values reported under the vertical integration columns in Tables 2 and 3 suggest that the degree of vertical integration changes from commodity to commodity. *The market for fresh vegetables has the highest degree of vertical integration.* Nearly 72% of the fluctuations in the retail market prices are transmitted to the wholesale market and vice versa. This is followed by the market for Rice, Chicken, Eggs, Masoor dal (pulses), Tomato and Onion where around 66%, 61%, 58%, 44%, 30% and 28% of the variations is vertically transmitted from the wholesale (retail) market to the retail (wholesale) market respectively. The degree of vertical integration in other markets is either statistically or economically insignificant. Most of the fluctuations in these markets are therefore idiosyncratic in nature. Moreover, there is heterogeneity in the degree of market integration in the same category of goods, such as pulses where there is evidence of some degree of vertical integration in the market for Masoor, the market for Mong and Gram is not integrated. A similar trend can be observed in the vegetables market.

6.3.Temporal price transmission between the wholesale and retail markets

Time series analysis typically uses an error correction mechanism to quantify the speed of adjustments in prices over time towards its long run equilibrium. This in a sense looks at market integration across time. In essence the analysis measures the response of prices to temporal price changes in the past. We refer to this as temporal price transmission or temporal market integration. We can use our model to quantify the response of current price in the retail (wholesale) market to changes in the wholesale (retail) prices of the commodities *in the previous period*. We can do so by replacing changes in the current year's CPI with its lag values to see how WPI in the current period responds to change in the CPI in the previous period (month). Similarly, we replace current year's changes in WPI with its lag values to see how the relevant retail market responds to changes in the wholesale market prices in the previous period. These results are reported in Table 4 together with the base case results reported in Table 3 for comparison.

With the exception of the market for rice and Masoor, retail or wholesale prices in all other commodities do not respond to lagged price shocks. In the rice and pulses markets, the response of CPI to changes in past month's prices in the wholesale market tend to be relatively stronger than the response of WPI to changes in the lagged prices of CPI. Overall, the degree of temporal price integration in the rice market is at least twice as much as the pulses market.

Table 4: Degree of Vertical Market Integration over time.

WPI Variable	CPI Variable	Base case result	Temporal Market Integration: The response of	
			wpi_t to cpi_{t-1}	**cpi_t to wpi_{t-1}**
Vegetables (V)	Tomato	29.5%***	0.9%	0.9%
	Potato	10.7%*	3.1%	5.0%
	Onion	27.7%***	4.3%	2.0%
	Fresh vegetables	71.9%***	0.3%	2.1%
Fresh Fruits (F)	Fresh Fruit	21.8%**	1.7%	0.4%
Dry Fruits (D)	CPI_D	3.2%	2.5%	9.8%*
Chicken (C)	CPI_C	60.7%***	0.0%	0.1%
Milk (M)	CPI_M	15.8%**	3.9%	0.3%
Eggs (E)	CPI_E	57.8%***	0.0%	0.1%
Wheat (W)	CPI_W	10.0%	1.9%	0.0%
Rice	Rice	65.6%***	26.0%***	47.4%***
Pulses	CPI_{Masoor}	43.7%***	13.0%***	19.1%**
	CPI_{Moong}	7.0%	0.5%	1.0%
	CPI_{Gram}	12.9%**	3.2%	15.8%**

6.3.1. Temporal spatial price transmission between Pakistan and India

Table 5 reports the contribution of fluctuations in current market prices in one country to price shocks in the previous month for tomato, potato, onion and milk. The potato market stands out again. The response of potato prices in India to a one period lagged price shocks in Pakistan triggers 3 times more fluctuations in India than the retail market potato prices in Pakistan in response to lagged shocks in the potato prices in India. Interestingly, whereas there is no evidence of instantaneous market integration in the case of onion and milk, around $1/5^{th}$ of the variations in Pakistani onion prices are due to lagged price shocks in the Indian market and around $1/10^{th}$ of the variation in Milk prices in India are triggered by price shocks in Pakistan. The tomato market seems to be operating independent of each other on average.

Table 5: Temporal price transmission between Pakistani and Indian retail markets.

Spatial markets	Base Case	The response of	
		$cpi_{t,Pak}$ to $cpi_{t-1,India}$	**$cpi_{t,Ind}$ to $cpi_{t-1,Pak}$**
Tomato	0.1%	5.2%	0.0%
Potato	55.7%***	12.5%**	37.1%***
Onion	4.2%	28.1%***	0.0%
Milk	5.4%	5.7%	8.9%*

6.3.2. Asymmetry in vertical price transmission

Another aspect of price transmission that is of interest to researchers and practitioners is to assess if the response of positive changes is prices in a market is any different from negative changes in prices. We refer to this as positive and negative shocks. Table 6 reports the response of vertical horticulture markets to positive and negative shocks in prices. Our results indicate evidence of asymmetry in price transmission between the wholesale and retail markets of onion and Fresh fruits. The transmission of positive changes in prices in the fresh fruits markets is much stronger than negative shocks. Around two third of the positive price shocks in the market for fresh fruits in one market are vertically transmitted to the other as opposed to around a fifth of the negative shocks. There is also some evidence of asymmetry in vertical transmission of price shocks in the onion market where only positive shocks are transmitted.

Table 6. Asymmetry in vertical price transmission

	Base case	Positive shocks	Negative shocks
Tomato	29.5%***	16%*	15%*
Potato	10.7%*	02%	6.4%
Onion	22.7%***	15.2%*	11.4%
Fresh Fruits	71.9%***	67.8%***	19.4%**

Table 7. Asymmetry in spatial price transmission between Pakistan and India.

	Base case	**Positive shocks**	**Negative shocks**
Tomato	0.1%	14.8%*	1.3%
Potato	55.7%***	10.7%	53%***
Onion	4.2%	9.3%	27.1%**

6.4.Spatial market integration and asymmetry in price transmission between India and Pakistan

The last column of Tables 3 provides estimates of the degree of spatial integration between the Pakistani and Indian retail markets for tomato, potato, onions and milk. These results are also reported in Table 7. Table 7 also reports the response of one country's retail prices for tomato, potato and onion to positive and negative shocks of another country. The only retail market that seems to be spatially integrated across Pakistan and India is the potato market. Around 56% of the fluctuations in the retail prices of potato in one country are transmitted to the other

country. The asymmetry analysis however suggests that only negative shocks are transmitted as almost all the transmitted shocks are triggered by negative price shocks. Moreover, the base case results also show that the tomato and onion markets are not integrated. However, around 15% of the positive shocks in tomato and 27% negative shocks in onion are transmitted from India to Pakistan and vice versa. These results reveal that there is asymmetry is the transmission of shocks as well as the type of asymmetry (whether positive or negative shocks are transmitted). Thus, the periodic opening of trade between the two countries in some commodities does create some price linkages between the two countries' markets in the case of tomatoes and onions, though markets are not well integrated. These linkages should be explored further as they have bearings on debates about the factors causing volatility in prices and management of trade between the two countries.

Table 8: Summary of the results.

Market	**Dominant Source of volatility**	**Vertical price transmission**	**Temporal transmission of shocks**	Asymmetry in vertical integration	**Spatial price transmission**	Asymmetry in spatial price transmission
Tomato	Idiosyncratic	Reasonable	No	No	No	Yes (Low)
Potato	Spatial	Low	No	No	Dominant	Yes (High)
Onion	Idiosyncratic	Reasonable	No	Yes (low)	No	Yes (high)
Fresh Fruits	Vertical	Dominant	No	Yes (High)	No	
Dry Fruits	Idiosyncratic	No	No			
Chicken	Vertical	Dominant	No			
Milk	Idiosyncratic	Low	No			
Eggs	Vertical	Dominant	No			
Wheat	Common	No	No			
Rice	Vertical	Dominant	Yes (High)			
Masoor	Idiosyncratic and vertical	Medium	Yes (Low)			
Moong	Idiosyncratic	No	No			
Gram	Idiosyncratic	Low	Yes (low, partial)			

7. Summary and conclusions

This paper uses a novel approach to model interaction between vertical and spatial prices of agriculture commodities in Pakistan as an alternative to the standard time series analysis. We model price transmission a contagious shock which spreads from one market to another while controlling for factors which may cause co-movement in prices using latent factors. We control for common factors which might have a uniform impact on all prices as well as for common factors which might have a variable impact on different prices. In time-series analysis jargon,

this is equivalent to having a non-stationary series with a constant a constant and a trend. The "trend" in our model is richer in the sense that we assume the trend to be a latent shock rather than a time-variable which admits a complex set of movements which may cause changes in the vertical and spatial prices. Moreover, unlike time-series analysis, our model relies on interaction of agriculture commodities in the entire market space. We exploit the variance and covariance of a variety of products in the retail and wholesale market to assess if (i) there are any common world or domestic shocks which might affect all prices at the same time; (ii) price shocks in one market are vertically transmitted to another (retail to wholesale and wholesale to retail); and (iii) price shocks in one country are transmitted to another (Pakistan to India and India to Pakistan).

Our base case analysis quantifies the degree of vertical and spatial market integration for a variety of agriculture commodities in Pakistan. We further analyse the response of retail and wholesale markets to vertical shocks and the response of spatial shocks in the retail market. Moreover, we also separate the degree of market integration during positive shocks from the degree of market integration during negative shocks, both vertically and spatially.

There is a great deal of heterogeneity in the degree of vertical and spatial market integration and the dominant source of price volatility. The following summarises some of the main results. Please see table 8 for a detailed summary of the results.

i. Vertical shocks play a dominant role in the market for fresh fruits, chicken, eggs and rice. At least 58% of the price shocks are transmitted from the retail market to the wholesale market and vice versa.
ii. Spatial price transmissions play a dominant role in the retail market for potato between India and Pakistan. Around 56% of the variation in one country's retail prices in the market are transmitted to the other country.
iii. Common factors, factors which cause fluctuation in the overall market, play a dominant role in the market for wheat explaining around 60% of the fluctuations in the wholesale and retail prices.
iv. Idiosyncratic factors, factors specific to the retail or wholesale market of individual commodities, are important in the market for tomato, onion, dry fruits, milk and pulses.
v. With the exception of rice and pulses, vertical shocks in previous periods do not trigger any vertical variations in prices.
vi. There is a high (low) degree of asymmetry in the transmission of positive vis-à-vis negative vertical shock in the market for potato (onion). There is no

different in the degree of vertical price transmission in response to a positive vis-à-vis negative shock in case of tomato and potato as fluctuations in the price of these crops are caused by idiosyncratic or spatial changes respectively.

vii. There retail markets in India and Pakistan respond to a negative spatial shock differently than a positive spatial shocks for the three commodities we investigated (tomato, potato and onion).

A message from these preliminary results is that there is a great deal of heterogeneity in terms of what triggers the fluctuations in prices of a commodity, indicating that no single 'broad brush' policy can improve price transmission. Efforts should be directed to a better understanding of each market, at the wholesale and retail level, to identify sources of inefficiency.

We emphasise that results reported here are preliminary results only and must be treated with caution. We investigate these issues in more depth and detail in ongoing research to cover not only the potato markets, but also more disaggregated analysis to explore individual markets of chillies and mangoes.

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