Dynamic Impacts of Export Controls on Price Transmission

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Introduction

The law of one price (LOP) is one of the fundamental concepts in trade theory. It states that homogeneous goods sold in different regions will sell at the same price when expressed in the same currency. The LOP has been considered as an important indicator of the efficiency of markets, as it indicates whether and to what extent markets are linked across space.

A rich empirical literature has investigated the LOP among spatially separated markets. Early studies used correlation coefficients and regression techniques to directly test the equality of prices in different regions (e.g., Isard 1977, Richardson 1978, Protopapadakis and Stoll 1986). Modern studies have noticed the nonstationary attribute of the price data and have proposed a different framework for testing the LOP. In particular, Engle and Granger (1987) point out that, given a pair of first-order integrated time series, if there is a combination between them which is stationary, the two processes are said to have a long-run equilibrium or are cointegrated. Their approach has provided researchers with valuable tools for jointly modeling and conducting inferences on the long-run price relationships, together with the short-run adjustments towards the equilibrium. Some economists (e.g., Goodwin and Piggott 2001) suggest that given cointegration, the short-run adjustments to the equilibrium may not be linear because of the transaction costs associated with arbitrage. Deviations from long-run equilibrium within the transaction cost band will not trigger any adjustment simply because it is not profitable to arbitrage; but deviations that fall outside of the band would trigger trade activities and thus should be mean reverting. Following this idea, an extensive literature has investigated spatial price transmission by taking the role of nonlinear adjustments into consideration and by using various versions of regime-switching vector error correction (VEC) models (i.e., threshold VEC, smooth transition VEC, and Markov-switching VEC). Supporting evidence for the LOP, utilizing these techniques, has been reported by Lo and Zivot (2001), Sephton (2003), Balcombe, Bailey, and Brooks (2007), Park, Mjelde, and Bessler (2007), and Goodwin, Holt, and Prestemon (2011).

An assumption underlying the above transaction-cost version of the LOP, and accordingly the utilization of various types of error correction models, is that trade is free and open (no official barriers, such as tariffs, quotas, or regional arbitrage interventions). However, contrary to the open trade hypothesis, restrictions on trade often exist in reality. Policy interventions may not only affect the short-run dynamic adjustments, but also alter or even eliminate any long-run market integration under certain conditions.

As measuring transaction costs, direct quantification of policy interventions is difficult. In reality, policy intervention often reflects a specific event-triggered reaction rather than constant behavior. Furthermore, although these modern empirical tools (such as the regime-switching autoregression technique) have provided some convenience in modeling price linkages, they are not flexible enough to represent constantly changing government interventions, especially short-run regulations under unusual market or political conditions. For example, a three-regime threshold or smooth transition error correction model allows price adjustment to have three different reactions based on the magnitude and/or direction of previous deviation from the long-run price equilibrium. However, the adjustment speeds are still assumed to be linear and constant within each regime. In reality, even given the similar levels of deviation, the adjustments can still differ based on other conditions such as volatility and market power. Another important feature in market integration is price transmission under extreme market conditions. For instance, we are interested in investigating the probability that one will observe an extremely large adjustment of domestic price given an extremely large decrease of world price (such as the food price crisis in 2007/08). In statistics, we call this “tail dependence.” The commonly used regime-switching models require the threshold to lie between the maximum and minimum values of the series. A congenital practice is between 15th and 85th quintiles of the observations. That said, the highest and lowest 15% of the values are excluded from the search so as to ensure an adequate number of observations on each side of the threshold/regime. Therefore, these regime-switching models cannot provide such close information as tail dependence.

These limitations motivate the search for more flexible alternative measures of relationship. A modeling technique, which allows for a more flexible dependence structure (such as nonlinear, time-varying, multi-variable driven, and handles tail dependence) to exist, will be helpful in better understanding price transmission and market integration issues under non-constant government interventions. Copula models separate marginals and dependence structures and allow more flexibility in modeling the dependence/relationship structures of price co-movements. The copula approach thus serves as a promising candidate.

The objective of this paper is to provide an investigation of the effects of non-constant policy interventions on spatial price transmission. Our empirical application is to the Ukrainian wheat market. We investigate the wheat price linkages between the Ukrainian domestic and world markets. Ukraine is a good case study, as it is a typical transition economy with active government intervention in its markets. Meanwhile, it is also one of the world's top grain exporters. Appropriate investigations between its domestic and world market integration will provide valuable information for future policy recommendations regarding food security, market efficiency, and trade liberalization.

Copula Approach

What is a copula? Copula means join, couple, tie, and bond. A copula is a multivariate distribution whose marginals are all uniform over (0, 1). Given the fact that any continuous random variable can be transformed to be uniform over (0, 1) by its probability integral transformation, , copulas can be used to provide multivariate dependence structure separately from the marginal distributions. For example, a two-dimensional joint distribution can be decomposed into two marginal distributions and a two-dimensional copula:

$$\text{Let } Y \equiv [Y_1, Y_2]' \sim F(y_1, y_2), \text{ with } \mathrm{Y}_1 \sim F_1 \text{ and } \mathrm{Y}_2 \sim F_2$$

$$\text{then } \exists \text{ C: } [0,1]^2 \to [0,1]$$

$$\text{s.t. } F(y_1, y_2) = C(F_1(y_1), F_2(y_2)) \ \forall (y_1, y_2) \in R^2$$

Patton (2006; 2012) extended the concept of standard copulas to conditional copulas:

$$\text{Let } Y \equiv [Y_1, Y_2 \mid M_{t-1}]' \sim F(y_1, y_2), \text{ with } \mathrm{Y}_1 \mid M_{t-1} \sim F_1 \text{ and } \mathrm{Y}_2 \mid M_{t-1} \sim F_2$$

$$\text{then } \exists \text{ C: } [0,1]^2 \to [0,1]$$

$$\text{s.t. } F(y_1, y_2 \mid M_{t-1}) = C(F_1(y_1 \mid M_{t-1}), F_2(y_2 \mid M_{t-1})) \ \forall (y_1, y_2) \in R^2$$

where M_{t-1} is the information set.

A copula function contains all the information about the dependence between random variables. In the price transmission case, if we know the specific copula of the two price adjustments, then we shall be able to obtain all the relevant information regarding the co-movements and transmission between the two prices. However, numerous different copulas exist and each is associated with different dependence attributes (e.g., asymmetry or symmetry, tail dependence or no tail dependence, both upper and lower tail dependence or just one side tail dependence).

For example, the Normal copula allows a symmetric dependence structure and does not allow the tail dependence; the Student's t copula allows for joint extreme events in both tails. Assume a positive shock occurs in one market, and that prices are more likely to be co-adjusted when an extremely big price change has been observed, but price shocks would not be transmitted to one another when the changes are very small. Then the Gumbel copula, which is an asymmetric copula, exhibiting greater dependence in the upper tail than in the lower, might be an appropriate choice. The Clayton copula is also an asymmetric copula, but it exhibits greater dependence in the lower tail than in the upper. For more detailed discussions regarding the dependence attributes associated with different copulas, we recommend readers to Joe (1997) and Nelsen (2006), among many others.

The empirical procedure for the copula application in the price transmission analysis can be divided into 4 steps. First, test cointegration of the two (or more) prices and see if there exist long-run relationships. Second, model the conditional marginal distribution functions for the two price adjustments. If there is a long-run equilibrium exist from the test results of step one, then include the error correction term into the marginal distribution modeling. Third, compare and select the appropriate copula(s) using certain selection criteria. Fourth, interpret the copula results and apply them to the analysis of APT.

Data

We use weekly observations for the world market price and Ukrainian domestic wheat and wheat flour market prices from January 2000 to February 2013 (see Figure 1). Ukrainian wheat price data are obtained from APK-Inform. Due to a change of the State Standard in the 2010 (class three before 2010 is equivalent to class one since 2010), we use the price of wheat of class three for the period from July 2009 to February 2013, and price for wheat of class one to represent domestic wheat price for Ukraine. We use the FOB price of wheat in Rouen, France as the relevant world market price for Ukraine.

Results

All analyses are conducted based on the data series in logarithms. To better investigate the impact of export controls on market integration, we also divide the data into two parts: pre-intervention period (2000-2005) and within-intervention period (2006-2013), and examine the price transmission and co-movement separately.

We begin by assessing the time series properties of price series using the standard Augmented Dickey-Fuller (ADF) test. The unit root tests fail to reject the unit root hypothesis for the price series, but are not able to reject stationarity for the price change series. Thus, the price change series may be considered as stationary processes. Summary statistics of three price change series are presented in Table 1.

Long-Run Relationship

Long-run price equilibrium relationship investigation results using trace tests are summarized in Table 2.

Short-Run Adjustment

Short-run adjustment estimate results are presented in Table 3.

Dependence Structure between Domestic and World Price Linkage

The estimate results from five constant and two time-varying copulas are listed in Table 4.

Conclusion

The extent and magnitude of policy intervention, when allowing specific event-triggered, time-varying, and tail-dependent attributes, on price transmission offer valuable information for understanding the price linkages and market integration. More generally, time-varying and non-constant price transmission can result from other factors, such as exchange rate pass-through and/or transportation costs. It is thus a useful extension and generalization of existing approaches for modeling price transmission that has appeared in the literature. However, the development of dynamic conditional copula techniques, especially the high-dimensional cases, and their application to price transmission are both in their infancy and call for farther research, and shall draw a lot of attention for the meeting session discussion.

Table 1. Unit Root Test

Dickey-Fuller Unit Root Tests					
Variable	**Type**	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**
World Price	Zero Mean	0.16	0.7217	0.76	0.8772
	Single Mean	-4.37	0.4990	-1.50	0.5317
	Trend	-9.88	0.4434	-2.21	0.4806
Ukraine Price	Zero Mean	0.20	0.7295	0.99	0.9157
	Single Mean	-3.85	0.5562	-1.36	0.6011
	Trend	-8.86	0.5170	-2.09	0.5486
Diff(WorldPrice)	Zero Mean	-589.00	0.0001	-17.12	<.0001
Diff (UkrPrice)	Zero Mean	-393.48	0.0001	-14.05	<.0001

Table 2. Cointegration Test

H0: Rank=r	H1: Rank>r	Eigenvalue	Trace	5% Critical Value	Drift in ECM	Drift in Process
Full Sample (n=670)						
0	**0**	0.0245	18.2719	15.34	Constant	Linear
1	**1**	0.0025	1.6947	3.84		
Long-Run Parameter Beta			0.89			
Short-Run Parameter Alpha			-0.025 (Ukraine)		0.012(World)	
2006-2013 (n=372)						
0	**0**	0.0755	34.7587	19.99	Constant	Constant
1	**1**	0.0156	5.7851	9.13		
Long-Run Parameter Beta			0.79			
Short-Run Parameter Alpha			-0.067 (Ukraine)		0.005(World)	
2000-2005 (n=298)						
0	**0**	0.0207	8.1176	15.34	Constant	Linear
1	**1**	0.0065	1.9332	3.84		
0	**0**	0.0208	8.3898	19.99	Constant	Constant
1	**1**	0.0074	2.1995	9.13		

Table 3. Model Parameter Estimates

Equation	Variable	Estimate Parameter	Standard Error	t Value	Pr > |t|
		2000-2013 (n=670)			
Diff(UkrPrice)	**CONST**	0.01152	0.00303	3.81	0.0002
	WorldPrice(t-1)	0.02210	0.00583		
	UkrPrice(t-1)	-0.02479	0.00654		
	D_UkrPrice(t-1)	0.16284	0.03747	4.35	0.0001
	D_ WorldPrice(t-2)	0.08604	0.02972	2.89	0.0039
	D_ UkrPrice(t-2)	0.16730	0.03751	4.46	0.0001
Diff(WorldPrice)	WorldPrice(t-1)	-0.01143	0.00766		
	UkrPrice(t-1)	0.01282	0.00860		
	D_ WorldPrice(t-1)	0.09510	0.03901	2.44	0.0150
		2006-2013 (n=372)			
Diff(UkrPrice)	**CONST**	0.06208	0.01137	5.46	0.0001
	WorldPrice(t-1)	0.05314	0.00978		
	UkrPrice(t-1)	-0.06665	0.01227		
	D_UkrPrice(t-1)	0.39440	0.04886	8.07	0.0001
	D_ WorldPrice(t-2)	0.09062	0.03187	2.84	0.0047
Diff(WorldPrice)	WorldPrice(t-1)	-0.00463	0.01685		
	UkrPrice(t-1)	0.00581	0.02113		
	D_ WorldPrice(t-1)	0.15425	0.05428	2.84	0.0047
		2000-2005 (n=298)			
Diff(UkrPrice)	D_ UkrPrice(t-2)	0.15075	0.05767	2.61	0.0094
Diff(WorldPrice)	D_ WorldPrice(t-1)	0.11561	0.05855	1.97	0.0493

Table 4. Estimates of Copula Models

Full Sample			2000-2005			2006-2013		
Copula	LL	AIC	Copula	LL	AIC	Copula	LL	AIC
TV_Normal	-2.6942	-5.379	TV_Normal	-3.9627	-7.9062	TV_Normal	-7.7195	-15.4224
Normal	-2.0836	-4.1608	Frank	-1.1361	-2.2658	Normal	-2.885	-5.7644
Frank	-1.7786	-3.5541	Plackett	-1.1337	-2.2611	Gumbel	-2.5867	-5.1623
Plackett	-1.765	-3.527	Normal	-0.8014	-1.5965	Plackett	-0.9763	-1.9471
Student t	-1.3981	-2.7931	Student t	-0.8096	-1.6063	Student t	-0.9334	-1.8613
Clayton	-0.6228	-1.2425	Clayton	-0.6703	-1.3343	Frank	-0.9081	-1.8106
Gumbel	-0.1121	-0.2211	Gumbel	1.121	2.2483	Clayton	-0.4719	-0.9383

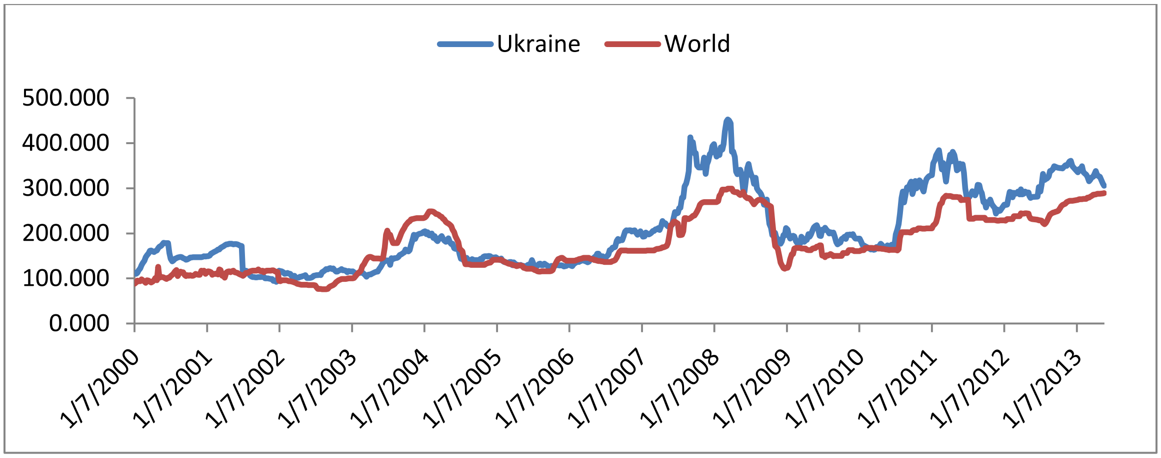

Figure 1. Wheat Prices of Ukraine and Rouen: 2000-2013

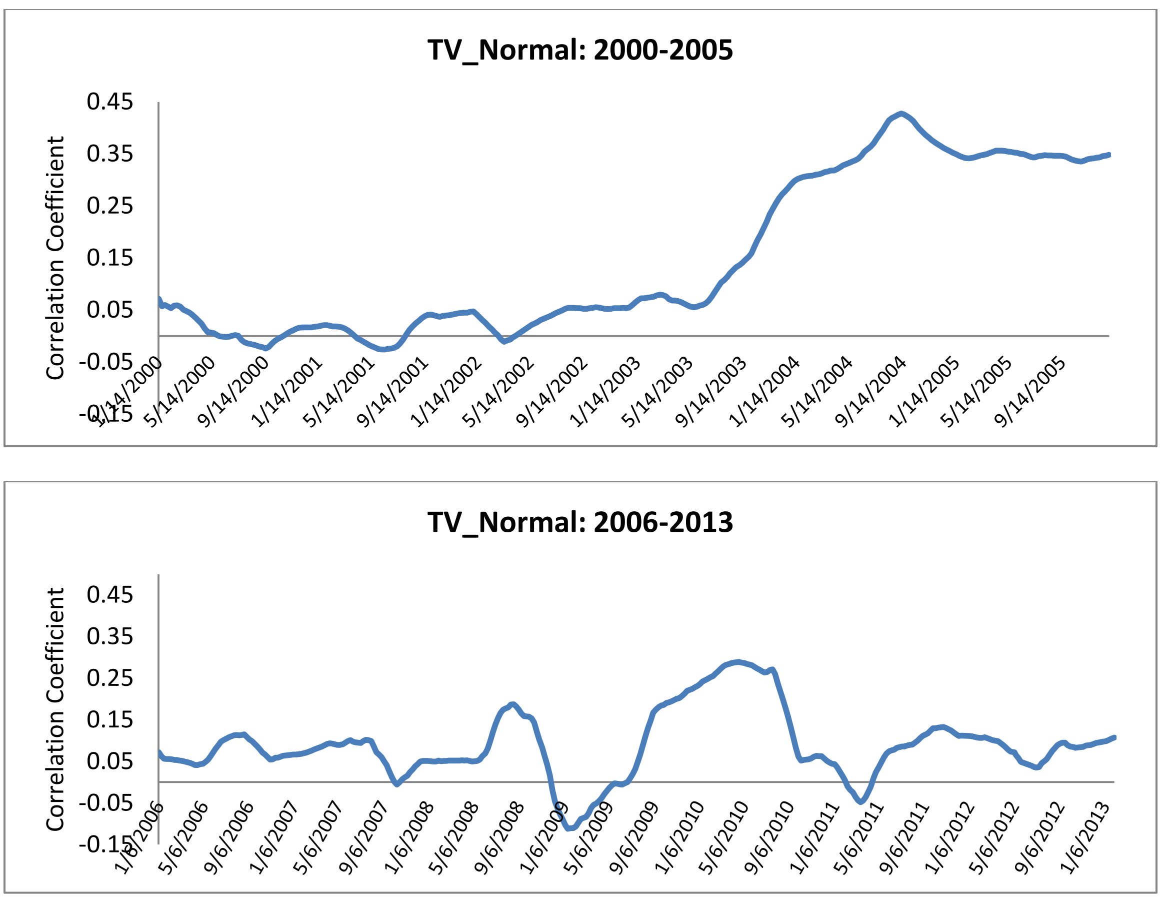

Figure 2. Estimates of Correlation Coefficients from Time-Varying Normal Copula