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Price and Volatility Transmission in International Wheat Futures Markets

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This study examines futures price and volatility transmissions among three major wheat production and exporting regions, the United States (US), Canada and the European Union (EU) over the recent six-year study period of 1996 - 2002. The price transmission pattern shows that Canadian prices are much more influenced by the US prices than the US prices are influenced by Canadian prices. The EU is highly self-dependent and may exert some influence on the US prices in the long run but not vice versa. The volatility transmission pattern, however, shows that volatility is transmitted from Canada and the EU to the US but not vice versa. The volatility is also transmitted from the EU to Canada but not vice versa. Overall, there is no distinctive leadership role in international wheat markets, with all three markets exhibiting features of price leadership to some extent.

Key Words: Price and volatility transmission; Generalized forecast error variance decomposition; Generalized impulse response analysis; Multivariate GARCH.

JEL Classification Numbers: C32, L13.

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1. INTRODUCTION

Imperfect competition and price discrimination in the international wheat market have received considerable attention, because the international wheat market is dominated by only a few major production and exporting regions, including the United States (US), Canada (CA), and the European Union (EU). The concern of imperfect competition and price discrimination has been reinforced because state trading is more the rule than the exception in international grain trade. In particular, the Canadian Wheat Board (CWB) is the largest state trading enterprise in the world. It has caused much concern that the CWB single-desk selling authority (a monopoly position) for wheat exports may significantly distort trade by exercising price discrimination (Mohanty et al., 1999). This concern has intensified since the 1990s when trade agreements promoting free international grain trade began to work[1]. The US General Accounting Office released at least three major reports in 1995, 1996, and 1998, which are directly related to imperfect competition in the international wheat market possibly caused by state trading enterprises such as the CWB. The US International Trade Commission also conducted several investigations in 1990, 1994, and 2001 on the ability of price discrimination by the CWB in international grain trade.

Many studies have explored dynamic/causal price relationships in the international wheat market to investigate possible discriminating price behavior. Using internal wheat market prices, Spriggs et al.(1982) and Gilmour and Fawcett (1987) did not find any significant price leadership role between the US and Canada. Using wheat export prices, Goodwin and Schroeder (1991) and Mohanty et al. (1995) provided evidence that the US tends to have a strong influence on the wheat prices of other major exporters but the reverse is not true. In particular, they also found that the US price has a significant effect on the Canadian price while the Canadian price does not affect the US price. These studies, however, generally fail to make appropriate allowance for the nonstationarity property of commodity prices. More recently, researchers have employed cointegration and error correction models (ECM) extensively to examine international wheat price relationships to address the issue of nonstationary commodity prices. Allowing for possible cointegration relationships is especially important because cointegration itself has important implications for causality (Engle and Granger, 1987). Both Mohanty et al. (1996) and Bessler et al. (2003) documented that the US wheat price is influenced by the Canadian price,

[1] It is interesting to note that little Canadian wheat was exported to the US until the beginning of the US-Canadian Free Trade Agreement in the late 1980s (USITC, 2001, p. 2-20). Also, as pointed out in Schmitz and Gray (2000, p.596), the marketing practices of the state trading enterprises such as the CWB have become under much closer scrutiny after the completion of the Uruguay Round trade negotiation in 1995.

while the reverse may not hold. By contrast, Mohanty et al. (1999) concluded that there is no distinctive price leadership among the five major wheat exporters[2]. Obviously, the empirical results are mixed and require further analysis.

This paper studies the wheat futures price and volatility transmission among markets in the United States, Canada, and the European Union. The paper extends previous studies in several aspects. First, commodity futures prices rather than cash/export prices are used to explore dynamic price relationships. Most previous studies use cash/export price data. However, as pointed out in Protopapadakis and Stoll (1983), an international commodity price relationship may be investigated in "its purest form" when commodity futures prices are used. Yang et al. (2001) also pointed out that futures prices may play a better informational role than cash prices in aggregating market information, particularly for the commodities traded largely in the international markets (e.g., wheat). Yang and Leatham (1999) documented the important difference between wheat cash and futures prices in processing and transmitting price information. Thus, this study can be expected to offer additional insight on international wheat price relationships using futures prices.

Second, this study covers a recent sample period from 1996 to 2002, which coincides with a more market-oriented period in international wheat production and trade. The sample periods covered by most previous studies end by the early 1990s. However, the changing global trade environment and domestic government policies make it meaningful to study a more recent period. As reviewed below, significant progress has been made since the mid-1990s toward market-oriented agricultural policy in all three countries under study.

Third, relatively new econometric techniques, generalized forecast error variance decomposition and generalized impulse response analysis (Koop et al., 1996; Pesaran and Shin, 1998) are employed in this study to better explore price interrelationships. This is motivated by the existence of strong contemporaneous correlations among international wheat market innovations as documented in Goodwin and Schroeder (1991). In the case of strong contemporaneous correlations, it is well known that traditional orthogonalized impulse response analysis or forecast error variance decomposition, based on the widely used Choleski decomposition, is sensitive to the ordering of the variables. By contrast, generalized forecast error vari-

[2]Some related studies explore existence of cointegration but not causal relationships in international wheat markets. For example, Booth, Brockman and Tse (1998) find a long-run relationship between the Canadian and the US wheat futures prices. Zanias (1993, 1999) report mixed evidence of cointegration among several European Union countries. This study also extends these studies in that it investigates both cointegration and causal relationships in international wheat markets.

ance decomposition or generalized impulse response analysis is invariant to the ordering of the variables.

Finally, extending the work of previous studies, volatility spillover in international wheat markets is examined for the first time in this study by applying multivariate GARCH modeling. The pattern of volatility spillover may provide additional insight into the dynamic price relationship in international wheat markets. The remainder of this paper is organized as follows. Section two briefly discusses the recent policy changes affecting international wheat markets, section three describes the data, section four presents empirical analysis of the data, and section five presents summary and conclusions.

2. RECENT POLICY CHANGES AFFECTING INTERNATIONAL WHEAT MARKETS

The wheat sectors in major wheat production countries historically have been subject to many regulations and policies. The interplay of these regulations and policies, together with economic considerations, affects the international wheat price relationships in a complex way. In this section, we discuss briefly recent market-oriented policy changes in each of the three major wheat production countries.

The US farm programs are probably the most important policy factor influencing the US wheat sector. The US farm program policy was characterized by the basic price support and production control system for non-perishable agricultural commodities. A key component of the system, production inflexibility, affected the US crop production in such a way that only acreage planted with specific farm program crops qualified to receive government deficiency payments. This system remained essentially unchanged for more than 50 years. The Food, Agriculture, Conservation and Trade (FACT) Act of November 1990 made significant progress in eliminating production control, which introduced 25% production flexibility to farmers' crop production. The 1996 Federal Agricultural Improvement and Reform (FAIR) Act forced US agricultural production to be more driven fully by market forces by bringing almost full flexibility to grain production and by replacing the deficiency payments provision with a series of seven-year annual fixed but declining "transition" payments over the period 1996-2002. Another relevant component of the US farm programs is the Export Enhancement Program (EEP), which was first introduced in 1985 to counter competition from EU-subsidized wheat in international markets. However, the EEP expenditures were capped by the 1996 FAIR Act and its importance declined because US commitments under the Uruguay Round Agreement in 1995 limited future use of Export Enhancement Program subsidies for wheat exports (Hasha, 1999).

The Canadian internal rail-freight subsidy and the Canadian Wheat Board (CWB) are the two most important factors shaping Canada's wheat sector. The Canadian rail-freight subsidy, under the Canadian Western Grain Transportation Act, provided transport subsidies for Canadian grain delivered to western and eastern Canadian ports, which was considered by many US policymakers as an "unfair" practice that resulted in increased imports of Canadian grain by the US This subsidy was in existence for several decades before being eliminated in August 1995. Its elimination fostered a substantially more liberalized trade environment between the US and Canada (Hasha, 1999). The CWB continues to influence Canadian wheat marketing and exports. The CWB is the single-desk seller of western Canadian wheat and barley for export destinations. The current CWB was created by the Canadian Wheat Board Act in 1935 as a result of low wheat prices and large stockpiles of grains during the Great Depression. The CWB operates as a marketing agency for producers and has adopted as its objective the maximization of returns from sales of wheat and barley. Single-desk selling is probably the CWB's greatest asset since it arguably may give the CWB monopoly power to create pricing differentials (often referred to as pricing to market). In fact, a major perceived benefit of the CWB for Canadian wheat producers is the additional producer revenue generated by the ability of the CWB to carry out price discrimination in international markets, which has triggered several recent investigations by the US International Trade Commission in 1990, 1994, and 2001.

The EU has been aiming at establishing an integrated agricultural market within EU, which is reflected in the Common Agricultural Policy (CAP). The backbone of CAP has been a common price policy. Prior to the 1992 CAP reform, the EU annually adopted a package of support/intervention prices along with other policies. Such a price package played a crucial role in its agricultural policy. The EU wheat sector was strongly influenced by support prices. In the past, the EU often relied on export subsidies to dispose of its grain production surpluses. Since 1992, the EU started its substantially market-oriented CAP reform. The reform includes substantial reductions in support prices, including the use of export subsidies. Under the Uruguay Round GATT agreements concluded in 1994, the EU (together with the US) agreed to dramatically reduce the use of export subsidies. The CAP reform caused the most significant change in the grains sector. Such reform aims to promote internal use of grains within the EU and to curb agricultural surpluses.

3. DATA

Three representative international wheat producers are considered in this study: the US, Canada, and the EU. These three producers are the most

TABLE 1.

Test for Stationarity of Price Series

Unit Root Tests[1]	Markets		
	US	EU	Canada
	Without Linear Trend		
ADF	-4.16^{*2}	-3.28^{*}	-4.52^{*}
PP	-11.86	-7.46	-10.01
	With Linear Trend		
ADF	-3.71^{*}	-3.93^{*}	-4.39^{*}
PP	-17.11	-17.86	-15.10

[1] The critical values of the Augmented Dickey-Fuller (ADF) unit root tests without trends are $-3.43, -2.86$ and -2.57, respectively at 1%,5%, and 10% level. The critical values of the ADF with trend are $-3.96, -3.41$ and -3.13 respectively at 1%, 5%, and 10% level. The critical values of the Philips-Peron (PP) unit root tests without trend are $-20.6, -14.1$ and -11.2 at 1%, 5%, and 10% level, respectively. The critical values of the PP unit root tests with trend are $-29.4, -21.7$ and -18.2 at 1%, 5%, and 10 % level, respectively.

[2] * indicates a significant statistic at 5% level.

important players in the international wheat market. Specifically, the price series used are daily nearby futures prices of wheat futures contracts traded on Chicago Board of Trade (CBT) for the US, the Winnipeg Commodity Exchange for Canada, and the London International Financial Futures Exchange for EU[3]. Although the underlying classes of wheat for these futures contracts are not homogenized, they may be generally considered substitutes in producing many products (Hasha, 1999; Yang and Leatham, 1999). The six-year study period is from May 1, 1996 to April 30, 2002, and totals 1565 observations. The price series are all converted into US dollar terms using appropriate daily exchange rates. All price and exchange rate data are obtained from Datastream and Bridge/CRB databanks.

Two test procedures, the augmented Dickey-Fuller (ADF) test and the Philips-Perron (PP) test, are commonly used to conduct unit root tests. Table 1 reports the test results using both methods. The nonstationarity of each series is rejected for all prices by the ADF test at the 5% significance level but not by the PP test. To sort out this inconsistency between the

[3] The prices of wheat futures contracts traded on Kansas City Board of Trade (KCBT) and the Minneapolis Grain Exchange (MGE) were also studied, respectively, as a proxy for the US market. The results based on these two prices are similar to those obtained using the price of CBT and are not reported here to conserve space.

ADF and PP test results, the trace test (Johansen and Juselius, 1990) was conducted on the three-variable system for the US, Canadian and EU markets. Results indicate the existence of three cointegrating vectors among the three-variable systems. This result immediately suggests the stationarity of all the three price-series in the system, thus a level VAR model is appropriate for the following time series analysis[4].

4. EMPIRICAL ANALYSIS

Generalized forecast error variance decomposition and generalized impulse response analysis are applied to summarize the price transmission pattern between the three wheat markets. Traditionally, it was customary to conduct such analysis based on a Choleski decomposition. This amounts to an arbitrary, pre-specified, recursive causal ordering among variables in the VAR (Swanson and Granger, 1997; Bessler and Yang, 2003). As noted previously, when the covariance matrix of market innovations is non-diagonal, the pre-specified ordering is important and can alter the dynamics of the VAR system.

In this study, generalized forecast error variance decomposition and generalized impulse response analysis are considered as alternatives to the traditional orthogonalized forecast error variance decomposition and impulse response analysis. Originally developed by Koop et al. (1996) and Pesaran and Shin (1998), these techniques can circumvent the dependence of the orthogonalized forecast error variance decomposition and impulse response analysis on the ordering of variables in the VAR, resulting in a unique solution. The use of such methods may be important to this study because of the strong correlation of the VAR residuals. The result of the generalized forecast error variance decomposition is presented in Table 2. At the longer horizon of 50 days ahead, the prices of both the EU and Canada markets explain about 10%, respectively, of price variation in the US market. By contrast, the price of the US market explains at least 30% of price variation in the Canadian market, but the EU market only explains 4% of the price variation. This suggests that between the US and Canadian markets, the US market tends to be a price leader. It is also interesting to note that about 97% the EU market price variation is explained by itself. Also, the price movements in the US or Canada have little impact on the market prices in the EU.

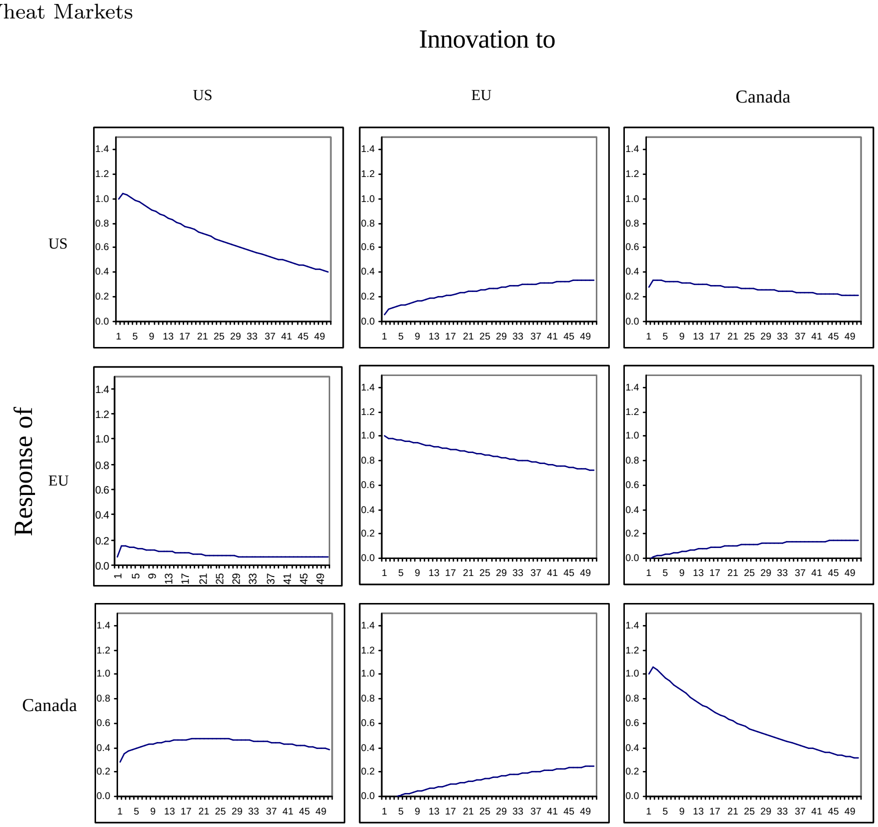
[4]In this study, the unit root property of the wheat futures prices was affected by choice of the sample period. Based on the same ADF and PP tests, we did not reject the existence of a unit root for all futures prices at the 5% significance level during the sample period of 1997-2000. We conducted similar analysis based on nonstationary futures prices and resulting error correction models. The basic inference obtained from the stationary and the nonstationary time series analysis was similar.

TABLE 2.

Generalized Forecast Error Variance Decomposition

Days Ahead	Market		
	US	EU	Canada
	Variance of US price (percentage) explained by shock to prices:		
1	0.91	0.01	0.08
5	0.90	0.01	0.09
10	0.88	0.02	0.10
20	0.86	0.04	0.10
30	0.84	0.06	0.11
40	0.81	0.08	0.11
50	0.78	0.10	0.11
	Variance of EU (percentage) explained by shock to prices:		
1	0.01	0.99	0.00
5	0.02	0.98	0.00
10	0.02	0.98	0.00
20	0.01	0.98	0.01
30	0.01	0.98	0.01
40	0.01	0.98	0.01
50	0.01	0.97	0.02
	Variance of Canada (percentage) explained by shock to prices:		
1	0.09	0.00	0.91
5	0.12	0.00	0.88
10	0.15	0.00	0.85
20	0.21	0.01	0.79
30	0.25	0.01	0.73
40	0.28	0.03	0.69
50	0.31	0.04	0.65

FIG. 1. Impulse Response Functions to Price Shocks in US, EU and Canadian Wheat Markets



An alternative summary of the dynamic price relationships for the US, EU, and Canadian markets is given by generalized impulse response functions (Figure 1). The impulse response functions have yielded an inference consistent with the result of generalized forecast error variance decomposition. Specifically, the price of the US market responds noticeably to shock from both the EU and Canadian markets, but the price of Canadian price responds very significantly to shocks from the US market but only mildly to shocks from the EU market. The price of EU market does not show much response to shocks either from the US or Canadian market.

Having studied the price transmission pattern, we next examine the volatility transmission between the three markets. Volatility as the second moment may provide further insight into the relationships of the market prices. We examined volatility transmission using the BEKK (Baba, Engle, Kraft and Kroner) specification of the multivariate GARCH model as follows (Engle and Kroner, 1995):

$$\{H_t\}_{ij} = h_{ijt} \quad i,j = 1,2,3$$

$$H_t = A_0' A_0 + \sum_{k=1}^{K} A_{1k}' \varepsilon_{t-1} \varepsilon_{t-1}' A_{1k} + \sum_{k=1}^{K} B_{1k}' H_{t-1} B_{1k}, \qquad (1)$$

where H_t is $N \times N$ covariance matrix given information available at $t-1$. The ECM residual or innovation vector is given by ε_t, and A_0, A_{1k}, B_{1k} are the $N \times N$ parameter matrices with A_0 being restricted to be upper triangular. The interpretation of the parameters from the general BEKK model is not straightforward, however. A parsimonious specification of $K = 1$ is adopted in our case, similar to Kasch-Haroutounian and Price (2001). Specifically, Equation (1) can be expanded as follows:

$$\begin{aligned} H_t &= \begin{bmatrix} a_{01} & a_{02} & a_{03} \\ 0 & a_{04} & a_{05} \\ 0 & 0 & a_{06} \end{bmatrix}' \begin{bmatrix} a_{01} & a_{02} & a_{03} \\ 0 & a_{04} & a_{05} \\ 0 & 0 & a_{06} \end{bmatrix} \\ &+ \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}' \begin{bmatrix} \varepsilon_{1,t-1}^2 & \varepsilon_{1,t-1}\varepsilon_{2,t-1} & \varepsilon_{1,t-1}\varepsilon_{3,t-1} \\ \varepsilon_{2,t-1}\varepsilon_{1,t-1} & \varepsilon_{2,t-1}^2 & \varepsilon_{2,t-1}\varepsilon_{3,t-1} \\ \varepsilon_{3,t-1}\varepsilon_{1,t-1} & \varepsilon_{3,t-1}\varepsilon_{2,t-1} & \varepsilon_{3,t-1}^2 \end{bmatrix} \\ &\times \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \\ &+ \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix}' \begin{bmatrix} h_{11,t-1} & h_{12,t-1} & h_{13,t-1} \\ h_{21,t-1} & h_{22,t-1} & h_{23,t-1} \\ h_{31,t-1} & h_{32,t-1} & h_{33,t-1} \end{bmatrix} \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix}, \qquad (2) \end{aligned}$$

where 1 = the US, 2 = the EU, and 3 = Canada.

TABLE 3.

The BEKK Model Estimation results

Coefficient	Estimate	t-value
a_{11}	0.90	15.13
a_{12}	0.10	3.27
a_{22}	−0.54	−5.41
a_{33}	0.95	42.37
b_{12}	−0.10	−3.90
b_{13}	−0.02	−2.37
b_{22}	0.22	2.95
b_{32}	−0.27	−2.98
b_{33}	0.33	4.96

Note: See Equation 2. Only statistically significant coefficients are reported.

With the above specification, the off-diagonal parameters in matrix B, given as $b_{ij}, i \neq j$, measure the dependence of the conditional return volatility in market i on that of market j. On the other hand, the off-diagonal elements of matrix A, given by parameters α_{ij}, capture the effect of return shocks originating in one market in the previous period on conditional volatility in another market in the current period.

The result of fitting the above BEKK specification is obtained. The residual diagnostic statistics generally support adequacy of the particular BEKK model specification. To conserve the space, only the statistically significant coefficients are reported in Table 3. Overall, the result indicates that the US price volatility is dependent to some extent on that of the Canada and EU markets, in addition to itself. As for EU, its price volatility depends solely on itself, not on the US and Canadian market. Finally, the price volatility in Canadian market is dependent on itself and the EU market. Overall, the volatility transmission pattern is largely consistent with the price transmission pattern in that it also underscores high self-dependence of the EU and the important role that the EU may play in transmitting volatility to other two markets. An important difference, however, is that the price volatility is transmitted from Canada to the US, but not vice versa.

5. SUMMARY AND CONCLUSIONS

This study investigates wheat futures price and volatility transmission for the three most important players in international wheat market. The period of study was May 1, 1996 to April 30, 2002. The generalized forecast error variance decomposition and generalized impulse response analysis consistently suggest that the US market has a significant impact on Canadian market. The EU market is self-dependent and is neither affected by the US nor by the Canadian market. The EU and Canadian prices influence the US market prices but the impact is not large.

The volatility transmission pattern shows that the volatility of the EU market depends on itself and plays a role in transmitting volatility to the US and Canada markets, but not vice versa. Also, the volatility in wheat prices is transmitted from Canada to US, but not vice versa. This result is different that what is found in the price transmission pattern.

The finding based on the price transmission pattern provides some support for the leadership role of the US market in the wheat trade between the US and Canada. This evidence is consistent with Goodwin and Schroeder (1991) and Mohanty et al. (1995), but contradictory to many other studies (Spriggs et al., 1982; Gilmour and Fawcett, 1987; Mohanty et al., 1996; Mohanty et al., 1999). In particular, the leadership role of Canadian market over the US market in price transmission, as reported in Mohanty et al. (1996) and Mohanty et al. (1999), is not supported by this finding. However, the US market is more endogenous than what is reported in the previous literature (e.g., Goodwin and Schroeder, 1991), particularly in the light of the price transmission pattern between the US and EU markets. Further analysis on the volatility transmission pattern, on the other hand, provides evidence for the leadership role of the Canada market in this regard. The US market is affected by volatility from the other two markets, but it does not transmit volatility to the other two markets. Such evidence provides support for the claim that US wheat producers are victims of the CWB pricing practice. Finally, both parts of finding demonstrate that the EU market is highly exogenous and is little affected by the US and Canada markets; but at the same time, its influence on the other two markets is not very significant. Nevertheless, the caveat is that exogeneity and influence of the EU market could be overestimated due to the time zone difference of futures trading between the Europe and North America. Future research may investigate the issue more accurately using transaction data from the overlapping trading hours between the Europe and North America. In sum, combining evidence from both price and volatility transmission patterns, in line with Mohanty et al. (1999), we conclude that there is no distinctive leadership role in international wheat markets while all three markets exhibit features of leadership to some extent.

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