Price Transmission throughout the U.S. Food Distribution System

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Vertical markets for foods are linked through pricing systems with much of the performance seen through how well price information is reflected at points of exchange. Failure for value changes at one point to be registered at other points can create major distortions and misallocations in the overall production and flow of food goods. For many commodities, the impact of policies at one exchange point (e.g., farm-gate) depend how prices are respond throughout the food chain. While the mechanisms for discovering the value at a point in time and space differs by commodities and industry structures, that value must ultimately reflect the underlying economic conditions. At each point in the distribution system prices should reflect the production and distribution costs, the relative levels of information, timing in the distribution, product form and differentiation, profits and losses, government regulations, and structural differences. Under some circumstances one might expect very little linkage between the farm-gate product and the final retail form particularly when the product is only a small part of the final retail product. Existence (or lack) of price linkages and measurable changes in the linkage over time provide parameters of the distribution system's ability to establish the economic value of foods as they move through the market channels.

Event though many studies have focused on individual commodities, there is less empirical information about commodity price linkages in general. To this end, this study draws on econometric methods to provide broad generalizations about pricing linkages across commodities in total and among groups of agricultural goods. A basic premise is that price changes, say at the farm-gate, get transmitted through the system but (1) the transmission may take time; (2) may be weak or strong; and (3) the responses may differ with rising versus falling prices. The third possibility suggests that there may be asymmetry in the price linkage with responses differing depending on the direction of change.

Papers by Appel, 1992; Boyd and Brorsen, 1988; Hahn, 1990; Hansmire and Willett, 1992; Kinnucan and Forker, 1987; Meyer and V. Cramon-Taubadel, 2004; Peltzman, 2000; Pick et al., 1990; Ward, 1982; Zhang et al., 1995 provide insight into price linkages and how they differ in rising and falling prices. Hahn found asymmetric price responses for pork and beef in which marketing chains were more sensitive to price-increasing than to price-decreasing shocks while Boyd and Brorsen did not find evidences of asymmetric price. Wolffram (1971)'s irreversible model, Gardner (1975)'s Markup model, and Tong (1978)'s threshold autoregressive (TAR) models have been widely used to estimate price linkage. Given the growing literature and growing databases, what generalizing can be drawn about pricing behavior within the U.S. food system.

Price linkages are expected to be dynamic given gradual structural changes, market innovations, efficiencies, and availability of information. Methods of time-varying parameters provide empirical way for both generalizing about the price transmission and if any transmission is evolving (i.e., strengthening or weakening). While there are many dimensions to the problem, in this paper we focus on the first issue of measuring price transmission and any potential dynamics to the process. In the conclusion, tying the dynamics back to conditions within the market is noted. The data base is described in the next section and then Wolffram's models are specified. Recursive estimation methods are applied to 199 pairs of commodities including reversed directions of price influences with the focus limited to the broader conclusions across these commodities.

Commodity Price Series

Monthly price data from 1970:1 through 2009:6 were collected for commodities broadly fitting into seven categories: food and feed grain, oil crops, animal meats, poultry and eggs, dairy, vegetables, and fruits. Price data on 100 commodities include both shipping point and retail prices and, in some cases, intermediate wholesale prices. Monthly retail prices are from the U.S. Bureau of Labor Statistics (BLS) average consumer price series and farm/shipping point and wholesale prices come from National Agricultural Statistics Service (NASS), Economics Research Service (ERS), and Agricultural Marketing Service (AMS) in United States Department of Agriculture (USDA). Table 1 includes general information about the series with values in parentheses indicating shares of U.S. farm sector cash receipts by the seven selected commodity groups. Given the diversity of products, all prices are expressed in dollars per pound. (In fact, dealing with units is a difficult problem.) There are 147 price pairs within the seven groups.

Table 1. Commodity groups and the number of commodity

Com. Groups \ MKT Channels	Farmers/Shipping	(Wholesalers)	Retailers	Sum
Food/feed grain	3 (84.39%)	6	7	16
Oil crops	2 (96.59%)	3	2	7
Animal meats	(2) 5 (99.24%)	6	9	20
Poultry/eggs	3 (97.03%)	8	6	17
Dairy	(1) 2 (100.00%)	4	5	11
Vegetables	5 (41.77%)	0	6	11
Fruits	8 (62.20%)	0	10	18
Total	28	27	45	100

Monthly data extending from the 1970's through June of 2009 show a history of both rising and falling prices as summarized in Figure 1. Somewhat surprising is the balance between the numbers of rising versus falling prices within groups. While the magnitude of rising and falling prices are not captured in Figure 1, the history of price movements in both directions suggest that the data do give opportunity for measuring price transmission and the level of reverse responses.

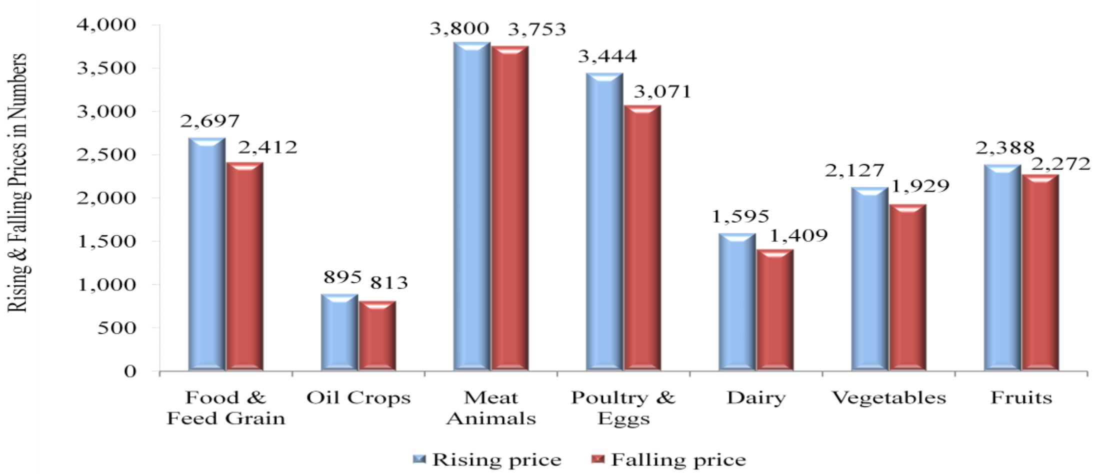


Figure 1. Frequency of rising and falling prices by group

Price Linkage Models

Price transmission models should allow for time delays in the transmission (i.e., distributed lags) and the potential for asymmetry in the behavior. By following Ward (1982) and Young (1980), an asymmetric model with distributed lags can be written:

$$R_t = \alpha_0 + \sum_{j=0}^{J}(\beta'_j F'_{t-j} + \beta''_j F''_{t-j}) + \varepsilon_t, \quad t = 1, \cdots, T \qquad \text{(Eq. 1)}$$

Where, $F'_t = \sum_{i=0}^{t}(F_{t-i} - F_{t-i-1})Z'_{t-i}$, $F''_t = \sum_{i=0}^{t}(F_{t-i} - F_{t-i-1})Z''_{t-i}$,

$Z'_{t-i} = \begin{cases} 1 & \text{if } F_{t-i} \geq F_{t-i-1} \\ 0 & \text{otherwise} \end{cases}$, and $Z''_{t-i} = \begin{cases} 1 & \text{if } F_{t-i} < F_{t-i-1} \\ 0 & \text{otherwise} \end{cases}$.

F'_t is the cumulated sum of increasing farm prices up to 't' and F''_t is the cumulated sum of decreasing farm prices up to 't'. J indicates the number of lags. Likewise Young (1980) and Ward (1982), the model can be simplified by using Gollnick's derivations[1].

$$R_t = \alpha_0 + \sum_{j=0}^{J}\left[\beta'_j(F_{t-j} - F_0) + (\beta''_j - \beta'_j)F''_{t-j}\right] + \varepsilon_t \qquad \text{(Eq. 2)}$$

Where, F_0 indicates the initial farm price in the data period.

[1] Gollnick provides the relationship in 1972 that $F_t = F_0 + F'_t + F''_t$ and then $F'_t = F_t - F_0 - F''_t$

Let α_0 captures marginal differences between farm and retail markers. The two coefficients, β'_j and β''_j measure the response to rising (‘) and falling (“) farm prices. If the two coefficients are positive and nearly equal, then the markets have a price linkage and symmetric responses. Differences between β'_j and β''_j indicate asymmetric behavior. If both coefficients are close to zero, then the markets have no linkage. Standard t-test for the estimated parameter provide the statistical conclusions.

A polynomial distributed lag is a well established method for capturing delayed responses and for most price linkage studies and second-order polynomial has proven quite robust. In all cases the polynomial degree and the number of lags must be specified. Adopting the 2nd order lag to the asymmetry models gives the structure in Eq. (3). While the completed research explores the range of specifications, in this paper we limit the analysis to a 2nd order using four lags with both restriction based on considerable background analyses.

$$\mathrm{B}'_j = \lambda'_0 + \lambda'_1 \phi_j + \lambda'_2 \phi_j^2, \text{ and } \left(\beta''_j - \beta'_j\right) = \lambda''_0 + \lambda''_1 \phi_j + \lambda''_2 \phi_j^2 \qquad \text{(Eq. 3)}$$

Table 2 provides the generalized signs and resulting delayed responses. Price linkage models are estimated for each commodity pair using recursive estimation techniques. Each estimate includes parameters for the rising and falling price linkages for a total of “z” parameter values for each variable in the models (.i.e., rising coefficient, falling, lags, the ratio of short run rising effect, the ratio of short run falling effect etc.).

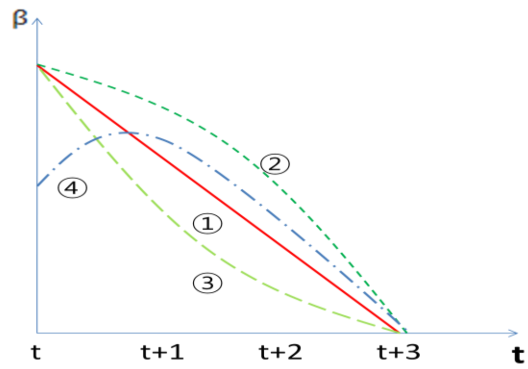
Now consider a general linear regression model in Eq. (4) where the coefficients carry a time subscript:

$$y_t = x'_t \beta_t + \varepsilon_t, \quad t = 1, 2, \cdots, T \qquad \text{(Eq. 4)}$$

where y_t is output variables associated with a time t. x_t represents independent variables with k regressors and ε_t is error term. Suppose that there are a total of T observations for a sample period.

Table 2. Polynomial distributed lags and associated shapes

Associated shapes	$\beta_j = \lambda_0 + \lambda_1 j + \lambda_2 j^2$		
	λ_0	λ_1	λ_2
①	+	-	0
②	+	-	-
③	+	-	+
④	+	+	-



Recursive least squares starts the estimation by using the first *r*th observations which provides coefficients for the sub-sample periods up to *r*th. The OLS estimator is $\hat{\beta}_r = (x'_r x_r)^{-1} x'_r y_r$ for the first *r*th observations, where the number of *r*th observations must be greater than or equal to the number of estimated parameters. Then the next estimation adds one more observation, thus giving $\hat{\beta}_{r+1} = (x'_{r+1} x_{r+1})^{-1} x'_{r+1} y_{r+1}$. For each pair, r is set to 36 for the starting estimations.

Short-run rising (SRRE) and falling (SRFE) effects follow immediately from β_0' and β_0''. Long-run rising (LRRE) and falling (LRFE) effects are summing the positive lags parameters, $\sum_{j=0}^{J} \beta_j'$ and $\sum_{j=0}^{J} \beta_j''$ (β_j' and $\beta_j'' \geq 0$) with the sum determined by the number of lags used. Ratios of short-run effects over long-run show how quickly pricing information moves through the system. Likewise, any evolution in the parameters gives a window into the dynamics of the price linkages.

Price Linkages and Granger-Causal

Granger-Causality tests provide the causal direction for exploring the direction of the price transmission when it exists. Granger (1969) developed the test method based on the premise that the future cannot cause the past as suggested with Eq. (5):

$$R_t = \sum_{i=1}^{m} \alpha_i F_{t-i} + \sum_{j=1}^{m} \beta_j R_{t-j} + \varepsilon_t,\ t = 1, \cdots, T \qquad \text{(Eq.5 a)}$$

$$F_t = \sum_{i=1}^{m} \gamma_i F_{t-i} + \sum_{j=1}^{m} \delta_j R_{t-j} + \eta_t,\ t = 1, \cdots, T \qquad \text{(Eq.5 b)}$$

where ε_t and η_t are two uncorrelated white-noise series, i.e. $E(\varepsilon_t \varepsilon_s) = 0 = E(\eta_t \eta_s)$, $s \neq t$ and $E(\varepsilon_t \eta_t) = 0$. In these models, m will be assumed finite and shorter than the given time series, T ($m<T$). To test causality from farm to retail, the model (Eq.5a) is used and to test causal influence from retail prices to farm prices, the model (Eq.5b) is used. The null hypothesis of causality is that farm prices are not Granger-Causal to retail prices or all of α_i, $i = 1, \cdots, m$ are zero. Rejecting the null hypothesis implies that farm prices are causing retail prices. Similarly, retail prices are causing farm prices if some δ_j for $j = 1, \cdots, m$ is statistically different from zero. It is called *unidirectional causality* (F→R or R→F) when the estimated coefficients of all α_i are statistically different from zero but the estimated coefficients of all δ_j are not statistically different from zero vise versa.

Price linkage models set with respected to the results of Granger-Causality; 77 pairs of commodities have shown unidirectional causality but prices of higher level markets influence to lower level markets in 16 pairs, 62 pairs have feedback relationships and 8 pairs are independent. Two equation pairs of peach prices excluded to estimate due to lots of missing values. Therefore, 199 commodity pairs applied to price linkage model with recursive techniques excluding independent relationship (see Figure 2).

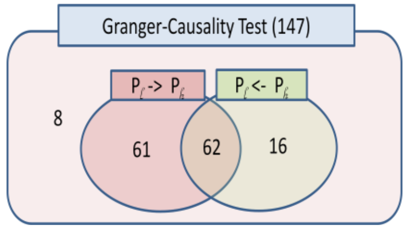


Figure 2. Results from the Granger causality test.

Price Linkages in the Food Distribution System

There are so many estimates corresponding to Eq. (1) that they are not shown in the paper. Instead, the short and long run estimates are calculated by averaging across the commodities. In general, this will work since all prices were expressed in similar units. We have further explored the results using standardized values but due to time and space, those results are not presented. Using the estimated parameters across commodities, the following graphs show the rising and falling linkages estimated recursively and averaged over the commodities for each iteration. Again, the same procedures are applied to the standardized betas but they are more difficult to interpret and not included in the current discussion.

Figure 3 is quite revealing for drawing generalizations about the pricing between exchange points in the U.S. food distribution system. First and foremost, price signals at one point do get registered at other points in the food chain. For the full data set including all prices up to 2009:6, short run responses have nearly equal values near .42. On average approximately 42 percent of a change, say at the farm-gate, is reflected at the retail (or another point) during the same month. This is true for either rising or falling price changes. Within four months, the models suggest that most of the responses are fully transmitted to the next level (e.g., farm-to-retail). Yet between the short and long run, evidence of asymmetry is seen where the long run raising exceeds the long run falling responses. After four months more of the rising prices at the farm-gate are passed through than for the falling prices as seen with LRRE =.86 and LRFE =.76.

It should be recognized that the long run is defined up to four month and could have been easily calculated for longer periods. The general conclusion would still be true, however.

Figure 3 shows the recursive averages for the short and long run with the coefficients covering fifteen years. All averages show a general decline throughout that indicates for the four month intervals less of the price signals are being transmitted to the next level in the more recent periods. For comparison, LRRE declined from a high of 1.09 to the low of .86 in the latter periods and LRFE changed from 1.01 to .76. At least, within the four month window less of the signals are passed through and especially so for the declining prices. It could be that in the long run it is taking longer or never fully passed through between the farm-gate and retail. For the short run, early periods point to more asymmetry than seen in the full dataset. Again compare the SRRE and SRFE for the period ending in 1995:1 to the same parameters for the period ending in 2009:6 where the differences are .07 versus -0.01. Overall, Figure 3 shows the price transmission works but is changing in a direction of less transmission in what is generally considered a reasonable strong linkage in the food chain.

Figure 4 shows the relative degree of transmission between the short and long run by simply expressing the short run coefficients to the long run. As a generalization, slightly more than half of the full responses to prices changes are seen within the first month and there is a reasonable level of consistency across the recursive values. There is no pronounced trend in these relative values except that the immediate responses to falling prices are a little faster than the rising after 2002. These differences are relatively small. Restating, on average about half of the prices signals are transmitted immediately within the same month.

Figure 5 provides another way for visualizing the same information by indexing all coefficients to the starting period (i.e., 1995:1=1). Between this period and the full dataset, the relative price transmission decreases by about 15% for SRFE and LRRE. In contrast, the long run falling (LRFE) and short run rising (SRRE) relative transmissions decline by 21% and 28% from the starting period, respectively. Again generalizing, the averages point to a decline in the system's transmission of price signals for the defined lags.

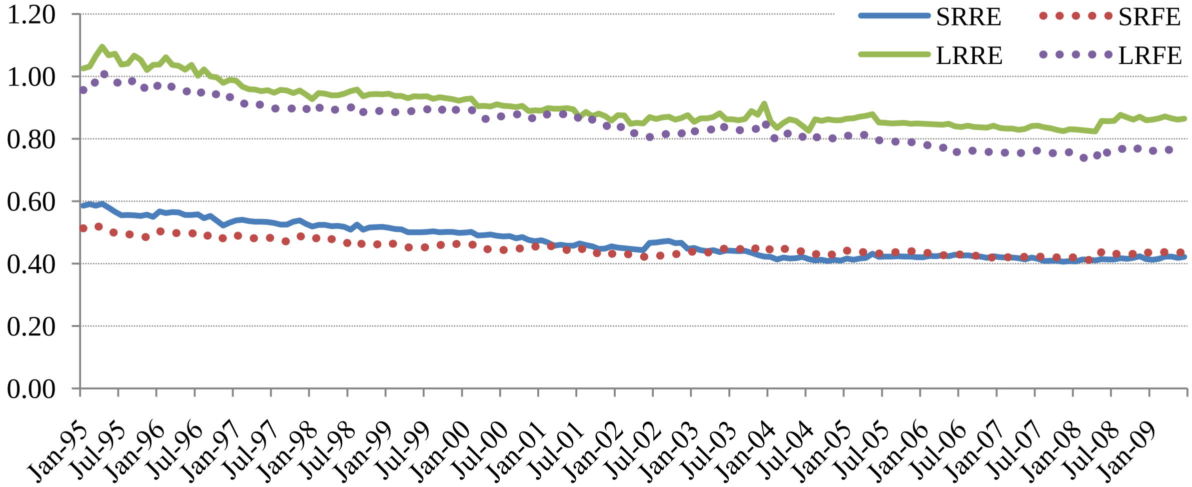


Figure 3. Average price linkages in short and long run

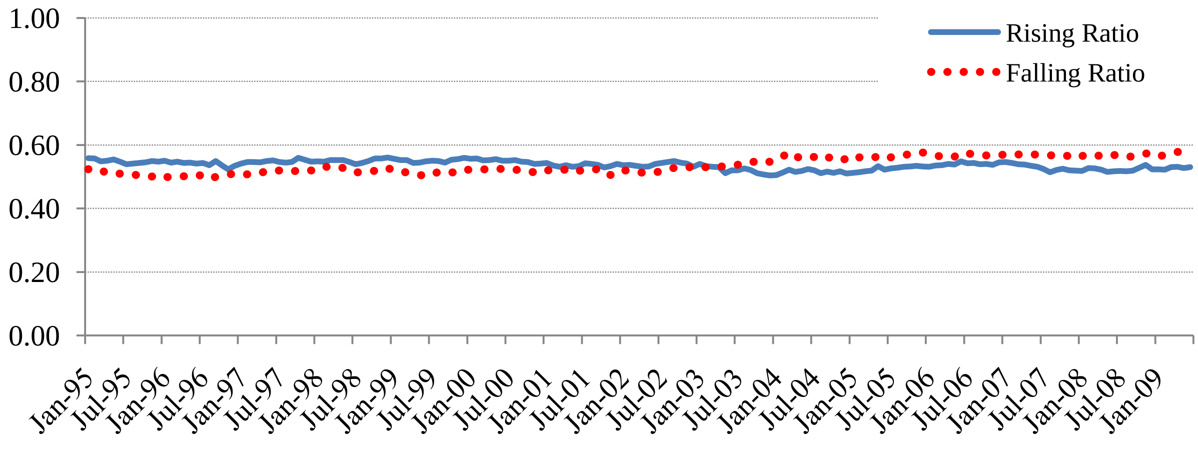


Figure 4. Average commodity price linkage short over long run

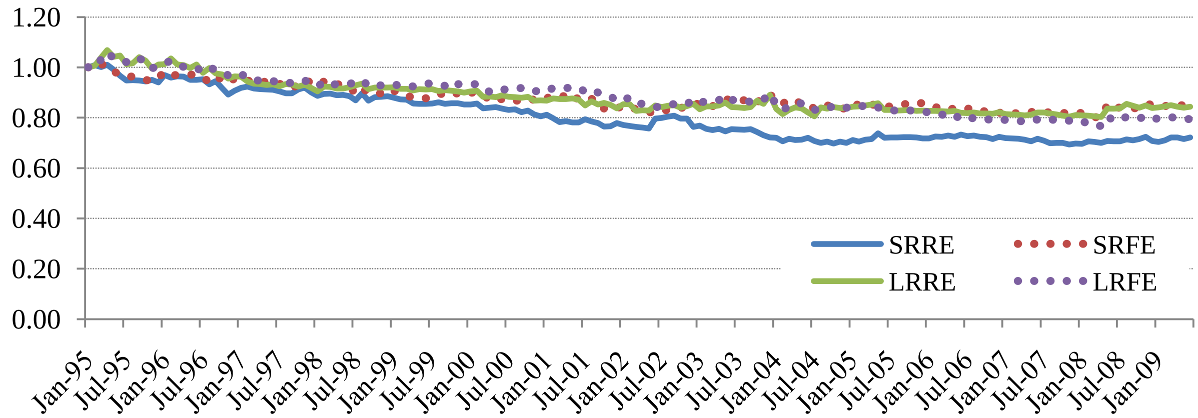


Figure 5. All commodity price linkages indexed to starting year=1.0

Differences Across Commodity Groups

The primary purpose of this analysis was to generalize about the price transmission as presented in the previous figures based on un-weighted averages across commodities. In the following figure (Figure 6) we have presented the short and long run rising and falling coefficient averages by commodity groups. Quite obvious, there are differences across the commodity groups that are hidden within the overall averages. Even with the diversities among commodities, there is a level of consistency across the groups. In every group, information is transmitted and generally the rising exceeds the falling in both the short and long run. The only except is for fruits and vegetables. Ward's (1982) study from several years ago pointed to this same response with fruits and vegetables. In most cases, the rule of nearly half of the price transmission within the first month holds with grains being the most noteworthy exception. Oil and dairy products are the most unusual where the long run coefficients are considerably below 1.0 for a four month interval. Both commodities have a number of processing uses where possibly some of the farm level product identity is lost as it flows through the distribution chains.

Similarly, some of these commodities include forward contracting and the use of formula pricing schemes between buyers and sellers.

Figure 6. Price linkages by commodity groups

Implications and Conclusions

The ability of the U.S. food distribution system to register prices responses up and down the exchange system is essential to the efficient performance and distribution of foods. Sometimes efforts to enhance demand at one point must be reflected in changes at other distribution points. For example, imposition of an assessment at the farm-gate may lead to higher farm prices and, depending on the price linkage, higher retail prices. Public policy directed to prices at one point impact prices at other points in the distribution system as long as the linkage occurs. Hence, it is essential for both public and private (industry) interest to understand the nature of the price transmission mechanism.

While this is a work in progress, analyses show that: (1) there is considerable linkage between exchange points in the food distribution system; (2) food price linkages have tended to be weaker over time in short and long run even though the linkage is still strong; (3) short run responses have changed but are generally quite stable in terms of the short run response relative to the long run with about half of the total response realized in the immediate month; and (4) in the long run there tends to be a level of asymmetry with rising prices being passed through quicker than falling prices.

Two limitations to the current analysis are dealing with the standardization of the estimates and the development of a weighting procedure when averaging. The results were not weighted in this analysis but are being explored along with the standardization procedures. The next step in the research is to explore conditions that have lead to the changes seen among the commodities and across time. That is, can we identify and measure factors contributing to the dynamics in the price transmission parameters?

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