

# *Structure, conduct and the stochastic volatility of food markets: theory and empirics*

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**Structure, Conduct and the Stochastic Performance of Food Markets:  
Theory and Empirics**

**Garth Holloway<sup>\*</sup> and Ahmet Bayaner**

**Abstract**

The relationship between price volatility and competition is examined. Atheoretic, vector auto regressions on farm prices of wheat and retail prices of derivatives (flour, bread, pasta, bulgur and cookies) are compared to results from a dynamic, simultaneous-equations model with theory-based farm-to-retail linkages. Analytical results yield insights about numbers of firms and their impacts on demand- and supply-side multipliers, but the applications to Turkish time series (1988:1-1996:12) yield mixed results.

**Keywords:** Conduct, food marketing, stochastic performance, structure, volatility.

**JEL Classifications:** L16, O25, Q13.

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## **Introduction**

That prices of farm commodities are more volatile than prices in other sectors is generally accepted. The usual argument relates inelastic farm-gate demand to shocks in supply due to biological and climatic factors. This paper employs a simple model of farm-to-retail price determination in order to examine the extent to which monopoly power in the food manufacturing sector may also affect price instability. The issue is investigated through successive applications to Turkish agriculture. These applications are interesting for three reasons. First, food-manufacturing in Turkey is highly concentrated, with levels of agglomeration in many marketing channels similar to those of the beef sector in the United States. Second, recent contributions using VAR techniques (eg., Orden and Fackler (1989), Robertson and Orden (1990), Dorfman and Lastrapes (1996)), have focused on developed-economy agriculture. The Turkish economy, with greater macroeconomic and trade instabilities, provides an important contrast with these studies. Third, argument that monopoly in processing may exacerbate price instability has received scant attention in the literature. Here, we argue, this hypothesis provides an appealing explanation of observed volatilities in commodity prices.

### **1. Conventional Wisdom**

The main ideas that underlie conventional wisdom are articulated in the following quotation (Robertson and Orden, 1990, p.161):

“At issue are whether levels of agricultural and non-agricultural prices respond proportionally to changes in the level of the money supply and whether there are predictable deviations from such neutrality in the short run. An important hypothesis concerning these issues is that agriculture is a competitive sector in which prices are more flexible than those in non-agricultural (fix-price) sectors. Under this hypothesis, it has been argued that expansionary monetary policy [interpret as ‘demand shocks’] favors agriculture and may cause short-run agricultural prices to over-shoot their long-run equilibrium levels, while contractionary monetary policy [interpret as ‘supply shocks’] shifts relative prices against agriculture.”

The justifications for interpreting expansionary policies as demand shocks and contractionary ones as supply shocks are twofold. First, expansionary policies that lead to hyperinflations of the type encountered in Turkey are likely to have their initial impacts on high-velocity markets. These markets are characterized by demand-side atomism and a high rate of repeat purchases. Second, contractionary policies that restrict access to capital markets, retard entry and exit from farming and

impede adjustment efficiencies are likely to have had initial impact on supply-side agents. We argue that in vertical farm-to-retail systems the former is best interpreted as a demand-side effect and the latter a supply-side effect. The substantive issue that we examine is whether competition mitigates or amplifies the impacts of these effects on farm prices.

## 2. VAR evidence from the Turkish wheat sector

In a set of vector autoregressive (VAR) experiments, with the VAR's applied to time series (1988:1-1996:12) on each of five constituent wheat-derivative products (flour, bread, pasta, bulgur and cookies), we consider the impacts of a one-standard-error increase in the consumer price index (CPI) within the vertical wheat-marketing channel. In all but one case, (bread) the impulses are monotonically increasing in the shock. In general, when measured relative to their means, the shocks are considerably larger in the farm sector. Specifically, by combining the variation in the impulse-response projections ( $\sigma$ ) with the corresponding mean adjustments ( $\mu$ ), we compute that the coefficients of variation ( $\sigma \div \mu$ ) for the downstream commodities flour, bread, pasta, bulgur and cookies are, respectively, 0.48, 0.27, 0.38, 0.43, 0.51. The corresponding coefficient of variation for the farm-gate commodity, which is wheat, is 0.67. The question we ask, specifically with reference to the farm price, is whether these responses would be greater under more competitive conditions. Criticisms of VAR are well-documented (see, for example, Darnell and Evans (1990) and the literature cited therein). Among the major criticisms is the lack of an (economic) theoretic basis for the estimating equations. This limitation is important in the current context. Accordingly, we develop a simple simultaneous-equations model.

## 3. A simple explanation

The 'Robertson-Orden hypothesis' (that competition leads to greater volatilities in farm-price movements) can be substantiated with monopoly as basis, in the following, simplified way. Let  $i, i = 1, 2, \dots, N$ , index processors and consider production of a food product,  $y_i$ , from combining a farm commodity,  $x_i$ , with another variable input,  $z_i$ , in the technology,  $y_i = \min\{x_i, z_i\}$ . Demand is  $p = A - aY$ ; supply is  $w = B + bX$ ;  $Y = \sum_i y_i$  and  $X = \sum_i x_i$ ; each of the parameters  $A, a, B$  and  $b$ , is positive; and, because technology is 'fixed proportions,' we set  $y_i = x_i = z_i$ . Consequently, we focus on the farm-to-retail part of profits. Processors maximize  $\pi(y_i) = (A - a\sum_i y_i) y_i - (B + b\sum_i y_i) y_i$ , and the corresponding first-order conditions yield, at the symmetric, Nash equilibrium,  $Y = N(A - B)/(N+1)(a+b)$ . Substituting for output in the commodity-supply relation yields comparative statics with respect to two effects, namely, a demand shock,  $\Delta A > 0$  and a supply shock  $\Delta B > 0$ . In particular,  $\partial w / \partial A = Nb/(N+1)(a+b)$  and  $\partial w / \partial B = 1 - Nb/(N+1)(a+b)$ . Both effects are positive, but, whereas the

first effect is increasing in  $N$ , the second declines. Thus, interpreting  $N$  as ‘the degree of competition present within the market.’ we obtain a basis for the hypothesis, that demand-side shocks to farm price are greater the greater is the degree of competition.

#### 4. Reduced-Form, Farm-to-Retail Linkages

Consider, now, the full reduced form that generates these comparative statics. From the structural equations underlying the equilibrium, the reduced-form linkages are

$$(1) \quad \mathbf{y} = \mathbf{z} \boldsymbol{\vartheta},$$

where  $\mathbf{y} \equiv (p, w)$ ,  $\mathbf{z} \equiv (A, B)$ , and  $\boldsymbol{\vartheta}$ , the matrix of reduced-form coefficients, is

$$(2) \quad \boldsymbol{\vartheta} \equiv \begin{pmatrix} \pi_{11} & \pi_{12} \\ \pi_{21} & \pi_{22} \end{pmatrix},$$

where  $\pi_{11} \equiv 1 - \frac{a}{a+b} \frac{N}{N+1}$ ,  $\pi_{12} \equiv \frac{a}{a+b} \frac{N}{N+1}$ ,  $\pi_{21} \equiv \frac{b}{a+b} \frac{N}{N+1}$ , and  $\pi_{22} \equiv 1 - \frac{b}{a+b} \frac{N}{N+1}$ . The coefficients  $\pi_{11}$  and  $\pi_{12}$  denote the impacts of demand and supply shocks on retail price, while  $\pi_{21}$  and  $\pi_{22}$  denote their impacts on farm price. A pattern emerges when the within-industry effects (retail-to-retail and farm-to-farm) are compared with the cross-industry effects (retail-to-farm and farm-to-retail). Increased competition, here exemplified by a larger value of parameter  $N$ , dampens the impact of the direct effects (retail-to-retail and farm-to-farm), but amplifies the magnitude of the indirect effects (retail-to-farm and farm-to-retail). The parameter definitions that generate these results are important for two additional reasons. First, a useful pair of within-equation restrictions,  $\pi_{11} + \pi_{12} = 1$  and  $\pi_{21} + \pi_{22} = 1$ , can be used to improve precision of estimation. Second, a set of cross-equation relations that follows from the parameter definitions plays a key role in subsequent analysis. These cross-equation relations are:

$$\pi_{11} + \pi_{12} = \frac{1}{N+1},$$

$$\pi_{22} - \pi_{12} = \frac{1}{N+1},$$

*Lemma:*  $\pi_{11} - \pi_{21} + \pi_{22} - \pi_{12} = \frac{2}{N+1},$

$$|\boldsymbol{\vartheta}| \equiv \pi_{11} \pi_{22} - \pi_{21} \pi_{12} = \frac{1}{N+1}.$$

To the extent that equation (1) can be estimated given data on  $p$ ,  $w$ ,  $A$  and  $B$ ; these definitions prove potentially useful estimators of the numbers of firms in the marketing channel. They are, thus, central to the exercise.

#### 5. Dynamic perspectives on the comparative statics

Analyses of volatility is incomplete without reference to dynamic adjustments. Lagged responses in commodity supply motivate concerns about adjustments in the farm sector, but the potential dynamic

effects at the consumption level are less clear. Nevertheless, own consumption by farmers and, with it, storage and inter-seasonal linkages are likely important in developing countries. We therefore consider price-lagged specifications of demand and supply equations and leave the matter of their significance to the empirics that follow. In this respect, and with the aid of a little algebra, the comparative-static results of the previous section can be given a dynamic interpretation. Consider the specifications of the exogenous variables A and B,

$$(3) \quad A \equiv \alpha_0 + \sum_{i=1}^D \alpha_i z_{dit} + \alpha p_{t-1},$$

$$(4) \quad B \equiv \beta_0 + \sum_{i=1}^S \alpha \beta_i z_{sijt} + \beta w_{t-1};$$

where the  $\alpha$ 's and  $\beta$ 's are parameters of indeterminate sign; the  $z$ 's denote relevant, contemporaneous demand shifters;  $p_{t-1}$  and  $w_{t-1}$  denote lagged realizations of the endogenous variables; and  $\alpha$  and  $\beta$  denote their respective, initial impacts. Importantly, the values  $\alpha$  and  $\beta$  cannot be constrained based on any theoretical basis and, ultimately, remain an empirical matter. However, like the parameters in the lemma, they play an important role in subsequent analysis. At points in the discussion it will prove useful, for pedagogic reasons, to normalize the parameters  $\alpha$  and  $\beta$ , both, at one. In this case the reader should keep in mind that the one-step-ahead impacts of changes in the lagged prices are the same as those derived above, with respect to shifts in A and B. Turning to these dynamic impacts and following a standard treatment (see, for example, Greene, 1993, pp. 619-25), the reduced-form for the two prices is

$$(5) \quad \mathbf{y}_t = z_t \mathbf{\Psi} + \mathbf{y}_{t-1} \mathbf{\Delta} + \mathbf{v}_t, \quad t = 1, 2, T;$$

where  $\mathbf{y}_t \equiv (p_t, w_t)$  denotes contemporaneous observations on the endogenous variables;  $z_t \equiv (z_{dt}, \dots, z_{dDt}, z_{st}, \dots, z_{sSt})$  denotes observations on the demand and supply shifters;  $\mathbf{y}_{t-1} \equiv (p_{t-1}, w_{t-1})$  denotes lagged observations on the endogenous variables;  $\mathbf{\Psi}$  denotes the instantaneous impacts of changes in the components of  $\mathbf{z}$ ; and the coefficient matrix of the lagged effects,

$$(6) \quad \mathbf{\Delta} \equiv \begin{pmatrix} \Delta_{11} & \Delta_{12} \\ \Delta_{21} & \Delta_{22} \end{pmatrix},$$

is related to the matrix  $\mathbf{\vartheta}$  in (2) by the condition

$$(7) \quad \mathbf{\Delta} \equiv \mathbf{E} \mathbf{\vartheta},$$

where  $\mathbf{E}$  is a (2x2) matrix with parameters  $\alpha$  and  $\beta$  on the diagonal, and zeros elsewhere. Thus, with  $\alpha$  and  $\beta$  normalized,  $\mathbf{E}$  becomes the identity matrix and  $\mathbf{\Delta}$  reduces to  $\mathbf{\vartheta}$ . We are interested in dynamic responses to exogenous shocks, whether the model is stable, and the pattern of adjustments to a stable equilibrium if, indeed, one exists. We are also interested in the extent to which competition affects any of these characteristics. The dynamic multipliers, stability conditions and adjustment paths depend crucially

on the elements of the matrix  $\mathbf{\Delta}$ . Thus, in characterizing these effects we will make use of the equality in (7) and, specifically, the relations below, which follow from combining the lemma with equation (7),

$$\begin{aligned}
\theta_1 &\equiv \Delta_{11} - \Delta_{21} = \frac{\alpha}{N+1}, \\
\theta_2 &\equiv \Delta_{22} - \Delta_{12} = \frac{\beta}{N+1}, \\
(8) \quad \theta_3 &\equiv \Delta_{11} - \Delta_{21} + \Delta_{22} - \Delta_{12} = \frac{\alpha+\beta}{N+1}, \\
\theta_4 &\equiv |\Delta| \equiv \Delta_{11} \Delta_{22} - \Delta_{12} \Delta_{21} = \frac{\alpha\beta}{N+1}.
\end{aligned}$$

Except for the presence of the terms  $\alpha$  and  $\beta$ , these conditions are identical to those of the lemma. As such, they do not yield any additional insights; but when combined in a particular fashion, they do. Specifically, combining the first, second and fourth relations in (8), we have

$$\begin{aligned}
\theta_5 &\equiv \frac{\theta_4}{\theta_2} = \alpha, \\
(9) \quad \theta_6 &\equiv \frac{\theta_4}{\theta_1} = \beta;
\end{aligned}$$

and, combining, in turn, these two relations with the four in (8), we have

$$\begin{aligned}
\theta_7 &\equiv \frac{\theta_5}{\theta_1} - 1 = N, \\
\theta_8 &\equiv \frac{\theta_6}{\theta_2} - 1 = N, \\
(10) \quad \theta_9 &\equiv \frac{\theta_5 + \theta_6}{\theta_3} - 1 = N, \\
\theta_{10} &\equiv \frac{\theta_5 \theta_6}{\theta_4} - 1 = N.
\end{aligned}$$

It is worth noting that each of the restrictions in (10) yields identical estimates of  $N$ . But we have yet to draw a relationship between  $N$  and the dynamic impacts of the shocks. The short-run effects of changes in the exogenous variables are contained within the coefficients of the matrix  $\mathbf{\Psi}$ . They are discussed above. From (5), the dynamic, cumulative, and long-run multipliers are, respectively,  $\boldsymbol{\mu}_t \equiv \mathbf{\Psi} \mathbf{\Delta}^t$ ,  $\sum_{t=0}^T \boldsymbol{\mu}_t = \sum_{t=0}^T \mathbf{\Psi} \mathbf{\Delta}^t$ , and  $\sum_{t=0}^{\infty} \boldsymbol{\mu}_t = \mathbf{\Psi} (\mathbf{I} - \mathbf{\Delta})^{-1}$ . They are void of analytical results. Thus, we turn to the relationship between competition and the stability conditions. Let  $\lambda_i$ ,  $i = 1, 2, \dots, M$ , denote the roots of the characteristic equation,  $|\mathbf{\Delta} - \lambda \mathbf{I}| = 0$ . Stability requires  $|\lambda_i| \leq 1$  for all  $i = 1, 2, \dots, M$ . Real-valued  $\lambda_i > 0$  ( $\lambda_i < 0$ ) add damped exponential (saw-tooth) terms, whereas  $\lambda_i$  complex adds a sinusoidal term. The roots solve  $\lambda^2 + \delta_1 \lambda + \delta_2 = 0$ , where  $\delta_1 \equiv (\Delta_{11} + \Delta_{22}) = \text{trace}(\mathbf{\Delta})$  and  $\delta_2 \equiv \Delta_{11} \Delta_{22} - \Delta_{12} \Delta_{21} = |\Delta|$ . Clearly, the question of whether  $\mathbf{\Delta}$  converges depends crucially on the parameters  $\alpha$  and  $\beta$ . Inevitably, this question can only be resolved empirically. However, momentarily fix  $\alpha$  and  $\beta$  at one. In terms of (7),  $\mathbf{E}$  reverts to the identity matrix and  $\mathbf{\Delta} = \boldsymbol{\vartheta}$ , permitting us to focus on the parameter definitions below (2). Signing the roots and examining their magnitude is now a simple matter of employing two standard results (see, for

example, Chiang, 1984, p. 505-506), namely  $\lambda_1\lambda_2 = |\theta|$  and  $\lambda_1+\lambda_2 = \text{trace}(\theta)$ . Making use of the definitions below (2), and the fourth line of the lemma; we have the two conditions

$$(11) \quad \lambda_1\lambda_2 = \frac{1}{N+1} > 0,$$

$$(12) \quad \lambda_1+\lambda_2 = \frac{N+2}{N+1} \in [1, 3/2].$$

Thus, both roots have the same sign and must sum to a positive number. Therefore, they are both positive. The radical in the solutions,  $\text{trace}(\theta)^2 - 4|\theta| = (\Delta_{11} + \Delta_{22})^2 - 4(\Delta_{11}\Delta_{22} - \Delta_{12}\Delta_{21})$  is positive, so sinusoidal effects are ruled out. Thus, the time path offers either dampened or explosive exponential terms, and depends on the dominant root. It may be greater than one, but from (12), in the limit as N gets large, both roots are fractional. It follows, accordingly, that for small N, a window of opportunity for instability exists, and it vanishes as the degree of competition rises. Specifically, and in contrast to the Robertson-Orden prediction, competition may induce stability. That is, the greater the degree of competition, the less likely are price explosions. That these results depend on assumptions (viz.,  $\alpha = \beta = 1$ ), which may be invalid, generates scope for empirical enquiry.

## 6. Empirical evidence

We seek to identify the magnitude of responses to shocks in the marketing system and identify a correspondence between it and the number of firms. The coherent Bayes solution is to parameterize the structural system over N and derive conditional distributions of the dynamic multipliers, whereupon the effect of N is easily established. Arranging the observations on the variables  $y_t$ ,  $z_t$  and  $y_{t-1}$ , we can rewrite equation (5) as

$$(13) \quad \mathbf{Y} = \mathbf{Z} \mathbf{D} + \mathbf{V},$$

where  $\mathbf{Y}_{(T \times M)}$  are T observations on  $y_t$ ;  $\mathbf{Z}_{(T \times K)}$  are T observations on the M components of  $y_{t-1}$  and the L components of  $z_t$ ; and  $\mathbf{V}_{(T \times M)}$  is a matrix of error terms assumed to be distributed  $N(\mathbf{0}, \mathbf{\Sigma} \otimes \mathbf{I})$ , where  $\mathbf{0}_{(T \times M)}$  is a null matrix,  $\mathbf{I}_{(T \times T)}$  is the T-dimensional identity matrix, and  $\mathbf{\Sigma}_{(M \times M)}$  specifies covariance among the columns of V. Because the posterior distributions have well-known forms, they lend themselves readily to investigation through resampling techniques. Our approach is to work exclusively through equations (8), (9) and (10); obtain estimates of  $\alpha$  and  $\beta$  and N and, then, conditional on the estimates of  $\alpha$  and  $\beta$ , obtain a sequence of estimates for the dynamic multipliers from the sequence of posterior distributions conditioned by chosen values of N. We do this by resampling from the coefficient matrix of the reduced form. Specifically, let  $\{\mathbf{\Sigma}^{(s)}, s = 1, 2, \dots, S\}$  and  $\{\mathbf{D}^{(s)}, s = 1, 2, \dots, S\}$  denote a sequence of draws from the posteriors corresponding to (13), where the draws in the second sequence are conditioned by the ones in the first. Then, from the draws on the coefficient matrix, we can extract estimates of the restrictions in equations (8),  $\{\theta_i^{(s)}, s = 1, 2, \dots, S; i = 1, 2, 3, 4\}$ ; (9)  $\{\theta_i^{(s)}, s = 1, 2, \dots, S; i = 5, 6\}$ ; and (10),  $\{\theta_i^{(s)}, s = 1, 2, \dots, S; i = 7, 8, 9, 10\}$ ; plot posterior distributions for  $\alpha$ ,  $\beta$  and N; compute their means

$$\begin{aligned}
& \hat{\alpha} = \frac{1}{S} \sum_{s=1}^S \theta_5^{(s)}, \\
(14) \quad & \hat{\beta} = \frac{1}{S} \sum_{s=1}^S \theta_6^{(s)}, \\
& \hat{N} = \frac{1}{S} \sum_{s=1}^S \frac{1}{4} \sum_{i=7}^{10} \theta_i^{(s)},
\end{aligned}$$

and then derive conditional estimates of the dynamic multipliers of farm- and retail-price responses in relation to a change in the CPI. Unfortunately, space limits the presentation to just one of the groups.

Figure 1 reports results for the estimations of the parameters  $\alpha$ ,  $\beta$  and  $N$  for the flour-milling sector. The figure reports distributions based on a Gibbs samples of size  $S = 100,000$ . As can be observed from the figure, both  $\alpha$  (the distribution shaded in blue) and  $\beta$  (the distribution shaded in green) have well defined distributions over a narrow range, with means of 0.81 and 0.89, respectively. The distribution for  $N$  (the distribution shaded in brown), however, is less well defined and has negative components.

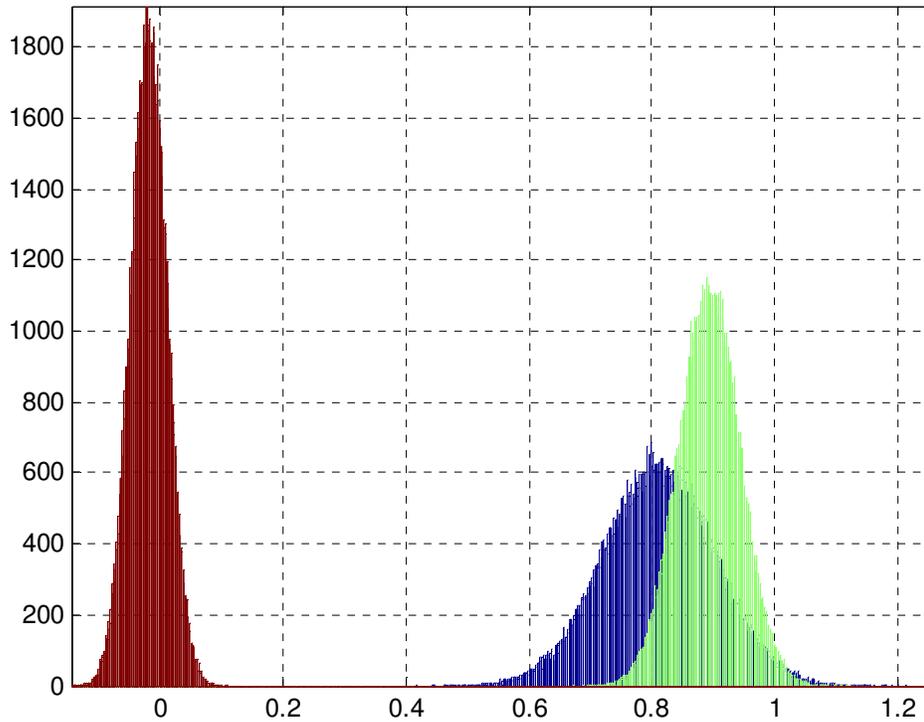


Fig. 1. Posterior distributions of parameters:  $\alpha$  (blue),  $\beta$  (green) and  $N$  (brown).  
Source: Authors' estimation results.

Figure 2 reports the corresponding estimates of the retail-product multipliers derived for the twenty-period-ahead predictions. The multipliers are derived in response to a CPI shock on retail and farm prices. The distribution shaded in blue reports estimates of the retail-product multipliers when the numbers of firms,  $N$ , is left unconstrained; the distribution shaded in green reports results when  $N$  is constrained to be equal to one; and the distribution shaded in brown reports results when  $N$  is constrained to equal one hundred.

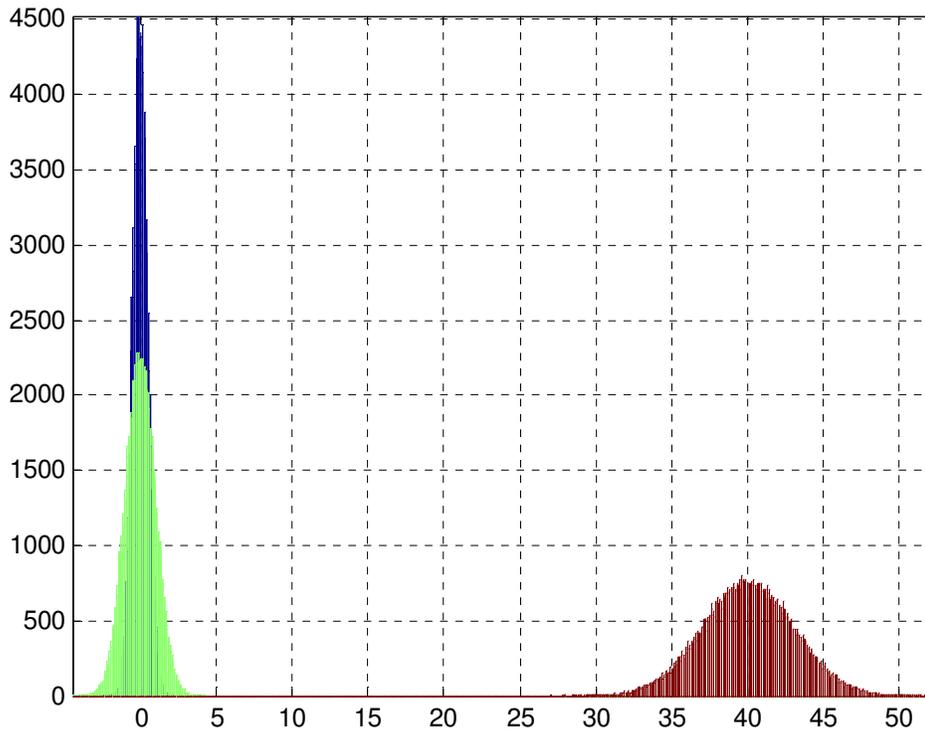


Fig. 2. Retail multipliers, twenty-steps-ahead posterior predictions: unconstrained (green),  $N=1$  constrained (blue) and  $N=100$  constrained (brown). Source: Authors' estimation results.

Figure 3 reports similar information, but this time with respect to the farm-gate multipliers in response to the CPI shock. With reference to the retail price reports (figure 2), the effect of constraining  $N$  is to lower, slightly, the magnitude of the multipliers, but then increase them substantially such that, for  $N=100$ , the market becomes unstable. With reference to the farm price reports (figure 3), increasing  $N$  leads to increasing but convergent effects, beyond which, at some  $N < 100$ , explosion occurs.

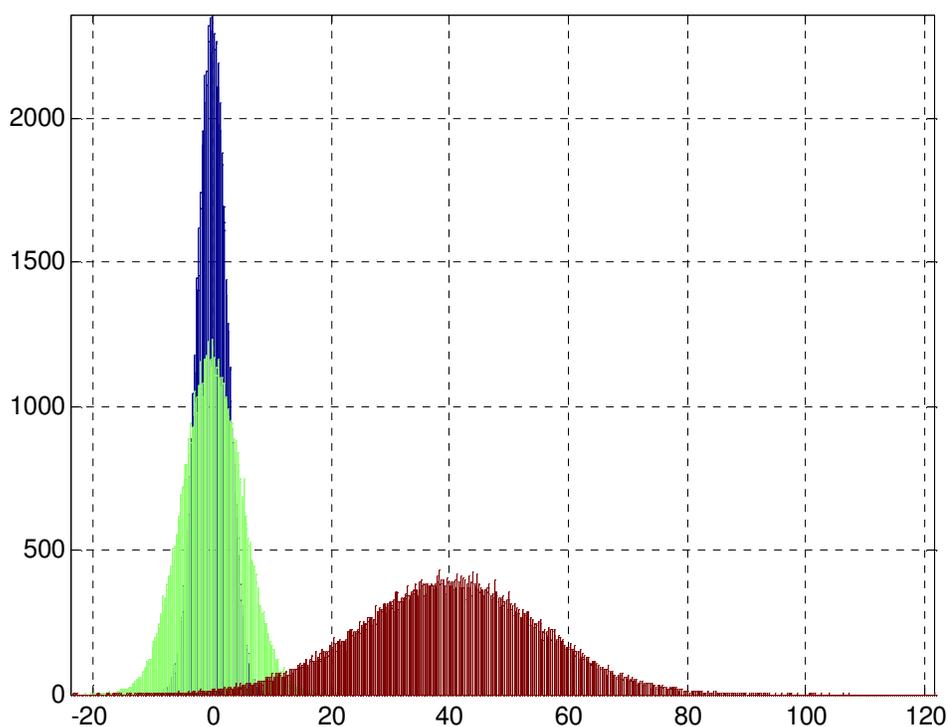


Fig. 3. Retail multipliers, twenty-steps-ahead posterior predictions: unconstrained (green), N=1 constrained (blue) and N=100 constrained (brown). Source: Authors' estimation results.

Thus, the effect of competition seems on the one hand to contradict the results of the dynamic SEM, but substantiate the notion espoused by Robertson and Orden, namely that competition leads to volatility. Space limitations prevent reporting results for the remaining sectors but, briefly, can be summarized as follows. Bread: Competition raises the initial impact of the shocks but lowers the length of their inter-temporal effects, and generates stable equilibria. Pasta: Competition is once again stable, leads to larger initial impacts and shortened duration of effect. Bulgur: Competition leads to stable equilibria and lengthened duration of effect. Cookies: Competition leads to instabilities.

## 7. Conclusions and Extensions

Empirical evidence in support of the 'competition-breeds-volatility' hypothesis is mixed. In two cases (flour and cookies) it appears to be confirmed. The remaining examples seem to conform to an alternative thesis derived from a two-equation, dynamic simultaneous-equations

model. This thesis is that competition enhances the likelihood of stable price movements. More work is needed before any firm conclusions can be drawn, and the results thus far are subject to a number of limitations. The, most notable of these is the assumption of constant variance. Plots of residuals based on posterior means suggest that there are at least two, possibly three, distinct regimes within the time series. Consequently, work continues along the lines of a recent contribution to mixed-density estimation (Lavine and West, 1992).

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