Farmgate versus retail prices and supermarkets' pricing decisions: an integrated approach

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Abstract
Food and agricultural commodity prices exhibit several empirical regularities, including asymmetric price transmission, higher farmgate price volatility, and relatively low correlation between farmgate and retail prices. Supermarket pricing behaviors include promotions, loss-leaders, and unadvertised sales. Existing explanations tend to focus on either the behavior of farmgate and retail prices or on supermarkets' pricing decisions. We develop a model that integrates them. It has three core assumptions: consumers are basket shoppers, each consumer has a preferred store, and consumers cannot observe the full set of prices freely before entering the store. The phenomena listed above are all outcomes of the model.
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1. Introduction

The behavior of food and agricultural commodity prices exhibits several empirical regularities, including asymmetric price transmission, farmgate prices that are much more volatile than food prices, relatively low correlation between farmgate and food retail prices, and supermarket pricing behaviors including promotions, loss-leaders, and unadvertised sales. These topics are of particular interest to economists because these empirical regularities are inconsistent with predictions derived from perfect competition or traditional market power models (e.g., Li et al. 2006). There are explanations in the economic literature, often based on complex dynamic models. However, most of these explanations address one or in some cases two of these observations. Broadly speaking, these analyses focus on either the behavior of farmgate and retail prices or on supermarkets' pricing decisions. Our goal is to develop the simplest possible model that integrates these two strands of the literature and derive jointly the largest number possible of these observed empirical regularities.

Three core assumptions underlie our approach. First, consumers are basket shoppers. Second, each consumer has a preferred store. Third, consumers cannot observe the full set of prices freely before entering the store although they do observe prices for advertised goods and obtain other information provided by supermarkets. As we will demonstrate, empirical regularities that are not explained easily by conventional models are natural outcomes of this approach. Furthermore, the model allows us to discuss the impact of supermarket practices on agricultural and food price distribution.

Section 2 provides a brief description and literature review of the empirical regularities we aim to explain with our analysis, section 3 describes the model, sections 4 and 5 examines the main characteristics of the market outcomes from the behavioral model, section 6 discusses welfare implications, and section 7 concludes.

2. Empirical regularities in agricultural and food prices distributions

The classic market power approach cannot explain the behavior of agricultural commodity and food prices. Consider an oligopolistic, multi-product retailing firm buying *n* products from procurement markets and selling them to consumers. For each product sold, supermarkets adopt a fixed proportion technology converting one unit of input into one unit of output. There are two costs, the cost of the base input, and an additional cost of retail services for the product which is a constant-return-to-scale function of the firm's output quantity (q). The firm's cost function for good h is

$$C = \sum_{h=1}^{n}(f_h \cdot q_h) + \sum_{h=1}^{n}(mc_h \cdot q_h) \tag{1}$$

where c is the total cost of production, f_h is the input price in the procurement market for good h and mc_h is the constant marginal cost for retail services. Equation (1) assumes there are no economies or diseconomies of scope. Under these assumptions a typical static approach derives the following implicit pricing rule:

$$p_i + \sum_{j=1}^{n}\sum_{h=1}^{n} p_j \frac{q_j}{q_i}\frac{\xi_{hi}}{\varepsilon_{jh}} = mc + f_i + \sum_{k=1}^{n} f_k \frac{q_j}{q_i}\frac{\theta_{ki}}{\eta_{kk}}, \tag{2}$$

where p is the output price, q is quantity, mc is marginal retail cost, f is the input price, ε_{jh} is the elasticity of consumer demand for good j with respect to the price of good h, η_{kk} is input supply elasticity of good k. The behavioral parameters ξ and θ describe the degree of rivalry in the consumer and procurement market, respectively and range between 0 and 1 (e.g. Schroeter and Azzam 1990).

Equation (2) cannot explain the empirical regularities in price distributions that are the main topic of this paper: the process is symmetric, the variance of consumer and input prices does not exhibit volatility or rigidity, and there are no sales (advertised or unadvertised) or loss leaders. To explain these features, agricultural economists have developed a wide array of models and assumptions. The remainder of this section provides a brief summary of these contributions along with working definitions of the empirical regularities that are explained by our model.

Asymmetric price transmission has been the subject of considerable attention in agricultural economics (Meyer and von Cramon-Taubadel 2004). We consider a price distribution asymmetric if the expected variation in price conditional on a positive change in an exogenous shifter is different in absolute value from the expectation conditional on a negative change of the same magnitude, i.e. $|E(\Delta p|\Delta s=|\psi|)| \neq |E(\Delta p|\Delta s=-|\psi|)|$, where Δp is the price change, Δs is the change in the shifter and ψ is the magnitude of the variation. Previous literature provides many possible explanations (Bakucs, Fałkowski and Ferto 2013), including market power (e.g., McCorriston, Morgan and Rayner 1998, 2001), asymmetric adjustment costs (e.g. capacity constraints), market share considerations (Ward 1982) and asymmetric information (e.g., Bailey and Brorsen 1989). In a dynamic framework, Azzam (1999) concluded that retail-price transmission asymmetry can arise from intertemporal optimizing behavior among spatially competitive retailers facing concave spatial demand.

Rigid (or sticky) prices are resistant to change, i.e., their reaction to changes in market conditions is either slower or smaller in magnitude than predicted by standard economic theory. We define a price distribution as "rigid" if its variance is lower than the one obtained from Equation (2). Previous literature provides several explanations for food and agricultural price rigidity including the existence and magnitude of menu costs in the retail industry (e.g., Dutta et al. 1999; Azzam 1999), the high incidence of indirect costs (Shonkwiler and Taylor 1987), the facilitation of collusion (Richards and Patterson 2005), legal liability and reputation (Levy et al. 1998), and psychological prices (Herrmann and Moeser 2006).

Agricultural commodity price volatility has been a core interest for agricultural economists for many decades (Miranda and Helberger 1988). The balance between consumption, available supply, and stocks is considered a key determinant of price volatility (e.g., Wright and Williams 1991). We define a price distribution as volatile if its unconditional variance is larger than the prediction from Equation (2).

***Farmgate and retail prices are not highly correlated*.** Li et al. (2006, p. 224) note "Retail price changes are at most loosely related to price changes for the farm commodity, and, thus, acquisition costs play a comparatively minor role in the retail pricing decision." Our model generates price distributions that are consistent with this remark; correlations between consumer and farmgate prices are lower than those predicted by Equation (2).

Sales are ubiquitous in retailing and have generated a large economic literature. Some contributions are particularly pertinent. Richards (2006) showed that multiproduct retailers could use sales to attract customers. Volpe (2012) discussed promotions as an alternative to price wars. Richards and Patterson (2005) derived sales within a tacit collusion framework.

We define a sale as a consumer price that is lower than expectations (for example, lower than the one from Equation (2)). Our analysis identifies two kinds of sales: promotions, which are temporary, advertised discounts, and (simple) sales, which are unadvertised discounts. A special case of promotion is the loss leader, which is a product that is sold for a price that is lower than its average cost of production. Our model uses an equilibrium concept similar to Richards (2006) to derive both types of sales and loss leaders without assuming collusion. Stores choose whether or not to utilize promotions heavily. Obviously, this choice affects price distributions. We simply model the pricing strategy announcement as information influencing consumers' price expectations. Thus, the optimal choice depends on how consumers build expectations regarding prices that are not advertised explicitly.

This brief review demonstrates the importance of our questions and shows that the regularities in price distribution are often addressed as independent topics. We now develop a simple theoretical model that is able to derive jointly and explain such regularities within a single framework, under a limited set of assumptions regarding consumer behavior.

3. A model of store-traffic competition.

Our model describes competition among M identical, independently operated supermarkets. For simplicity, we assume that retailers do not exert oligopsony power and that they sell all N products that consumers are willing to buy, and only those N products. The supermarket strategy set X is $X= \{A, F, P_F, P_{N\text{-}F}\}$, where $F \subseteq N$ is the set of products that the supermarket advertises, P_F is the price vector for those goods and $P_{N\text{-}F}$ is the price vector for the other $N\text{-}F$ goods. P_F is known to a consumer before choosing the store, while $P_{N\text{-}F}$ is revealed when the consumer goes to the store. A represents the information from the supermarket which consumers use when forming expectations regarding the prices of the N-F unadvertised goods. We refer to A as an "announcement" that the supermarket releases, such as adopting an every-day-low-prices strategy rather than emphasizing promotions. Consumers' set of available information I includes A and B which represents any other information that the consumer might use to build expectations. B is exogenous. Consumers' expected surplus $E(cs)$ is a function of I.

Consumers are basket shoppers and homogeneous except for their exogenous preferences over the set of stores. The marketing literature stresses the importance of basket shoppers who purchase from multiple categories (e.g., Manchanda et al. 1999). These consumers buy their entire baskets from the store that grants them the highest total surplus, regardless of the surplus from individual products (Bell and Lattin 1998). The existence of basket shoppers makes store traffic a key competitive element: stores compete to attract shoppers knowing that they will buy their entire baskets from it. We refer to this behavioral model as "store-traffic" competition (STC).

Consumer preferences over the set of stores are represented with a penalty function, $d(S)$. If S is the consumer's preferred store, then $d(S)= 0$. If S is the second best alternative, $d(S)= K$. For all other S, $d(S)>K$. We remain agnostic about the source of these preferences, and do not model them structurally. They could be a function of distance/transportation time, the quality of the shopping experience, specific store characteristics such as available parking, other considerations, or some combination of these factors.[1] Consumers are divided into M groups on the basis of their favorite store. We assume that the groups are of equal size. For ease of reference, we label the consumers for which $d(S_i)=0$ as “locals” to the ith supermarket and consumers for which $d(S_i)=K$ as “close neighbors”.

Each group is modeled by a representative consumer who maximizes utility by choosing $\boldsymbol{q}$, the nx1 quantity vector of the shopping basket, and the store (S) under the constraint that all goods must be bought at the same store. When information is complete and perfect, consumers can compare prices for all goods across stores freely and choose their shopping location accordingly, so S and $\boldsymbol{q}$ are jointly determined. However, this assumption is rather unrealistic, as it is unlikely that consumers visit all available stores to collect information before shopping. Therefore, we assume that prices are not observable unless advertised by the store, so the consumer’s store choice is based on advertised prices and expectations regarding unadvertised prices formed using advertised prices and other information provided by the store (A). The risk-neutral consumer’s objective function g_E is

$$g_E = E\left(\sum_{h=1}^{N} cs_h\left(P^S\right)\middle| A\right) - d(S) \tag{3}$$

where cs indicates consumer surplus, the subscript h refers to the h-th product in a basket composed of N goods, and P^S is the vector of prices at store S. The surplus expectation is conditional to the information provided by the supermarket announcement and any prices advertised by the supermarket. Given these assumptions, consumers’ choice of $\boldsymbol{q}$ and S is sequential. First, they choose where to shop, based on advertising, supermarket announcements, and conditional price expectations, and then they set $\boldsymbol{q}$ based on the prices in their chosen stores. If they cannot obtain surplus above their reservation surplus by purchasing any amount of any good(s) then they do not purchase at all.

Similarly, the supermarket’s profit maximization problem can be represented in a multi-stage model. In stage 1 it decides which goods are in the set F of advertised goods and the content of the announcement A. In stage 2 it sets the price vector $\boldsymbol{P_F}$ of the advertised products under a *store traffic constraint*: consumers’ expected total surplus from selecting a supermarket must be at least equal to their expected total surplus from their best alternative. In stage 3, once any uncertainty regarding supply and demand is realized, it sets the prices on the N-F unadvertised goods subject to a *customer satisfaction* constraint:

$$g = \sum_{h=1}^{N} cs_h\left(P^S\right) - d(S) \geq g_E \tag{4}$$

The consumer must obtain at least his expected total surplus, but prices of individual goods may differ from their expected prices. The three-stage model can be solved by backward induction.

3.1 *Stage 3: optimal pricing of unadvertised goods*.

In this stage, the supermarket chooses the prices of the N-F unadvertised goods to maximize profits, subject to the realization of shocks to supply and demand, the customer satisfaction constraint, and consumer expectations regarding the prices of unadvertised goods. The solution requires that the following equality holds for any pair of goods i and j

[1] The penalty function *d(S)* can be interpreted as a measure of consumer loyalty to the store.

[2] The result is similar to Bliss (1988), who derived the optimal pricing rule assuming a diagonal cross-

in the set of the *N-F* unadvertised products:

$$\left[1+\frac{\sum_{h=1}^{N}\left(p_h-f_h-mc_h\right)\varepsilon_{h,i}Z_{h,i}}{p_i}\right]\left(1-\Omega_i\right)^{-1}=\left[1+\frac{\sum_{h=1}^{N}\left(p_h-f_h-mc_h\right)\varepsilon_{h,j}Z_{h,j}}{p_j}\right]\left(1-\Omega_j\right)^{-1},\text{[2]}\qquad(5)$$

where $\Omega_l=\sum_{k\neq l}^{N}\frac{\partial cs_k}{\partial p_l}/q_l$ is the summation of the derivatives of consumer surplus with respect to the price of good *l* across all goods except *l*, with *l=i,j*. Each side of the equation is composed of two groups of terms. $1+\frac{\sum_{h=1}^{N}\left(p_h-f_h-mc_h\right)\varepsilon_{h,i}Z_{h,i}}{p_i}=1+WGL_i$ is the derivative of profits with respect to price of good *i*, and it is equal to one plus the generalized weighted Lerner index (WGL_i). $-(1-\Omega_i)$ is the derivative of the constraint with respect to the price of good *i*. The interpretation of equation (5) is straightforward. It states that at the solution of the optimization problem, the slope of the firm's isoprofit curve must be equal to the slope of the consumer's isobenefit line, which is the line that shows all combination of prices that provide the total consumer surplus. The comparison of equation (1) and equation (5) shows that under store-traffic competition the optimal relative prices are different with respect to the prediction from equation (2).

The solution of the system of *N-F*+1 variables and *N-F*+1 equations composed of equations (4) and (5) gives the optimal prices for any given expected total consumer surplus and any vector $\boldsymbol{P_F}$. Obtaining a closed form solution requires assumptions on the functional forms of demand and supply relationships and may require numerical techniques.

3.2 Stage 2: promotions

In stage 2 the supermarket compete for store traffic by choosing the advertised goods and setting their prices to attract customers after observing the realizations of shocks to demand and supply. The supermarket's profit-maximizing choice can be conceptualized as one that equates the returns from two approaches: focusing on its local consumers (conservative), or lowering prices to attract neighboring ones also (aggressive). If a store chooses an aggressive strategy then it must lower the price of the *N*-good basket sufficiently to offset the penalty *K* incurred by neighboring consumers. Those consumers also have a local store, which can charge a price for the *N*-good basket that is higher than the aggressive store's price, and retain its local consumers. Given that response, the aggressive store does not obtain any returns from neighboring customers and sacrifices the revenues lost due to charging lower prices to its local consumers. In the symmetric pure strategy Nash equilibrium all supermarkets sell only to local customers, providing them with just enough surplus to ensure that an aggressive strategy is unprofitable for a neighboring store.

Formally, the stage 2 decision variables are *F*, the set of advertised products, and the vector of prices $\boldsymbol{P_F}$ for the *F* advertised products ($\boldsymbol{P_{N-F}}$ was derived in stage 3). The equilibrium conditions for the problem are:

$$\pi_i\left(F^c,\boldsymbol{P}_F^c\mid\boldsymbol{P}_{N-F}^c\right)=\pi_i\left(F^a,\boldsymbol{P}_F^a\mid\boldsymbol{P}_{N-F}^a\right),\qquad(6)$$

[2] The result is similar to Bliss (1988), who derived the optimal pricing rule assuming a diagonal cross-elasticity matrix and that retailers maximize profits subject to a constraint on consumers' indirect utility.

$$g_E\left(F^c, \boldsymbol{P}_F^c \mid \boldsymbol{P}_{N-F}^c\right) = g_E\left(F^a, \boldsymbol{P}_F^a \mid \boldsymbol{P}_{N-F}^a\right) - K \tag{6'}$$

with

$$\boldsymbol{P}_F^c, F^c = \arg\max\left\{\pi_i^c \mid g_E\left(\boldsymbol{P}^c\right) = g_E\left(\boldsymbol{P}^a\right) - K\right\} \tag{7}$$

$$\boldsymbol{P}_F^a, F^a = \arg\max\left\{\pi_i^a \mid g_E\left(\boldsymbol{P}^c\right) = g_E\left(\boldsymbol{P}^a\right) - K\right\} \tag{7'}$$

where $\boldsymbol{P}_F^c$ and $\boldsymbol{P}_F^a$ are, respectively, the *F*x1 advertised price vectors for the conservative and aggressive strategies, $\boldsymbol{P}_{F-N}^a$ and $\boldsymbol{P}_{N-F}^c$ are the corresponding *N-F*x1 price vectors for unadvertised goods from stage 3, and $\boldsymbol{P}^c$ and $\boldsymbol{P}^a$ are the Nx1 price vectors for the two strategies for all goods.

The economic interpretation of the equilibrium conditions is straightforward. Condition (6) states that the *i*th supermarket tries to attract close neighbor customers as long as it is profitable to do so. Condition (6') states that the *i*th supermarket must provide its local consumers with at least as much total surplus as an aggressive neighboring store does, net of the penalty *K*.

Conditions (7) and (7') imply that the relative prices of the *F* advertised goods are governed by a Ramsey pricing rule equivalent to the one governing the relative prices of the *N-F* unadvertised goods described in equation (5). The pricing decision that maximizes profits given condition (6') requires that the supermarket equates the product $\left(1+WGL_k\right)\left(1-\Omega_k\right)^{-1}$ across all products in the set *F.* Consistent with the literature, the choices of the set *F* and $\boldsymbol{P}_F$ are interdependent (e.g., Richards 2006; Loy and Weiss 2009).

3.3 Stage 1: optimal announcement.

In stage 1 each supermarket chooses the remaining element of its strategy: the information provided to consumers about the surplus they can obtain from their shopping (A). Supermarkets can release signals and messages to affect consumer expectations. *A* is released before the supermarkets observe the realization of demand and supply shocks.

The optimal announcement (A^*) for a supermarket and its closest neighbor must satisfy the following Nash equilibrium conditions, given that the prices of both advertised and unadvertised goods are set at the optimal level found in stages 2 and 3:

$$A^* = \arg\max\left\{\pi_i(A) \mid A_a = A_a^*\right\} \tag{8}$$

where A_a is the announcement of the closest competitor and A^*_a indicates the closest competitor's best response.

A pair of strategies satisfying conditions (4), (5), (6), (6'), (7), (7') and (8) is a solution of the store-traffic competition model. The numerical simulation in section 4 provides an example of equilibrium under a STC model.

4. Implications for agricultural and food price distributions

This section describes the properties of the agricultural and food price distributions under a STC model and compares them to those obtained from Equation (2) using simulation analysis. In order to simplify the discussion by eliminating the potentially confounding effects of cross-good relationships, we assume that consumer demand and farmer supply are linear and have diagonal cross-elasticity matrices (no complements or substitutes). We normalize *mc* to 0. Under these assumptions, Equation (2) simplifies to a standard Cournot-oligopoly pricing equation

$$\frac{p_i - f_i}{p_i}\varepsilon_i = \theta_i, \tag{2'}$$

and Equation (5) simplifies to

$$\frac{p_i - f_i}{p_i} \varepsilon_i = \frac{p_j - f_j}{p_j} \varepsilon_j. \qquad (5')$$

Comparing the two expressions, in the absence of cross-good relationships Cournot oligopoly pricing is independent for goods *i* and *j* while STC pricing adjusts margins based on a Ramsey pricing rule.

We limit our simulation to three goods (X, Y and Z). The consumer demand and inverse farmer supply functions that the supermarket faces are $Q_x = 20 - P_x + \beta_x$, $f_x = Q_x - 1 + \alpha_x$. $Q_y = 15 - 2P_y + \beta_y$, $f_y = 2Q_y + 1 + \alpha_y$, $Q_z = 25 - P_z + \beta_z$, and $f_z = 3Q_z + \alpha_z$ where Q is quantity, β_i and α_i are uniform random variables that are i.i.d. as U(-1,1), and P and f are consumer and farmgate prices. The simulation includes 100,000 replications of simultaneous random shocks to the intercepts of the six demand and supply functions. The penalty parameter K=3.817, or 5% of the consumer surplus from perfect competition.

Supermarkets advertise the price of exactly one product each period. The choice of the advertised product and its price maximizes profits. The consumer information set I includes the supermarket announcement (A) and the mean of the price distributions conditional on A, which means that consumers cannot observe the realizations of the exogenous supply and demand shocks affecting the αs and βs. A represents the mark-up on the unadvertised goods. The smaller is A, the larger is the mark-up and the lower the level of surplus the consumer expects. When A=1, the consumer anticipates the monopoly mark-up on the unadvertised goods. For computational purposes, the relationship between A and the expected mark-up is modeled as the mark-up from A symmetric firms engaging in Cournot competition, where A is allowed to be continuous and not limited to integers. A is the same for all unadvertised goods and is chosen by the firm before the realizations of the αs and βs are revealed.[3] A grid search showed that A=8 maximizes the supermarket's expected profits given the values of K and other parameters. Consumer expectations are calculated accordingly.

We compare the empirical distributions obtained from the STC model to the values obtained from a symmetric Cournot oligopoly model (SCO) providing exactly the same profit level.[4] The expected consumer prices (p_x, p_y and p_z) and demand and supply elasticities (ε and η respectively) at the STC equilibrium are $E(p_X) = 10.029$, $E(\varepsilon_X) = -1.005$, $E(\eta_X) = 0.899$, $E(p_Y) = 6.236$, $E(\varepsilon_Y) = -4.934$, $E(\eta_Y) = 1.198$, $E(p_Z) = 19.062$, $E(\varepsilon_Z) = -3.210$, and $E(\eta_Z) = 1.000$.

Table 1 reports the summary statistics of prices, price-cost margins (pcm), quantities, supermarket's profits (π), total consumer surplus (Σcs), producer surplus (ps) and total social welfare (sw) for the STC and the SCO distributions. The table reports also τ, the probability that the advertised good is perceived by consumer as a promotion (i.e., the promotion constraint (7) is binding or satisfied with equality), ρ, the probability that the advertised good is a loss leader, and φ the probability of having a sale on an unadvertised good.

The STC price distributions follow an endogenous regime-switching process. There are three possible regimes depending on which product is advertised (X, Y or Z). In each regime, the prices of the unadvertised goods are determined according to equations (4') and (5') and the price of the advertised good is derived from equations (6) and (6') and

[3] The assumptions enable us to keep consumer expectations constant across replications (as they do not depend on α and β), reducing the computational burden considerably.

[4] The behavioral parameters $_i$ from equation (2') equal .128 for all products (equivalent to 7.8 symmetric firms). This value was set so that total SCO profits equal total STC profits, and was identified using a grid search.

constraint (7). Thus, a change in regime triggers a change in the pricing rules. Table 1 compares the sample and conditional (regimes 1, 2 and 3) price means and standard deviations. Simple pairwise t-tests show that the conditional means of the variables are significantly different across regimes. This result is of particular importance for empirical studies, because estimations failing to control for the endogenous switching regimes might produce biased estimates. Y is advertised in 52.4% of cases, Z in 40.9%, and X in 6.7%. The STC model generates a pricing process where the choice of the advertised product is endogenously determined, depending on market conditions.

Table 1: summary statistics

	Unconditional (Total sample: 100,000 obs.)				Regime 1 (X is advertised: 6,666 obs.)				Regime 2 (Y is advertised: 52,440 obs.)				Regime 3 (Z is advertised: 40,894 obs.)			
	STC		SCO		STC		SCO		STC		SCO		STC		SCO	
	mean	st dev	mean	s. dev	mean	s. dev	mean	s. dev	mean	s. dev	mean	s. dev	mean	s. dev	mean	s. dev
p_X	10.029	0.166	10.130	0.410	10.114	0.013	10.688	0.207	9.968	0.203	9.981	0.404	10.094	0.067	10.229	0.325
f_X	8.969	0.822	8.868	0.410	10.002	0.409	9.428	0.205	8.732	0.860	8.718	0.404	9.105	0.641	8.970	0.324
pcm_X	1.060	0.858	1.261	0.049	0.112	0.407	1.259	0.034	1.236	0.954	1.263	0.048	0.989	0.643	1.260	0.052
q_X	9.972	0.590	9.872	0.382	10.431	0.359	9.858	0.265	9.896	0.614	9.883	0.372	9.995	0.551	9.860	0.410
p_Y	6.236	0.198	6.232	0.259	6.071	0.181	6.042	0.175	6.189	0.081	6.179	0.234	6.323	0.259	6.331	0.263
f_Y	6.052	0.731	6.070	0.259	5.762	0.221	5.881	0.177	5.974	0.955	6.017	0.234	6.199	0.290	6.169	0.264
pcm_Y	0.184	0.667	0.162	0.016	0.310	0.180	0.161	0.016	0.215	0.912	0.162	0.016	0.124	0.086	0.162	0.016
q_Y	2.525	0.377	2.534	0.251	2.458	0.282	2.517	0.252	2.514	0.453	2.535	0.256	2.551	0.263	2.536	0.245
p_Z	19.062	0.277	18.943	0.460	19.006	0.076	18.845	0.247	19.184	0.332	19.186	0.446	18.915	0.068	18.647	0.298
f_Z	17.811	1.167	18.169	0.449	17.591	0.855	18.075	0.237	18.412	0.868	18.405	0.436	17.077	1.111	17.882	0.291
pcm_Z	1.251	1.003	0.774	0.025	1.416	0.824	0.769	0.026	0.772	0.631	0.781	0.024	1.838	1.094	0.765	0.024
q_Z	5.937	0.387	6.056	0.198	5.861	0.345	6.023	0.201	6.113	0.299	6.111	0.188	5.723	0.381	5.991	0.187
π	17.574	11.236	17.574	1.014	9.880	4.946	17.472	0.742	16.556	12.941	17.687	0.980	20.133	8.513	17.447	1.076
Σcs	69.223	6.710	68.777	3.967	73.235	3.888	68.378	2.902	69.516	7.289	69.217	3.834	68.193	5.976	68.278	4.212
ps_X	49.226	5.896	48.128	3.395	54.320	3.623	48.472	2.454	48.317	6.171	48.067	3.283	49.561	5.350	48.151	3.654
ps_Y	6.518	1.963	6.484	1.276	6.120	1.375	6.401	1.261	6.523	2.379	6.490	1.296	6.575	1.352	6.489	1.250
ps_Z	53.009	6.818	54.989	3.516	51.628	5.977	54.391	3.543	56.118	5.388	55.998	3.385	49.248	6.616	53.794	3.270
sw	195.550	9.843	195.950	9.664	195.180	7.930	195.110	7.829	197.030	9.551	197.460	9.319	193.710	10.173	194.160	10.038
τ	0.249	0.433			0.108	0.311			0.321	0.467			0.181	0.385		
ρ	0.243	0.429			0.416	0.493			0.362	0.481			0.063	0.242		
φ	0.624	0.484			0.291	0.454			0.573	0.495			0.745	0.436		

4.1 Promotions, sales and loss leaders.

The STC model predicts promotions because competition among retailers can drive the price of the advertised good below consumer's expectations (constraint (7) holds with strict inequality). Table 1 reports that promotions occurred in 24.9% of cases and they are more likely to occur when Y is advertised. The simulation shows that the STC model can derive a price distribution where the frequency and the depth of the promotions vary across products and are endogenously determined, depending on market conditions.

Loss leaders emerge in the STC model. Competition for store traffic can drive the price of the advertised good below the farmgate price. In our simulation, the supermarket offered loss-leader promotions in 24.3% of cases. The probability τ of having a loss leader conditional on being advertised is higher for X and Y (being equal to .416 and .362) than for Z (.108).

The model predicts in-store unadvertised discount (sales). We define such practice as the occurrence of an unadvertised price that is lower than the corresponding SCO price. This definition implies that the sale is a decrease in consumer price p_i for an unadvertised good that is not due to changes in the product's cost and that is not observable by the consumers before entering the store. Table 1 reports that the unconditional probability of having an unadvertised sale (i.e., a STC price lower than the SCO price for an unadvertised good) was .624. The conditional probability is significantly higher under regime 3 (.745) and 1 (.573) than under regime 1 (.291). Unlike promotions, unadvertised sales are derived from the customer satisfaction constraint (4'), not from the store traffic one (6'). Constraint (4') requires that any variation in the price of l_1 must be compensated by a variation of opposite sign in the price of other goods. The first order approximation of constraint implies that:

$$\sum_{l=1}^{N-F} \Delta p_l q_l^0 = 0, \qquad (4'')$$

where Δp_l is the change in price of good l and $q^0{}_l$ is the traded quantity before the change in p_l. Equation (4'') shows that the slope of the isobenefit curve at the equilibrium is equal to the slope of the isoexpenditure curve. This implies that for small variations in prices the supermarket keeps consumer expenditure constant. In general, as long as the isobenefit is convex, constraint (4') implies that an increase (decrease) in the price of one good l_1 requires a decrease (increase) in the price of at least another good l_2, although total expenditure might increase for large variations. This effect on the price of l_2 is determined by the effect of the constraint alone.

4.2 *Consumer price rigidity.*

Because equation (5) must hold for all goods that are not on sale, a shock affecting the WGL for good l_1 requires that all other prices must be adjusted. The combination of equations (5) and (4') prevents supermarket from following the oligopoly pricing rule from Equation (2). Because the consumer must be compensated, the marginal benefit of each price change is lower in a STC model than under a SCO. Therefore STC prices are less volatile than under a SCO. Equalities (5) and (4'') can be used to derive price rigidity without invoking pricing or menu costs. The numerical simulation confirms this result. F-tests on the results from Table 1 show that the unconditional variance of farmgate and consumer prices are significantly lower under the STC model than under the SCO process at the 99% confidence level.[5]

Intuitively, consider the case of a typical oligopolist facing an exogenous increase in marginal cost of good l_1. The shock triggers a change in consumer prices of the good and its complements and substitutes such that equation (2') is preserved for all goods. A supermarket following the STC model cannot follow the same pricing rule. The increase in l_1 price must be compensated by a decrease in the price of other goods such that consumer expenditure is (approximately) constant. Ceteris paribus, the compensating sales reduce the WGL of the other goods below oligopoly level. Consequently, equation (5) requires that the price increase of good l_1 is lower than under the unconstrained model.

4.3 Farmgate price volatility.

Farmgate price volatility is a logical consequence of consumer price rigidity. If supermarkets cannot freely adjust prices, exogenous shocks cause variations in equilibrium quantity that are larger than those predicted by Equation (2). Farmgate prices are subject to larger-than-expected variations to ensure market clearing. The numerical simulation supports this conclusion. The unconditional variances of farmgate prices are significantly higher under the STC model than under the SCO process at 99% confidence level.

4.4 Low correlation between farmgate and consumer prices.

The model predicts low correlation between farmgate and consumer prices. Table 2 reports the pairwise correlation indices and shows that the values for the STC model are lower than the ones from the SCO model.

[5] The test statistic is the ratio between the variances of CD prices and STC prices. The statistic follows a F(N-1,N-1) distribution where N is the number of replications.

Table 2: Pairwise correlations between consumer and farmgate price.

	Unconditional		Regime 1		Regime 2		Regime 3	
	STC	C5	STC	C5	STC	C5	STC	C5
p_X, f_X	-.118	.993	.167	.987	-.371	.993	.033	.987
p_Y, f_Y	.444	.998	.616	.996	-.563	.998	.957	.998
p_Z, f_Z	.668	.999	.440	.995	.809	.999	.281	.997

4.4 Asymmetric price shock transmission.

Exogenous supply or demand shocks affect price distribution. Shock transmission under a Cournot model has two fundamental characteristics: it is perfectly symmetric and has a block-diagonal transmission matrix (i.e., a shock in the demand or supply for one good affects only the price of the good and its complements and substitutes). The simulation shows that the STC model can generate price distributions without these properties. Table 3 reports the expected changes in consumer price ($E(\Delta p_i)$) or farmgate price ($E(\Delta f_i)$) due to a unit shock in demand or supply shifters for the three goods ($\Delta\beta_i$ and $\Delta\alpha_i$, respectively) and shows that price distributions under the STC model are asymmetric.

Table 3: Asymmetric price shock transmission

	$\Delta\alpha_X$=-1	$\Delta\alpha_X$=1	$\Delta\alpha_Y$=-1	$\Delta\alpha_Y$=1	$\Delta\alpha_Z$=-1	$\Delta\alpha_Z$=1	$\Delta\beta_X$=-1	$\Delta\beta_X$=1	$\Delta\beta_Y$=-1	$\Delta\beta_Y$=1	$\Delta\beta_Z$=-1	$\Delta\beta_Z$=1
$E(\Delta p_X)$	-.024	.016	.024	-.029	.088	-.093	-.026	.016	.040	-.060	.162	-.495
$E(\Delta f_X)$	-.977	.984	-.025	.028	-.089	.092	-.974	.983	-.040	.059	-.162	.494
$E(\Delta p_Y)$	-.003	-.009	-.135	.143	.006	-.006	-.001	-.006	-.309	.291	-.017	-.045
$E(\Delta f_Y)$	.011	.035	-.459	.427	-.023	.025	.005	.025	-.764	.838	.068	.178
$E(\Delta p_Z)$	.038	-.008	.003	-.011	-.163	.158	.036	-.012	.008	-.039	-.311	.871
$E(\Delta f_Z)$	-.112	.027	-.011	.030	-.511	.524	-.108	.038	-.026	.116	-2.066	3.386
$E(\Delta\pi)$	10.419	-10.110	1.563	-1.534	3.971	-4.072	8.329	-10.043	1.819	-3.910	10.963	-22.960
$E(\Delta\Sigma cs)$	.003	-.065	.086	.007	.106	-.005	-9.453	10.396	-.887	1.443	-5.366	11.647
$E(\Delta ps_X)$	-1.267	.332	-.243	.279	-.865	.921	-9.228	10.279	-.401	.585	-1.546	4.891
$E(\Delta ps_Y)$	.077	.070	1.421	-1.355	-.077	.086	.050	.043	-1.728	2.426	.187	.580
$E(\Delta ps_Z)$	-.750	.255	-.078	.204	2.472	-2.840	-.711	.321	-.165	.752	-11.601	19.834
$E(\Delta p(R1))$	-.040	.194	.029	-.033	-.003	-.003	-.042	.185	.086	-.064	-.107	-.027
$E(\Delta p(R2))$	.319	-.170	.079	-.090	-.103	.124	.230	-.185	-.050	-.341	.009	.619
$E(\Delta p(R3))$	-.279	-.024	-.108	.123	.106	-.121	-.188	.000	-.037	.405	.098	-.592
$E(\Delta\tau)$	.064	-.135	.119	-.115	.056	-.023	.074	-.123	.574	.045	.283	-.165
$E(\Delta\rho)$	.126	.137	-.097	.091	-.057	.058	.086	.132	-.205	.146	-.011	.314
$E(\Delta\varphi)$	-.468	.123	.011	.009	-.023	.041	-.426	.156	-.117	.209	-.006	.404

The asymmetry is due to the endogeneity of the pricing regimes. Table 3 shows that an exogenous shock change the probability of each regime ($E(\Delta p(Ri))$), of having promotions ($E(\Delta\tau)$) or loss leaders ($E(\Delta\rho)$). Thus, the expected change in price reflects the switch in the pricing rule. A change in any exogenous shifter affects the prices of all goods, even if they are neither complements nor substitutes. This outcome is the direct consequence of equations (4') and (5') requiring that all prices are jointly determined. The result is of outmost importance for empirical studies. If the true data-generating process follows a STC model, any empirical price analysis including only the prices of close substitutes or complements as explanatory variables might suffer from an omitted variable bias.

5. Sensitivity analysis

The results reported in section 4 are conditional on the simulation parameters. In this section we provide a sensitivity analysis to show the robustness of the results to changes in the parameter values. The results of the sensitivity analysis can be interpreted as a comparative static exercise.

5.1 Changes in K.

The parameter *K* represents the penalty that the consumers must pay to shop at the close neighbor store. A decrease in *K* implies that, ceteris paribus, supermarket achieves lower profits because it must grant consumer a larger surplus to prevent defection. The exogenous value of *K* affects the optimal announcement A (and, consequently, price expectations): the larger is K, the higher are consumer price expectations. Table 4.a reports the effect of an exogenous change in K on the mean values of price distributions, social welfare and the regime probabilities. The numbers in parentheses express K as a percentage of the total consumer surplus under perfect competition.

As K increases, the value of A decreases, meaning that supermarkets commit to higher price levels, and consumers adjust expectations accordingly. Consequently, consumer prices increase with K, and farmgate prices decrease. Intuitively, the more supermarkets are differentiated, the more surplus they can extract from consumers. Consumer and producer surplus decrease with K while profits increase. As expected, total social welfare decreases with K. The value of K affects the probability of the pricing regimes. As K increases, the probability that Y is advertised decreases and the probability Z is advertised increases. The probability that X is advertised is a convex function of K. The more differentiated are the supermarkets, the less likely are loss leaders. Conversely, the probability of unadvertised sales increases.

Table 4: Sensitivity to K and to change in elasticity parameters

	4.a Changes in K						*4.b Changes in elasticity parameters*		
	1.909	3.817	7.635	11.452		$E(\varepsilon_X)$	-1.078	-1.005	0.943
	(2.5%)	(5%)	(10%)	(15%)		$E(\eta_X)$	1.000	0.899	0.806
A	20	8	4	2		A	5	8	14
$E(p_X)$	9.683	10.029	10.561	11.501		$E(p_X)$	10.377	10.029	9.707
$E(f_X)$	6.200	6.236	6.291	6.306		$E(p_Y)$	6.263	6.236	6.237
$E(p_Y)$	18.925	19.062	19.272	19.566		$E(p_Z)$	19.162	19.062	19.100
$E(f_Y)$	9.315	8.969	8.437	7.497		$E(f_X)$	9.621	8.969	8.291
$E(p_Z)$	6.198	6.052	5.832	5.775		$E(f_X)$	5.944	6.052	6.048
$E(f_Z)$	18.223	17.811	17.181	16.301		$E(f_X)$	17.512	17.811	17.699
p(R1)	.085	.067	.061	.016		*p(R1)*	0.413	0.067	0.117
p(R2)	.609	.524	.457	.437		*p(R2)*	0.310	0.524	0.534
p(R3)	.306	.409	.482	.548		*p(R3)*	0.277	0.409	0.349
$E(\pi)$	7.168	17.574	32.049	52.182		$E(\pi)$	16.622	17.574	22.431
$E(\Sigma cs)$	73.652	69.223	62.722	52.594		$E(\Sigma cs)$	65.187	69.223	72.258
$E(ps_X)$	52.744	49.226	44.057	35.623		$E(ps_X)$	46.396	49.226	50.979
$E(ps_Y)$	6.915	6.518	6.014	5.818		$E(ps_Y)$	6.232	6.518	6.520
$E(ps_Z)$	55.445	53.009	49.392	44.455		$E(ps_Z)$	51.364	53.009	52.343
E(sw)	195.924	195.550	194.230	190.670		E(sw)	185.800	195.550	204.530
τ	.314	.249	.020	.338		τ	0.094	0.067	0.159
ρ	.406	.243	.150	.108		ρ	0.222	0.524	0.237
φ	.543	.624	.661	.731		φ	0.634	0.409	0.201

5.2 Sensitivity to elasticity parameters. The numerical results of the simulation vary with changes in the value of elasticity parameters. Table 4.b compares results for selected values of the unconditional expectations of demand and supply elasticities of X at the STC equilibrium and shows that even small changes might determine non-negligible differences in the mean values. Nevertheless, the main characteristics of the price distributions, as discussed in the previous sections, are robust to changes in the parameters.

6. Welfare analysis.

Comparing the STC model, the SCO model, and a perfect competition model highlights important differences in social efficiency and welfare distribution. The STC model is less efficient than a SCO model resulting in the same supermarket profits. The comparative social loss is small (.2% of the STC total welfare) but statistically significant (Table 1). Thus, the deadweight loss from supermarket competition might be larger than predicted by standard oligopoly theory.

The social loss has two sources: the penalty for defecting from the preferred store (K) and imperfect information regarding the prices of unadvertised goods. Table 4 shows that as K decreases, the social welfare in the STC model increases. Reducing the penalty K

is socially efficient and increases producer and consumer surpluses, although it reduces supermarket profits. However, even for K=0 a deadweight loss remains due to consumers' imperfect information. If K=0 and consumers are perfectly informed then the deadweight loss vanishes.

Compared to the SCO model, the STC model transfers surplus from the producers of good Z to consumers and producers of Y and X. Z is the good with the steepest inverse supply curve, so the supermarket's ability to make advertising and pricing decisions jointly rather than for individual products has a relatively large effect on the producers of Z. In the baseline scenario the magnitude of the transfer is small but statistically significant. Producers of Z lose 3.6% of the surplus they could obtain from the SCO model. Consumers gain .6%, producers of X gain 2.3% and producers of Y gain .5% (Table 1). Thus, supermarket practices can affect the distribution of the gain from trade across suppliers.

7. Conclusion

This paper proposes a simple theoretical framework which explains empirical regularities in the behavior of agricultural and food prices. Competition among supermarkets is described using a multi-stage model. Supermarkets compete to attract store traffic by advertising sales over a subset of products in the consumers' baskets. In a second stage, supermarkets act as price-setting monopolists under the constraint that consumer surplus must be greater or equal to expectation.

The resulting price distribution follows an endogenous switching regime, where the prices of all goods in the consumer basket are jointly determined, including those that are neither complements nor substitutes. Our analysis shows that the regularities in the price distribution can be explained by general behavioral assumptions. The pricing model generates sales, loss leaders, food price rigidity, agricultural price volatility and asymmetric price shock transmission relying simply on three fundamental assumptions about consumer behavior: consumers are basket shoppers, cannot freely observe prices before choosing the store where to shop and have exogenous preferences over the set of stores.

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