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A model of pricing behavior: An econometric case study

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Abstract

Empirical pricing studies are scarce in the modern literature in spite of their obvious importance for understanding competition. The present study employs a structural model to identify deviations of individual pricing routines from the commonly assumed single-period profit maximization. It is applied to individual wholesale firms, because wholesale pricing has a decisive influence on the price formation in the entire economic system and because hardly any research exists in this area. The results show that wholesale firms operate in imperfectly competitive world markets providing a highly differentiated service package. Traders apply pricing rules consistent with cost mark-up pricing. The mark-up varies among traders with the extent to which a firm's pricing strategy deviates from full profit maximization. This divergent behavior is associated with firm size, the type of buyers served and other aspects of the wholesale service package.

JEL classification: C52; D43; L21; L81

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1. Introduction

Costs have played a controversial role in the pricing literature since early survey studies by Hall and Hitch (1939), Andrews (1949), Kaplan et al. (1958) and Lanzillotti

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(1958) identified cost mark-up as the dominating pricing strategy in manufacturing. The traditional response to this evidence has been to question the research method, to point at the suboptimality of pricing rules and to emphasise the lack of theory explaining the size and variability of the mark-up until, in the course of time, these pricing rules were believed to be a specific expression of imperfectly competitive behaviour (Machlup, 1946; Robinson, 1953; Silberston, 1970). See Lee and Irving-Lessman (1992) for a historical exposition of this controversy. Subsequent decades have periodically seen corresponding empirical analyses addressing the variability of mark-ups during the business cycle (Eckstein and Fromm, 1968; Nordhaus and Godley, 1972; Nordhaus, 1974; Gordon, 1975), the interactive impact of oligopolistic market structures (Blair, 1974; Eckstein, 1964; Eichner, 1973), and the incidence of pricing rules in other industries, notably retailing (Nooteboom, 1985; Nooteboom and Thurik, 1985; Bode et al., 1986; Nooteboom et al., 1988). However, empirical pricing analyses are a scarce topic in modern literature, despite the theoretical progress in explaining the mark-up (Day et al., 1971; Goldstein, 1986; Naish, 1990) and the obvious importance of pricing policies for competition in real world markets.

The scarcity is particularly felt for wholesale pricing which, for the central position of wholesale firms at the nexus of commodity, information and money flows, has a crucial influence on the price formation of the entire economic system (Beckman and Engle, 1949; Bucklin, 1972; Dalen and Thurik, 1995a). The present study enters the pricing debate with a study of a particular wholesale industry employing firm-level data of the Dutch exporting flower trade: a global industry largely controlled by Dutch exporters and – as far as the Netherlands are concerned – a major sector in a middle-sized open economy. Following Cubbin (1974, 1988) and Bode (1990), a particular type of monopolistic pricing model is assumed that enables us to assess the extent and variability of the mark-up of individual traders and to examine the degree to which wholesale pricing behaviour is in conformity with single-annum profit maximisation. It observes the intrinsic simultaneity of the economic conditions met by firms by estimating a structural-equations system of demand, trade costs and pricing behaviour, which is in line with early remarks by Koopmans (1947) and, in the industrial organisation context, by Cowling (1976) and Sawyer (1982), but rarely applied in practice. It also takes into account the differentiation of the wholesale service package by incorporating firm-specific choices with respect to trade assortment, export markets, buyers and transport modalities, into the demand-and-cost relations and by explicitly considering individual differences in pricing objectives. The latter variation has been recognised in the early literature (Lanzillotti, 1958; Haynes, 1964) as well as in the more recent studies (Jobber and Hooley, 1987; Samiee, 1987), but is seldom embedded in structural models. Moreover, the model assumes that wholesale firms have a discretion to set above normal trade margins, which follows their dominant presence in the international flower market. This typical feature relates our analysis to recent studies of imperfectly competitive behaviour in export markets by Yerger (1996), Gagnon and Knetter (1995) and Knetter (1989).

Our results support the assumption of imperfectly competitive export behaviour in that wholesalers are found to meet a downward sloping foreign demand with a significantly differentiated service product. Also, traders are found to apply cost mark-up strategies, which vary, however, with the extent to which firms depart from profit maximisation.

This variation is associated with firm-size and other characteristics of the firm. Small wholesale firms exhibit a strikingly heterogeneous behaviour: some are seen to over-price and others to under-price their wholesale services in a manner consistent with a sales strategy. Larger firms show a more uniform behaviour, though they still charge prices below the profit-maximising level.

The present paper is organised as follows. Section 2 explains the structure of the pricing model and elaborates the empirical specifications of the demand-and-cost relationship. Section 3 discusses the estimation results and Section 4 concludes the paper.

2. The pricing model

2.1. Structure of the model

Our pricing model, which draws from Cubbin (1974, 1983) and Bode (1990), begins with the basic assumption that the annual demand for wholesale services, q^{d}, is a decreasing function of the price of wholesale services, p_{w}:

$$q^{\mathrm{d}} = q^{\mathrm{d}}(p_{\mathrm{w}}; X^{\mathrm{d}}) \quad \partial q^{\mathrm{d}}/\partial p_{\mathrm{w}} < 0 \tag{1}$$

where X^{d} summarises company and market characteristics which affect the demand for wholesale services next to the price, such as the types of buyers served and the choice of export markets. The price of wholesale services, p_{w}, is defined as the difference between the average unit selling price p (measured as the ratio of the annual sales *value* and the annual sales *volume*) and the average unit purchasing price p_i (measured as the ratio of the annual purchasing *value* of flower sales and the annual sales *volume*). Moreover, the supply of wholesale services is assumed to be perfectly elastic, thus implying that the service capacity is always large enough to meet the annual demand. The assumed absence of excess demand situations (at least at an annual base) implies that the demand for wholesale services can be measured by the realised volume of wholesale services. As shown by several authors (see Dalen et al., 1990; Dalen and Thurik, 1991; Dalen, 1992), the latter can be satisfactorily proxied by the sales volume, q:

$$q^{\mathrm{d}} = q \tag{2}$$

The cost structure of flower exports is examined by dividing the total costs of trade into K cost categories and assuming that the level of each category of costs, C_k, depends on the scale of operations, q, and various firm-specific characteristics, X_k^{c}:

$$C_k = C_k(q; X_k^{\mathrm{c}}) \quad \partial q^{\mathrm{d}}/\partial p_{\mathrm{w}} < 0 \tag{3}$$

Traders are expected to exploit the information about the demand and cost structures for the benefit of their business aims. The pricing behaviour of flower exporters is assumed to satisfy:

$$\underset{p}{\mathrm{Max}}\ \Pi_{\lambda} = pq - \lambda\left(p_{iq} + \sum_{k=1}^{K} C_k(q; X_k^{\mathrm{c}})\right) \tag{4}$$

where λ is an indicator of the pricing behaviour applied by flower traders. If λ is equal to one, exporters aim at maximum annual net profits; if λ is equal to zero, traders strive for maximum annual sales; arbitrary positive values of λ represent deviations from the rigid single-annum optimisation behaviour implied by Eq. (4).[2] The maximisation of Π_λ with respect to the average annual selling price, p, yields the following optimal selling price for each flower exporter:

$$p = \frac{\eta}{1+\eta}\lambda\left(p_i + \sum_{k=1}^{K}\frac{\mathrm{d}C_k}{\mathrm{d}q}\right) \tag{5}$$

where η is the price elasticity of the flower demand.[3] Rearranging terms yields the following expression for the revealed annual pricing behaviour:

$$\lambda = \frac{p(1+1/\eta)}{p_i + \sum_{k=1}^{k}\mathrm{d}C_k/\mathrm{d}q} \tag{6}$$

The complete model consists of the demand Eq. (1), the K cost relationships Eq. (3) and the expression for the annually revealed pricing behaviour Eq. (6).

2.2. Empirical specifications

Wholesale traders operate in highly differentiated real world markets which implies that the general demand and cost structures Eqs. (1) and (3) should be enhanced to take the varying firm characteristics into account. Also, the definition of particular demand and cost equations allows one to make more specific inferences about the pricing behaviour implied by λ. Below, the empirical specification of these equations is dealt with in a rudimentary manner; a more detailed explanation of the underlying hypothesis may be found in Dalen and Thurik (1995b).

[2] Such deviating policies may have several backgrounds. If traders maximise a weighted average of annual revenues and profits (because of transaction-specific objectives), the maximand in (4) becomes $\Pi_\lambda=\nu pq-(1-\nu)(pq-c(q))$, and λ is equal to the weight profit maximising transactions, $\lambda=1-\nu$. If traders maximise annual sales under a binding target profits constraint π^0, the maximand in (4) becomes $\Pi_\lambda=pq+\nu(pq-c(q)-\pi^0)$, the optimal price level (5) becomes $p=(\eta/(1+\eta)))((\nu/(1+\nu))(p_i+mc)$, and λ is a function of the shadow costs of foregone revenues due to binding profit targets, $\lambda=\nu/(1+\nu)$. If traders maximise net profits under a binding sales restriction (for instance, if they choose not to grow beyond a certain capacity q^0), the maximand in (4) becomes $\Pi_\lambda=pq+\nu(q^0-q)$, the optimal price level (5) becomes $p=(\eta/1+\eta)(p_i+mc+\nu)$; and if the shadow price of the sales restriction is proportional to marginal trade costs, $\nu=\nu' mc$, λ coincides with $(1+\nu')$. Alternatively, λ may deviate from 0 or 1 because of traders lacking a consistent view of demand and cost conditions, which may easily occur as a result of a high degree of unpredictability of auction prices and exchange rates and of considerable demand fluctuations throughout the year.

[3] As Cubbin (1983), Cowling and Waterson, 1976, Clarke and Davies (1982), Clarke et al. (1984) and others point out, the elasticity of demand depends on a firm's own price elasticity η_f, the industry elasticity of demand η_i and the degree of apparent collusion among rival exporters α: $\eta=\alpha\eta_\mathrm{i}+(1-\alpha)\eta_\mathrm{f}$. The extent of apparent collusion varies with the availability and accuracy of information, the pricing behaviour of rival exporters and lags in the reaction of competitors to price cuts. We have chosen not to explicate a trader's relations with competing exporters or local suppliers in (4), since it adds little to the basic structure of the model and cannot be substantiated in the empirical analysis. The effect of variations in competition is represented in the empirical model through crude measures like the type of buyers served and the export markets supplied.

The demand for wholesale services is assumed to decrease exponentially with respect to the average annual price level of wholesale services:

$$q = \theta_1 \exp(-p_w/\theta_2) \quad \theta_1, \theta_2 > 0 \tag{7}$$

implying a price elasticity $\eta = -p/\theta_2$ and a constant additive mark-up θ_2 (see below). Wholesale merchants are expected to influence their demand conditions by offering a service package that is differentiated with respect to type of buyers served (*BU*), promotional activities (*PR*), trade assortment (*AS*), export markets (EX^d), market growth (Δq), and financial services (*DT*). These firm-specific characteristics enter the demand Eq. (7) via the elasticity parameter θ_2 and the shift factor θ_1 as shown in Table 1.

Trade costs are analysed by separately modelling labour costs, three types of transport costs and remaining costs. The explicit focus on labour and transport costs follows the importance of the associated services for the wholesale trade. Following Nooteboom (1980, 1982), Thurik (1986), Nooteboom (1987), Frenk et al. (1991), Dalen et al. (1990) and Dalen and Thurik (1991), labour costs are studied using a linear inhomogeneous labour relationship:

$$C_L = w_L L \tag{8}$$
$$L = \beta_0 + \beta_1 q$$

Table 1
Summary of the specification of firm-specific characteristics[a,b,c]

$$\theta_1 = \theta_{10}(BU_2 + BU_3 + \theta_{11}BU_1)PR^{\theta_{12}}$$

$$\theta_2 = \theta_{20}(AS_1 + \theta_{21}AS_2)(BU_2 + BU_3 + \theta_{22}BU_1)(EX_1^d + \theta_{23}EX_2^d + \theta_{24}EX_3^d)\exp(\theta_{25}\Delta q)DT^{\theta_{26}}$$

$$\beta_1 = \beta_{10}LQ^{\beta_{11}}DEX^{\beta_{12}}AUT^{\beta_{13}}(AS_1 + \beta_{14}AS_2)(BU_1 + BU_3 + \beta_{15}BU_2)(TR_1 + \beta_{16}TR_2 + \beta_{17}TR_3)$$

$$\tau_1 = \tau_{11}DIS^{\tau_{12}}(BU_1 + BU_3 + \tau_{13}BU_2)$$

$$\tau_2 = \tau_{21}DIS^{\tau_{22}}(AS_1 + \tau_{23}AS_2)$$

$$\tau_3 = \tau_{31}(AS_1 + \tau_{32}AS_2)(EX_1^t + \tau_{33}EX_2^t + \tau_{34}EX_3^t)$$

$$\gamma_1 = \gamma_{11}(AS_1 + \gamma_{12}AS_2)$$

[a] The influence of sales to mass retailers and other businesses (BU_3) is restricted to that of sales to florists (BU_2) in the case of demand and to that of sales to foreign wholesalers (BU_1) in the case of costs. The main reason to restrict the influence of this variable is its poor information content. Free estimation of the impact of this sales category on demand and costs has a disturbing effect on the estimation procedure – most likely due to an ill conditioned information matrix.

[b] Advertising efforts are generally taken to exclude potential entrants from the market, allowing incumbents to maintain prices above competitive levels. Following Comanor and Wilson (1967), Phillips (1976) and others, we measure these efforts by the absolute costs of acquisition activities rather than by the promotion-sales ratio. Moreover, promotional activities are represented in a multiplicative way to reflect their direct influence on demand.

[c] The rough classification of geographical export markets is not a major drawback. A previous study by Dalen and Thurik (1991) using a more detailed classification, shows that differences with respect to the effects of various European countries are negligible. The specification of export markets takes former West-Germany a benchmark, because of it's importance for Dutch exporters: Germany consumes about 40% of total exports.

where L denotes the labour volume (excluding truck drivers) in full-time equivalents; w_L the average annual wage rate and C_L the annual labour costs, excluding driver wages. The parameter β_0 is interpreted as the minimum amount of labour necessary to operate an export firm, and β_1 as the scale-independent part of labour intensity. The latter is supposed to vary from one trader to another as a result of differences in labour quality (*LQ*), assortment composition (*AS*), the dispersion of export markets (*DEX*), the degree of automation (*AUT*), the types of buyers served (*BU*) and the mode of delivery (*TR*), which are included in (8) via β_1 (see Table 1).

The costs of transportation are divided into the costs of shipments through transport firms (C_T) and the costs of one's own transportation which comprise driver wages (C_D) and other expenses for travelling, lodging, fuel and depreciation of vehicles (C_O). The associated cost structures are specified as follows:

$$\begin{array}{ll} C_D = w_D L_D & \text{if } TR_1 > 0 \\ L_D = \tau_{10} + \tau_1 TR_1 q & \text{if } TR_1 > 0 \\ C_O = \tau_{20} + \tau_2 TR_1 q & \text{if } TR_1 > 0 \\ C_T = \tau_{30} + \tau_3 TR_2 q & \text{if } TR_2 > 0 \end{array} \tag{9}$$

where L_D is the number of truck drivers and their mates in full-time equivalents, w_D the wage rate of drivers, and TR_1 and TR_2 the respective shares of sales shipped with one's own means and those through carriers. The linearity of the driver–costs relationship is assumed in analogy to the labour–costs equation. For the other two equations, experiments show that linearity is a good approximation. The parameters τ_{10} and τ_{20} are interpreted as the minimum number of truck drivers and the minimum amount of expenses required for self-transportation, given the initial decision to deliver orders with one's own vehicles and personnel. The intercept in the relationship for the costs of transport by carriers, τ_{30}, merely serves to represent a possible scale effect: a positive intercept may be evidence of costs associated with seeking and contracting carriers, while a negative intercept may be due to a minimum required service capacity to undertake world-wide export activities. Differences in unit transport costs are explained by differences in loading rates, tariffs, and distance which are represented through assortment (*AS*), buyers served (*BU*), annual distance covered by unit of sales (*DIS*), and export markets (EX^t); see Table 1.

The remaining costs, C_R, which cover expenses for housing, packing, depreciation and other types of costs, are assumed to be non-linearly related to the scale of export activities (following preliminary estimates of this relationship):

$$C_R = \gamma_0 + \gamma_1 q^{\gamma_2} \tag{10}$$

where γ_2 allows for an ultimate test on the linearity of the remaining costs relationship. The parameter γ_1 is extended to account for variations in assortment composition. Other sources of variation are not considered, because of the lack of adequate data and hypotheses.

Substituting the demand elasticity $\eta = -p/\theta_2$ into Eq. (5), inserting the expressions for the marginal trade costs derived from Eqs. (8)–(10), and solving for the selling price p, yields a convenient expression of the optimal annual price level:

$$p = \lambda(p_i + \beta_1 w_L + (\tau_1 w_D + \tau_2)TR_1 + \tau_3 TR_2 + \gamma_2 \gamma_1 q^{\gamma_2 - 1}) + \theta_2 \tag{11}$$

which shows that the annual price level emerges as a mark-up on average variable costs conditional on the pricing behaviour implied by λ and the non-linearity of the remaining costs given by γ_2-1. Alternatively, the optimal price condition may be written in terms of the underlying pricing behaviour as:

$$\lambda = \frac{p - \theta_2}{p_i + \mathrm{MC}} \tag{12}$$

where MC represents marginal costs.

3. Estimation method and results

3.1. Stochastic specification of the model

The stochastic specification of the model without the behavioural restriction is given as:

$$\begin{aligned} u_{\mathrm{q}} &= \ln q - \theta_1 + p_{\mathrm{w}}/\theta_2 \\ u_L &= C_L - w_L(\beta_0 + \beta_1 q) \\ u_{\mathrm{D}} &= C_{\mathrm{D}} - w_{\mathrm{D}}(\tau_{10} + \tau_1 TR_1 q) \quad && \text{if } TR_1 > 0 \\ u_{\mathrm{O}} &= C_{\mathrm{O}} - \tau_{20} - \tau_2 TR_1 q && \text{if } TR_1 > 0 \\ u_{\mathrm{T}} &= C_{\mathrm{T}} - \tau_{30} - \tau_3 TR_2 q && \text{if } TR_2 > 0 \\ u_{\mathrm{R}} &= C_{\mathrm{R}} - \gamma_0 - \gamma_1 q^{\gamma_2} \end{aligned} \tag{13}$$

where the disturbance vector $\boldsymbol{u}=(u_{\mathrm{q}}, u_L, u_{\mathrm{D}}, u_{\mathrm{O}}, u_{\mathrm{T}}, u_{\mathrm{R}})^{\mathrm{T}}$ is assumed to have a multivariate normal distribution with mean zero and covariance matrix $\boldsymbol{\Sigma}$. The likelihood function as well as the econometric problem arising from the conditional nature of the transport costs are dealt with in Appendix B. As it stands, model (13) can be estimated to explore the existence of demand and cost relations in this particular industry. However, if traders employ some sort of pricing policy covered by Eq. (4), more efficient use of the available information is made by incorporating the behavioural condition Eq. (6) into the model. In this present analysis, this has been done by assuming that the annually revealed pricing behaviour λ in Eq. (12) is normal-distributed[4] (with mean μ_λ and variance σ_λ^2). Characteristic for this approach is that pricing strategies are not restricted to one particular routine uniformly imposed to all exporters in the industry.[5] The discussion below subsequently deals with the results for the demand and cost relations (see Table 2), and the predicted pricing behaviour of flower traders (see Table 3).

[4] The model has also been estimated with the more plausible assumption of gamma-distributed λ's. The impact of this alternative assumption is moderate and largely confined to the demand equation. We, therefore, limit the discussion of the estimates to those obtained for the normal-distributed λ's.

[5] Alternatively, the optimal price condition might be reformulated (cf. Thurik and Koerts, 1985) as: $u_{\mathrm{p}} = p - \lambda(p_i + \beta_1 w_L + (\tau_1 w_{\mathrm{D}} + \tau_2)TR_1 + \tau_3 TR_2 + \gamma_2\gamma_1 q^{\gamma_2 - 1}) - \theta_2$, after which it is added to (13). Though straightforward, this approach is not adopted here, since it treats λ as a parameter fixed for all traders instead of as a stochastic variable reflecting variations in the annual optimisation schemes.

Table 2
Estimation results for the model with, and without, the pricing condition[a]

	Variable	without λ	With λ		Variable	without λ	With λ
	Labour costs, C_L (Nobs=123)				*Remaining costs, C_R (Nobs=123)*		
β_0	threshold labour	1.165	3.410	γ_0	threshold costs	−0.168	0.225
		(0.763)	(0.708)			(0.150)	(0.157)
β_{10}	average intensity	11.155	9.319	γ_{10}	average costs	1.160	0.755
		(0.811)	(0.769)			(0.164)	(0.189)
β_{11}	wage rate	−0.293	−0.566	γ_{11}	share potted plants	0.646	0.524
		(0.155)	(0.180)			(0.098)	(0.140)
β_{12}	dispersion market	−0.374	−0.492	γ_2	scale effect	1.003	1.178
		(0.065)	(0.076)			(0.084)	(0.163)
β_{13}	automation	0.008	−0.075	μ	mean residuals	0.010	0.017
		(0.054)	(0.061)				
β_{14}	share potted plants	0.239	0.056	σ^2	estimated variance	0.398	0.379
		(0.095)	(0.105)				
β_{15}	sales to retailers	1.660	1.723	ρ^2	squared correlation[b]	0.722	0.738
		(0.193)	(0.231)				
β_{16}	transport by carriers	1.309	1.269				
		(0.120)	(0.136)				
β_{17}	transport by buyers	0.568	0.512				
		(0.207)	(0.259)				
μ	mean residuals	0.008	0.013				
σ^2	estimated variance	0.107	0.101				
ρ^2	squared correlation[b]	0.869	0.883				
	Wage costs of drivers, C_D (Nobs=92)				*Demand for wholesale services, ln q (N_{obs}=123)*		
τ_{10}	threshold labour	0.471	0.664	θ_{10}	autonomous shift	2.470	2.280
		(0.325)	(0.319)			(0.400)	(0.610)
τ_{11}	average intensity	4.896	4.767	θ_{11}	sales to wholesalers	0.793	2.803
		(0.246)	(0.247)			(0.114)	(0.913)
τ_{12}	distance	0.662	0.644	θ_{12}	promotional activities	0.734	0.606
		(0.082)	(0.080)			(0.043)	(0.069)
τ_{13}	sales to retailers	1.710	1.465	θ_{20}	average elasticity	2.169	2.869
		(0.419)	(0.418)			(0.355)	(0.343)
μ	mean residuals	0.001	0.001	θ_{21}	share potted plants	1.589	0.577
						(0.547)	(0.076)

σ^2	estimated variance	0.008	0.009	θ_{22}	sales to wholesalers	2.500	0.609
						(0.697)	(0.082)
ρ^2	squared correlation[b]	0.915	0.914	θ_{23}	exports within Europe	2.029	1.098
						(0.431)	(0.096)
	Other costs of one's own transportation, C_O (Nobs=92)			θ_{24}	exports outside Europe	1.392	1.922
						(0.238)	(0.190)
τ_{20}	threshold costs	0.061	0.087	θ_{25}	export growth	−0.151	0.249
		(0.025)	(0.025)			(0.346)	(0.137)
τ_{21}	average costs	0.226	0.197	θ_{26}	debt term	−0.453	0.042
		(0.026)	(0.026)			(0.193)	(0.066)
τ_{22}	distance	0.591	0.665	μ_λ	mean residuals	−0.006	0.009
		(0.135)	(0.148)				
τ_{23}	share potted plants	0.820	0.847	σ^2	estimated variance	0.212	0.242
		(0.361)	(0.426)				
μ	mean residuals	0.003	0.002	ρ^2	squared correlation[b]	0.791	0.769
σ^2	estimated variance	0.021	0.021				
ρ^2	squared correlation[b]	0.678	0.679				
	Costs of shipment through carriers, C_T (Nobs=107)				*Pricing behaviour, λ (N_{obs}=123)*		
τ_{30}	threshold costs	0.123	0.157	μ_λ	mean λ	0.892	
		(0.051)	(0.051)				
τ_{31}	average costs	0.803	0.654	σ^2_λ	variance λ	0.029	
		(0.111)	(0.112)				
τ_{32}	share potted plants	0.651	0.577				
		(0.232)	(0.266)				
τ_{33}	exports to North America	1.750	2.480	L	likelihood value	−110.90	−396.55
		(0.550)	(0.780)				
τ_{34}	exports to the rest of the world	1.040	2.190	LRT	likelihood ratio test [c]	127.88	105.32
		(0.770)	(1.090)				
μ	mean residuals	0.031	0.039				
σ^2	estimated variance	0.176	0.174				
ρ^2	squared correlation[b]	0.533	0.540				

[a] Asymptotic standard errors are presented between parenthesis below the parameter estimates.

[b] The squared correlation coefficient refers to the Pearson correlation between the actual and the predicted values of the dependent variables.

[c] The LRT-statistics are used to test the hypothesis that $\boldsymbol{\Sigma}$ is diagonal or, alternatively, that the covariance between the equation errors are zero. They should be compared with a critical value from a χ^2 distribution with 15 (the number of covariances) degrees of freedom. At a 1% significance level, $\chi^2_{15,0.01} = 30.578$, and the diagonality of $\boldsymbol{\Sigma}$ is rejected in all three cases. The estimated $\boldsymbol{\Sigma}$ exhibits substantial correlations between the residuals of the relationships for the demand (ln q), labour costs (C_L), remaining costs (C_R) and the costs of shipments through carriers (C_T).

Table 3
Some characteristics of the predicted pricing indicator

Model	Min	Max	Mean	St. dev	Number of λ's	
					<0	>1
Without pricing condition	−2.729	1.255	0.246	0.735	22	5
Normal-distributed λ	0.207	1.301	0.892	0.172	0	33
Gamma-distributed λ	0.311	1.335	0.924	0.166	0	45

3.2. *Results for the demand and cost relationships*

The estimation results for the demand equation support the assumption of imperfectly competitive behaviour in export markets as advanced by Knetter (1989) and others. Merchants meet a positive, downward sloping and differentiated foreign demand for their services $(\hat{\theta}_{10}, \hat{\theta}_{20} > 0)$. The average price elasticity $-p/\theta_2$ is equal to -2.5 for the unrestricted model and -6.4 for the model with the normal-distributed pricing condition. Both outcomes are plausible: the latter corresponds with the implicit price elasticity for the German wholesale trade reported by Dalen et al. (1990); whereas the relatively low -2.5 may be attributed to the advantageous access of Dutch exporters to an abundant, high-quality and widely varied domestic flower supply embedded in a unique infrastructure. A closer look at the differentiating impact of the firm-specific demand conditions reveals that most parameter estimates of the model with the normal-distributed pricing condition are in accordance with our expectations, contrary to those of the unrestricted model. In particular, the shift factor θ_1 is found to be positively influenced by sales to foreign wholesalers and promotional activities $(\hat{\theta}_{11} > 1, \hat{\theta}_{12} > 0)$. Moreover, the price elasticity of the demand increases with sales to wholesalers $(\hat{\theta}_{21} < 1)$ and the marketing of potted plants $(\hat{\theta}_{22} < 1)$, whereas it decreases with the share of exports to regions other than Germany $(\hat{\theta}_{23} > 1, \hat{\theta}_{24} > 1)$, export growth $(\hat{\theta}_{25} > 0)$ and collection period $(\hat{\theta}_{26} > 0)$. The model with explicit reference to variations in pricing strategies is, therefore, to be preferred to the unrestricted model. This preference is maintained, despite the (slight) reduction in fit due to the incorporation of the price condition.

In addition, all cost categories reveal economies of scale as a result of threshold expenses. The minimum labour requirements for regular personnel are estimated at about three full-time employees $(\hat{\beta}_0 = 3.4)$ and for drivers at about a half full-time employee $(\hat{\tau}_{10} = 0.6)$. Similar threshold expenses exist for the other costs of one's own transportation $(\hat{\tau}_{20} = 0.087)$ and for the order delivery via carriers $(\hat{\tau}_{30} = 0.157)$, where the difference is due to the inclusion of costly air transport in the latter category. No additional scale effect is found for the remaining cost category $(\hat{\gamma}_2 \approx 1)$. Also, trade costs are significantly affected by a firm's choices with respect to assortment composition, the types of buyers and export markets served and the transport modalities adopted. For example, labour productivity is positively affected by the labour quality, the dispersion of export markets, and self-transporting buyers $(\hat{\beta}_{11}, \hat{\beta}_{12} < 0; \hat{\beta}_{17} < 1)$, while selling to retailers and subcontracting transport activities tend to raise the labour intensity $(\hat{\beta}_{15}, \hat{\beta}_{16} > 1)$.

3.3. Results for the pricing behaviour of flower exporters

Table 3 presents some characteristics of the distribution of the predicted pricing indicators that have been obtained by evaluating the right-hand side of the behavioural condition Eq. (12). It follows that the mean predicted pricing indicator differs significantly from both zero and one in all models considered, which implies that both sales maximisation and full profit maximisation are rejected as general characterisations of pricing behaviour in this particular wholesale industry.[6] Instead, a tendency is observed among flower exporters to give up annual net profits in return for a higher sales level. Clearly, the model with the normal-distributed pricing condition, showing an average λ equal to 0.892, is to be preferred over the unrestricted model: its inferences are robust to assumptions about the error structure, differ marginally from alternative distributional assumption, and imply plausible, non-negative predictions of pricing behaviour.

Furthermore, individual pricing indicators vary considerably from one trader to another. The majority of firms appears to charge prices at or below the annually profit maximising level, while a significant number of traders is seen to over-price. This variation is consistent with early survey findings described by Lanzillotti (1958), Haynes (1964) and Skinner (1970) among others, and may be viewed as supportive to Earl's (1991) plea for a more 'pluralistic' approach to pricing. More interesting, however, is the question whether this behavioural variation can be attributed to firm or market specific characteristics. Findings of Jobber and Hooley (1987) and Shipley (1981), for instance, suggest pricing objectives to depend on firm size and stage of market development. Small firms are more likely to pursue a profit maximising strategy than larger firms, while the development of markets from emergence to growth induces business orientation to shift from a sales strategy to profit maximising. We shall explore these claims by relating our pricing indicators to firm size and other characteristics.

First, predicted pricing indicators are found to be non-linearly related to firm size. Larger firms reveal a comparatively homogeneous pricing behaviour involving price levels slightly below the annual profit maximising level. Small firms, on the contrary, show a considerable heterogeneity in pricing strategies involving both over-pricing (λ>1) and under-pricing (λ<1) firms.[7] This contradicts previous findings which predict a profit maximising attitude among small firms and target strategies among larger firms. An explanation may be that neither Jobber and Hooley, nor Shipley, truly analyse small firms and that their small firms correspond with our larger firms. In any case, it is surprising to find that pricing policies of small firms are relatively heterogeneous and those of larger firms comparatively uniform though still diverging from annual profit maximisation. The diverging behaviour of small firms may be evidence of their active presence in relatively

[6] At first sight, this cannot be maintained for the behaviour of *individual* traders: the 95% prediction interval for individual pricing indicators based on the information in Table 3 is equal to (0.55, 1.23); and hardly affected by the inclusion or exclusion of the observation for which the prediction is made. However, this method is not appropriate since it disregards the fact that the pricing equation is part of a structural model. A more sophisticated approach would be to follow the procedures described by Amemiya (1989: 162*vv*) which is not pursued here in view of the prohibitively burdensome calculations involved.

[7] A cross tabulation of pricing indicators (with cutting points at 0.8 and 1.0) against firm size (with cutting point at 20 full-time employees) reveals a significant over-representation of small firms in the areas $\lambda \leq 0.8$ and $\lambda > 1.0$, and of larger firms in the area $0.8 < \lambda \leq 1.0$ ($\chi^2 = 14.594$, $p = 0.001$).

dynamic export markets or market segments, which induces some traders to adopt a sales strategy in order to penetrate new or existing markets and others to over-price their services because of higher expected future costs or the involvement in relatively risky transactions requiring high safety margins. Second, pricing objectives are seen to vary with the dimensions of the service capacity of wholesale firms. A short-cut regression of the pricing indicators on various firm-specific characteristics yields:

$$\lambda = \underset{(0.032)}{0.720} + \underset{(0.003)}{0.010L} - \underset{(0.041\times10^{-3})}{0.126\times10^{-3}L^2} + \underset{(0.052)}{0.115BU_2} - \underset{(0.066)}{0.026\Delta q} + \underset{(0.073)}{0.342EX_3^{\mathrm{d}}} + \underset{(0.041)}{0.046TR_2} \tag{14}$$

$$R^2 = 0.34,\ \hat{\sigma}^2 = 0.02,\ n = 123$$

where L is labour volume in full-time employees. These results re-emphasise the non-linear association between pricing behaviour and the size of the firm: the larger the firm, the more closely prices are set to the profit maximising level. The estimates further indicate that the relative weight of sales to small-sized, down-channel retailers (BU_2) and that of exports outside Europe (EX_3^{d}) increase the likelihood that firms charge profit maximising prices. This may reflect the ability of local wholesalers and mass retailers to exercise bargaining power and, similarly, the benefit for European buyers of a comparatively fierce competition. Firm growth (Δq) and transport via carriers (TR_2) have plausible but insignificant effects.

Summarising, the plausibility of the predicted pricing strategies and the comparative stability of the outcomes under different model assumptions indicate that the incorporation of the pricing condition in a structural model is essential to making reliable inferences about industry pricing. Considerable pricing variation exists among the firms in this specific industry. Small firms are particularly heterogeneous in this respect: some tend to over-price their wholesale activities, while others are seen to adopt a sales strategy. Pricing behaviour is more uniform for larger firms, yet still implying below profit maximising price levels. The behavioural variation is partly associated with firm size and dimensions of the service facility of exporting wholesale firms.

4. Concluding remarks

Our empirical analysis of wholesale pricing extends the familiar 'single-equation' approach of industrial performance studies by simultaneously considering relations for the demand and costs of wholesale activities, by endogenising the pricing behaviour of individual firms, and by incorporating the varying characteristics of individual businesses. The model is applied to individual firms in the Dutch exporting flower trade: the internationally most competitive industry in the Netherlands. Three findings are briefly elucidated. To begin with, firms are seen to meet a downward sloping foreign demand with a significantly differentiated wholesale service package. This finding favours the Cubbin (1983) formalisation of pricing in differentiated product markets and adds to the growing empirical evidence of competitive behaviour in export markets initiated by Knetter (1989). Also, the simultaneous influence of a firm's decisions regarding which buyers to serve, what assortment to carry and which mode of delivery to apply, on the demand and costs of wholesale intervention, emphasises the need of elaborate models to analyse pricing behaviour. Furthermore, the corroboration of linear, inhomogeneous cost equations is in accordance with findings in retailing (Nooteboom, 1987; Frenk et al., 1991) and again demonstrates the importance of threshold expenses as a major source of scale economies. Naturally, these threshold costs are particularly relevant for small firms. More importantly, firms are seen to employ pricing rules which are consistent with cost mark-up pricing. These rules vary among traders with the extent to which a firm's pricing strategy diverges from full profit maximisation. The majority of flower exporters tend to charge prices below the single-annum profit-maximising level in favour of higher annual revenues. Some, mostly small, traders are found to set prices above the profit-maximising level which causes both, lower sales revenues and lower profits. Also, firms serving large buyers, such as foreign distributors and mass retailers, and firms operating in nearby European markets reveal a tendency towards sales maximising strategies. Possible sources of this variation are: the availability of market and cost information, the occurrence of bargaining power, transaction-specific pricing policies, and the prevalence of longer-term business strategies which, in the short term, cause the observed price level to deviate from the single-period profit-maximisation level. The existence of these pricing differences is nothing new: it has been recorded in various survey studies since Hall and Hitch (1939). However, the derivation of such behavioural variation from a comprehensive structural model does provide a preferable alternative to the survey methodology. By explicitly specifying the economic conditions faced by firms and their response in terms of their particular service package, more precise and informative inferences about individual business pricing objectives are obtained.

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Appendix

Data

The Dutch flower trade fills a predominant role in the world flower market. Annual sales of cut-flowers and potted plants in 1994 amount to 6.7 billion Dfl (or about 3.7 billion US$; at auction prices), of which about 75% is exported and 25% sold domestically. The Dutch flower trade is involved in almost two-thirds of the world exports of cut-flowers and in more than a half of worldwide exports of potted plants. As a result, the Dutch cut-flower and potted-plant industries take hold of positions one and four in the Top-10 internationally most competitive industries in the Netherlands. The main causes of this economic success of the exporting flower trade are the Dutch auction system and infrastructure. Almost all flowers, domestically cultivated as well as imported, are offered for sale at one of the several auctions. The two largest auctions (each with an annual turnover of well over 2 billion Dfl or 1.1 billion US$; together controlling more than 80% of total auction sales) are situated close to one of Europe's largest airports (Schiphol, Amsterdam), and within a dense highway and railway network, which secures an efficient worldwide supply. Moreover, various high-tech product-refining firms and knowledge institutes contribute to the continuous supply of a high quality, widely varied assortment of flowers (figures obtained from the Flower Council of Holland, 1995 and the Dutch Floricultural Wholesale Board, 1995).

The Dutch distribution system is quite unique. In the US, for instance, there exist some wholesale markets (Los Angeles, Boston, Chicago, etc.), but no centrally located, trade co-ordinating and price forming institutes like the auction. Moreover, the US had a domestic production of cut-flowers and potted plants in 1993 equal to about 1.6 billion US$ at wholesale prices. Total imports of cut-flowers amounted to 0.37 billion US$ in 1993 (68% from Colombia, 13% from the Netherlands and 12% from Mexico), whereas total exports are only 0.04 billion US$ (70% to Canada, 15% to Japan and 3.7% to Eire). Total domestic consumption of cut-flowers and potted plants in 1993 amounts to 12.9 billion US$ at retail prices. Contrasted with a total supply (imports plus domestic production) of about 2 billion US$ at wholesale prices, this figure reveals the existence of extremely high distribution margins in the US.

The data used in the present study are obtained from the Dutch Floricultural Wholesale Board in Aalsmeer and the Wholesale Management Consultants in Rijswijk, the Netherlands. The data refer to individual Dutch flower exporters. The confidential nature of the data does not allow us to provide firm-level information. However, we are able to present an overview of the main numerical characteristics of the variables in Table 4.

Appendix B

Derivation of the likelihood functions

The parameters of the model are estimated by full information maximum likelihood. The disturbance vector $\boldsymbol{u}=(u_{\mathrm{q}}, u_L, u_{\mathrm{D}}, u_{\mathrm{O}}, u_{\mathrm{T}}, u_{\mathrm{R}})^{\mathrm{T}}$ is assumed to have a multivariate normal distribution with mean zero and covariance matrix Σ. An econometric problem occurs when traders exclusively exploit one type of transportation. In such cases, the relationship for the other type of transportation costs is no longer part of the model and the associated disturbances have to be excluded from $\boldsymbol{u}$. As a result, the likelihood function cannot be found by multiplying the densities of $\boldsymbol{u}$ across all observations.

To solve this problem, the observations are divided into three sets according to the way orders are delivered: T_0, observations with both types of transportation; T_1, observations with own transportation only; and T_2, observations with transportation entirely put out to transport firms. The number of observations in each set is given by N_0, N_1, and N_2, respectively, which sum up to the total number of observations, N. Moreover, the complete stochastic model is written as $\boldsymbol{u}_i=\boldsymbol{F}(\boldsymbol{y}_i; \boldsymbol{X}_i, \boldsymbol{\theta})$ for each observation i, where $\boldsymbol{y}_i$ is

Table 4
Numerical characteristics and descriptions of the variables used

Variable	Description	N [a]	Min	Max	Mean	Std. dev.
q	sales volume	123	0.015	4.857	1.222	1.009
TR_1q	exports by own transport means	92	0.061	3.378	0.975	0.776
TR_2q	exports by carriers	107	0.004	1.895	0.451	0.486
p	unit selling price	123	2.764	33.328	13.592	5.959
p_i	unit purchasing price	123	2.468	24.075	10.188	4.060
μ	gross trade margin	123	0.070	0.460	0.230	0.080
L	labour volume (in fte)	123	1.000	74.000	16.154	15.302
w_L	wage costs per employee	123	0.026	0.098	0.063	0.015
w_D	wage costs per driver	92	0.025	0.080	0.053	0.011
C_L	labour costs (excl. driver wages)	123	0.040	4.745	0.976	0.904
C_D	wages of chauffeurs	92	0.035	1.257	0.272	0.282
C_O	remaining own transportation costs	92	0.017	0.837	0.251	0.223
C_T	costs of transport by carriers	107	0.003	2.367	0.522	0.574
C_R	remaining operating costs	123	0.032	5.697	1.167	1.188
Δq	sales growth	123	−0.409	0.736	0.000	0.198
DT	annual debt term	123	0.224	2.461	1.000	0.435
LQ	share of wage costs	123	0.545	1.591	1.000	0.214
DEX	dispersion of export markets	123	0.175	1.766	1.000	0.448
AUT	share of depreciation costs	123	0.058	2.272	1.000	0.543
PR	expenses on promotional activities	123	0.020	5.309	1.000	1.138
DIS	Distance covered per unit sales	92	0.086	3.461	1.000	0.694
AS_1	percentage sales of cut-flowers	123	0.000	1.000	0.832	0.229
AS_2	percentage sales of potted-plants	123	0.000	1.000	0.168	0.229
BU_1	percentage sales to wholesalers	123	0.000	1.000	0.764	0.291
BU_2	percentage sales to retailers	123	0.000	1.000	0.176	0.266
BU_3	percentage sales to retail chains	123	0.000	0.950	0.060	0.146
TR_1^-	percentage transport by own means	92	0.100	1.000	0.709	0.235
TR_2^-	percentage transport by carriers	107	0.010	1.000	0.449	0.383
TR_1	percentage transport by own means	123	0.000	1.000	0.530	0.370
TR_2	percentage transport by carriers	123	0.000	1.000	0.391	0.388
TR_3	percentage transport by buyers	123	0.000	0.940	0.079	0.133
EX_1^t	percentage export within Europe	123	0.012	1.000	0.896	0.206
EX_2^t	percentage export to North America	123	0.000	0.919	0.077	0.168
EX_3^t	percentage export to rest of world	123	0.000	0.749	0.027	0.095
EX_1^d	percentage export to West Germany	123	0.000	1.000	0.429	0.381
EX_2^d	percentage export to rest of Europe	123	0.000	1.000	0.468	0.373
EX_3^d	percentage export outside Europe	123	0.000	0.988	0.104	0.206

[a] The number of observations involved in the calculations. The total number of firms is equal to 123; 92 exporters use their own means of transportation and 107 traders make use of transport firms.

the vector of endogenous variables, $\boldsymbol{X}_i$ the matrix of exogenous variables and $\boldsymbol{\theta}$ the parameter vector. In addition, the density function of $\boldsymbol{u}_i$ is represented by $f(\boldsymbol{u}_i;\ \boldsymbol{\Sigma})$. The joint density for all observations now follows as:

$$f(u_1,\ldots,u_N)=\prod_{i\in T_0} f(u_i;\Sigma)\times\prod_{i\in T_1}\int_{-\infty}^{\infty} f(u_i;\Sigma)\mathrm{d}u_{T_i}\times\prod_{i\in T_2}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(u_i;\Sigma)\mathrm{d}u_{D_i}\mathrm{d}u_{O_i} \quad \text{(A1)}$$

The contribution to this density of observations from T_1 and T_2 consists of the marginal densities of the remaining disturbance vectors: $\boldsymbol{u}_1=(u_q, u_L, u_D, u_O, u_R)^T$ and $\boldsymbol{u}_2=(u_q, u_L, u_T, u_R)^T$.

Furthermore, it is known that, if a random vector $\boldsymbol{x}$ has a multivariate normal distribution $n(\boldsymbol{0};\ )$, any linear transformation of the type $\boldsymbol{Dx}$, where $\boldsymbol{D}$ is a real matrix, also has a normal distribution with density $n(\boldsymbol{0};\ \boldsymbol{DD}^T)$. In the present situation, two real matrices $\boldsymbol{P}_1$ and $\boldsymbol{P}_2$, can be defined such that $\boldsymbol{u}_1=\boldsymbol{P}_1\boldsymbol{u}$ and $\boldsymbol{u}_2=\boldsymbol{P}_2\boldsymbol{u}$, which can be done by taking $\boldsymbol{P}_1$ and $\boldsymbol{P}_2$ equal to the identity matrix from which the rows referring to the missing equations are deleted. Consequently, the marginal densities of $\boldsymbol{u}_1$ and $\boldsymbol{u}_2$ are equal to normal densities with mean zero and covariance $\boldsymbol{\Sigma}_1 = \boldsymbol{P}_1\boldsymbol{\Sigma}\boldsymbol{P}_1^T$ and $\boldsymbol{\Sigma}_2 = \boldsymbol{P}_2\boldsymbol{\Sigma}\boldsymbol{P}_2^T$ respectively. The joint density of the $\boldsymbol{u}_i$ is accordingly defined as:

$$f(u_1,\ldots,u_N) = \prod_{i\in T_0} f(u_i;\Sigma) \times \prod_{i\in T_1} f_1(u_{1i};\Sigma_1) \times \prod_{i\in T_2} f_2(u_{2i};\Sigma) \tag{A2}$$

The likelihood function of the sample is found by switching from the distribution of the $\boldsymbol{u}_i$ to the distribution of the endogenous variables represented by the $\boldsymbol{y}$:

$$\begin{aligned} L(\boldsymbol{\theta},\boldsymbol{\Sigma}) &= \prod_{i\in T_0} |J_i| f(y_i;\boldsymbol{\theta},\boldsymbol{\Sigma}) \times \prod_{i\in T_i} |J_{1i}| f_1(y_{1i};\boldsymbol{\theta},\boldsymbol{\Sigma}_1) \times \prod_{i\in T_2} |J_{2i}| f_2(y_{2i};\boldsymbol{\theta},\boldsymbol{\Sigma}_2) \\ &= \prod_{i\in T_0} |J_i|(2\pi)^{1/2(N_0K)} |\boldsymbol{\Sigma}|^{1/2(N_0)} \exp\left(-\frac{1}{2}\sum_{i\in T_0} F_i'\boldsymbol{\Sigma}^{-1}F_i\right) \\ &\quad \times \prod_{i\in T_1} |J_{1i}|(2\pi)^{1/2(N_1K)} |\boldsymbol{\Sigma}_1|^{1/2(N_1)} \exp\left(-\frac{1}{2}\sum_{i\in T_1} F_{1i}'\boldsymbol{\Sigma}_1^{-1}F_{1i}\right) \\ &\quad \times \prod_{i\in T_2} |J_{2i}|(2\pi)^{1/2(N_2K)} |\boldsymbol{\Sigma}_2|^{1/2(N_2)} \exp\left(-\frac{1}{2}\sum_{i\in T_2} F_{2i}'\boldsymbol{\Sigma}_2^{-1}F_{2i}\right) \end{aligned} \tag{A3}$$

where $\boldsymbol{F}_i$, $\boldsymbol{F}_{1i}$ and $\boldsymbol{F}_{2i}$ are abbreviations for $\boldsymbol{F}(\boldsymbol{y}_i;\ \boldsymbol{\theta},\ \boldsymbol{\Sigma})$, $\boldsymbol{F}_1(\boldsymbol{y}_{1i};\ \boldsymbol{\theta},\ \boldsymbol{\Sigma}_1)$ and $\boldsymbol{F}_2(\boldsymbol{y}_{2i};\ \boldsymbol{\theta},\ \boldsymbol{\Sigma}_2)$ and where $|J_i|$, $|J_{1i}|$ and $|J_{2i}|$ denote the absolute values of the Jacobians: $|\mathrm{d}\boldsymbol{u}_i/\mathrm{d}\boldsymbol{y}_i|$, $|\mathrm{d}\boldsymbol{u}_{1i}/\mathrm{d}\boldsymbol{y}_{1i}|$ and $|\mathrm{d}\boldsymbol{u}_{2i}/\mathrm{d}\boldsymbol{y}_{2i}|$. It follows that:

$$\begin{aligned} \ln L(\boldsymbol{\theta},\boldsymbol{\Sigma}) &= -\frac{1}{2}NK\ln 2\pi - \sum_{i\in T_0}\ln|J_i| - \sum_{i\in T_1}\ln|J_{1i}| - \sum_{i\in T_2}\ln|J_{2i}| \\ &\quad -\frac{1}{2}N_0\ln|\boldsymbol{\Sigma}| - \frac{1}{2}N_1\ln|\boldsymbol{\Sigma}_1| - \frac{1}{2}N_2\ln|\boldsymbol{\Sigma}_2| - \frac{1}{2}\sum_{i\in T_0}F_i'\boldsymbol{\Sigma}^{-1}F_i \\ &\quad -\frac{1}{2}\sum_{i\in T_1}F_{1i}'\boldsymbol{\Sigma}_1^{-1}F_{1i} - \frac{1}{2}\sum_{i\in T_2}F_{2i}'\boldsymbol{\Sigma}_2^{-1}F_{2i} \end{aligned}$$

which is the log-likelihood of the unrestricted model Eq. (13).

The likelihood functions of the complete models, i.e. including the behavioural condition implied by Eq. (12)), are obtained as follows. The joint density functions of the disturbances from the demand and cost relationships $\boldsymbol{u}$ and the indicator of the pricing behaviour λ is given as $f(\boldsymbol{u},\lambda)=f_1(\boldsymbol{u})\times f_2(\lambda)$, where

$$f_2(\lambda) = (2\pi\sigma_\lambda^2)^{-1/2} \exp\left(-\frac{1}{2}\frac{(\lambda-\mu_\lambda)^2}{\sigma_\lambda^2}\right) \quad -\infty < \lambda < \infty$$

in the case of the normal-distributed λ. The density of the disturbances $\boldsymbol{u}$ is the same as in Eq. (A2). The log-likelihood functions are again determined by changing from the stochastic variables $\boldsymbol{u}$ and λ to the endogenous demand and costs represented by $\boldsymbol{y}$ and the endogenous pricing behaviour represented by the optimal price p and, subsequently, taking logs, which yields:

$$\ln L(\boldsymbol{\theta}, \boldsymbol{\Sigma}, \mu_\lambda, \sigma_\lambda) = \ln L_1(\boldsymbol{\theta}, \boldsymbol{\Sigma}) + \ln L_2(\mu_\lambda, \sigma_\lambda)$$

with

$$\ln L_2(\mu_\lambda, \sigma_\lambda) = -\frac{N}{2}\ln 2\pi - \frac{N}{2}\ln \sigma_\lambda^2 + \sum_i \ln|J_i| - \frac{1}{2}\sum_i \left(\left(\frac{p-\theta_2}{p_i + \mathrm{MC}}\right)_i - \mu_\lambda \right)^2 \Big/ \sigma_\lambda^2.$$

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