European Review of Agricultural Economics Vol **27 (1)** (2000) pp. 1–16

Incomplete transmission of coffee bean prices: evidence from The Netherlands

L. Bettendorf

OCFEB, Erasmus University Rotterdam, The Netherlands

F. Verboven

Universiteit Antwerpen (UFSIA), Belgium, and Tilburg University, The Netherlands

Received April 1998, final version received October 1999

Summary

This paper seeks to explain the incomplete transmission of coffee bean prices to consumer prices. We adopt and estimate an aggregate model of oligopolistic interaction. We obtain demand and cost parameter estimates that are consistent with conventional wisdom in the industry. Conduct is estimated to be relatively competitive. Our results imply that the relatively large share of costs other than bean costs accounts for the greater part of the incomplete price transmission. The remaining part is due to mark-up absorption, but is less important as oligopolistic interdependence is relatively competitive.

Keywords: coffee market, input price transmission, oligopoly

JEL classification: D4, L11, Q11

1. Introduction

World coffee bean prices have shown large fluctuations during the past years. Consumer prices for roasted coffee, in contrast, have varied considerably less. Figure 1 illustrates the relationship between coffee bean and consumer prices in the Netherlands. Bean prices dropped at the end of 1992, but consumer prices hardly responded. When bean prices more than doubled in the middle of 1994 (because of a frost in Brazil), consumer prices increased by only 50 per cent. Dutch industry observers have offered two possible, and not necessarily exclusive, explanations for the observed incomplete transmission of coffee bean prices to consumer prices.[1] First, coffee beans constitute only a part of the production costs for roasted coffee. Labour costs and packaging costs are other potentially important determinants. Second, coffee roasters may feel constrained from raising their prices by too much

1 See, for example, the Dutch newspaper *Nieuw Rotterdamse Courant* (*NRC*), 29 March 1997, 'Sterk Pak Koffie'.

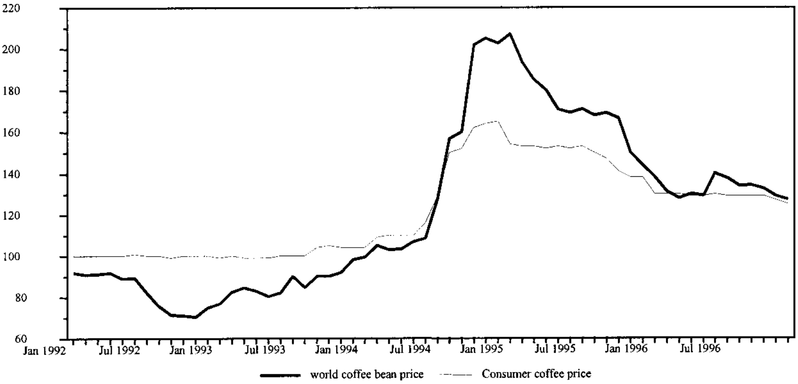

Figure 1. Evolution of coffee bean price indices (1990 = 100), 1992–1996.

when their costs increase; they may decide to absorb cost increases by lowering their mark-ups.

This paper seeks to evaluate the relative importance of cost and mark-up factors as explanations for the observed relationship between coffee bean and final consumer prices. For that purpose, we estimate a structural model of coffee supply and demand, following recent advances in the field of the 'New Empirical Industrial Organization' (Bresnahan, 1989; Slade, 1995). The supply side of the model shows that price may be decomposed into a marginal cost and a mark-up. The mark-up depends on the price elasticity of demand and the degree of oligopolistic interdependence (competitive versus collusive behaviour). The theoretical framework reveals that the first explanation offered by industry observers may be relevant to the extent that labour and packaging constitute an important fraction of the marginal cost of producing coffee. The second explanation may be relevant in our framework depending on the degree of oligopolistic interdependence and on the curvature of the price elasticity of demand. More specifically, if firms behave non-competitively and if the price elasticity of demand is increasing in price, one may expect that firms absorb cost shocks such as bean price changes by reducing their mark-ups. Our econometric framework thus makes the two intuitive explanations of the industry observers more precise. The structural parameter estimates of our model will enable us to quantify the relative importance of both explanations for the incomplete transmission of bean prices to consumer prices.[2] Within our structural oligopoly framework, the strong volatility in bean prices, mainly caused by weather conditions such as a late frost or enduring drought, provides a

2 A third popular explanation for the incomplete bean price transmission, also offered in the *NRC* article, is based on the fact that coffee roasters insure themselves against the price volatility of their main inputs by making long-term future contracts. The problem with this argument is that it does not distinguish between historical accounting costs and economic (or opportunity) costs. Whatever the price at which the contract ensures a firm to purchase its beans, its opportunity cost will still be the spot price of coffee beans, as that is the price at which it would be able to resell its beans if it decided to do so.

unique natural experiment to analyse the transmission of bean price changes to consumer prices for roasted coffee.

Our results show that the relatively large share of costs other than bean costs in the overall marginal costs accounts for the most important part of the incomplete price transmission in the Dutch coffee market. A smaller remaining part follows from mark-up adjustments. Our results are robust with respect to various alternative specifications of demand and cost. We experimented with various alternative demand functions. We focus on specifications with price elasticities of demand that are increasing in price. Under the reverse assumption, mark-ups would actually increase when bean prices increase, so that the relatively large share of costs other than bean costs would be an even more important explanation.

Using a different econometric approach, Feuerstein (1996) considered incomplete price transmission in the German coffee market. She estimated the long-run relationship between bean prices and consumer prices in a dynamic error correction model. Her approach is commonly found in the literature to describe the transmission of intermediate goods prices into final goods prices. Although this approach has been successful in several respects (e.g. forecasting), it does not allow one to unravel the precise economic determinants of the relationship between both price series.

We are not aware of other econometric studies that analyse the incomplete transmission of input prices within an oligopoly framework in detail.[3] A few papers have adopted similar econometric oligopoly models to focus on the presence of market power (rather than price transmission) in the food-processing industries; the reader is referred to, for example, Lopez (1984) on the Canadian aggregate food sector, Buschena and Perloff (1991) on the coconut oil export market, and Genesove and Mullin (1998) on the US sugar industry at the beginning of this century. Roberts (1984) considered the US coffee industry and found relatively competitive behaviour. A similar approach is followed by Bhuyan and Lopez (1997) to estimate oligopoly power in 40 US food and tobacco industries, including coffee. Our approach differs significantly from those used in these papers.[4] First, unlike Roberts we estimate rather than assume the price elasticity of demand. We also investigate the robustness of our results with respect to the choice of functional form for demand. Second, we do not make use of historical accounting data to obtain a direct estimate of marginal costs (see the above discussion, and more generally Bresnahan (1989), for potential problems with such data). Instead, we indirectly infer marginal costs from the evolution of input prices, making use of *a priori* knowledge of the coffee roasting production

3 Theoretical analysis on the incomplete transmission of intermediate goods prices dates back to the perfect competition model of Gardner (1975). McCorriston *et al.* (1998) provide an integrated theoretical analysis containing both cost and market power explanations for incomplete input price transmission. Wohlgenant (1999) analyses the role of product heterogeneity, and emphasises the role of input substitution.

4 Another study is by Karp and Perloff (1996), who consider a dynamic model of the coffee market. Their focus is on export markets.

process. An interesting property of our specification is that the technical cost parameters measure concepts for which numbers circulate in the industry (e.g. the transformation rate of beans into roasted coffee). This allows us to confront our parameter estimates with the prevailing industry wisdom. It turns out that the estimated cost parameters are in fact of the same order of magnitude as the numbers appearing in industry reports.

Our study makes use of aggregate, publicly available data. The Dutch coffee market is characterised by one dominant firm, Sara Lee. This company owns the brands Douwe Egberts and Van Nelle, and had a market share of 74 per cent in the early 1990s (Rabobank, 1993). As is the case in most other European countries, many small firms compete in the remaining segment. It is not clear how the market share of Sara Lee is evolving, although the increasing share of imports (on average about 19 per cent during 1992–1996) suggests it may be slowly declining. As we have only aggregate data at our disposal, it is not possible to draw conclusions on individual firm behaviour from our analysis. Our approach does, however, say something on aggregate conduct, which is sufficient for analysing the transmission of bean prices to final coffee prices. As our approach has only moderate data requirements, we believe that it can be successfully generalised to many other agricultural sectors and countries to investigate the transmission of intermediate goods prices.

The outline of the paper is as follows. The next section presents the econometric model that is used to understand the determinants of bean price transmission. Section 3 discusses the data and the estimation procedure. Section 4 covers the parameter estimates. Section 5 uses these estimates to explain the evolution of consumer prices by marginal cost or mark-up changes. Section 6 concludes.

2. The model

The model consists of a demand and a supply side. As we use aggregate data, coffee is assumed to be a homogeneous good. Consumer demand for coffee is represented by an aggregate demand function, homogeneous of degree zero in prices and income:

$$Q_t = Q\left(\frac{p_t}{p_t^0}, \frac{p_t^s}{p_t^0}, \frac{y_t}{p_t^0}\right) \tag{1}$$

where Q_t represents total coffee demand in period t; p_t is the consumer price of coffee; p_t^s is the price of a potential substitute, tea; p_t^0 is the price of other goods; and y_t is consumers' income.

The supply side of the coffee market refers to the behaviour of firms. As we have only market-level data at our disposal, we use an aggregate model of supply, after making explicit the required assumptions. The profit of firm i is given by

$$\pi_{it} = \frac{1}{1+\tau} p(Q_t)Q_{it} - C_i(Q_{it}, w_t) \tag{2}$$

where $Q_t = \sum_i Q_{it}$ is total industry output, and $p_t = p(Q_t)$ is the inverse function of the demand function (1), suppressing the variables p_t^s/p_t^0 and y_t/p_t^0. $C_i(Q_{it}, w_t)$ is the cost function, depending on output Q_{it} and on a vector of input prices w_t. The parameter τ reflects factors, such as value added taxes, that drive a wedge between the consumer price p_t and the wholesale price for coffee. Taking the derivative of (2) with respect to Q_{it}, we obtain the profit-maximising condition that firm i's perceived marginal revenue equals its marginal cost:

$$\frac{1}{1+\tau}[p_t + p'(Q_t)Q_t\theta_{it}] = \frac{\partial C_i}{\partial Q_{it}} \tag{3}$$

where $p'(Q_{it})$ is the derivative of $p(Q_t)$ with respect to Q_t and $\theta_{it} = (\partial Q_t/\partial Q_{it})(Q_{it}/Q_t)$ is a conjectural variation elasticity between zero and one, measuring the degree of competition. There has been much discussion in the literature on the interpretation of θ_{it} (see Bresnahan (1989) and Slade (1995) for a detailed discussion[5]). From an empirical point of view, it is common to treat the term θ_{it} as a parameter to be estimated.

To aggregate the model over all firms, we follow Appelbaum (1982) and adopt the necessary assumption that the cost functions follow the Gorman polar form:

$$C_i(Q_{it}, w_t) = MC(w_t)Q_{it} + G_i(w_t) \tag{4}$$

which implies that marginal costs are constant and equal across firms. This does not imply, however, that the firms are of equal size in equilibrium, as the conduct parameters may differ across firms (Bresnahan, 1989). Multiplying (3) by the weights Q_{it}/Q_t and adding up over all firms, we obtain the following aggregate 'supply relation':

$$\frac{1}{1+\tau}[p_t + p'(Q_t)Q_t\theta_t] = MC(w_t) \tag{5}$$

where $\theta_t = \sum_i (Q_{it}/Q_t)\theta_{it}$ is an average 'industry conduct' parameter. An estimate of θ_t close to unity indicates that the industry as a whole behaves collusively. An estimate of θ_t equal to zero reflects competitive behaviour. Positive estimates of θ_t indicate oligopolistically interdependent behaviour.

Our main research objective is to understand the relationship between coffee bean prices and consumer prices. To explain this relationship intuitively, one

5 As stated by Slade (1995), the reason why the term θ_{it} appears in (3) is that, for a Nash equilibrium, the partial derivatives are taken holding the rival strategies constant, and the choice variable is not necessarily output. In the Cournot model, firms choose output, holding their rivals' output strategies constant, so that $\partial Q_t/\partial Q_{it} = 1$ and $\theta_{it} = Q_{it}/Q_t$. In the Bertrand model, firms choose prices holding the rivals' price strategies constant, so that $\theta_{it} = 0$. If firms successfully collude, $\theta_{it} = 1$. As a final example, in the dominant firm/competitive fringe model (e.g. Gisser, 1986), $\theta_{it} = 0$ for the fringe firms, and $\theta_{it} = (Q_{Dt}/Q_t)\varepsilon_t/[\varepsilon_t + \nu_t(1 - Q_{Dt}/Q_t)]$ for the dominant firm D, where ε_t is the industry elasticity of demand, and ν_t is the elasticity of fringe supply.

can rewrite the supply relation (3) as

$$p_t = (1+\tau)MC(w_t) + \frac{\theta}{\varepsilon_t} p_t \qquad (5')$$

where $\varepsilon_t = -(\partial Q_t \partial p_t)(p_t/Q_t)$ is the industry elasticity of demand, and where the conduct parameter θ is assumed to be time-invariant.[6] Intuitively, bean prices influence consumer prices both directly through their impact on marginal cost, and indirectly through their impact on the price elasticity of demand, provided that there is not perfect competition ($\theta > 0$). McCorriston *et al.* (1998) perform detailed comparative statics on an equation similar to (5′). Assuming constant marginal costs and a fixed input proportions technology,[7] their formula for the elasticity of bean price (w_t^b) transmission may be simplified to (in our notation)

$$\frac{\mathrm{d}p_t}{\mathrm{d}w_t^b}\frac{w_t^b}{p_t} = \frac{s_t^b}{1+\mu_t}$$

where s_t^b is the share of (bean) inputs in (average) costs, $\mu_t = \phi_t\theta/(\varepsilon_t - \theta)$, and ϕ_t is the elasticity of ε_t with respect to price. It should be noted that, equivalently, $\mu_t = \phi_t(p_t - MC_t)/MC_t$ (with $MC_t = (1+\tau)MC(w_t)$). If markets are perfectly competitive ($\theta = 0$), then $\mu_t = 0$, so that the elasticity of price transmission is just equal to the cost share of beans. If, in contrast, there is market power ($\theta > 0$), then the elasticity of price transmission may become smaller than the bean cost share, provided that the price elasticity of demand ε_t is increasing in price (i.e. $\phi_t > 0$). In this case, the firms absorb cost increases by reducing their mark-ups. This discussion shows that, to understand the determinants of price transmission, it is necessary to estimate the demand, cost and conduct parameters. We accordingly specify the adopted functional forms for marginal cost and demand in the coffee market.

2.1. Demand

We specify the following functional form for demand equation (1):

$$Q_t = \alpha_0 + \alpha_1 \frac{(p_t/p_t^0)^\lambda - 1}{\lambda} + \alpha_2 D_t^2 + \alpha_3 D_t^3 + \alpha_4 D_t^4 + \alpha_5 \frac{p_t^s}{p_t^0} + \alpha_6 \frac{y_t}{p_t^0} \qquad (6)$$

where D_t^i is a dummy variable for the ith quarter ($i = 2, 3, 4$). The parameter λ performs a Box–Cox transformation on the coffee price variable, and is a convenient way to flexibly model the curvature of the demand curve. If $\lambda = 1$, demand is linear; if $\lambda < 1$, demand is convex; and if $\lambda > 1$, demand is concave. Below we present estimates of the demand equation under three scenarios for the price variable: logarithmic ($\lambda = 0$), linear ($\lambda = 1$) and quadratic ($\lambda = 2$). The data did not show sufficient variability to estimate λ precisely, so one

6 As discussed in the empirical section, we also considered specifications in which θ_t is variable, but did not find evidence on this.

7 For details on the role of non-constant marginal costs and variable proportions, we refer to the general analysis of McCorriston *et al*.

should essentially view (6) as a convenient way to present the three demand specifications. Given that we aim to understand the transmission of intermediate bean prices into final consumer prices, it is important to check the robustness of our results with respect to these alternative specifications.

2.2. Marginal costs

The theory of cost minimisation implies that marginal costs are homogeneous of degree 1 in input prices. In addition to this restriction, we use knowledge of the coffee roasting production process to impose two further restrictions on the cost function. As discussed, for example, in Sutton (1991), the production process is simple.[8] It involves roasting and grinding the coffee beans into the final coffee substance, which is then packaged for consumer use. Coffee beans, packaging and labour are essentially used in fixed proportions. Furthermore, economies of scale in production are extremely limited, which makes the aggregation assumption (4), of constant average variable and marginal cost, more intuitive.[9] These facts lead us to the following fixed proportions, constant-returns-to-scale specification for marginal cost:

$$MC(w_t) = \beta_0 w_t^0 + \beta_1 w_t^b + \beta_2 w_t^l \tag{7}$$

where w_t^b is the price of coffee beans, w_t^l is the wage rate and w_t^0 is the price of other inputs (mainly packaging). The coefficient β_1 can be interpreted as the transformation rate of beans into roasted coffee. According to experts, e.g. the International Coffee Organization, the production of 1 kg of roasted coffee requires 1.19 kg of beans. About 19 per cent of the raw coffee beans consists of water and evaporates during the roasting process. This value is roughly confirmed by our data: during our complete sample period, the total input demand for coffee beans (in kg) was 1.2 times the total output of roasted coffee (in kg).[10]

It is now straightforward to complete the specification of the supply side (5′). Computing the demand derivatives from (6) and substituting marginal cost given by (7), we rewrite the supply relation as

$$\frac{p_t}{p_t^0} = (1+\tau)\left(\beta_0 \frac{w_t^0}{p_t^0} + \beta_1 \frac{w_t^b}{p_t^0} + \beta_2 \frac{w_t^l}{p_t^0}\right) - \frac{\theta}{\alpha_1}\left(\frac{p_t}{p_t^0}\right)^{1-\lambda} Q_t \tag{8}$$

where λ is specified as 0, 1 or 2, in the logarithmic, linear and quadratic demand specifications, respectively. We add error terms to equations (6) and (8), and estimate the system simultaneously using the generalised

8 We limit ourselves to a discussion of 'regular' coffee. The production process of instant coffee, which differs in the required capital investments, can be safely ignored as it has a relatively small consumption share of 12 per cent, as reported in VNKT (1997).

9 It should be noted that this does not imply there are no overall economies of scale. Fixed costs, e.g. advertising costs, may be high and firm-specific, as discussed by Sutton (1991). See Bhuyan and Lopez (1997), who find evidence of economies of scale.

10 We decided not to introduce a factor demand equation for coffee beans, although our data allow for this. The main reason is that short-run factor demand follows a complicated process because of speculative inventory behaviour.

method of moments (Hansen, 1982). This is a consistent and asymptotically efficient estimator. It takes into account the endogeneity of price and quantity, using the exogenous demand and cost shifters as instruments. Furthermore, it incorporates possible correlation between the error terms in both equations. Finally, it computes standards errors that are heteroscedasticity-consistent and robust to autocorrelation.

3. Data sources and definitions

The analysis is performed on the aggregated Dutch market with publicly available monthly data for the years 1992–1996. Production is measured as the sum of quantities sold by domestic producers on the domestic and foreign markets (source: Commissie voor Koffie en Thee). Data on imports and exports of roasted coffee are taken from the Central Bureau for Statistics (CBS; *Maandstatistiek van de Buitenlandse Handel*). As figures on stock changes are missing, coffee consumption Q_t is approximated as production minus net exports of roasted coffee. Series on consumer prices are reported by the CBS *Bijvoegsel van de Maandstatistiek van de Prijzen*. The same source reports total consumer expenditures, our measure for income.

Taxes, represented by τ, were constant at 6 per cent during our sample period. The price of beans, w_t^b, is computed as the ratio of the value to the volume of imported green coffee, as published by the CBS in *Maandstatistiek van de Buitenlandse Handel*. By taking this measure for the bean price, an automatic correction is involved for the possibly changing mix between the varieties arabica and robusta.[11] Similarly, exchange rate movements are automatically taken into account. Figure 1 plots the coffee bean and consumer price series. Wages, w_t^l, are represented by the collectively negotiated wage for the food sector (source: *Statistisch Bulletin*, CBS). Data for prices of other variable inputs, w_t^0, mainly packaging, are not publicly available for the coffee industry. We therefore assume (as is done implicitly in other studies, e.g. Genesove and Mullin, 1998) that other input prices, w_t^0, evolve proportionally to the general price index, i.e. $w_t^0 = \omega p_t^0$, where ω is the factor of proportionality. With this assumption, the first term in equation (8) effectively becomes a constant, i.e. $\beta_0^* = \omega\beta_0$.

4. Results

Before considering the empirical results of the full structural model, it is useful to discuss the results from estimating the demand side separately (equation (6)). All specifications (logarithmic, linear and quadratic) yield positive but insignificant coefficients for the tea price and income variables, so we drop them in our full model. The price coefficient is significantly negative. The implied price elasticity of demand roughly takes the same mean value of -0.2 in all specifications, consistent with estimates for the USA and

11 VNKT (1997, Table 7) reports that the share of arabica and robusta in total imports of green coffee was 70 per cent and 30 per cent in 1996, respectively.

Germany.[12] We can draw a first inference about conduct from this robust result. As marginal costs cannot be negative, supply relation (5′) implies that θ_t cannot exceed the price elasticity ε_t. With our estimated elasticity, this means that θ_t cannot exceed 0.2, so that cartel behaviour can be rejected. This finding is just a restatement of the intuition that a 'monopolist' (or cartel) operates on the elastic part of its demand function.

We now turn to the results for the full model. We first estimated the model without imposing constraints. Most estimates were of a plausible order of magnitude, consistent with industry wisdom. Nevertheless, we found that some parameters were estimated rather imprecisely, in particular β_0^*, measuring the marginal costs per kilogram attributable to inputs other than beans. Under linear demand, for example, we obtain an estimate for β_0^* of 4.4 with a standard error of 1.4, implying a 95 per cent confidence interval for the marginal cost per kilogram other than bean costs of 1.6–7.2 guilders of January 1990.[13] We therefore impose some extra structure on β_0^*, based on the industry wisdom about the cost share of beans. Assuming that bean costs on average accounted for a fraction γ of unit costs, one can check that β_0^* may be pinned at $\beta_0^* = \beta_1(1/\gamma - 1)(\bar{w}^b/\bar{p}^0)$, where $\bar{w}^b$ and $\bar{p}^0$ are sample means. Using a rule of thumb in the industry that, on average, about 60 per cent of total costs consists of bean costs (*Financieel Dagblad*, 3 May 1997), we may set γ equal to 0.6. The fraction of bean costs in marginal costs may be even larger, because of fixed costs (such as advertising, as emphasised by Sutton (1991)). Table 1 presents the estimates imposing both a 60 per cent and a 70 per cent constraint, for the logarithmic ($\lambda = 0$), linear ($\lambda = 1$) and quadratic ($\lambda = 2$) demand specifications.[14]

The *t* statistics in the first row test whether the 60 per cent and 70 per cent constraints are rejected by the data, conditional on the maintained demand specification.[15] The *t* statistics reveal that the constrained model cannot be rejected in the linear and quadratic specification, under either the 60 per cent or the 70 per cent rule. In these two specifications, we may therefore interpret the constraints as a way to incorporate our prior information to increase the precision of our estimates. In the logarithmic specification, in contrast, both the 60 per cent and the 70 per cent rule of thumb are rejected; the results in this case should be interpreted with care. We therefore begin our discussion with the results from the linear and the quadratic specifications.

The estimates of the demand coefficients are similar to the single equation estimates discussed above. The price elasticity of demand varies between

12 For the US, Roberts (1984) reported a price elasticity of −0.25 whereas Pagoulatos and Sorensen (1986) estimated a value of −0.11. However, Bhuyan and Lopez (1997) estimated an elasticity of −0.53. The estimate for Germany given by Feuerstein (1996) equals −0.18.

13 Similar findings were obtained for the other demand specifications. The complete results from the unconstrained model are available on request, or in Bettendorf and Verboven (1998).

14 The data did not show sufficient variability to estimate λ precisely: a point estimate of around −3.2 was obtained, with a large standard deviation of 16.8.

15 More formally, on the basis of the parameter estimates of the unrestricted specification, they test the hypothesis that the constant β_0^* equals $\beta_1(1/\gamma - 1)(w_a^b/p_a^0)$ where γ is 0.6 or 0.7.

Table 1. Empirical results, for alternative demand specifications (equations (6) and (8))

	Logarithmic demand		Linear demand		Quadratic demand	
γ :	0.6	0.7	0.6	0.7	0.6	0.7
t statistic:	4.299	6.909	0.128	1.220	−0.001	0.644
α_0	1.206	1.211	0.788	0.796	0.714	0.715
	(0.103)	(0.106)	(0.046)	(0.045)	(0.026)	(0.026)
α_1	−0.216	−0.214	−0.109	−0.114	−0.816	−0.816
	(0.040)	(0.042)	(0.031)	(0.032)	(0.212)	(0.214)
α_2	0.029	0.018	0.033	0.032	0.033	0.034
	(0.013)	(0.010)	(0.016)	(0.015)	(0.017)	(0.016)
α_3	0.040	0.028	0.040	0.041	0.038	0.040
	(0.017)	(0.013)	(0.019)	(0.018)	(0.019)	(0.019)
α_4	0.061	0.040	0.098	0.086	0.103	0.100
	(0.017)	(0.014)	(0.018)	(0.016)	(0.019)	(0.018)
β_1	1.309	1.078	1.679	1.703	1.812	1.930
	(0.168)	(0.157)	(0.057)	(0.064)	(0.034)	(0.041)
θ	0.107	0.169	0.031	0.056	0.016	0.032
	(0.024)	(0.022)	(0.008)	(0.013)	(0.004)	(0.008)
ε	0.315	0.313	0.211	0.219	0.232	0.232
	(0.058)	(0.061)	(0.060)	(0.060)	(0.060)	(0.061)
L index	0.340	0.539	0.147	0.258	0.069	0.138
	(0.086)	(0.070)	(0.028)	(0.027)	(0.014)	(0.015)

GMM estimates with heteroscedasticity-consistent standard errors, robust to autocorrelation. The price coefficient and the corresponding standard error are multiplied by 10 and 1000 in the linear and the quadratic specification, respectively. The Lerner index is the price minus marginal cost divided by price, and equals θ/ε_t. The price elasticity and Lerner index are evaluated at sample means. The standard error of the Lerner index is computed using the delta method (see, e.g. Judge *et al.*, 1988: 524).

−0.21 and −0.23. The seasonal dummy variables show that coffee demand is lowest in the first quarter and highest in the final quarter of the year. The technical cost coefficients are significant, with the expected positive sign. Their order of magnitude is also plausible. The estimates of the bean coefficient β_1 vary between 1.7 and 1.9. Interestingly, this is of a similar order of magnitude, although larger than the commonly assumed transformation rate of 1.19, to the value implied by the transforming process of roasting beans into roasted coffee. One explanation for the overestimation is that there is not just a 19 per cent physical loss (of water) in the coffee production process, but also a percentage monetary loss on the value of output, involved in the long chain from production to final consumption. Taxes are one source of monetary loss, and have already been taken into account through the observed tax parameter τ, set equal to 6 per cent. In addition, distribution and transportation costs may account for a systematic monetary loss. To some extent these service charges may be a percentage of the value of output. They may also be dependent on other variables such as weight. As our data do not allow us to take these into account, the coefficient β_1 may take over their effect. Interpreting the overestimation of β_1 as capturing percentage monetary losses (in addition to observed taxes), and assuming that the physical rate of transformation is exactly equal to 1.19, our estimates for β_1 would imply percentage monetary losses on the value of output of around 41.1 per cent and 52.3 per cent, in the linear and quadratic specifications, respectively.[16]

Finally, the estimated conduct parameter θ is rather small. The hypothesis of monopoly ($\theta = 1$) is rejected at the 5 per cent significance level. The hypothesis of perfect competition ($\theta = 0$) may be rejected in favour of oligopolistic interdependence (θ significantly greater than zero).[17] To compare our estimates with other studies, we computed the Lerner index as a measure of market power. This index is defined as the price minus marginal cost divided by the price, and equals θ/ε_t, as can be verified from rearranging ($5'$). Despite the relatively small estimates of θ, the Lerner index is relatively high, especially under the 70 per cent rule; this is of course due to the low estimate of the price elasticity of demand. The outcomes are between the US estimates for the Lerner index of 6 per cent, obtained by Roberts (1984), and 51 per cent by Bhuyan and Lopez (1997).

Now, we briefly consider the logarithmic specification, in which the 60 and 70 per cent restrictions were rejected by the data according to the t statistics. More care in the interpretation should be taken here, as an increased efficiency may go at the cost of some bias. An example of this may be the estimated value of -0.3 for the price elasticity (evaluated at the sample mean), which is smaller than the estimates of -0.2 in the other specifications and in the single equation regressions. The estimate of the conduct parameter is also larger. The overall effect of the greater elasticity and increased conduct parameter on the estimated Lerner index is positive: it reaches values of 0.34 and 0.54.

5. Understanding the evolution of consumer prices

We now use our estimates to analyse the evolution of the consumer prices for roasted coffee during our sample period, 1992–1996. Our goal is to understand better the incomplete transmission of changes in bean prices to consumer prices, and to assess the relative importance of the cost and market power explanations. We focus on the changes that occurred during 1994, the year of the drastic bean price increases caused by the frost in Brazil.

16 For example, for the second regression under 0.6 rule, if we add a monetary loss of 41.1 per cent to the assumed technical rate of 1.19 (i.e. 1.19×1.411), this gives the number 1.679, our estimate of β_1.

17 The regression results assume that the conduct parameter θ is constant. More generally, one may allow θ_t to depend, in a reduced form manner, on other variables. We experimented with several alternative specifications for θ_t. In particular, we allowed θ_t to follow a trend, which may, for example, capture an increase or decrease of a dominant position. We also allowed θ_t to follow a 'structural break' after the sudden jump in coffee bean costs. None of these determinants turned out to be significant.

Table 2. Evolution of the Dutch coffee industry

	Summary statistics 1992–1996				Change from Jan. 1994 to Jan. 1995	
	Mean	SD	Minimum	Maximum	Absolute change	% change
Bean price	3.78	1.17	2.28	6.35	+3.23	+103.6
Roasted coffee price	13.19	2.09	11.02	17.71	+5.08	+44.5
Marginal cost	11.21	2.07	8.53	15.78	+5.42	+57.3
Absolute mark-up	1.93	0.21	1.46	2.40	−0.34	−8.1
Elasticity	0.215	0.048	0.154	0.337	+0.108	+64.8

The results are based on the estimates of the linear demand specification in Table 1 ($\gamma = 0.6$). Marginal cost and prices are expressed in guilders of January 1990 per kilogram.

To illustrate our findings, we base our discussion on the estimation results of the linear demand specification, under the constraint that bean costs were on average about 60 per cent of costs. The main conclusions derived below remain robust when the 60 per cent constraint is removed, or when the other demand specifications were used.

Table 2 provides information on the evolution of bean and consumer prices, marginal cost, absolute mark-up and the price elasticity of demand. The first four columns provide summary statistics over the whole period 1992–1996. This illustrates the high volatility of bean prices compared with consumer prices and marginal costs. Absolute mark-ups have been much smaller than marginal costs, and the standard deviation correspondingly drops.

Now let us consider the changes that took place during 1994. Largely as a result of a late frost in Brazil, the bean prices jumped by 3.23 guilders/kg, or 104 per cent. Consumer prices increased by a larger absolute amount during this period, 5.08 guilders/kg, but by a smaller percentage of only 45 per cent. To interpret this, we consider equation (5′), from which it can be derived that consumer price changes (in percentage terms) can be decomposed into (i) marginal cost changes and (ii) changes in the price elasticity of demand (interacting with the term $\theta/(\varepsilon_t - \theta)$):

$$\frac{\Delta p_t}{p_{t-1}} = \frac{\Delta MC_t}{MC_{t-1}} - \frac{\theta}{\varepsilon_t - \theta}\frac{\Delta \varepsilon_t}{\varepsilon_{t-1}}. \tag{9}$$

The reader is referred to the Appendix for a derivation of (9). If the changes are large, an interaction term needs to be added for (9) to hold exactly. Intuitively, if the mark-up term is small, either because θ is small or because ε_t is large, then price changes mainly follow from marginal cost changes; when the mark-up term is large, then price changes also follow to an important degree from changes in the price elasticity of demand.

The percentage increase in marginal cost in (9) can in turn be written as the weighted sum of percentage increases in bean prices and other factor prices:

$$\frac{\Delta MC_t}{MC_{t-1}} = (1 - s_t^b)\frac{\Delta w_t^0}{w_{t-1}^0} + s_t^b\frac{\Delta w_t^b}{w_{t-1}^b}$$

where the weight s_t^b is the share of bean costs in marginal costs.

The jump in bean prices of 3.23 guilders/kg, or 104 per cent, is directly expressed in an increase in marginal costs by the larger absolute amount of 5.42 guilders/kg (Table 2). This follows from the estimated bean price coefficient of 1.68, implying physical and monetary losses in the production process of transforming beans into roasted consumer coffee. The percentage increase in marginal costs, however, is much smaller than the increase in bean prices, i.e. only 57 per cent. This is due to the relatively large average share of costs other than bean costs, which did not follow the drastic bean price changes. As shown in the previous section, an average share of 40 per cent could not be rejected by the data.[18] Therefore, the cost argument hypothesised in the Introduction accounts for at least part of the explanation for the weak relationship between bean and consumer prices.

A second potentially dampening effect on consumer prices may stem from mark-up absorption. How important was this during the 1994 bean price shock? As can be read from the second term in equation (9), mark-up absorption takes place provided that (i) there is oligopolistic interdependence ($\theta > 0$), and (ii) the price elasticity of demand increases with consumer prices. Table 2 shows that the price elasticity indeed increased during the 1994 bean price shock, an increase of about 65 per cent. This led to a reduction in the mark-up of 8.1 per cent under linear demand, and of 7 per cent under quadratic demand. This is not much, owing to the fact that the conduct parameter θ, though significant, was estimated to be relatively small. In sum, we find that the 1994 increase in consumer prices of 44.5 per cent, compared with an increase in the bean prices of 104 per cent, can be partly explained by mark-up absorption, but for the most significant part by the modest increase in marginal cost, which follows from the relatively large share of other costs than bean costs. It should be noted that the mentioned mark-up change and marginal cost change do not exactly add up to the consumer price increase of 44.5 per cent. This is because the changes are large, so that the interaction term cannot be neglected. This term equals -4.6 per cent (i.e. $-0.081 \times 0.573 \times 100$).

We now briefly discuss the robustness of the results with respect to other model specifications. First, if we had not adopted the 60 per cent constraint, the estimated increase in marginal cost during 1994 would be slightly smaller (56.2 per cent); mark-up absorption would account for -7.5 per cent (an interaction term of -4.2 per cent needs to be added to obtain the total price increase). With logarithmic demand, there would be less mark-up

18 It should be recalled that this was also true for the quadratic demand specification. For the logarithmic specification, a share of 40 per cent was rejected, because a share of other inputs even larger than 40 per cent is in fact favoured by the data.

absorption; this is intuitively obvious given the convex shape of the logarithmic demand curve. With a quadratic (concave) demand curve, there would be slightly more mark-up absorption. Under all specifications, our conclusion remains that it is marginal costs rather than mark-ups that explain the incomplete transmission of bean prices to consumer prices.[19]

6. Concluding remarks

This paper has analysed the observed weak transmission of coffee bean prices to consumer prices, using data for the Netherlands for 1992–1996. Using a structural model of oligopolistic interaction, it is shown that the relatively large share of costs other than bean costs is responsible for a substantial part of the observed weak relationship. The remaining part follows from mark-up absorption, but is quantitatively less important as oligopolistic interdependence is relatively competitive.

We used publicly available data on the Dutch coffee market. The strong volatility of bean prices has provided a natural experiment to analyse the transmission of bean prices. Given the relatively moderate data requirements, we hope that our oligopoly approach will stimulate further research on the transmission of input prices into output prices in other sectors of the economy.

At the same time, there is room for further analysis and extensions of the model. For example, our approach treated the production and distribution as an integrated sector. With more detailed information on both sectors, it would be feasible to analyse the separate role of both sectors in the incomplete price transmission. Furthermore, a more in-depth analysis of firm-specific oligopoly behaviour in the coffee industry, based on firm-level data, would be interesting. The present analysis reveals interdependent, though rather competitive conduct at the aggregate level, but it is possible that one of the firms possesses strong individual market power. Furthermore, more detailed data would allow the consideration of interesting dynamic aspects in the industry. For example, inventory costs, adjustment costs or consumer loyalty may to some extent influence the relationship between bean prices and consumer prices.

Acknowledgements

We thank R. Alessie, J. Boone, M. Canoy, H. Degrijse, R. van Assouw, H. Vandenbussche and three anonymous referees for helpful comments. We are grateful to R. Rosenbrand (CPB) and P. van der Salm (Commissie voor Koffie en Thee) for data collection. The research was conducted while the first author was at the CPB Netherlands Bureau for Economic Policy Analysis.

19 It should be noted that the demand specification (6) implies (for our three specifications) that the price elasticity of demand is increasing in price (in absolute value). We did not consider a constant elasticity specification, implying constant percentage mark-ups, because in this case the conduct parameter θ is not identified (Bresnahan, 1982). A specification with decreasing (in absolute value) price elasticity of demand is somewhat unconventional and economically unappealing. If we had imposed such a specification on the data, then the reverse of mark-up absorption would have occurred (if $\theta > 0$). In any event, our conclusion that marginal costs rather than mark-ups explain the weak transmission of coffee bean prices into consumer prices would be reinforced.

References

Appelbaum, E. (1982). The estimation of the degree of oligopoly power. *Journal of Econometrics* 19: 287–299.

Bettendorf, L. and Verboven, F. (1998). Competition on the Dutch coffee market. CentER Discussion Paper 9810. Tilburg University.

Bhuyan, S. and Lopez, R. A. (1997). Oligopoly power in the food and tobacco industries. *American Journal of Agricultural Economics* 79: 1035–1043.

Bresnahan, T. F. (1982). The oligopoly solution concept is identified. *Economics Letters* 10: 87–92.

Bresnahan, T. F. (1989). Empirical studies of industries with market power. In R. Schmalensee and R. D. Willig (eds), *Handbook of Industrial Organization*. Amsterdam: North-Holland.

Buschena, D. and Perloff, J. (1991). The creation of dominant firm market power in the coconut oil export market. *American Journal of Agricultural Economics* 73: 1000–1008.

Feuerstein, S. (1996). Do coffee roasters benefit from high prices of green coffee? Tinbergen Institute Working Paper, TI 96-133/4. Rotterdam: Tinbergen Institute.

Gardner, B. L. (1975). The farm–retail spread in a competitive food industry. *American Journal of Agricultural Economics* 57: 399–409.

Genesove, D. and Mullin, W. P. (1998). Testing static oligopoly models: conduct and cost in the sugar industry 1890–1914. *RAND Journal of Economics* 29(2): 355–377.

Gisser, M. (1986). Price leadership and welfare losses in US manufacturing. *American Economic Review* 76(4): 756–767.

Hansen, L. P. (1982). Large sample properties of Generalized Method of Moments estimation. *Econometrica* 50: 1029–1054.

Judge, G., Hill, R. C., Griffiths, W. E., Lutkepohl, H. and Lee, T. (1988). *Introduction to the Theory and Practice of Econometrics*. New York: John Wiley.

Karp, L. S. and Perloff, J. M. (1996). Dynamic models of oligopoly in rice and coffee export markets. In D. Martimort (ed.), *Agricultural Markets: Mechanisms, Failures and Regulations*. Amsterdam: North-Holland, 171–204.

Lopez, R. E. (1984). Measuring oligopoly power and production responses of the Canadian food processing industry. *Journal of Agricultural Economics* 35: 219–230.

McCorriston, S., Morgan, C. W. and Rayner, A. J. (1998). Processing technology, market power, and price transmission. *Journal of Agricultural Economics* 49: 185–201.

Pagoulatos, E. and Sorensen, R. (1986). What determines the elasticity of industry demand? *International Journal of Industrial Organization* 4: 237–250.

Rabobank (1993). The world coffee market. Agrobusiness research. Amsterdam: Rabobank.

Roberts, M. J. (1984). Testing oligopolistic behavior. *International Journal of Industrial Organization* 2: 367–383.

Slade, M. E. (1995). Empirical games: the oligopoly case. *Canadian Journal of Economics* 28: 368–401.

Sutton, J. (1991). *Sunk Costs and Market Structure*. Cambridge, MA: MIT Press.

Vereniging van Nederlandse Koffiebranders en Theepakkers (Association of Dutch Coffee and Tea Producers) (1997), Jaarverslag 1996, Amsterdam (in Dutch).

Wohlgenant, M. K. (1999). Product heterogeneity and the relationship between retail and farm prices. *European Review of Agricultural Economics* 26: 219–227.

Appendix: Decomposition of price changes

In this Appendix, we compute the derivation for the decomposition of percentage price changes as approximated by equation (9). We may rewrite (5′) as

$$p_t = \frac{\varepsilon_t}{\varepsilon_t - \theta} MC_t$$

where $MC_t = (1+\tau)MC(w_t)$. We then may write

$$\begin{aligned} p_t - p_s &= \frac{\varepsilon_t}{\varepsilon_t - \theta} MC_t - \frac{\varepsilon_s}{\varepsilon_s - \theta} MC_s \\ &= \frac{\varepsilon_s}{\varepsilon_s - \theta}(MC_t - MC_s) + \left(\frac{\varepsilon_t}{\varepsilon_t - \theta} - \frac{\varepsilon_s}{\varepsilon_s - \theta} \right) MC_s \\ &\quad + (MC_t - MC_s)\left(\frac{\varepsilon_t}{\varepsilon_t - \theta} - \frac{\varepsilon_s}{\varepsilon_s - \theta} \right). \end{aligned}$$

where the subscript $s = t - 1$. From this we obtain

$$\frac{p_t - p_s}{p_s} = \frac{MC_t - MC_s}{MC_s} \cdot \frac{\varepsilon_s - \theta}{\varepsilon_s} \left(\frac{\varepsilon_t}{\varepsilon_t - \theta} - \frac{\varepsilon_s}{\varepsilon_s - \theta} \right).$$

As

$$\frac{\varepsilon_s - \theta}{\varepsilon_s} \left(\frac{\varepsilon_t}{\varepsilon_t - \theta} - \frac{\varepsilon_s}{\varepsilon_s - \theta} \right) = \frac{-\theta}{\varepsilon_t - \theta} \frac{\varepsilon_t - \varepsilon_s}{\varepsilon_s}$$

we may write the expression for $(p_t - p_s)/p_s$ as

$$\frac{\Delta p_t}{p_s} = \frac{\Delta MC_t}{MC_s} - \frac{\theta}{\varepsilon_t - \theta} \frac{\Delta \varepsilon_t}{\varepsilon_s} - \frac{\Delta MC_t}{MC_s} \frac{\theta}{\varepsilon_t - \theta} \frac{\Delta \varepsilon_t}{\varepsilon_s}$$

where the operator Δ denotes the difference between two variables. The third term is an interaction term, which will be negligible if the percentage changes in marginal costs and elasticity are small.

Corresponding author: L. Bettendorf, OCFEB Erasmus University H7-34, PO Box 1738, 3000 DR Rotterdam, The Netherlands. E-mail: bettendorf@few.eur.nl