Competition on the Dutch coffee market

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Publication date:
1998

Citation for published version (APA):
Bettendorf, L., & Verboven, F. L. (1998). *Competition on the Dutch coffee market*. (CentER Discussion Paper; Vol. 1998-10). Unknown Publisher.

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Discussion paper

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Tilburg University

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for
Economic Research

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No. 9810

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February 1998

ISSN 0924-7815

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ABSTRACT

World coffee bean prices have shown large fluctuations during the past years, whereas consumer prices for roasted coffee have varied considerably less. In this paper, we seek to explain the weak relationship between coffee bean and consumer prices. We adopt and estimate an aggregate model of oligopolistic interaction. It is shown that the relatively large share of costs other than bean costs accounts for the most important part of the weak relationship between bean and consumer prices. The remaining part follows from markup absorption, but is less important since oligopolistic interdependence is relatively competitive. The estimates are used to simulate the model under alternative behavioral assumptions: duopoly and monopoly. The computations show that consumer prices would have been much higher and would have fluctuated even less (due to greater markup absorption) under these alternative regimes.

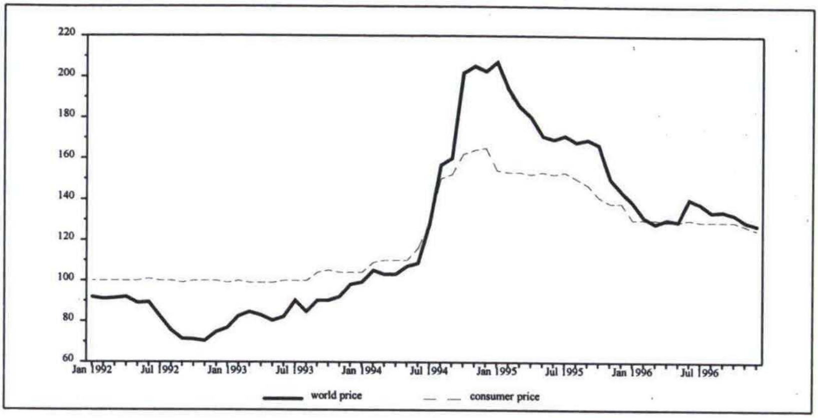
We would like to thank Rob Alessie, Jan Boone, Hans Degryse, and Hylke Vanden Bussche for helpful comments. We are also grateful to R. Rosenbrand (CPB) and P. van der Salm (Commissie voor Koffie en Thee) for data collection. Corresponding author: L. Bettendorf, CPB, P.O. Box 80510, 2508 GM Den Haag, The Netherlands, email: ljhb@cpb.nl

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 did hardly respond. When bean prices more than doubled in the middle of 1994 (due to a frost in Brazil), consumer prices increased by only 50 percent. Dutch industry observers have offered two alternative explanations for the observed weak relationship between coffee bean and consumer prices (N.R.C., 29 March 1997). First, coffee beans constitute only a part of the production costs for roasted coffee. Labor costs and packaging costs are also potentially important determinants. Second, coffee roasters may feel constrained to raise their prices by too much due to negative demand responses by consumers. If this is the case, firms may absorb bean price increases by reducing their markups.

In this paper we seek to carefully evaluate both the cost and the markup explanations that have been advanced 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 growing field of the "New Empirical Industrial Organization" (Bresnahan, 1989). The theoretical framework reveals that the cost explanation may be relevant to the extent that labor and packaging influence the *marginal* cost of producing coffee. The markup explanation may be relevant to the extent that firms recognize their oligopolistic interdependence and behave closer to the cartel rather than the competitive outcome. Our structural parameter estimates make it possible to assess the relative importance of both explanations. In addition, they allow us to simulate the model and ask how prices would have evolved under alternative assumptions on firm behavior, such as full cartel, Cournot duopoly or perfect competition.

A third explanation that is often used to explain the weak relationship between bean and consumer prices (or, more generally, input and output prices) goes as follows. Coffee roasters insure themselves against the price volatility of their main input by making long term future contracts. If a coffee roaster has a contract that guarantees the sale of coffee beans in six months at a price per kg of 3 guilders, an unexpected jump in the spot price to 6 guilders does not affect its costs, so that there is no need to increase consumer prices. The problem with this argument is that it fails to distinguish between accounting costs and economic (or opportunity) costs. Even if the futures contract enables the firm to purchase a certain amount at a cost of 3 guilders per kg, its opportunity cost is still the spot price of 6 guilders, since that is the price at which it would be able to resell its beans if it decided to do so. A main advantage of the "New Empirical Industrial Organization" approach is precisely that it does



not rely upon accounting data to measure cost, but instead indirectly infers marginal costs from firm behavior, see Bresnahan (1989).

Within our structural framework the strong volatility in bean prices, mainly caused by exogenous weather conditions such as a late frost or enduring drought, provides a unique natural experiment to analyze the coffee roasters' oligopolistic behavior. We believe this is relevant, given the widespread suspicion that market power is significant in the food-processing industries. Sutton (1991, Table 4.3) provides ample evidence that a small number of firms dominates many food-stuff markets. Furthermore, OECD (1996a) reports that the agri-food sector, after employment, is the second most excluded, exempted, or favorably treated area under competition laws[1]. According to this study (p. 23) "the limited coverage of competition laws in agriculture may depend less on judgements about 'appropriate' economic considerations of natural monopoly and economies of scale and more on protectionist, political, cultural or national security considerations". It is stated that efforts to improve competition in the production and sale of agricultural goods would be desirable.

Figure 1: Evolution of coffee prices (1990=100)

Despite the attention paid by policy makers, structural empirical applications on the presence of market power in the food-processing industries remain relatively scarce, see for example Lopez (1984) on the Canadian aggregate food sector, Buschena and Perloff (1991) on the coconut oil export market, and Genesove and Mullin (1995) on the U.S. sugar industry at the beginning of this century. Roberts (1984) considered the U.S. coffee industry and found quite competitive behavior. Our approach differs quite significantly from Roberts'. First, we do not make use of accounting data to obtain a direct estimate of marginal costs, but instead

[1]The application of competition policy in the agro-food sector is discussed in OECD(1996b).

indirectly infer marginal costs. Furthermore, we fully integrate the demand side into our structural model, and carefully investigate the robustness of our results with respect to the choice of functional form. Our approach is made feasible by the large fluctuations of coffee bean prices.

Finally, Feuerstein (1996) considered the German coffee market. She estimates the long-run relationship between bean prices and consumer prices in a dynamic error correction model. Her approach, however, is not structural and does not allow to understand the precise economic determinants of the relationship between both price series. Explanations of her empirical findings need to be found outside of her econometric framework.[2]

Our study makes use of publicly available data. The Dutch coffee market is characterized by one dominating firm, Douwe Egberts. This firm roughly obtains between 60% and 70% of total sales. Many small firms compete in the remaining segment. Imports are relatively small, though increasing.

The outline of the paper is as follows. Section 2 presents the econometric model based on our prior knowledge of the coffee sector. In contrast to most previous work we consider various alternative demand specifications to test for the robustness of our results. Section 3 discusses the data and the estimation procedure. Section 4 covers the empirical results. A final section uses our estimates to explain the evolution of consumer prices and simulate the model under alternative behavioral assumptions.

2. The Model

The market for roasted coffee consists of a demand and a supply side. Consumer demand for coffee is perfectly competitive and is represented by an aggregate demand function that is homogeneous of degree zero in prices and income:

[2] Karp and Perloff (1996) consider a dynamic model of the coffee market. Their focus is on export markets, whereas we consider a domestic market. An alternative approach to estimate market power is proposed by Hall and refined by Roeger (see Oliviera Martins et al., 1996). This analysis is based on the definition of the Solow residual and applied at a sectoral level, for which (annual) data on growth rates are available. This technique estimates the Lerner index (or markup ratio) directly, assuming it is a constant. In contrast, our industry-level approach focuses on the two components of a time-varying markup, i.e. a conduct parameter of oligopolistic interdependence and the price elasticity of demand. Oliviera Martins et al. report a markup of 59 percent for the Dutch beverage sector.

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

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 income. An increase in the coffee price may reduce demand for several reasons. First, consumers may drink less and switch to substitutes. Second, they may use a lower dosage of coffee. Finally, consumers may become more careful and prevent spilling.[3]

Notice that equation (1) ignores possible dynamic aspects of coffee demand, arising from habit formation. We did experiment with a more general, dynamic demand specification, based on Becker and Murphy's (1988) rational addiction model, as implemented on the U.S. coffee market by Olekalns and Bardsley (1996). Our empirical results generated very imprecise parameter estimates, from which it was not possible to draw reliable inferences on habit formation and long term price elasticities. This follows from the fact that our data set covers a relatively short time period (5 years), with a strong multicollinearity between the lagged and leaded variables in the dynamic specification. A longer time period is required to study the dynamic implications of habit formation.

Coffee supply is determined by the condition that perceived marginal revenue equal the marginal cost of production. Following the New Empirical Industrial Organization (Bresnahan, 1989), this condition can be written in aggregate form in the following flexible way:

$$\frac{1}{1+\tau}\left(p_t + \theta\frac{Q_t}{\partial Q / \partial p_t}\right) = mc_t \tag{2}$$

where mc_t denotes marginal cost in period *t*. The left hand side is the firms' perceived marginal revenue and is now explained intuitively. The parameter τ reflects factors that drive a wedge between the coffee price consumers pay and the wholesale price coffee roasters receive, e.g. value added taxes. The parameter θ captures the degree of oligopolistic interdependence in the industry. If θ equals zero, perceived marginal revenue is equal to the (wholesale) market price, and coffee supply is perfectly competitive. If θ equals 1, perceived marginal revenue is equal to the marginal revenue of a monopolist, so that the coffee industry

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[3] According to marketing studies, up to 25 percent of prepared coffee now ends in the kitchen sink (Trends, 27 February 1997).

effectively behaves as a cartel. In between these two extremes lie various models of oligopolistic interdependence, such as the well-known Cournot model. When an estimate of θ between zero and one is found, it is useful to stick to one clear interpretation of θ. In the discussion of the parameter estimates below, we follow the interpretation of $1/\theta$ as the "Cournot-equivalent number of firms". This is the number of firms that is consistent with the data if one believes that the industry behaves according to the symmetric Cournot oligopoly model.[4] For example, an estimate of θ of 0.25 implies that the industry behaves *as if* there are four identical Cournot-competing firms in the industry. It is important to emphasize that the parameter θ summarizes *aggregate* conduct in our framework. The degree of anti-competitive behavior by *individual* firms may deviate from this.

Our main research question is in understanding the relationship between coffee bean and consumer prices. This does not imply, however, that we should focus exclusively on estimating the supply equation (2). As can be seen from slightly rearranging (2), the consumer price for coffee depends on both marginal costs and the price elasticity of demand, $\varepsilon_t = -(\partial Q/\partial p_t)(p_t/Q_t)$:

$$p_t = (1+\tau)mc_t + \frac{\theta}{\varepsilon_t}p_t \qquad (2)'$$

Bean prices influence consumer prices both directly through their impact on marginal cost, and indirectly through their impact on the price elasticity of demand. Given our research question, it is therefore necessary to specify functional forms for both marginal cost and demand in the coffee market.

Before we turn to this specification, it is useful to introduce the Lerner-index, L. This index measures market power, and is defined by the percentage markup of price over marginal cost. It can be easily computed from (2):

$$L = \frac{p_t\ /(1+\tau)\ -\ mc_t}{p_t\ /(1+\tau)} = \frac{\theta}{\varepsilon_t} \qquad (2)''$$

According to the Lerner index, market power is strong if there is strong oligopolistic

[4] Various alternative interpretations for θ have been given in the literature, such as the conjectural variation (the expected reaction of rival firms to output changes), or the weight firms put on other firms profits. These interpretations have game-theoretic problems, so we prefer not to use these interpretations.

interdependence or if consumers have an inelastic demand.

Demand

Specify the following functional form for demand equation (1):

$$Q_t = \alpha_{0t} + \alpha_1 \frac{(p_t / p_t^o)^\lambda - 1}{\lambda} \tag{3}$$

The intercept α_{0t} contains a constant, linear terms for the price of tea and income, and three quarterly season effects. The parameter λ performs a Box-Cox transformation on the coffee price variable, and is a convenient way to flexibly model the shape of the demand curve. If λ is equal to 1, demand is linear; if λ is less than 1, demand is convex; and if λ is greater than 1, demand is concave. Below we present estimates of the demand equation under three scenarios for the price variable: logarithmic (λ=0), linear (λ=1) and quadratic (λ=2). The data did not show sufficient variability to estimate λ precisely, so one should essentially view (3) as a convenient way to present the three demand specifications.

Marginal costs

The theory of cost minimization 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 quite simple.[5] It involves roasting and grinding the coffee beans into the final coffee substance, which is then packaged for consumer use. Coffee beans, packaging and labor are essentially used in fixed proportions. Furthermore, economies of scale in production are extremely limited, making average variable and marginal cost independent of output. These facts allow us to adopt the following fixed proportions, constant returns to scale specification for marginal cost:

$$mc_t = \beta_o w_t^o + \beta_1 w_t^b + \beta_2 w_t^l \tag{4}$$

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

[5] 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 since it has a relatively small consumption share of 12 percent, as reported in VNKT (1997).

(mainly packaging). The coefficient β_1 can be interpreted as the transformation rate of beans into roasted coffee. According to experts, the production of one kg of roasted coffee requires 1.19 kg of beans. About 20 percent of the raw coffee beans consists of water and evaporates during the roasting process. This number 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).[6]

It is now straightforward to complete the specification of the supply side (2). Computing the demand derivatives from (3) and substituting marginal cost given by (4), rewrite the supply equation after some rearrangements as:

$$\frac{p_t}{p_t^o} = (1+\tau)\left(\beta_0 \frac{w_t^o}{p_t^o} + \beta_1 \frac{w_t^b}{p_t^o} + \beta_2 \frac{w_t^l}{p_t^o}\right) - \frac{\theta}{\alpha_1}\left(\frac{p_t}{p_t^o}\right)^{1-\lambda} Q_t \qquad (5)$$

where λ is specified as 0, 1 or 2, in the logarithmic, linear and quadratic demand specifications, respectively. We add error terms to equations (3) and (5), and estimate the system simultaneously using the generalized method of moments (Hansen, 1982). This is a consistent and asymptotically efficient estimator. It takes into account the endogeneity of price and quantity, using all 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 heteroskedasticity-consistent and robust to autocorrelation.

3. Data sources and data handling

The analysis is performed on the aggregated Dutch market with publicly available monthly data over 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). Since figures on stock changes are missing, coffee consumption Q_t is approximated as production minus net exports of roasted coffee. On average, 19% of consumption is imported. Series on consumer prices are reported in CBS, Bijvoegsel van de Maandstatistiek van de Prijzen. The same source reports total consumer expenditures, our measure for income.

[6] 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 due to speculative inventory behavior.

Taxes, represented by τ, were constant at 6 percent 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 in CBS, 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 variants arabica and robusta[7]. Similarly, exchange rate movements are automatically taken into account. Figure 1 (presented in the introduction) plots the coffee bean and consumer price series. Wages, w_t^1, 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. To resolve this issue, we conduct three alternative "experiments". In our first experiment, we assume that other input prices evolve according to the general price index; in our second experiment, we impose a further restriction on the share of bean costs in average variable costs, based on industry wisdom; in our final experiment, we take a different perspective and assume that other input prices evolve according to the coffee bean price index.

4. Results

Before we present and discuss the empirical results of the full supply and demand model, it is useful to start with a brief discussion of the demand side separately. All specifications (logarithmic, linear and quadratic) yield positive, but insignificant estimates for the tea price and income variable, so we drop them in our full model. The coffee price coefficient is significantly negative. The implied price elasticity of demand roughly takes the same mean value of about 0.2 (in absolute terms) in all specifications, consistent with estimates for the U.S. and Germany[8]. We can draw a first inference about industry conduct from this robust result. Since marginal costs cannot be negative, supply equation (2)' implies that the conduct parameter θ cannot exceed the price elasticity ε_t, i.e. $\theta \leq \varepsilon_t$. With our estimated elasticity, this means that θ cannot exceed 0.2 so that cartel behavior can be rejected. This finding is just a restatement of the intuition that a monopolist (or cartel) operates at the elastic part of its demand function. More precisely, we may expect that the industry behaves as if there are *at least* five Cournot-competing firms.

We now turn to the results from the full model. Recall that we present results for three alternative demand specifications: logarithmic (λ=0), linear (λ=1) and quadratic (λ=2). The data did not show sufficient variability to estimate λ precisely: a point estimate of around -3.2

[7] VNKT (1997, Table 7) reports that the share of arabica's and robusta's in total imports of green coffee was 70% and 30% in 1996, respectively.
[8] For the U.S. Roberts (1984) reported a price elasticity of 0.25 whereas Pagoulatos et al. (1986) estimated a value of 0.11.

was obtained, with a large standard deviation of 16.8.

4.1. Experiment 1

In the first experiment, we assume that the 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 (5) effectively becomes a constant, i.e. $\beta_0^*=\omega\beta_0$. The insignificant parameter estimates (for tea price, income and wages) are excluded in our presented regressions.

The estimates of the demand coefficients are similar to the single equation estimates discussed above. Coffee demand is lowest in the first quarter and highest in the final quarter of a year. The marginal costs per kilo attributable to inputs other than beans, β_0^*, vary between 4.5 and 5 real 1990 guilders in all three specifications. Interestingly, the transformation rate of beans into roasted coffee varies between 1.4 and 1.8. This is of a same order of magnitude, though somewhat larger than the rate of 1.19 implied by the production process of roasting coffee. One explanation for this result is that there is not just a physical loss (of water) in the coffee production process, but also a percentage monetary loss on the value of output, as reflected by the parameter τ in equation (5). Taxes are one source of monetary loss, and have already been taken into account using the observed tax rate of 6 percent. In addition, distribution and transportation costs may account for a systematic monetary loss, at least to the extent that coffee manufacturers need to pay for these services as a percentage on the value of output. At present, we have no prior knowledge on the magnitude of these percentage monetary losses. Assuming that the physical rate of transformation equals 1.19, our results imply percentage monetary losses on the value of output of around 18%, 41% and 52%, in the three respective specifications.

The estimate for Germany in Feuerstein (1996) equals 0.18.

Table 1. Empirical results of experiment 1.

	Logarithmic demand		Linear demand		Quadratic demand	
	coefficient	stand. error	coefficient	stand. error	coefficient	stand.error
α_0	1.012	0.123	0.788	0.047	0.716	0.027
α_1	-0.143	0.046	-0.109	0.031	-0.819	0.209
α_2	0.032	0.016	0.032	0.017	0.031	0.017
α_3	0.039	0.019	0.038	0.019	0.035	0,019
α_4	0.094	0.020	0.099	0.020	0.101	0.020
β_0^*	5.147	0.571	4.400	1.382	4.560	2.244
β_1	1.408	0.151	1.676	0.055	1.810	0.179
θ	0.033	0.022	0.028	0.025	0.016	0.026
ε	0.209	0.067	0.211	0.061	0.233	0.060
L-index	0.156	0.087	0.134	0.112	0.070	0.110

Notes: GMM estimates with standard errors that are heteroskedasticity-consistent and robust to autocorrelation. The price coefficient is multiplied by 10 in the linear specification, and by 1000 in the quadratic specification. The price elasticity of demand and the Lerner index (computed by (2)'') are evaluated at sample mean values. The standard error of the estimated Lerner index is computed using the delta-method.

Finally, the conduct parameter θ is estimated rather small in all specifications. In all specifications, the hypothesis of monopoly (θ=1) is rejected at a 5 percent significance level; the same is true for Cournot duopoly (θ=0.5) and for any Cournot-equivalent number of firms less than twelve (θ>.083). The hypothesis of perfect competition cannot be rejected (θ=0), but neither can the hypothesis of oligopolistic interdependence with a Cournot-equivalent number of 15 or more firms (θ<.068). Despite the relatively small estimates of θ, the Lerner index of market power is relatively high, though imprecisely estimated. This is of course due to the low estimate for the price elasticity of demand, as can be seen from (2)''.

4.2. Experiment 2

In the previous experiment the part of costs attributable to inputs other than beans (the constant) is estimated between 4.5 and 5 guilders per kilo, with a quite high standard error in the linear and quadratic specifications. With a bean price of about 3 guilders during the first (relatively stable) years of the studied period, beans have a cost share of about 55%, 52% and 54% in the logarithmic, linear and quadratic specifications, respectively. Although of a reasonable order of magnitude, we find these point estimates rather low. A rough rule of thumb in the industry states that -- on average -- about 60% of total costs consists of bean costs (Financieel Dagblad, 3 May 1997). Given the importance of fixed costs (e.g. advertising, as emphasized by Sutton, 1991), the share of beans in the *variable* and *marginal* costs may even be higher, say 70%. We therefore now conduct a second experiment. If one assumes that bean costs have on average been a fraction ω of unit costs, it can be checked that the constant may be pinned at $\beta_0^*=\beta_1(1/\omega-1)(w_a^b/p_a^o)$, where the subscript *a* denotes the average of a variable over the studied period. We estimate the three specifications with this restriction, setting ω equal to 60% or 70%. The results are presented in Table 2.

Table 2. Empirical results of experiment 2.

	Logarithmic demand		Linear demand		Quadratic demand	
	60 %	70 %	60 %	70 %	60 %	70 %
t-test	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)

Note: see notes under Table 1 of Experiment 1.

The t-statistics on the first row test whether the 60 % and 70 % restrictions are rejected by the data, *conditional* on the maintained demand specification. More formally, based on the parameter estimates of Experiment 1, they test the hypothesis that the constant β_0^* equals $\beta_1(1/\omega-1)(w_a^b/p_a^o)$ where ω is 60% or 70%. The t-statistics reveal that the restricted model cannot be rejected by the data in the linear and quadratic specification, both when the 60% and when the 70% rule are applied. This is intuitive given the relatively high standard errors of the constant in the unrestricted model of experiment 1. In these two specifications, we may therefore interpret our second experiment as a way to incorporate our prior information to increase the precision of our estimates. In the logarithmic specification, in contrast, both the 60% and the 70% rule of thumb are rejected. The results in this case should therefore be interpreted with care: an increase in precision may here go at the cost of possible bias.

First consider the results from the linear and logarithmic specifications. The demand coefficients and their standard errors are hardly affected, as could be expected. The major change occurs at the supply side: the standard errors drop quite dramatically in comparison with the results in Table 1. We can therefore become more confident in our results on cost and conduct, which were still presented very cautiously in the unrestricted first experiment. Since our estimate of β_1 remains quite high compared to the value of 1.2 for the physical rate of transformation of beans into roasted coffee, it is likely that there are indeed also systematic monetary losses involved in the long chain from production to final consumption. The point estimates of the conduct parameter increase, especially under the 70% rule. Due to the substantially increased precision of our estimates (at no cost of bias), we now reject the hypothesis of perfectly competitive behavior in favor of oligopolistic interdependence. The industry roughly behaves as if there were a Cournot-equivalent number of firms between 25 and 30. Finally, the Lerner index which summarizes market power is estimated much more precisely. Under the 70 % rule it becomes quite high, e.g. compared to the estimate of 6% obtained by Roberts for the U.S.

Next consider the logarithmic specification, in which the 60 % and 70 % restrictions were not supported by the data. More care in the interpretation should be taken here, since some of the parameters may now be biased. One example of this may be the estimate of the price elasticity (evaluated at the sample mean), which becomes much larger than in the other specifications. The estimate of the conduct parameter is also much larger, consistent with a Cournot equivalent number of firms of 10 (60 % case) and 6 (70 % case). The overall effect of the increased elasticity and increased conduct parameter on the estimated Lerner-index is positive: it reaches values of .34 and .54.

4.3. Experiment 3

Experiment 1 and 2 have been based on the assumption that other factor prices move according to the general price index. In our final experiment, we take a quite different direction and arbitrarily assume that other factor prices evolve according to bean prices. This is equivalent to assuming that coffee beans have a constant share of marginal costs, i.e. $\beta_1 w_t^b = \omega mc_t$, at *every* period t. The specification for marginal costs then becomes $mc_t = \beta_1 w_t^b / \omega$, where ω is set to 60%. Note that in this specification the constant term of experiment 1 effectively drops, so that we can apply a standard nested hypothesis test (as in experiment 2) to examine the plausibility of our third experiment. The results are presented in Table 3. The t-statistics (based on Table 1 estimates) reveal that for all specifications the restriction implied by Experiment 3 is rejected.

Table 3. Empirical results of experiment 3.

	Logarithmic demand		linear demand		quadratic demand	
	coefficient	stand. error	coefficient	stand. error	coefficient	stand.error
t-test	9.010		3.183		2.032	
α_0	1.152	0.114	0.805	0.044	0.717	0.025
α_1	-0.189	0.045	-0.117	0.031	-0.805	0.212
α_2	0.010	0.006	0.027	0.012	0.033	0.014
α_3	0.016	0.008	0.039	0.015	0.042	0.018
α_4	0.025	0.009	0.065	0.013	0.088	0.016
β_1	0.453	0.089	1.067	0.047	1.318	0.037
θ	0.215	0.040	0.103	0.024	0.065	0.016
ε	-0.275	0.065	-0.226	0.060	-0.229	0.060
L-index	0.782	0.047	0.458	0.023	0.284	0.015

Note: see notes under Table 1 of Experiment 1.

Given the high t-statistics, extreme caution should be taken in interpreting the -- possibly biased -- parameter estimates in this experiment. We note here that the bean price coefficient is significantly *below* the physical rate of transformation, a result that is difficult to interpret economically. We also observe that the precision of the supply parameters is not improved relative to the unrestricted model of Experiment 1. We leave an interpretation of the other parameter estimates to the reader.

5. Understanding the evolution of the Dutch coffee industry

We now use our estimates to more closely analyze the evolution of the Dutch coffee industry during our sample period, 1990-1996. Based on our parameter estimates, we first simulate our two equation model (3)-(5) and compute the endogenous price and quantity variables under alternative behavioral scenarios: perfect competition (θ=0), duopoly (θ=0.5) and monopoly (θ=1).[9] Next, we explain the evolution of *actual* prices, and compare this with the evolution of prices under alternative modes of conduct. We focus on the changes that occurred during 1994, the year of the drastic bean price increases due to the frost in Brazil.

We base our analysis on the results of experiment 2 (60 % case), our preferred model. As discussed above, experiment 2 imposed the restriction based on our prior information that bean costs on average made up about 60 % of marginal costs. This restriction was not rejected by the data in the second and the third specification.

[9] An analytic solution to (3) and (5) is easily obtained for the linear and quadratic demand specification; for the logarithmic specification, the solution was obtained numerically.

Consider first the prices evaluated at the sample mean. If the industry would be able to enforce a cartel (monopoly) instead of the current situation, prices would more than double (+120 %) in the quadratic specification, more than triple (+230 %) in the linear specification, and increase to almost 10 times the current value in the logarithmic specification. In contrast to our econometric estimates, the simulation results are quite sensitive to the demand specification that has been used. This is quite intuitive: the monopoly prices are an out of sample prediction and depend crucially on the specified curvature of the demand function, which could not be estimated precisely. Naturally, monopoly prices are predicted to be the largest in the convex demand specification. A more precise idea on the monopoly prices may be obtained if the curvature of the demand function can be estimated more precisely. Whatever the specification, the simulations show that prices would increase substantially if the monopoly outcome could be enforced. Even a duopoly would charge much higher prices than is presently the case. These findings should be kept in mind if concentration in the coffee sector would grow in the future and move the equilibrium closer to the monopoly outcome.

Table 4. Evolution of the Dutch coffee industry under alternative behavioral assumptions, 1992-1996.

	mean	standard deviation	minimum	maximum	change from 1:1994 to 12:1994
logarithmic demand specification (convex)					
elasticity	0.319	0.035	0.254	0.418	+ 0.040
Lerner-index	0.340	0.037	0.257	0.422	- 0.047
marginal cost	8.25	1.53	6.29	11.61	+ 4.23
actual price	13.19	2.09	11.02	17.71	+ 5.08
duopoly price	56.17	5.18	47.31	67.15	+ 6.20
monopoly price	121.90	11.86	103.83	140.59	+ 3.88
linear demand specification					
elasticity	0.215	0.048	0.154	0.337	+ 0.108
Lerner-index	0.151	0.030	0.092	0.201	- 0.073
marginal cost	10.58	1.96	8.05	14.88	+ 5.42
actual price	13.19	2.09	11.02	17.71	+ 5.08
duopoly price	32.26	1.77	29.52	36.74	+ 3.61
monopoly price	43.11	1.97	40.08	47.72	+ 2.71
quadratic demand specification (concave)					
elasticity	0.244	0.097	0.139	0.462	+ 0.253
Lerner-index	0.075	0.026	0.035	0.116	- 0.064
marginal cost	11.42	2.11	8.69	16.07	+ 5.85
actual price	13.19	2.09	11.02	17.71	+ 5.08
duopoly price	24.38	1.18	22.68	27.38	+ 2.97
monopoly price	29.97	1.06	27.36	31.68	+ 2.30

bean price	3.78	1.17	2.28	6.35	+ 3.23

Note: The results are based on the estimates of Table 2 (60 % case). Model simulations on equation (3) and (5) for perfect competition (θ=0), duopoly (θ=0.5) and monopoly (θ=1). Marginal cost and prices are in real terms.

Next, consider the evolution of actual and simulated prices during our studied period. Consider in particular the changes that took place during 1994, in response to the upward jump of bean prices by 3.23 guilders, or 104%. Consumer prices increased by only 45%. To interpret this, consider equation (2)', from which it can be seen that consumer price changes (in percentage terms) can be decomposed in marginal cost changes and changes in the price elasticity of demand:

$$\frac{\Delta p_t}{p_t} = \frac{\Delta mc_t}{mc_t} - \frac{\theta}{\varepsilon_t - \theta}\frac{\Delta \varepsilon_t}{\varepsilon_t} \qquad (6)$$

The percentage increase in marginal cost in (6) can in turn be written as the weighted sum of percentage increase in bean prices and other factor prices:

$$\frac{\Delta mc_t}{mc_t} = (1 - s_t^b)\frac{\Delta w_t^o}{w_t^o} + s_t^b \frac{\Delta w_t^b}{w_t^b}$$

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

The jump of the bean prices by 3.23 guilders, or 104%, is directly expressed in an increase in marginal costs by a larger absolute amount, between 4.23 and 5.85 guilders in Table 4. The *percentage* increase in marginal costs, however, is much smaller, e.g. only 57% in the linear demand case. This is due to the relatively large share of costs other than bean costs, which did not follow the same evolution as the bean prices. A share of at least 40 % (on average) could not be rejected by the data.[10] Therefore, the cost argument hypothesized in the introduction, accounts for at least part of the explanation for the weak relationship between bean and consumer prices.

A second dampening effect on consumer prices may stem from markup absorption. How important was this during the 1994 shock? As can be read from the second term in equation (6), markup absorption takes place provided that (1) there is oligopolistic interdependence

[10] For the linear and the quadratic specification, this is directly clear from our reported t-statistics in Table 2 which do not reject a share of other inputs of 40 %. For the logarithmic specification, a share of 40 % is rejected, because shares of even *larger* than 40 % are in fact favoured by the data.

($\theta>0$), and (2) the price elasticity of demand increases with consumer prices. Table 4 shows that the price elasticity indeed increased during the 1994 bean price shock, especially in the linear and quadratic specifications (increases by about 50% and 100%, respectively). This led to a reduction in the markups, e.g. by -8% in the linear demand case. This is not much, due 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 by 45%, compared to an increase in the bean prices by 104%, can be explained partly by markup absorption (-8% under linear demand), but for the most significant part by the modest increase in marginal cost (only 57% under linear demand) because of the relatively large share of other costs than bean costs.[11, 12]

We finally ask how prices would have responded in 1994 if behavior had been different from what we actually observed. We consider both duopoly ($\theta=0.5$) and monopoly ($\theta=1$). In this case, markups would be much larger as shown by the mean predicted prices discussed above. Equilibrium price elasticities of demand (not shown) would be well above unity. As the last column of Table 4 indicates, both the absolute and percentage increases of coffee prices would be even less than what was actually observed.[13] In the linear demand case, for example, percentage price increases would be 12 % under duopoly, and 7% under monopoly. This follows of course from the fact that under duopoly and monopoly, markup absorption becomes quantitatively much more important.

6. Concluding remarks

This paper has analyzed the observed weak relationship between coffee bean and consumer prices in the Netherlands. 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 markup absorption, but is less important since oligopolistic interdependence is relatively competitive. Simulations of the model show that consumer prices would have been much higher and fluctuated even less in response to bean price fluctuations if the industry had behaved according to a Cournot duopoly or a monopoly.

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[11] Our results on markup absorption partly follow from the demand specification (3), which 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 markups, since in this case the conduct parameter θ is not identified (Bresnahan, 1982). A specification with decreasing (in absolute value) price elasticity of demand is unconventional and economically unappealing. If we had imposed such a specification, then the reverse of markup absorption would have occurred (if $\theta>0$). In any event, our conclusion that marginal costs rather than markups explain the weak relationship between coffee bean and consumer prices would remain unaltered.

[12] Note that the mentioned markup change (-8%) and marginal cost change (+57%) do not exactly add up to the consumer price increase of 45%. This is because the changes are large, so that an interaction term cannot be neglected.

[13] The only exception to this statement is the move towards duopoly in the logarithmic specification. In this case prices would have increased by more than was actually the case in *absolute* (though not in percentage) terms.

Our approach has made use of publicly available data on the Dutch coffee market. The strong volatility of bean prices has provided a unique natural experiment to analyze firm behavior. Given the moderate data requirements, we hope that our analysis will stimulate further research to investigate firm behavior and market power in other sectors of the economy.

At the same time, there is room for a more in-depth analysis of firm behavior in the coffee industry, provided that additional data can be obtained. With firm-level data, it becomes possible to analyze firm-specific oligopoly behavior. The present analysis reveals interdependent, though rather competitive conduct at the *aggregate* level. It is possible, however, that that one of the firms possesses strong *individual* market power with all other firms acting as a competitive fringe. More detailed data would also allow to consider 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.

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