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A DUALITY APPROACH TO TESTING THE ECONOMIC BEHAVIOUR OF DAIRY-MARKETING COOPERATIVES: THE CASE OF IRELAND

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ABSTRACT

The main objectives of this paper are: (i) to establish whether Irish dairy marketing cooperatives behaved "as if" they were profit maximisers over the period 1961 to 1987 and (ii) to determine the response of the sector to the imposition of the milk production quota in 1984. The theory of the cooperative managed firm (CMF) is first recast in a duality framework. The CMF differs from the profit maximising firm (PMF) in (a) having as its objective the maximisation of the price paid to its members for the raw material they supply and (b) being obliged to process all the raw material supplied by its members. A formal test as to whether the Irish dairy-processing sector could be characterised as "virtual" profit maximisers was implemented and could not be rejected. This finding was reinforced by our finding that the elasticity of milk price with respect to the volume of milk processed was zero. Milk price was found to be driven mainly by exogenous changes in the price of processed output. The impact of the quota was to obviously reduce the level of processed output but not proportionately. Our results suggest that every 10% fall in the amount of milk processed reduces processed output of the sector by 6%. We also found a negative relationship between the amount of the milk raw material processed and the demand for labour implying that the introduction of the quota would not of itself have adversely affect employment in the sector.

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1. Introduction

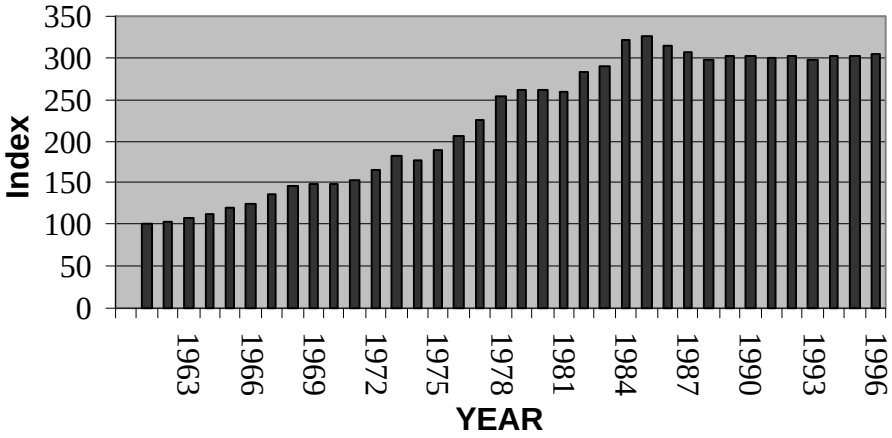
Since the introduction of production quotas in 1984 there has been a substantial amount of analysis of the impact on the choices of primary milk producers in European economies. This trend has accelerated in the wake of the 1992 "MacSharry CAP Reforms". In contrast with the voluminous amount of material dealing with primary producers there appears to have been relatively little analysis of decision-making by the processors of farm output. Yet there are several important reasons to analyse the behavior of these firms.

For one the processors of milk output are predominantly organised as cooperatives. This raises interesting issues about the appropriate behavioural framework for the empirical modelling of such firms. A particular concern in this paper is to explore, in the case of Ireland, whether cooperatives are fundamentally different in their economic behaviour to profit-maximising firms. Specifically, if cooperatives are found to be no different in their behaviour to profit-maximising firms it calls into question the generally favourable fiscal treatment of such entities in most jurisdictions. In Ireland, for instance, up to April 1992 dairy-processing cooperatives were exempt from corporation tax.

A second major issue of interest arises out of the 1994 reforms themselves. The imposition of the quota system had a major impact on the dairy-processing sector as Chart 1 demonstrates. Up to 1985[1] milk production in Ireland was growing at a rate of about 5% per year and the intake of milk for processing would have grown at about the same rate. From this date raw material available for processing has been more or less fixed. Such an imposition can be expected to have led to significant adjustment in the output supply and input demands of dairy processors.

[1] Ireland was exempted from the quota regime in 1984.

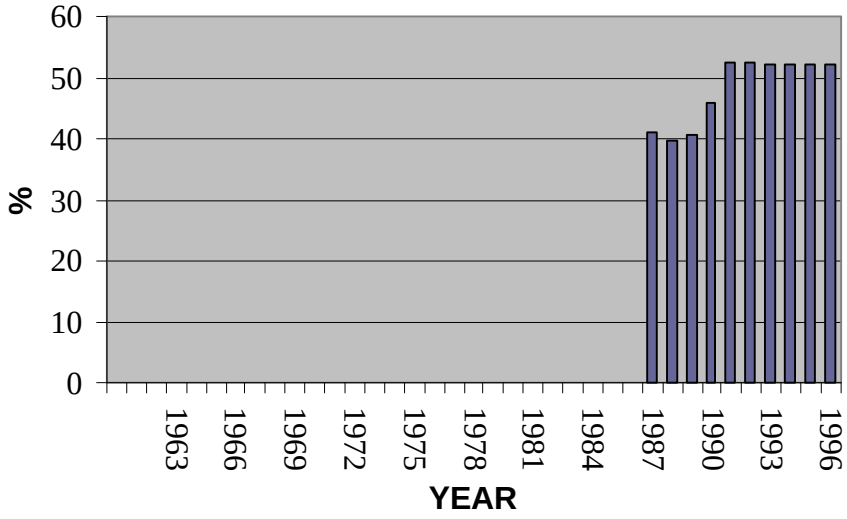
Chart 1: Milk Production(1960=100), 1961-1996



A third notable development in the behaviour of dairy-marketing cooperatives in Ireland at any rate has been the huge structural change in their organisational structure. Specifically from about 1987 onwards there has a substantial widening in the ownership base of cooperatives through the public floatation of these entities. A graphic illustration of the sea change which has occurred in organisation structure is given in Chart 2 where it can be seen that from 1961 to 1986 none of the total milk supplied was processed by publically-owned entities[2]. This percentage had jumped to 41% by 1987 and a steady growth is evident since then to 1996 where an estimated 52.2% of total supply is now processed by public companies. It is beyond the scope of this paper to speculate as to the reasons for the structural change (see, for example, Harte (1994), for a discussion of possible reasons) but it may not be entirely coincidental that the change coincided with the advent of production quotas. Dairy-processing firms, facing a profit squeeze as their raw material was fixed in amount, were forced to diversify and for this capital was needed. The most efficient way to raise capital was through a public floatation. Farmers on the other hand were prepared to cede part of their assets on the prospect of compensating for the profit losses likely to flow from the imposition of quotas.

[2] Farmers as milk suppliers still retain a majority shareholding in these public companies.

Chart 2 : Processing of Milk by PLC Co-ops (%), 1961-1996



The ability of the cooperatives to respond so expeditiously and, on the face of it, so successfully[3], to the challenges posed by the quota provides *prima facie* evidence that they were compelled by the desire to maximise profits or, at the very least, were no less capable of adjusting to changed circumstances as firms which explicitly conformed to the traditional profit-maximising paradigm.

Our objectives in this paper are first and foremost to analyse the economic behaviour of dairy-marketing cooperatives using Ireland as an illustrative case. Specifically we want to explore the extent to which cooperatives diverge or converge towards the framework of the profit-maximising firm. Second, we want to establish the economic responses of these firms to changes in exogenous variables and in particular to the imposition of the milk quota in 1984.

[3] At present there are three publically-quoted milk processing companies in Ireland: the Kerry Group, the Avonmore, Waterford Group (AWG) and the Golden Vale Group. Kerry over the coarse of 25 years has evolved from a regional Irish milk-processing co-operative to one of the world's leading specialist food ingredients and food manufacturing businesses. Through an extensive and careful acquisition policy it has gone from a market capitalisation of IR£50 million in 1986 to a current market capitalisation of IR£1.6 billion. Since the Group's listing in 1986 it has had an unbroken record of profit and earnings growth with a current P/E ratio of 24.6. AWG was formed in 1997, which emerged from the takeover of Waterford Foods by Avonmore Foods (listed in the late eighties on their conversion from co-operative friendly societies). The group is the largest cheese producer in Ireland and the largest cheese processor in the UK. The current P/E ratio is 19.3 and growing. Another company that was a co-operative for most of its existence is Golden Vale, which was listed in 1990. The market capitalisation of this company now stands at IR£801.3 million with a P/E ratio of 19.3. This information was taken from DAVY (1997 and 1998).

The plan of the paper is as follows. Section 2 sets out a theoretical framework designed to provide guidelines for the empirical application. We draw on the traditional and seminal analysis of Helmberger and colleagues (1962, 1964, 1966) and recast it in a duality framework which proves highly convenient for the empirical analysis. Section 3 outlines how the theoretical framework could be applied to achieve the objectives established for the paper. Section 4 sets out the data used in the empirical application and reports the econometric results. Finally in Section 5 we draw some conclusions.

2. Theoretical framework

Suppose a dairy-marketing cooperative were classed as a profit-maximising firm (PMF) facing given prices for all variable inputs, including its principal raw material, and its processed output. Also let's suppose that the capital input is short-run quasi fixed. The profit function for such a firm is given by equation (1):

$$\pi_k = \pi_k(p_y,\ w,\ k) \qquad \textbf{(1)}$$

where,

π_k = short-run maximum restricted profits, given k.

p_y = price of processed output.

w = vector of input prices.

k = short-run quasi-fixed capital stock.

Equation (1) can be thought of as giving the maximum returns to the quasi-fixed input k.

Hotelling's Lemma gives us the processed output supply and input-demand functions consistent with maximising the returns to capital as equations (2)(a) and (2)(b):

$$\left(\frac{\P p_k}{\P p_y}\right) = y = y(p_y, w, k) \quad \text{(a)}$$
$$\left(\frac{\P p_k}{\P w}\right) = -x = x(p_y, w, k) \quad \text{(b)} \qquad \textbf{(2)}$$

where,

x = vector of variable input quantities.

The path-breaking and enduring work on the economic behaviour of the dairy-marketing cooperative was developed in a series of seminal papers in the early 1960s by Peter Helmberger and colleagues (see Helmberger and Hoos (1962), Helmberger (1964) and Helmberger and Youde (1966)). For convenience we will hereafter refer to this body of work as the theory of the Cooperative-Managed Firm (CMF). According to this theory the objective function of the cooperative firm is different to the price-taking profit-maximising firm. The CMF seeks to maximise the price paid per unit of raw material supplied by its farmer members. The CMF is also obliged to process all the raw material supplied by its member suppliers.

CMFs are divided into "restricted" and "open" membership forms. In the "restricted" form the cooperative is constituted as a club and can decide to admit new members as it wishes and thus adjust its raw material supply through its membership policy. However, it has to process all the raw material supplied by its current membership. In the "open" co-operative there is little or no restriction on entry that can be exercised by the cooperative itself. In other words the existing membership cannot preclude new members from joining. Irish dairy cooperatives and we would

presume most dairy cooperatives conform to the "open" model[4]. This fact makes the CMF quite different to the closely related labour-managed firm since the latter commonly exists in the "restricted" form (see Kahana (1989) and Kahana and Nitzan (1989) for a modern theoretical treatment).

In Helmberger's framework the "open" CMF's objective is not to maximise profits but instead seeks to maximise the average milk price paid to its supplier members[5]. This price is equivalent to the maximum cooperative surplus (defined as the difference between the value of revenue less all variable and fixed-input costs) relative to the total amount of milk supplied by its farmer members:

"We may assume that the non-cooperative firm seeks to maximise profit whereas the cooperative seeks as an "intermediate" objective to maximise cooperative surplus for any given level of M *[level of milk supplies[6]]*" (Helmberger (1964)).

The Helmberger framework is developed using the tools of classical comparative static analysis. One of the contributions of this paper is to recast the classical theory of the CMF in a duality framework. This task results in two important insights. First, it affords a ready comparison between the theory of the CMF and the PMF and allows clear inferences to be drawn about the relative economic behaviour of the two forms of organisation[7]. Second, the duality approach provides us with a convenient template for testing the competing CMF and PMF formulations.

Using the language of modern duality theory (see for example Chambers (1988) and Brown and Christensen (1981)), Helmberger's stated objective for the CMF can be equivalently stated as seeking to maximise short-run restricted profit where all inputs, bar the raw material milk, is short

[4] The imposition of the dairy quota system in 1984 means that new members cannot join unless through inheritance, purchase or lease of quota. However, this development does not transform the cooperative from an "open" to a "closed" structure since this restriction is policy driven and hence beyond the control of the cooperative.
[5] Harte (1992) argues that "… the milk price paid by a cooperative to its members is more like a transfer price between two related businesses than a market price".
[6] Our italics.
[7] In the case of the labour-managed firm the failure to utilise the duality approach has led to serious errors in the analysis of such forms of organisation (see Kahana (1989)). No such errors appear to have afflicted the analysis of the CMF. While this may be considered a fortuitously welcome outcome it is nonetheless odd given the virtually identical forms of organisation in both cases.

run variable and the firm faces given prices for its output and all other inputs, bar milk. Short-run restricted profits are simply, $p_m m$, where, p_m is the price of milk and m is the level of milk supplied by members. If the CMF maximises $p_m m$, then p_m is also maximised.

Thus the firm must process all the milk its suppliers deliver for processing. The level of raw material processed or demanded by the cooperative is a given for the "open" cooperative firm but the price paid for the raw material is a choice variable.

Let's now characterise the dairy cooperative as an "open" entity but unlike, Helmberger and Hoos, let's retain the assumption, as a maintained hypothesis, that capital is a short-run quasi-fixed input. The behavioural objective of such a firm will be to maximise short-run restricted profits conditional on a given level of raw material (m) and capital stock (k). This can be thought of as maximising the returns to capital and raw materials. The profit function of the dairy-processing firm will now be given by equation (3):

$$\pi^{c}_{k,m} = \pi^{c}_{k,m}(p_y, \overline{w}, m, k) \qquad \textbf{(3)}$$

where,

$\pi^{c}_{k,m}$ = maximum short-run profit for the cooperative firm.

m = level of raw material (milk) which the cooperative must process.

$\overline{w}$ = vector of variable input prices such that $\overline{w} < w$.

Hotelling's Lemma (Varian (1978)) gives us the processed output supply and variable input demand equations for the cooperative firm as equations (4)(a) and (4)(b):

$$\left(\frac{\partial \pi^{c}_{k,m}}{\partial p_y}\right) = y^{c} = y^{c}(p_y, \bar{w}, m, k) \quad \text{(a)}$$
$$\left(\frac{\partial \pi^{c}_{k,m}}{\partial p_y}\right) = -\bar{x}^{c} = \bar{x}^{c}(p_y, \bar{w}, m, k) \quad (b) \qquad \textbf{(4)}$$

where,

$\bar{x}^{c}$ = profit-maximising quantities of variable inputs demanded by the cooperative firm such that $\bar{x}^{c} < x$.

On the face of it equations (3) - (4) appear quite different from the system in (1) - (2). However, under certain additional assumptions the derivative relationships may be shown to be identical. This is of course an implication of the well-known Le Chatelier-Samuelson principle or the Envelope Theorem (Varian (1978)).

To see the correspondence between the system (1) - (2) and (3) - (4), consider the implied returns to capital for the cooperative firm which are defined in equation (5) as:

$$\pi^{c}_{k} = \pi^{c}_{k,m}(p_y, \bar{w}, m, k) - p_m m \qquad \textbf{(5)}$$

where,

p_m = price of milk paid to cooperative members.

Now,

$$\begin{aligned}
&\pi_k = \pi_k^c = o, \text{ iff} \\
&\pi_k(p_y, w, k) - \pi_{k,m}^c(p_y, \overline{w}, m, k) + p_m m = 0 \\
&\text{or,} \qquad \textbf{(6)} \\
&\left(\frac{\partial \pi_k}{\partial m}\right)(p_y, w, k) - \left(\frac{\partial \pi_{k,m}^c}{\partial m}\right) + p_m = 0 \\
&\Rightarrow p_m = \left(\frac{\partial \pi_{k,m}^c}{\partial m}\right) = p_m^v
\end{aligned}$$

If condition (6) holds then the cooperative firm is behaving "as if" it were maximising π_k. The price it pays for its raw material p_m is chosen consistent with maximising the returns to the given quantity of raw materials and the capital stock. Hence this price is sometimes referred to as the "virtual" price (Neary and Roberts (1980)) denoted here for convenience as p_m^v. In other words, if (6) holds then the amount of raw material processed is exactly equivalent to what a profit-maximising firm would have freely processed when faced with a given price p_m. Thus from an economic perspective if $p_m = p_m^v$ then equations (3) - (4) are identical to (1) - (2). We could thus characterise such a cooperative as a virtual profit-maximising firm (VPMF for short).

Of course this conceptual framework can be extended further to the case where capital is assumed to be variable even in the short run. The conditions for the cooperative firm to be a "virtual" profit maximiser in these circumstances are given in (7):

$$\begin{aligned}
p_m &= \left(\frac{\partial \pi_{k,m}^c}{\partial m}\right) = p_m^v \\
p_k &= \left(\frac{\partial \pi_{k,m}^c}{\partial m}\right) = p_k^v
\end{aligned} \qquad \textbf{(7)}$$

where,

p_k^v = the "virtual" price of capital.

A big advantage of the duality approach is that is allows a clear comparison between the behaviour of the CMF and the PMF. In general:

$$p_k \geq p_k^c \qquad \textbf{(8)}$$

This expression is referred by Chambers (1988) as the "fundamental duality inequality". It implies that profits of the PMF must be at least equal to those generated by the CMF. More specifically it implies that the profit function of the PMF is in general "more convex" in respect of output and variable input prices. By implication responses to price changes will be more sluggish for the CMF compared to the PMF[8]. The intuition for this result can be understood by comparing the price responses of the PMF and the CMF.

If the cooperative firm behaves as a virtual profit maximiser then:

$$y^c(p_y, \bar{w}, k, m(p_y, \bar{w}, k, p_m)) = y(p_y, \bar{w}, k, p_m)$$

$$\left(\frac{\mathrm{d}\, y^c}{\mathrm{d}\, p_y}\right) + \left(\frac{\mathrm{d}\, y^c}{\mathrm{d}\, m}\right)\left(\frac{\mathrm{d}\, m}{\mathrm{d}\, p_y}\right) = \left(\frac{\mathrm{d}\, y^c}{\mathrm{d}\, p_y}\right) + \left(\frac{\mathrm{d}\, y}{\mathrm{d}\, p_m}\right)\left(\frac{\mathrm{d}\, m}{\mathrm{d}\, p_y}\right) \Big/ \left(\frac{\mathrm{d}\, m}{\mathrm{d}\, p_m}\right) = \left(\frac{\mathrm{d}\, y}{\mathrm{d}\, p_y}\right) \qquad \textbf{(9)}$$

$$\Rightarrow \qquad \left(\frac{\mathrm{d}\, y}{\mathrm{d}\, p_y}\right) \geq \left(\frac{\mathrm{d}\, y^c}{\mathrm{d}\, p_y}\right)$$

Similar results can be established for the all other price responses[9]. It will be noted that a sufficient condition for the cooperative and profit maximising firms to have identical price responses is if:

$$\left(\frac{\mathrm{d}\, m}{\mathrm{d}\, p_m}\right) = \infty \qquad \textbf{(10)}$$

[8] It is important to note that the CMF will not exhibit perverse price responses.

This case occurs where the processors are perfectly competitive sellers in their product market. One would have a strong prior that such a structure would characterise the dairy processing sectors in most countries. In this situation the price of milk is a given (demand for the raw material is perfectly elastic) and the quantity of the raw material processed is determined solely by the supply behaviour of farmers (see Helmberger (1964) and Figure 1).

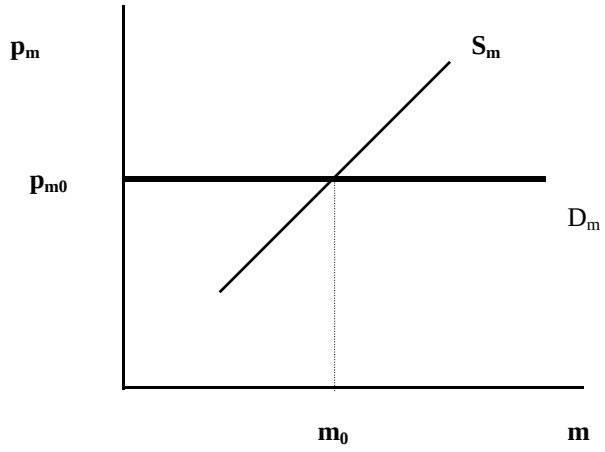


Figure 1: Equilibrium for a processor who is a perfectly competitive seller in his product market

This result has important implications for empirical analysis that can be illustrated by assuming a simple Cobb-Douglas profit function:

$$\log(\pi) = \log(p_m m) = a_0 + a_y \log(p_y) + a_w \log(\bar{w}) + a_k \log(k) + a_m \log(m) \qquad \textbf{(11)}$$

[9] The result that $(\partial y^c/\partial m)=(\partial y/\partial p_m)/(\partial m/\partial p_m)$ is derived in Deaton and Muellbauer (1980).

The cooperative firm seeks to maximise the price paid to its members for a given raw material supply:

$$\overline{p_m} = (\pi / m) \Rightarrow \left(\partial \overline{p_m} / \partial m\right) = (a_m - 1)(\pi / m^2) \qquad \textbf{(12)}$$

The profit-maximising firm chooses the price that maximises profits for a given level of raw material supply:

$$p_m^v = a_m(\pi / m) \Rightarrow (\partial p_m^v / \partial m) = a_m(a_m - 1)(\pi / m^2) \qquad \textbf{(13)}$$

The partial derivatives (12) and (13) will vanish if:

$$(\partial \log(\pi) / \partial \log(m)) = a_m = 1 \qquad \textbf{(14)}$$

3. Applying the theoretical framework

The theoretical framework set out above can be exploited to address the issues raised in our introduction. The first issue was whether Irish dairy cooperatives could be classified as "virtual" profit maximisers. For instance, if cooperative firms were under pressure to maximise the milk price paid to its members at the expense of adequately remunerating its capital stock this would imply $p_m > p_m^v$. Whether this outcome is consistent with the empirical evidence can be tested using the framework suggested by Conrad and Unger (1987). This approach involves estimating a system given in (15):

$$\begin{aligned}
\pi_{k,m}^c &= \pi_{k,m}^c(\beta; p_y, \overline{w}; m, k) \quad \text{(a)} \\
y^c &= y^c(\beta; p_y, \overline{w}; m, k) \quad \text{(b)} \\
-\overline{x}^c &= \overline{x}^c(\beta; p_y, \overline{w}; m, k) \quad \text{(c)} \\
p_m^v &= p_m^v(\beta; p_y, \overline{w}; m, k) \quad \text{(d)}
\end{aligned} \qquad \textbf{(15)}$$

where,

β = a vector of parameters.

The system in (15) implies that the cooperative firm is a "virtual" profit maximiser. In other words the price of milk paid to suppliers is restricted in the estimation to be equivalent to the "virtual" price implied by Hotelling's Lemma.

To statistically test the validity of the system in (15) we can compare the log-likelihood value obtained from estimation of this system with that yielded by estimation of a modified system which involves replacing (15)(d) by (16):

$$p_m = p_m(\gamma; p_y, \overline{w}; m, k) \qquad \textbf{(16)}$$

where,
$\gamma \neq \beta$ is a vector of parameters.

The modified system does not impose the condition that the actual milk price is got by applying Hotelling's Lemma. The Conrad and Unger (1987) test ascertains whether p_m systematically differs from p_m^v over the entire sample[10].

4. Data and empirical estimation

Our empirical model is tested by estimating the systems (15)(a), (b), (c), (d) and (15)(a), (b), (c), (16) using time-series data on the dairy-processing sector. Short-run profits were defined to be functions of the price of processed output (p_y), the wage rate (w_1), the price of non-milk materials

(w_2), the volume of milk materials (m) and the level of the capital stock (k). A time trend (t) was added to the complement of variables in both systems and a simple first-order autocorrelated error structure was also appended to each equation of the system. With the exception of the trend variable all variables are normalised to 1987=1. The functional form was assumed to be *translog*. The estimator used in both cases was maximum likelihood with cross-equation symmetry restrictions and price homogeneity imposed[11].

The data are available from 1961 to 1987 and, apart from the milk output variable (m), are obtained from the *Census of Industrial Production* compiled by the Central Statistics Office and maintained in a databank by the Economic and Social Research Institute, Dublin[12]. The milk raw material (m) is got from the Central Statistics Office *Irish Agricultural Output* table with an adjustment for farm home consumption. While this aggregate includes milk that is used for both further processing and final consumption, the vast bulk of farm output is processed and hence it is felt the variable we use is a very good proxy for the true variable.

Detailed coefficient estimates are given in Table 1. The log-likelihood from estimation of the system (15)(a)-(15)(d) was estimated as 279.37 and was found to be 286.86 for the system (15)(a), (b), (c) and (16) and –2*(286.86-279.37) = 15.7 is distributed as a $\chi 2$ statistic with 6 degrees of freedom. Critical values at the 1%, 2.5% and 5% are respectively 16.8, 14.4 and 12.6 respectively and thus we cannot reject the null-hypothesis that the cooperatively-managed dairy processing sector behaves as a virtual profit maximiser.

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[10] An alternative test is proposed by Kulatilaka (1985) which involves testing whether p_m differs from p_m^v at every datapoint.

[11] The actual computational routine employed was the TSP 4.3 LSQ estimator.

[12] From 1961 to 1973 the dairy processing sector is obtained as ISIC category “creamery butter, cheese, condensed milk, chocolate crumb, ice cream and other edible milk products” and from 1973 to 1987 the sector is given by NACE code 413 “manufacture of dairy products”.

Table 2: Coefficient Estimates of Virtual Profit Maximising Behaviour

Variable	Coefficient	Standard Error	Coefficient	Standard Error
	System 15(a)-15(d)		*System 15(a)-15(d), 16*	
Intercept	**4.5733**	**0.6624**	**6.3249**	**1.5093**
p_y	**1.5721**	**0.2437**	**1.1230**	**0.3526**
w_1	**-0.1541**	**0.0351**	**-0.0917**	**0.0389**
t	**0.1811**	**0.0530**	**0.0446**	**0.1063**
m	**1.3493**	**0.1376**	**8.5428**	**2.2910**
k	**-0.8096**	**0.6020**	**-2.6511**	**0.8896**
p_y*p_y	**-0.0614**	**0.1076**	**-0.0051**	**0.1170**
w_1*w_1	**-0.0905**	**0.0128**	**-0.0861**	**0.0113**
t*t	**-0.0071**	**0.0022**	**-0.0019**	**0.0040**
m*m	**0.2188**	**0.1084**	**7.1624**	**2.2455**
k*k	**-0.1777**	**0.3558**	**-0.6801**	**0.4810**
p_y*w_1	**0.1773**	**0.0099**	**0.1768**	**0.0086**
p_y*t	**0.0055**	**0.0111**	**0.0240**	**0.0150**
p_y*m	**-0.3594**	**0.0661**	**-0.7384**	**0.2947**
p_y*k	**0.2913**	**0.1250**	**0.2885**	**0.1318**
w_1*t	**0.0013**	**0.0014**	**-0.0013**	**0.0016**
w_1*m	**0.1264**	**0.0144**	**0.1713**	**0.0295**
w_1*k	**-0.0539**	**0.0106**	**-0.0521**	**0.0114**
t*m	**-0.0206**	**0.0059**	**-0.3016**	**0.0972**
t*k	**0.0302**	**0.0271**	**0.1223**	**0.0426**
m*k	**0.0514**	**0.0660**	**-0.6090**	**0.5672**
r_1	**0.5558**	**0.0942**	**0.7203**	**0.0963**
r_2	**0.5002**	**0.0919**	**0.5913**	**0.0932**
r_3	**0.3212**	**0.0987**	**0.4283**	**0.0985**
r_4	**0.6677**	**0.1273**	**0.6902**	**0.1604**
Intercept (Eqt. (16))			**0.7111**	**0.2154**
p_y			**-0.2654**	**0.0697**
w_1			**-0.1392**	**0.0873**
t			**0.0039**	**0.0085**
m			**0.0249**	**0.1172**
k			**0.0267**	**0.0642**
Log –Likelihood	**279.37**		**286.855**	

Key: p_y = price of processed output; w_1 = is the wage rate; **t** = time trend; **m** = volume of milk raw material; **k** = capital stock; r_1 - r_4 are the estimated first-order autocorrelation coefficients for the equations estimated. (Note: the numeraire in the imposition of zero homgeneity was the price of non-milk materials.)

Proceeding on this basis we furnish in Table 2 estimates of elasticities for the endogenous variables calibrated to the 1987 data point.

Table 2: Elasticity Estimates for the Dairy-processing sector, Ireland, 1987

	Exogenous Variables					
Endogenous Variable	**Price of Proc. Output**	**Wage Rate**	**Price of Non-Milk Materials**	**Time Trend**	**Volume of Milk Materials**	**Capital Stock**
Processed Output	0.69 (11.13)	-0.02 (3.08)	-0.68 (0.00)	-0.01 (0.99)	0.60 (15.71)	0.17 (2.41)
Labour	0.25 (3.08)	-0.37 (3.44)	0.11 (0.00)	-0.02 (1.68)	-0.24 (2.03)	0.45 (5.13)
Non-Milk Materials	1.92 (0.00)	0.02 (0.00)	-1.94 (0.00)	0.00 (0.00)	0.43 (0.00)	0.40 (0.00)
Milk Price	1.28 (15.71)	0.04 (2.03)	-0.32 (0.00)	-0.04 (4.83)	0.08 (0.59)	0.07 (0.85)

$\overline{\Re}^2$ by equation:	First-order autocorrelation parameter by equation:	D.W. by equation:
15(a): 0.99	15(a): 0.56	15(a): 1.85
15(b): 0.85	15(b): 0.50	15(b): 1.56
15(c): 0.74	15(c): 0.32	15(c): 1.64
15(d): 0.41	15(d): 0.67	15(d): 2.49

t-ratios in parentheses beneath the coefficient estimates.

The most interesting results concern the milk price responses. The elasticity of milk price with respect to milk volume implies a perfectly horizontal demand curve for milk materials. The milk price is only affected positively by shifts in the exogenously determined processed output price and while variations in the price of non-milk materials affect the milk price negatively the elasticity is not statistically significant. This finding is of course consistent with our earlier mentioned result

that the dairy-processing sector can be modelled "as if" it were behaving as a virtual profit maximiser. It is also consistent with the finding reported by Higgins (1981) who estimated a cost function for the sector in the only previous analysis of this type and found that the own-price elasticity of demand for the milk raw material was not significantly different from zero.[13]

The elasticity estimates obtained with respect to the volume of milk materials yield interesting results. Labour, for instance, is negatively affected by variations in the volume of milk employed as a raw material so the introduction of the milk quota did not adversely affect its use. Processed output is observed to fall by 6% for every 10% fall in the level of milk supplied for processing. The labour-demand elasticity implies that every 10% of an increase in relative wages reduces employment by about 4%. The elasticity estimates reported for non-milk materials (mainly energy) are found to be statistically insignificant which may simply reflect their relatively small share of total costs. The finding that labour and capital are complements is at first glance surprising. However, the result may point to the limited usefulness of the *ceteris paribus* assumption in this case. The cooperative processing sector is driven by the supply of milk supplied to it by its farmer members. Since labour is seen to be a substitute for the milk input the capital input is possibly taking up the slack.

5. Concluding remarks

The motivation for this paper was twofold. First, we wanted to establish whether Irish dairy marketing cooperatives behaved "as if" they were profit maximisers. On the face of it the alacrity with which many dairy marketing cooperatives diversified their activities in the wake of the introduction of the dairy quota in 1984 was consistent with profit-maximisation being a strong behavioural motivation. It would have been impressive if these firms had simply diversified out of milk processing into related agricultural activities. Not alone did this occur but many firms also radically altered their ownership structure by becoming *Public Limited Companies* while still

[13] The author speculated that the reason for this unexpected result was that dairy-processing did not simply minimise costs but minimised costs "… subject to paying the maximum price possible for its main raw material - milk".

retaining majority dairy farmer ownership. A second objective of the paper was to examine how these firms responded to the imposition of the dairy quota by way of their output supply and input demand decisions.

The traditional theory of the cooperative managed firm (CMF) developed by Helmberger and others was recast in a duality framework. The CMF firm differs from the profit maximising firm (PMF) in (a) having as its objective the maximisation of the price paid to its members for the raw material they supply and (b) being obliged to process all the raw material supplied by its members. The CMF in practice differs from its close relative - the labour managed firm - in usually having an "open" rather than a "restricted" membership policy. This means that the only requirement in being a member of a typical dairy cooperative is that one produces and supplies milk.

The duality framework assisted in clarifying the behavioural objective of the CMF and in particular in drawing out its relationship with the PMF. In the duality framework the CMF's objective can be stated as one of maximising short-run restricted profits, where the main restriction is the amount of raw material (milk) supplied by its membership which it is obliged to process. The CMF thus maximises the product of the milk price and the given amount of raw material processed which is equivalent to maximising the milk price paid to its membership. Expressed in this way the principal difference between the CMF and the PMF (assuming price-taking behaviour in input and output markets) is that in the former case the milk price is the choice variable and the amount of raw material processed is a given variable while the opposite situation holds for the PMF.

The key to testing the equivalence of the competing behavioural objectives is thus to establish whether the CMF behaves "as if" it were a PMF, or, in our terminology, is a virtual profit maximiser. At the margin the PMF will only demand additional units of the raw material, given its price, if short-run profits are enhanced whereas at the margin the CMF will only increase the price it's prepared to pay for the raw material, given the amount supplied to it for processing, if short-run profits are increased at the margin. The equivalence between these two approaches was formally tested for the Irish dairy-processing sector over the period 1961 to 1987 using a procedure suggested by Conrad and Unger (1987).

The results suggested that the hypothesis that dairy-marketing cooperatives behaved as virtual profit maximisers could not be rejected. This raises the interesting question as to why such firms received highly favourable fiscal treatment for most of the period under review since on the face of it these firms appear to have operated no differently to the classic PMF. In other words we could find no strong evidence of externalities in the form of lower profits as a consequence of possible pressures to pay “excessive” prices for raw materials to their member suppliers.

This finding was reinforced by our finding that the elasticity of milk price with respect to the volume of milk processed was zero. This result is of course a sufficient condition for CMFs and PMFs to have identical price responses. Milk price was found to be driven mainly by exogenous changes in the price of processed output.

The impact of the quota was to obviously reduce the level of processed output but not proportionately. Our results suggest that every 10% fall in the amount of milk processed reduces processed output of the sector by 6%. We also found a negative relationship between the amount of the milk raw material processed and the demand for labour implying that the introduction of the quota would not of itself have adversely affect employment in the sector.

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