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Steve McCorriston is Reader, School of Business and Management, University of Exeter, Wyn Morgan is Senior Lecturer and Tony Rayner is Professor, both in the School of Economics, University of Nottingham

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S.McCORRISTON[1]

C.W.MORGAN[2]

A.J.RAYNER[2]

[1] University of Exeter

[2] University of Nottingham

July, 2000

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Abstract

Much of the recent literature on price transmission focuses on whether price changes occurring at one stage of the food sector are fully transmitted in changes to retail prices. The role of market structure in determining the degree of price transmission is often emphasised, the presumption being that if downstream markets are imperfectly competitive price transmission will be less than complete. However, an important feature of market structure, often by-passed in empirical studies of market power is the nature of the underlying cost conditions. In this paper, it is shown that if the industry is characterised by non-constant marginal costs, there can be a significant impact on price transmission in the agro-food sector. Specifically, it is shown that the nature of the returns to scale that characterises the food industry cost function will either increase or decrease the degree of price transmission. Of particular note, is the result that, under certain reasonable conditions, with industries characterised by increasing returns to scale, price transmission may *exceed* the level for price transmission in markets characterised by perfect competition and constant returns to scale. This outcome reverses the common presumption that characteristics of market structure serves to reduce the level of price transmission between stages in the food sector.

Introduction

There has been considerable attention in recent years to the issue of price transmission in both academic and policy circles. In the academic literature, there have been a number of studies that have attempted to measure the degree of price transmission between price changes occurring at the farm gate and the commensurate change in price at the retail level. Recent studies that have measured this from an econometric perspective include Goodwin and Holt (1999) for the US, Chang and Griffith (1998) for Australia and von Cramon-Taubadel (1998) for Germany with all studies relating to the livestock sectors in these countries. In policy circles, the issue of price transmission has also received attention. For example, the current investigation by the UK's Competition Commission into market power in the retailing sector was based initially on the observation that price declines at the farm level were not being reflected fully in changes in prices in supermarkets. These issues suggest a broader policy concern: if prices are not being fully transmitted between stages, then consumers cannot be benefiting from declining farm-level prices. Depending on the source of this problem, this suggests a re-distribution of consumer welfare. For example, if lower than expected levels of price transmission were caused by market power in the food sector, this in turn suggests an increase in rents for the firms in the downstream sector.

The focus on measuring the degree of price transmission is, implicitly or explicitly, premised on the concern that there is some characteristic of downstream food markets that results in less than full pass-through of prices. There is a broad literature that can be drawn upon to provide some justification why this should be the case. For example, from the macroeconomics literature, prices at the retail stage may not adjust due to 'menu costs' (i.e. the costs of changing prices at frequent periods and uncertainty that the source of the exogenous shock may be permanent. See, for example, Ball and Mankiw, 1994). In the main, this literature relates to an adjustment problem in that prices may be 'sticky' in the short-run but prices at the retail sector will adjust fully in the long-run. However, the idea that a 'level' effect may persist in the long-run is often seen as being due to imperfect competition. For example, from public economics, the tax incidence literature focuses on oligopolistic behaviour in determining the incidence of taxes (see, for example, Seade 1985). The international economics literature has focused on the issue of exchange rate pass-through;

again the cause of imperfect pass-through being due to oligopolistic behaviour in the relevant domestic market (see, for example, Feenstra, 1989).

The agricultural economics literature has been less forthcoming on modelling the determinants of price transmission. The obvious framework to analyse this issue is in the context of the equilibrium displacement model developed initially by Gardner (1975). However, the assumption of perfect competition in the food sector that is typically employed in these equilibrium displacement models does not appear to fit the facts. There is a growing literature that suggests that the food sector in developed countries is more appropriately characterised as being oligopolistic. Most empirical studies used to detect market power have used US data with the studies by Azzam and Pagoulatos (1990), Wann and Sexton (1992) and Bhuyan and Lopez (1997) being some of the recent examples. Comparable studies are generally lacking for Europe, though casual observation (at least via concentration ratios) would suggest that similar results may not be unexpected for the food industries in many European countries. Of the only published empirical studies incorporating data for European countries, Gohin and Guyomard (2000) have concluded that the French food retailing sector is characterised by market power. Bettendorf and Verboven (2000) test for market power in the Dutch coffee market and conclude that it was relatively competitive. In relation to how market power affects price transmission, McCorriston, Morgan and Rayner (1998) have, in turn, incorporated imperfect competition into the equilibrium displacement framework. They have shown that (subject to the functional form of the demand curve) market power in the food sector will reduce the degree of price transmission between the farm and retail stages[1].

However, a common assumption of empirical studies of market power is the assumption of constant marginal costs. This restricts the focus of market structure to the behaviour of firms only while ignoring the fact that the extent of any firm mark-up is dependent on the nature of the firm's costs. As Morrison-Paul (1999) notes, 'Mark-up models are often based on constructing product demand functions without detailed consideration of the underlying cost structure. In fact, constant returns to scale are often assumed, thus ignoring the potential linkage between scale economies and mark-up behaviour' (Morrison Paul, 1999, page 67). Of course, some empirical studies have attempted to account for non-constant returns to scale.

[1] Azzam (1999) takes an alternative theoretical approach to modelling price transmission with imperfect competition in the context of a spatial oligopoly.

For example, Bhuyan and Lopez (*op. cit.*) showed that across the 40 food industries comprising the US food sector, constant returns to scale was evident in only 7 cases. In 20 industries, the cost function was characterised by increasing returns to scale, while the remaining 13 industries were characterised by decreasing returns to scale. However, one potential problem with this study is that they assumed the industries to be in long-run equilibrium (i.e. where observed levels of output and capital are consistent with optimising behaviour). A variety of papers have questioned this assumption. For example, in developing formal tests, Conrad and Unger (1987) have rejected this outcome in an application to the German manufacturing industry. Morrison Paul (*op. cit.*) has also made use of the distinction between short and long-run equilibrium (where capital is a quasi-fixed factor in the short-run) in an application to the US food and fibre sectors.

Again, examples relating to the role of the cost function in determining market power in the European food sector are very thin. Casual observation would nevertheless lead us to expect that economies of scale are likely to be a relevant feature of market structure. For example, in a number of case studies of the UK food sector in Strak and Morgan (1995), several contributors highlight the importance of economies of scale in a number of food industries. In addition, the recent studies of the 'Single Market Programme' in Europe have reported the relevance of economies of scale in the European food sector (see, Allen *et al*., 1998, table 3) although this is based on data from the 1960s. The only study which we are aware of that addresses these issues formally is the recent paper by Millan (1999). In this study, Millan applies the Conrad and Unger (*op. cit.*) methodology to the Spanish food sector. Depending on the restrictions imposed on the measure of the Lerner index, he finds that the Spanish food sector is characterised by non-constant returns to scale with the exception of the milling and soft drinks industries. All other industries exhibit increasing returns to scale (including oils and fats, meat products, the dairy and sugar industries and so on) except the bread and flour industries which exhibit decreasing returns to scale.

Why does all this matter for the topic of price transmission? Essentially recent theoretical work has attempted to incorporate characteristics of industries as the principal determinants of the degree of price transmission that would likely arise. However, like the majority of empirical studies of market power, the focus has been on firm behaviour with little attention being paid to the assumption of constant returns to scale (see, for example, McCorriston *et al., op. cit.*) As recent criticisms of this empirical literature have shown, this assumption is questionable and may likely bias the conclusion reached. The same is true for the study of price transmission. We show formally that the assumption of non-constant returns to scale will affect not only the degree of price transmission but also, under certain circumstances, may offset the influence of market power. Specifically, while market power will reduce the level of price transmission (relative to the perfectly competitive case), if the industry is characterised by increasing returns to scale, the level of price transmission will increase. Under reasonable conditions, the degree of price transmission may be greater than the constant returns, perfectly competitive case.[2] In other words, from a policy perspective, industry structure may lead to consumers gaining from agricultural price reform more than they would otherwise have if the food industry was characterised by perfect competition.

The paper is organised as follows. In section 1, the theoretical framework is presented. This extends the McCorriston *et al*. (*op. cit.*) framework to allow for non-constant returns to scale. We consider the role of returns to scale in influencing the degree of price transmission and derive the competitive benchmark for the price transmission elasticity against which price transmission with alternative features of market structure can be easily compared. Section 2 presents some numerical examples to highlight the interaction between market power and returns to scale in determining the level of price transmission. We also relate the theoretical model to the empirical study of the Spanish food sector by Millan (*op. cit.*).The conclusions are presented in section 3.

[2] Of course, the long-run competitive equilibrium for the industry could be characterised by zero profits and economies of scale. However, the competitive benchmark used here relates to the perfectly competitive case with constant returns to scale which is consistent with the definition implicit in most policy analyses.

1. Theoretical Framework

In the theoretical framework presented below, firms are assumed to produce a homogenous product and pursue quantity-setting strategies. For convenience, in terms of the empirical application, these firms constitute a 'food' industry. This food industry uses agricultural inputs in combination with other inputs (materials, labour, etc) to produce a processed food product: to keep the algebra manageable, these non-agricultural inputs are subsumed into a single 'materials' input. This specification is consistent with short-run equilibrium with capital being a quasi-fixed factor such that firms can vary only the variable inputs in maximising profits. Further, the industry cost function is characterised by a variable proportions technology which allows for potential substitutability between (the variable) inputs. However, while the food industry is modelled as being oligopolistic, we assume that it cannot exert oligopsony power vis-à-vis the supply of inputs. In deriving the price transmission elasticity, the focus is on the agricultural sector's output as the source of the exogenous change to the food industry cost function.[3] Finally, firms' interactions are modelled through the use of conjectural variations. While the theoretical inadequacies of this approach are duly acknowledged, it nevertheless allows us to tie the theoretical framework directly with the econometric measures of market power which have typically measured conjectural elasticities (see Bresnahan (1989) for a review of early work in this area). As Karp and Perloff (1989) note, empirical estimates of this parameter can be interpreted as an index of market power i.e. the weighted mark-up of price over marginal cost.

The model presented here follows the standard specification of equilibrium displacement models though, as with McCorriston *et al.* (*op.cit.*), allowing for market power in the food industry. As such, to economise on the algebra, we adopt only a parsimonious description of the model. The inverse demand function of the processed product is given by:

$$R = h(Q) \tag{1}$$

where R is the price of the processed product and Q is the level of food sector output.

[3] This is not restrictive; the analysis can be easily extended to deal with other sources of exogenous changes to the industry's cost function.

The food industry production function is uses agricultural and materials inputs (in combination with capital assumed to be a quasi-fixed factor) and is given by:

$$Q = f(A,M) \tag{2}$$

where A and M represent the agricultural and materials inputs respectively (with the notation for the capital input being suppressed for convenience). The production function is assumed to be homogeneous of degree ρ.

The input supply functions for the agricultural (A) and marketing inputs (M), in inverse form, are:

$$P = k(A, Z) \tag{3}$$

$$W = g(M) \tag{4}$$

where P and W are the prices of A and M. The variable Z is the exogenous shift factor (which represents the source of the supply shock affecting the agricultural sector).

In the food sector, firms maximise profits. For a representative firm, the profit function is given by:

$$\pi_i = (R(Q)\, Q_i - C_i(P, W, Q_i)) \tag{5}$$

The first-order condition for profit maximisation gives:

$$s_{Qi}\left(1 - \frac{\theta_i}{\eta}\right) = \frac{\partial \ln C_i}{\partial \ln Q_i} \tag{6}$$

where s_{Qi} ($=RQ_i/C_i$) is the firm's revenue to cost ratio, $\partial lnC_i/\partial lnQ_i$ is the cost elasticity for fim i with respect to output, η is the absolute value of the industry elasticity of demand and where $\theta_i = \partial lnQ/\partial lnQ_i$ is the conjectural variation elasticity for firm i. For $\theta_i = 0$, the market is competitive while $\theta_i = 1$ implies a monopoly or collusive outcome. Using market shares as weights and summing over i firms, (6) can be simplified as:

$$R = \lambda MC \tag{7}$$

$$\text{where} \qquad \lambda = \frac{\eta}{\eta - \theta}$$

which reflects the industry mark-up of price over cost and can be described as the industry (weighted) mark-up coefficient. θ is the industry-level (weighted) market power parameter and MC is the industry-level (weighted) marginal cost. As is common with industrial organisation models of this type, there are notable assumptions to make about this process of aggregation most notably that, in aggregating the conjectural elasticities, it is assumed that the conjectural variation parameters are identical across all firms. In addition, the market shares are independent of industry output and, by extension, the market share weighted conjecture is independent of industry output. Consequently, the weighted mark-up of price over marginal cost is independent from the total quantity produced.

Focusing on the measure of price transmission, it is assumed that the source of the supply shock arises in the agricultural sector as given by Z. The procedure for deriving the transmission elasticity is to use equations (1) to (7) and solve for changes in the endogenous variables following a shock to the agricultural supply function given by Z. The Appendix outlines specifically the derivation of the price transmission elasticity (τ) which is given by:

$$\tau = \frac{\alpha\rho\,(1 + \gamma\sigma)}{(\rho + \alpha\gamma\sigma)\,((1 + \mu)\,\rho - \eta\,(\rho - 1)) + \beta\gamma\eta} \tag{8}$$

where α and β are output elasticities with ($\alpha + \beta = \rho$); ρ is the returns to scale measure with ρ greater (equal, less) than 1 representing increasing (constant, decreasing) returns to scale, σ is the elasticity of substitution between agricultural and materials inputs, γ is the inverse elasticity of supply of marketing inputs, η is the industry elasticity of demand and μ is the elasticity of the industry mark-up where $\mu=\omega(\theta/\eta-\theta)$ with ω representing the change in the elasticity of demand for a given change in the retail price.

Noting that α equals $s_A\rho$ and β equals $s_M\rho$ where s_A (s_M) is the share of agricultural (materials) inputs in the industry cost function, equation (8) can be re-written as:

$$\tau = \frac{s_A\rho\ (1 + \gamma\sigma)}{(1 + s_A\gamma\sigma)\ ((1 + \mu)\ \rho - \eta\ (\rho - 1)) + (1 - s_A)\gamma\eta} \tag{9}$$

To see these influences more clearly, it is useful to define a benchmark for the transmission elasticity that would arise in competitive markets. With constant returns to scale ($\rho = 1$) and the absence of market power ($\mu = 0$), the transmission elasticity in a competitive market, τ_c, will be given as:

$$\tau_c = \frac{s_A\ (1 + \gamma\sigma)}{(1 + s_A\gamma\sigma) + (1 - s_A)\gamma\eta} \tag{10}$$

For a relatively small value for the elasticity of substitution and a relatively elastic supply function for materials inputs, τ_c will approximate s_A i.e. the value of the transmission elasticity will be close to the share of agricultural inputs in the industry's cost function. With $\gamma = 0$, $\tau_c = s_A$, the share of agricultural inputs in the industry's cost function.

Equations (9) and (10) can be readily compared to highlight the impact of market power and returns to scale on price transmission. This can be done by dividing τ_c by τ to give:

$$\frac{\tau_c}{\tau} = 1 + \frac{\mu(1+s_A\gamma\sigma) - \eta[(\rho-1)/\rho][(1+s_A\gamma\sigma)+(1-s_A)\gamma]}{[(1+s_A\gamma\sigma)+(1-s_A)\gamma\eta)]} \tag{11}$$

To see the role of market structure more transparently, assume γ=0. Then (11) can be re-written as:

$$\frac{\tau_c}{\tau} = 1 + \mu - \eta(\rho - 1)/\rho \qquad (12)$$

Suppose, for example, the industry was characterised by constant returns to scale (ρ=1). Then μ will determine the extent of the deviation of the price transmission elasticity from the competitive benchmark. With a linear demand function and θ>0, then there will be 'under-shifting' as τ_c will now exceed τ by μ. Note, however, that since μ represents the change in the perceived marginal revenue function, if the demand function is log-linear, μ will equal zero even if θ>0. In this case, there will be no difference between the competitive benchmark transmission elasticity and the price transmission elasticity that accounts for market power.

Consider now the role of returns to scale and, assume for convenience, μ=0. In this case, the deviation from the competitive benchmark will be given by 1-$\eta(\rho$-1)/ρ. If ρ<1 (i.e. decreasing returns to scale), the price transmission elasticity will decrease i.e. there will be 'under-shifting' as τ_c exceeds τ. Note, however, that if ρ>1, then the price transmission elasticity will be greater than the competitive benchmark i.e. there will be 'over-shifting'. Clearly, the role of ρ can either reinforce or offset the impact of market power θ depending upon whether the industry is characterised by decreasing or increasing returns to scale.

In summary:

$$\frac{\tau_c}{\tau} = 1 + \mu \text{ when } \rho=1 \Rightarrow \frac{\tau_c}{\tau} > 1 \; for \;\; \mu>1$$

$$\frac{\tau_c}{\tau} = 1 - \eta(\rho - 1)/\rho \text{ when } \mu=0 \Rightarrow \frac{\tau_c}{\tau} > 1(<1) \; for \;\; \rho<1(>1) \qquad (13)$$

The impact of returns to scale on the change in the elasticity of price transmission can be readily confirmed by differentiating (9) with respect to ρ, to give:

$$\frac{d\tau}{d\rho}=\frac{s_A(1+\gamma\sigma)\eta[1+\gamma(1-s_A(1+\sigma(\rho-1))]}{\psi^2} \qquad (14)$$

where $\Psi=(1+s_A\gamma\sigma)((1+\mu)\rho-\eta(\rho-1))+(1-s_A)\gamma\eta$

Assuming $\gamma=\mu=0$, (14) can be simplified to:

$$\frac{d\tau}{d\rho}=\frac{s_A\eta}{[\rho-\eta(\rho-1)]^2} \qquad (15)$$

(15) is greater than zero. In other words, as ρ increases, the elasticity of price transmission rises.

2. Interpreting the Incidence Elasticity

The above analysis has shown that either 'under-' or 'over-shifting' is a feasible outcome. Intuitively, in the constant marginal cost case, when the price of agricultural inputs declines, the degree of price transmission is determined by adjustments on the 'demand side', specifically by the change in the industry mark-up over marginal cost to restore equilibrium. The extent of this adjustment (and hence the degree of price transmission) will depend not only on the degree of market power but also on the functional form of the demand curve. However, in the non-constant returns to scale case, adjustment to equilibrium also depends on changes on the cost side. In the case of increasing returns to scale, to restore equilibrium, output has to expand by relatively more compared to the constant cost case. Hence the level of price transmission rises as the fall in the price of the agricultural input is reflected in a corresponding decrease in consumer prices. Thus while market power tends to dampen the degree of price transmission, if the industry exhibits increasing returns to scale, the level of price transmission will be greater than the constant returns to scale case. Moreover, if the latter outweighs the former, the decline in agricultural prices may be reflected in a greater decline in retail prices compared to what would be expected with perfect competition. However, with decreasing returns to scale, the output expansion to restore equilibrium is lower than the constant cost case. As such, with decreasing returns to scale, this will serve to reinforce the market power effect, and reduce even further the relative decline in consumer prices for a given decrease in agricultural prices.

To illustrate the relative magnitude of these effects, we consider some numerical examples. Specifically, we return to equation (9) and focus on the primary determinants of price transmission and assume alternative parameter values for each of the key determinants. In addition, since the functional form of the demand function plays an important role, we consider two alternative specifications that are commonly specified in econometric studies of market power namely a constant elasticity form which implies that $\omega=0$ (so $\mu=0$) and a linear form such that $\omega=(1+\eta)$.[4] The share of agricultural inputs is assumed to be 50 per cent.

The results are presented in Table 1 and highlight the influence of the functional form of the demand curve, the extent of market power and returns to scale in influencing price transmission.[5] With the linear demand function, in the perfect competitive case, the transmission elasticity equals 0.51. With market power, the transmission elasticity is reduced to 0.162 and though the existence of increasing returns to scale serves to raise it, there is still 'under-shifting'. In the log-linear case, market power plays no role in influencing the price transmission elasticity, which is equal to the competitive case. However, the extent of increasing returns to scale causes the price transmission elasticity to rise such that there is 'over-shifting' i.e. the price transmission elasticity is greater than the competitive benchmark. In this case, for a given decline in agricultural prices, the decline in consumer prices would be greater compared to the case with perfect competition and constant returns to scale. The example also serves to highlight the relevance of the functional form of the demand function in markets where market power is perceived to be prevalent. Obviously, it would be straightforward to carry to comparable analysis of the case with decreasing returns to scale and to also vary the nature of the technology to account for fixed proportions which is also common in many industrial organisation studies of the food sector.

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[4] The linear and the log-linear forms are among the most common functional forms used in empirical analysis. However, more generally, the demand curve could be expressed by a general Box-Cox transformation given by $(Q^{\delta} - 1) / \delta = a - b (R^{\delta} - 1 / \delta)$ where δ is an index of convexity. For example, with $\delta = 1$, we have the linear demand case; with $\delta = 0$, the log-linear case. More (less) convex functional forms have $\delta < 0$ ($\delta > 0$).

[5] Of course, it should be noted that we use the same value for the measure of market power in both cases. In an econometric study, the estimates for market power may vary depending on the assumptions made about the cost function. Moreover, although varying the values of the other parameters has a slight impact on the value of the transmission elasticity, it does not affect the qualitative impact on the transmission elasticities reported in Table 1.

Table 1. Price Transmission Elasticities given Alternative Aspects of Market Structure[1]

	Linear Demand	Log-linear Demand
Perfect competition	0.51	0.51
Imperfect competition and constant returns to scale	0.162	0.51
Imperfect competition and increasing returns to scale	0.167	0.56

[1] In each case, the following parameter values were assumed. With perfect competition, $\theta = 0$; with imperfect competition, $\theta = 0.25$. With a variable proportions technology, $\sigma = 0.5$. With constant returns to scale, $\rho = 1$; with increasing returns to scale, $\rho = 1.25$. With a linear demand function, $\mu = 2.333$; with a log-linear demand, $\mu = 0$. Other parameter values were assigned the following values: $\varepsilon = 5$ (which implies an elasticity of supply of agricultural inputs equal to 0.2); $\gamma = 0.5$ (which implies an elasticity of supply of material inputs equal to 2); $\eta = 0.4$; and $s_A = s_M = 0.5$.

Given the information required to fully evaluate the transmission elasticity coupled with the paucity of studies of market power in the European food industries, it is difficult to apply equation (9) directly to a European example. Nevertheless, perusal of Millan's (op. cit.) study of the Spanish food sector would give us an indication of what may be expected with relation to price transmission in Spain. Recall that Millan focussed on testing for short- and long-run equilibrium in the Spanish food sector and rejected the latter outcome. In the short-run, his 'best' results rejected the assumption of constant returns to scale (assuming the Lerner index to be zero) with the exception of the milling and soft drinks industries. Of the remaining 16 industries studied, all exhibited increasing returns to scale with the exception of the bread and flour industry which showed decreasing returns to scale. Taking these results as a fair description of the Spanish food sector, what would we expect from the price transmission elasticity in this setting? Assuming a log-linear demand function, we would expect the transmission elasticity to show 'over-shifting' for the 15 industries that exhibit increasing returns to scale. In other words, if agricultural prices in Spain were to decline, the corresponding decline in food prices in these 15 industries would be greater than we would expect from a model assuming perfect competition[6].

3. Conclusion

This paper has explored the issue of price transmission when downstream food markets are characterised by market power and non-constant returns to scale. Specifically, the price transmission elasticity was formally derived which accounted for these aspects of market structure. The analysis showed that price changes can be greater or less than the competitive benchmark case depending on the interaction between market power and returns to scale. This is particularly pertinent for policy analysis: under certain circumstances, the nature of industry cost function will reinforce the dampening effect of market power i.e. when the cost function is characterised by decreasing returns to scale. However, if the cost function is characterised by increasing returns to scale, the influence of market power is offset. Moreover, depending on the nature of the demand function (or if market power is relatively insignificant), the level of price transmission may increase relative to the competitive benchmark case. In such cases, consumers will benefit relatively more from policy reform than is commonly assumed.

There are two important lessons from this analysis for the study of the industrial organisation of European food markets. First of all, market structure (encompassing both market power and the nature of the industry cost function) will have an important bearing on who gains and by how much from exogenous shocks affecting the European food sector whether these shocks are policy-orientated or otherwise. Second, market structure considerations should not be confined to identifying the existence of market power only. As the recent studies by Conrad and Unger (*op. cit.*), Morrison Paul (*op. cit.*) and Millan (*op. cit.*) recognise, assuming constant returns to scale may be inappropriate in econometric models that attempt to identify and measure characteristics of market structure. As we have shown here, this also holds for the analysis of price transmission. The implication of the theoretical model of price transmission is that returns to scale are a significant determinant of price transmission. For

[6] No details of the estimates for the demand elasticities were reported by Millan (1999). Millan also noted that alternative specifications for the demand function were tried, but no details were reported in the paper.

example, in the context of Millan's study of the Spanish food sector, given that he finds 15 of the 18 industries studied to exhibit increasing returns to scale (with the Lerner index equal to zero), we would expect 'over-shifting' in these 15 cases i.e. if agricultural prices were to decline, we would expect the corresponding change in food prices to be greater than would be expected with perfect competition.

Finally, there is much scope for extending the theoretical treatment of market structure of the food sector. This paper has extended the model of McCorriston *et al*. (*op.cit.)* by adding returns to scale to market power. Both of these characteristics are important aspects of industry structure. Other obvious extensions include dis-aggregating the downstream food sector to more than one stage for example, by differentiating between processing and retailing. In this case, and assuming constant returns to scale, price transmission should decrease further if both sectors are characterised by market power (see McCorriston and Morgan, 1998). The obvious other extension would be to include oligopsony though the extent of oligopsony power may depend on the nature of price support policies at the farm-level and/or the possibility of oligopsony power at the spatial rather than aggregate level. No model is likely to incorporate all these aspects in a single framework, but the analysis outlined in this paper shows that the nature of the industry cost function is an important determinant of price transmission and an often ignored characteristic of the structure of the food sectors in most developed countries.

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Appendix. Deriving the Price Transmission Elasticity

The analysis presented below is based on the Gardner (1975) examination of a competitive food marketing sector to a situation where the food sector is imperfectly competitive and where the food industry production function is not restricted to be a constant returns to scale function; whilst it is assumed to be homogenous, it allows for the possibility of decreasing or increasing returns to scale. However, the analysis assumes, as does Gardner, that the marketing inputs and the agricultural product are supplied by competitive industries and that the food sector is unable to exert market power in the purchase of marketing and food inputs.

The food industry production function is:

$$Q = f(A, M) \tag{A1.1}$$

where Q, A and M are respectively food sector output, agricultural food input and marketing services. The food industry production function is assumed to be homogenous of degree ρ.

The retail food demand function is:

$$Q = h(R) \tag{A1.2}$$

where R is the retail price of food.

The input supply functions in inverse form are:

$$P = k(A, Z) \tag{A1.3}$$

$$W = g(M) \tag{A1.4}$$

where P and W are the prices of A and M. The variables Z is an exogenous shift factor that affects the agricultural sector.

Cost minimisation in the food sector implies:

$$P = Cf_A \tag{A1.5}$$

$$W = Cf_M \tag{A1.6}$$

where C is marginal cost

Using the first-order conditions for profit maximisation and aggregating by market shares, equilibrium in the food sector is represented as:

$$R(1-\frac{\theta}{\eta})=C \qquad \text{(A1.7a)}$$

or, equivalently

$$R=\lambda C \qquad \text{(A1.7b)}$$

where θ is the market power parameter, $\eta=\left|h_R(R/Q)\right|$ is the absolute value of the retail food price elasticity of demand evaluated at equilibrium and $\lambda=\eta/(\eta-\theta)$ reflects the mark-up of price on cost; $(\lambda-1)=(R-C)/C$.

Totally differentiating the system of equations (A1.1) to (A1.7) and converting to percentage changes written in logarithmic form yields:

$$d\ln Q=\alpha d\ln A+\beta d\ln M \qquad \text{(A2.1)}$$

$$d\ln Q=-\eta d\ln R \qquad \text{(A2.2)}$$

$$d\ln P=\varepsilon d\ln A+\varphi\, d\ln Z \qquad \text{(A2.3)}$$

$$d\ln W=\gamma d\ln M \qquad \text{(A2.4)}$$

$$d\ln P=d\ln C-\frac{\beta}{\sigma\rho}(d\ln A-d\ln M)+\frac{\sigma(\rho-1)}{\sigma\rho}d\ln Q \qquad \text{(A2.5)}$$

$$d\ln W=d\ln C+\frac{\alpha}{\sigma\rho}(d\ln A-d\ln M)+\frac{\sigma(\rho-1)}{\sigma\rho}d\ln Q \qquad \text{(A2.6)}$$

$$d\ln R=d\ln\lambda+d\ln C \qquad \text{(A2.7b)}$$

or, equivalently

$$d\ln R=-\mu d\ln R+d\ln C=d\ln C/(1+\mu) \qquad \text{(A2.7c)}$$

where $\mu=\omega\theta/(\eta-\theta)$ and $\omega=\partial\ln\eta/\partial\ln R$

In the equations above, α and β are output elasticities with $(\alpha+\beta=\rho)$, ε, φ and γ are partial inverse input supply elasticities, and σ is the elasticity of substitution between A and M, all evaluated at equilibrium. Note that:

$\alpha=f_A\frac{A}{Q}$ and $\beta=f_M\frac{M}{Q}$ so that cost shares are $s_A=\frac{PA}{\rho CQ}$ and $s_M=\frac{WM}{\rho CQ}$

In addition, $\mu=-(d\ln R-d\ln C)/d\ln R$ represents a fall (rise) in price-cost margins as retail price rises if ω is positive (negative).

The percentage changes in the seven endogenous variables ($Q, A, M, R, P, W,$ and C) can be solved in terms of the percentage changes in the exogenous variable Z from equations (A2.1) to (A2.7c). As a first step, it is convenient to substitute equations (A2.3), (A2.4) and (A2.7c) into (A2.5) and (A2.6) and substitute (A2.1) into (A2.2) to obtain a three equation system:

$$\varphi d\ln Z = -(\frac{\beta + \varepsilon\sigma\rho - \alpha\sigma(\rho-1)}{\sigma\rho})d\ln A + (\frac{\beta + \beta\sigma(\rho-1)}{\sigma\rho})d\ln M + (\frac{(1+\mu)\sigma\rho}{\sigma\rho})d\ln R \tag{A3.1}$$

$$0 = (\frac{\alpha + \alpha\sigma(\rho-1)}{\sigma\rho})d\ln A - (\frac{\alpha + \gamma\sigma\rho - \beta\sigma(\rho-1)}{\sigma\rho})d\ln M + (\frac{(1+\mu)\sigma\rho}{\sigma\rho})d\ln R \tag{A3.2}$$

$$0 = \alpha d\ln A + \beta d\ln M + \eta d\ln R \tag{A3.3}$$

Solving the full system yields solutions for each of the endogenous variables. Focussing on the transmission of prices from the farm-gate to the retail level, we have:

$$d\ln R = \frac{1}{D}(\alpha\rho(1+\gamma\sigma))\varphi d\ln Z \tag{A4.1}$$

$$d\ln P = \frac{1}{D}((1+\mu)\rho(\rho+\alpha\gamma\sigma) + \beta\gamma\eta - \alpha\gamma\eta\sigma(\rho-1) - \eta\rho(\rho-1))\varphi d\ln Z \tag{A4.2}$$

where

$$D = (1+\mu)\rho(\rho+\alpha\gamma\sigma+\beta\varepsilon\sigma) + \eta[\ \alpha\varepsilon + \beta\gamma + \varepsilon\gamma\sigma\rho - \beta\varepsilon\sigma(\rho-1) - \alpha\gamma\sigma(\rho-1) - \rho(\rho-1)\ ]$$

The general expression for farm to retail price transmission stemming from a shift in the inverse farm supply schedule is therefore given by:

$$\frac{d\ln R/d\ln Z}{d\ln P/d\ln Z}=\tau=\frac{\alpha\rho(1+\gamma\sigma)}{(1+\mu)\rho(\rho+\alpha\gamma\sigma)+\beta\gamma\eta-\eta(\rho-1)(\alpha\gamma\sigma+\rho)} \qquad \text{(A5.1)}$$

or equivalently:

$$\frac{d\ln R/d\ln Z}{d\ln P/d\ln Z}=\tau=\frac{\alpha\rho(1+\gamma\sigma)}{(\rho+\alpha\gamma\sigma)((1+\mu)\rho-\eta(\rho-1))+\beta\gamma\eta}$$

which is equation (7) in the text.