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Abstract. *Globalisation and international integration can yield efficiency gains through the promotion of competition and trade in markets for internationally traded goods. At the firm level, exposure to competitive pressures has created a necessity for firms to operate as close as possible to the technology frontier in order to survive. Furthermore, increased integration has lead to an influx of investment by Multinational corporations who bring with them technological innovations. This has the effect of improving overall productivity by shifting the best practice technology frontier while at the same time making it increasingly difficult for smaller competitors to survive. In an Irish context, the food industry has recently been acknowledged in national policy as an important sector for future development. The aim of this paper is to measure the productivity performance of the food processing industry in Ireland and establish the extent to which globalisation has brought about efficiency and productivity gains to the industry.*

Key Words: Food Industry, Ireland, Productivity, Stochastic Production Function

JEL Codes: D24, L66

1. Introduction

Over the course of the 1990s the Irish economy grew at an unprecedented rate. Between 1990 and 2003 the numbers in employment expanded by 55 per cent and output grew at an average of 9 per cent per annum. The most often cited explanation for Ireland's success story was the change in policy emphasis, dating back to the 1960s, toward an outward-looking focus in terms of encouraging exports and inward investment, particularly in the manufacturing sector. Over the course of the 1990s the industrial sector in Ireland grew by 27 per cent in terms of employment, with 67 per cent of this accounted for by foreign-owned enterprises, and 249 per cent in terms of net output, 88 per cent of which was due to foreign-owned enterprises (CSO, 1991; 2001). By 2001, foreign-owned enterprises constituted 87 per cent of net output in the manufacturing sector. At an aggregate level research has shown that in general foreign-owned companies in the Irish manufacturing sector are more productive[1] and export intensive than their indigenous counterparts (Ruane and Ugur, 2004). However, in the

[1] Based on partial productivity measures.

face of an increasing cost environment, poor economic conditions in export markets and given the sector's increasing reliance on foreign-owned enterprises, productivity is a key issue of concern for business and policy makers in Ireland as the future competitiveness of all sectors is pushed to the forefront of the policy agenda. An important question, therefore, for the future of manufacturing is to ascertain the extent to which the sector has remained productive in the face of such pressures. In addition, the impact of globalisation in the form of foreign ownership of firms and an export oriented focus on productivity is also important to understand.

Of particular interest in an Irish context is the food processing industry. The food drinks and tobacco sector in Ireland directly employed 54,000 people in 2004 (2.9 per cent of total employment) and contributed 6.4 per cent to GDP (Department of Agriculture and Food, 2005). In 2003, the value of exports from the food and drinks sector was estimated at €6.7 billion (An Bord Bia, 2004). Unlike the rest of the manufacturing sector in Ireland, food and drinks processing is still very indigenous in nature with foreign companies constituting approximately 25 per cent of employment in 2001 (compared with 49 per cent for manufacturing as a whole) (CSO, 2001). Indigenous firms in the food and drinks sector, however, account for 55 per cent of total indigenous exports suggesting that the sector performs well in terms of competitiveness in world markets. The sector has recently been acknowledged in national public policy as an important sector for the future development of Irish industry having been given a specific sub-programme in the Operational Programme for Industrial Development (1994-1999) and subsequently a series of initiatives in the National Development Plan 2000-2006.[2] Previous research has found that the Irish food industry performed well relative to other EU countries in terms of its competitiveness in the mid-1990s, but not in the high growth sectors (Teagasc, 2001). Enhancing the competitiveness of the sector has been cited as being a particularly important factor in ensuring the future of the industry and Irish indigenous industry in general. Whilst facing the same challenges as the manufacturing sector as a whole in terms of cost pressures, maintaining competitiveness is even more crucial for the food manufacturing sector; firstly, given the significant shifts in consumer preferences over the last decade leading to a fundamental change in what domestic and international consumers demand; secondly, given the necessity of firms to adhere to increasingly stringent food safety regulations and the cost pressures this imposes; and finally, given the substantial reforms of the Common Agricultural Policy and the general trend toward a more liberal trading environment for food products (An Bord Bia, 2004).

A key indicator of competitiveness is productivity and as such the focus of this paper is on analysing the productivity performance of the food manufacturing sector in Ireland between 1995 and 2003 using firm level data provided by Census of Industrial Production (CSO, 1995-2003). This will be achieved through the parametric estimation of stochastic production functions of the technology used by NACE 3-digit sub-sectors of firms and the construction of indexes of productivity change for each of these sub-

[2] These measures include; capital investment to encourage increased efficiency; the provision of a research, technology and innovation fund; the provision of a fund to support promotional work by An Bord Bia and to enhance the marketing capabilities of individual firms; and the provision of a fund to assist in human resource development particularly in the area of training (Department of Agriculture and Food, 2001).

sectors. Given the indigenous nature of the sector and the importance of export markets for many food production firms, this study will analyse productivity performance by ownership and export status to ascertain who the key drivers of productivity growth in the sector really are. Section 2 of this paper outlines the model and methods used to achieve these aims. Section 3 presents the data. The empirical results are detailed in section 4 and the paper concludes with section 5.

2. Methods

The production technology in the food processing industry is first defined using a stochastic production frontier. Productivity changes are then measured by analysing changes in components of this frontier over time. In the stochastic production frontier, output is expressed as a function of inputs, technical inefficiencies capturing the degree to which firms produce below the optimal level of production and a random error component.

$$y_i^t = f\left(x_i^t;\beta\right) + v_i^t - u_i^t \tag{1}$$

where y_i^t is the output of the ith firm in time period t, x_i^t is the vector of inputs into the production process of the ith firm in time period t, β is the vector of parameters to be estimated capturing the relationship between inputs and outputs across firms and time, v_i^t represents statistical noise and other random external events influencing the production process[3] and u_i^t are the firm specific inefficiency effects, which may be time varying. Coelli *et al.*'s (1998) specification of the time-varying technical efficiency effects is considered, that is $u_i^t = \left(u_i \exp\left(-\eta\left(t-T\right)\right)\right)$ where η is a parameter to be estimated.[4] If $u_i^t = 0$ the firm is efficient and operates on the production frontier in that particular time period, while if $u_i^t > 0$, there are inefficiencies and the firm is operating beneath the frontier at time t. v_i^t and u_i^t are assumed to be independent.

The first step in estimating a stochastic production frontier is to specify an appropriate functional form for the model. In this paper a Cobb Douglas functional form is assumed.[5] The Cobb Douglas stochastic production frontier is presented in equation (2).

$$\ln y_i^t = \alpha_0 + \sum_{k=1}^{K} \beta_k \ln x_{ki}^t + v_i^t - u_i^t \tag{2}$$

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[3] v_i^t are assumed to be iid $N\left(0,\sigma_v^2\right)$.

[4] u_i are assumed to be iid as truncations of $N\left(\mu,\sigma_u^2\right)$.

[5] A translog functional form is also considered but in most cases is not found to significantly improve on the simpler Cobb-Douglas model. Furthermore, due to sample size and multicollinearity problems the translog is not suitable to this particular application.

By including a time trend and interactions between time and the inputs, technical change components can also be incorporated into the functional form of the model. This is illustrated in equation (3).

$$\ln y_i^t = \alpha_0 + \sum_{k=1}^{K} \beta_k \ln x_{ki}^t + \omega_0 t + \frac{1}{2}\omega_{00} t^2 + \sum_{k=1}^{K} \omega_{kt} \ln x_{ki}^t t + v_i^t - u_i^t \qquad (3)$$

Maximum likelihood estimation will produce consistent parameter and inefficiency estimates based on the stochastic production frontier.[6] The model is estimated using Stata/S.E. Version 8.0 (Stata Corporation, 2003).

The purpose of constructing a productivity index is to measure output growth that is net of input growth, that is output growth due to technical change, efficiency change or the contribution of returns to scale. For a stochastic production frontier, with a single scalar output, a Divisia index of the rate of productivity change can be defined as the difference between the rate of change of output and the rate of change of an input quantity index.[7]

$$T\dot{F}P_i^t = \dot{y}_i^t - \dot{X}_i^t \qquad (4)$$

To find the rate of change in output, $\dot{y}_i^t$, where output y_i^t is defined by the production function in equation (1), it is necessary to totally differentiate the log of the production function. This yields three components. First, the rate of technical change in firm i in period t:

$$\dot{TC}_i^t = \frac{\partial \ln f\left(x_i^t; \beta\right)}{\partial t} \qquad (5)$$

Second, the rate of technical efficiency change in firm i in period t:

$$\dot{EC}_i^t = -\frac{\partial u_i^t}{\partial t} \qquad (6)$$

Third, the rate of change in output as a result of a change in an input quantity on firm i in period t:

$$\frac{\partial \ln y_i^t}{\partial X_i^t} = \sum_k \varepsilon_{ki}^t \dot{x}_{ki}^t \qquad (7)$$

where ε_{ki}^t are elasticities of output with respect to each of the inputs.

Substituting equations (5), (6) and (7) into equation (4) yields:

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[6] The variance parameters $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2 / \sigma^2$, where γ measures the proportion of total variance attributed to the inefficiency effects, are also estimated.

[7] This approach follows that of Kumbhakar and Lovell (2000)[l].

$$T\dot{F}P_i^t = \dot{T}C_i^t + \dot{E}C_i^t + \sum_k \varepsilon_{ki}^t \dot{x}_{ki}^t - \dot{X}_i^t \tag{8}$$

$\dot{X}_i^t$, the rate of change in the input quantities in firm i in period t can be defined as the sum of the change in the individual inputs weighted by their proportional contributions to total output, i.e. $\varepsilon_{ki}^t \Big/ \sum_k \varepsilon_{ki}^t = \varepsilon_{ki}^t \big/ \varepsilon_i^t$. Using this definition equation (8) can be expressed as:

$$\begin{aligned} T\dot{F}P_i^t &= \dot{T}C_i^t + \dot{E}C_i^t + \sum_k \varepsilon_{ki}^t \dot{x}_{ki}^t - \sum_k \frac{\varepsilon_{ki}^t}{\varepsilon_i^t} \dot{x}_{ki}^t \\ &= \dot{T}C_i^t + \dot{E}C_i^t + \left(\varepsilon_i^t - 1\right) \sum_k \frac{\varepsilon_{ki}^t}{\varepsilon_i^t} \dot{x}_{ki}^t \end{aligned} \tag{9}$$

The first component of Equation (9) measures the rate of technical change, the second component measures the rate of technical efficiency change and the final component measures the rate of change in output as a result of a change in the scale of production.

Equation (10) describes how $\dot{T}C_i^t$ relates to the components of the Cobb Douglas production function given in equation (3).

$$\dot{T}C_i^t = \frac{\partial y_i^t}{\partial t} = \omega_0 + \omega_{00} t + \sum_{k=1}^{K} \omega_{kt} \ln x_{ki}^t \tag{10}$$

The first two components measure neutral technical change, common to all firms. A positive/negative sign on ω_0 indicates neutral technical progress/regress while a positive/negative sign on ω_{00} indicates that technical progress/regress is taking place at an increasing/decreasing rate. The third component measures non-neutral technical change. A positive/negative sign on ω_{kt} indicates that there is a positive/negative input bias associated with input k, leading to non-neutral technical progress/regress. The technical change index between periods t and $t+1$ is constructed based on an arithmetic average of this component each year.

$$TCI_i = 0.5 \times \left(\dot{T}C_i^t + \dot{T}C_i^{t+1}\right) \tag{11}$$

Since $\dot{E}C_i^t = -\partial u_i^t \big/ \partial t$, the efficiency change index between periods t and $t+1$ is constructed based on the change in the average efficiency levels in each year. That is:

$$ECI_i = \frac{TE_i^{t+1}}{TE_i^t} = \frac{E\left(\exp\left(-u_i^{t+1}\right) | \, v_i^{t+1}\right)}{E\left(\exp\left(-u_i^t\right) | \, v_i^t\right)} \tag{12}$$

Finally, each input elasticity can be evaluated as:

$$\varepsilon_{ki}^{t} = \beta_k + \sum_{k=1}^{K} \omega_{kt} t \tag{13}$$

and a scale effect index between periods t and $t+1$ can be constructed based on an arithmetic average of the scale effect on output of a change in inputs.

$$SEI_i = 0.5 \times \sum_{k=1}^{K} \left[\left(\varepsilon_i^{t+1} - 1 \right) \varepsilon_{ki}^{t+1} + \left(\varepsilon_i^{t} - 1 \right) \varepsilon_{ki}^{t} \right] \ln \left(\frac{x_{ki}^{t+1}}{x_{ki}^{t}} \right) \tag{14}$$

3. Data

The data are taken from the Census of Industrial Production (CIP) 1995-2003 provided by the Central Statistics Office of Ireland. The model is estimated for six sub-groups of the two-digit NACE classification, 15, of firms involved in the manufacture of food products (detailed in Table 1). This constitutes 1,102 firms and 6,251 observations over the entire sample period.

Table 1: NACE codes for the food manufacturing sector

15:	Manufacture of food products and beverages
151:	Production, processing and preserving of meat and meat products
152:	Processing and preserving of fish and fish products
153:	Processing and preserving of fruit and vegetables
155:	Manufacture of dairy products
156:	Manufacture of grain mill products, starches and starch products
157:	Manufacture of prepared animal feeds
158:	Manufacture of other food products

Note: The following two sub-sectors of the NACE 15 sector are excluded from the analysis. The former due to too few observations to facilitate the estimation of a production function and the latter due to the fact that it is not concerned with the food industry per se.
154: Manufacture of vegetable and animal oils and fats
159: Manufacture of beverages

The output variable is defined as the gross output of the firm deflated by the wholesale price index relevant to the 3 digit sub-sector. Four inputs are considered: variable inputs (VAR) consisting of the sum of the deflated value of materials used and industrial services[8]; labour (LAB) measured as the total number of persons employed; the deflated value of fuel and power expenditure (FUEL)[9]; and a proxy for capital usage (CAP). Data on capital stock are not provided in the CIP.[10] The approach used to develop a proxy for capital is based on a perpetual inventory model of capital usage. For each 3 digit sub-sector an index of capital usage is constructed in each year based on the fuel and power consumption of each firm in an attempt to capture the relative

[8] Each input is separately deflated before aggregating using the Wholesale Price Index.
[9] The energy component of the Wholesale Price Index is used for deflating the value of fuel and power consumption
[10] Data on capital inputs are rarely available in applications of this kind. Ugur (2004) uses fuel and power consumption as a proxy for capital stock in his study of the Irish electronics sector. Similarly, Bokusheva and Hockmann (2006) proxy capital using the value of depreciation, machinery maintenance and fuel costs in their study of technical efficiency in Russian agriculture.

position of each firm in terms of capital usage. For the year of entry of the firm the base level of capital usage is assumed to be €1,000 times this index, thus assuming a base level of capital usage for the least capital intensive firms in each sub-sector of €100,000. In each subsequent year the deflated value of net additions to capital stock are added to this value.[11]

4. Empirical results

4.1 Specification testing

Various specifications of the econometric model are considered. The first test considers the extent to which technology differences exist between the various three-digit sub-groups of food manufacturing to ascertain whether analysing sub-groups separately is necessary. This is achieved by comparing the log-likelihood value of an aggregate stochastic production function model using a pooled dataset and with the sum of the individual log-likelihood values for the same model estimated separately for each sub-group (see Battese *et al*. (2004)). The result of this test, presented in Table 2, concludes that significant technology differences exist between each sub-group justifying the disaggregate approach to analysing food manufacturing presented in this paper.[12] It is assumed that technology is homogenous across each 3-digit sub-sector analysed.

Table 2: Testing for technology gaps

H_0: All sub-sectors share the same technology
H_A: Significant technology gaps exist
Test Statistic: 1,718
Critical Value: 165
Reject Null at 1% Significance

Table 3: Testing the distance function approach

H_0: Deterministic approach ($\gamma = \eta = 0$) **H_A**: Stochastic approach				
Model	Log Likelihood Restricted Model	Log Likelihood Unrestricted Model	Test Statistic	Result $\chi^2_{2,0.01} = 9.21$
NACE 151	-439.27	-300.64	277.27	Reject
NACE 152	-205.93	-164.87	82.11	Reject
NACE 153	-91.28	-53.76	75.03	Reject
NACE 155	-349.13	-289.85	118.56	Reject
NACE 156/7	-395.80	-269.03	253.55	Reject
NACE 158	-1,221.28	-907.28	628.00	Reject

The second test aims to provide a justification for the use of the stochastic approach to analysing productivity over a deterministic approach. The stochastic approach is compared to a mean production function approach estimated by imposing the restriction that the inefficiency terms are equal to zero (Irz and Thirtle, 2004). The results of this test are presented in Table 3. Likelihood ratio tests lead to a rejection of these

[11] As a check on the appropriateness of this proxy for capital the model was also estimated by simply using fuel and power usage as in Ugur (2004) with similar results obtained.
[12] Sectors 156 and 157 are modeled together due to the fact that there are too few observations to model them separately.

restrictions implying that a stochastic rather than a deterministic approach is more appropriate.

The third set of tests relate to the choice of technology specification. Firstly, likelihood ratio tests are used to test for the neutral and non-neutral technical change components with the conclusion that both components are appropriate. Secondly, the appropriateness of the time varying inefficiency model is tested by comparing it against a time invariant model with the latter deemed more appropriate in four cases and the former in the remaining two. The results of each of these tests are presented in Table 4.

Table 4: Testing the technology specification

H_0: No technical change ($\omega_0 = \omega_{00} = \omega_{kt} = 0$) **H_A**: Neutral and non-neutral technical change				
Model	Log Likelihood Restricted Model	Log Likelihood Unrestricted Model	Test Statistic	Result $\chi^2_{6,0.01} = 16.81$ $\chi^2_{6,0.05} = 12.59$
NACE 151	-357.28	-300.64	113.28	Reject at 1% level
NACE 152	-183.82	-164.87	37.90	Reject at 1% level
NACE 153	-60.84	-53.76	14.16	Reject at 5% level
NACE 155	-313.45	-289.85	47.20	Reject at 1% level
NACE 156/7	-288.42	-269.03	38.78	Reject at 1% level
NACE 158	-936.92	-907.28	59.28	Reject at 1% level
H_0: Time invariant inefficiency ($\eta = 0$) **H_A**: Time varying inefficiency effects				
Model	Log Likelihood Restricted Model	Log Likelihood Unrestricted Model	Test Statistic	Result $\chi^2_{1,0.01} = 6.63$
NACE 151	-302.31	-300.64	3.34	Do not reject
NACE 152	-166.62	-164.87	3.49	Do not reject
NACE 153	-53.76	-53.76	0.00	Do not reject
NACE 155	-291.18	-289.85	2.67	Do not reject
NACE 156/7	-274.47	-269.03	10.89	Reject
NACE 158	-917.97	-907.28	21.40	Reject

4.2 Technology representation

The results of the stochastic production function model for each three-digit sub-sector considered are presented in Table 5. $\hat{\gamma}$, the share of technical efficiency in total variance is significant and in each case and $\hat{\eta}$, the parameter associated with time in the inefficiency effects, is negative and statistically significant at the 1 per cent level for NACE 156/7 (the manufacture of grain mill products, starches and starch products and the manufacture of prepared animal feeds) and for NACE 158 (the manufacture of other food products) indicating that over time there have been significant negative changes in the average levels of technical efficiency in these sectors.[13]

[13] Inefficiency effects are found to be time invariant for the other sub-sectors (see Table 4) and as such, $\hat{\eta}$ is restricted to zero in these models.

Table 5: Parameter estimates of production functions

	NACE 151	NACE 152	NACE 153	NACE 155	NACE 156/7	NACE 158
Constant	0.6134***	1.3526	1.5018	1.2644	0.5356***	1.1265***
	(0.1887)	(25.783)	(52.9538)	(18.4026)	(0.1521)	(0.1459)
$(\ln x_1)$	0.2764***	0.4399***	0.6232***	0.5232***	0.4550***	0.5967***
	(0.0201)	(0.0444)	(0.0729)	(0.0414)	(0.0330)	(0.0330)
$(\ln x_2)$	0.3783***	0.1904***	0.2833***	-0.0582	0.2549***	0.1425***
	(0.0326)	(0.0399)	(0.0704)	(0.0486)	(0.0453)	(0.0397)
$(\ln x_3)$	0.0373	0.0216	0.1296**	0.0076	0.0800**	0.0022
	(0.0247)	(0.0389)	(0.0535)	(0.0473)	(0.0329)	(0.0301)
$(\ln x_4)$	0.3488***	0.2563***	0.0225	0.4323***	0.2160***	0.2609***
	(0.0243)	(0.0356)	(0.0116)	(0.0497)	(0.0368)	(0.0273)
t	0.0334***	-0.0954***	0.0323	0.0641***	0.0515***	-0.0683***
	(0.0134)	(0.0190)	(0.0313)	(0.0226)	(0.0195)	(0.0162)
t^2	-0.0049*	0.0157***	-0.0060	-0.0098**	-0.0014	0.0154***
	(0.0025)	(0.0036)	(0.0059)	(0.0045)	(0.0038)	(0.0026)
$(\ln x_1)t$	0.0302***	0.0213***	0.0020	-0.0015	-0.0167***	-0.0213***
	(0.0035)	(0.0077)	(0.0016)	(0.0075)	(0.0061)	(0.0049)
$(\ln x_2)t$	-0.0125**	-0.0054	-0.0404***	0.0228***	0.0038***	0.0157***
	(0.00510	(0.0066)	(0.0119)	(0.0086)	(0.0075)	(0.0060)
$(\ln x_3)t$	0.0114***	0.0033	0.0021	0.0289***	0.0175***	0.0124***
	(0.0040)	(0.0069)	(0.0087)	(0.0084)	(0.0053)	(0.0047)
$(\ln x_4)t$	-0.0305***	-0.0120**	0.0231***	-0.0436***	-0.0041	0.0000
	(0.0043)	(0.0190)	(0.0089)	(0.0075)	(0.0060)	(0.0042)
σ^2	0.1244***	0.1030***	0.1172***	0.1664***	0.1775	0.2080***
	(0.0083)	(0.0067)	(0.0147)	(0.0122)	(0.0170)	(0.0109)
$\hat{\gamma}$	0.4637***	0.2732***	0.5041****	0.3674***	0.5349***	0.5214***
	(0.0400)	(.0470)	(0.0704)	(0.0483)	(0.0474)	(0.0280)
$\hat{\eta}$	…	…	…	…	-0.0421***	-0.0197***
					(0.0145)	(0.0048)
Log likelihood	-302.31	-166.62	-53.76	-291.18	-269.03	-907.28
No. of firms	255	125	67	124	144	404
n	1,451	781	331	707	849	2,132

$\ln x_1$ is the log of variable inputs, $\ln x_2$ is the log of labour, $\ln x_3$ is the log of fuel costs, $\ln x_4$ is the log of capital costs , t is the time trend, $\hat{\gamma}$ is an estimate of the share of technical efficiency in total variance and $\hat{\eta}$ is the estimated parameter associated with time in the inefficiency effects.

*Standard errors are given in parenthesis, *** indicates significance at the 1% level, ** indicates significance at the 5% level, * indicates significance at the 10% level*

The results accord with what would be expected from a theoretical point of view in that production is non-decreasing in inputs. Since the data are mean corrected prior to estimation the coefficients on each of the inputs can be interpreted as input elasticities. The elasticity on the variable input is significant and high in all sub-sectors. Capital inputs yield a particularly high return in both the manufacture of meat and in the manufacture of dairy products. In contrast, for the production and processing of fruit and vegetables capital is insignificant with fuel and power playing a more important role. Labour yields a relatively moderate return across all sub-sectors with the exception of the manufacture of dairy products for which it is insignificant.

4.3 Productivity results

The parameters of the stochastic production function are used to construct an index of productivity for the 1995 to 2003 period for each sub-sector of the Irish food industry as outlined in Section 2. As discussed, in this model productivity can be improved via three mechanisms: firstly, through improvements in the 'best practice' technology frontier; secondly, through improvements in the performance of the average firm relative to the best practice frontier; and finally, through changes in the input mix (scale effects), within the given technological constraints. The results are presented in Table 6.

Table 6: Productivity index and decomposition[a]

	Technical change	Efficiency	Returns to scale	Generalized Malmquist
NACE 151	103.67	103.53	100.51	106.13
		% Growth Rate		
1995-2003	0.46	0.55	0.10	0.87
1995-1999	1.61	0.25	-0.02	1.72
1999-2003	-0.63	0.94	0.05	-0.07
NACE 152	83.32	102.45	124.31	104.46
		% Growth Rate		
1995-2003	-2.00	0.28	5.35	2.40
1995-1999	-4.98	0.57	6.98	0.83
1999-2003	0.85	0.22	-2.13	-0.55
NACE 153	97.25	106.03	99.82	98.31
		% Growth Rate		
1995-2003	-0.23	1.34	0.08	0.13
1995-1999	0.03	0.87	0.02	0.24
1999-2003	-0.69	0.74	0.13	-0.41
NACE 155	119.38	100.25	99.26	118.59
		% Growth Rate		
1995-2003	2.46	0.23	-0.10	2.42
1995-1999	4.00	-0.14	-0.02	3.92
1999-2003	1.01	0.12	0.13	1.22
NACE 156/7	147.30	80.02	99.71	131.82
		% Growth Rate		
1995-2003	5.99	-2.52	-0.03	4.06
1995-1999	5.39	-2.70	-0.03	3.64
1999-2003	6.44	-2.33	-0.04	4.31
NACE 158	119.62	83.94	100.96	116.89
		% Growth Rate		
1995-2003	2.35	-1.95	0.12	2.03
1995-1999	-0.74	-2.20	0.09	-1.09
1999-2003	5.63	-1.89	0.10	5.22

[a] *Index in 2003 presented relative to base year 1995 (100.00)*

The productivity performance varies substantially across sub-sectors. In the first sub-sector, the production, processing and preserving of meat and meat products (NACE 151), productivity growth occurs at an average rate of close to 1 per cent per annum. This growth is driven by technical progress in first half of the sample period and improvements in average efficiency levels in the second half as the pace of technical progress slows and the average firms manage to catch up. [14]

The second sector, the processing and preserving of fish and fish products (NACE 152), on the overall figures experiences a similar performance to the previous sector, however, the decomposition of the productivity index reveals a very different story. Technical regress of 5 per cent per annum is evident in first 4 years of the sample with some recovery thereafter. Average efficiency levels remained static over the period suggesting that the negative impact on technology experienced by the sector affected all firms equally. In contrast, changes in the input mix over time contribute positively to productivity in the first 5 years of the sample leading to productivity improvements of almost 7 per cent per annum. While it is difficult to ascertain what factors caused this collapse, the way in which the sector to adjust its input mix to better suit its production constraints is impressive, leading to a moderate growth in overall productivity of 2 per cent per annum, highlighting the dynamic nature of the sector.[15]

The poorest performance is evident in the fruit and vegetables sub-sector (NACE 153) for which productivity remained virtually static with virtually no technical progress evident over the sample period. With little improvement in the technology frontier over time, it is unsurprising that there is some improvement evident in average efficiency levels with growth of just over 1 per cent per annum recorded.

The sector involved in the manufacture of dairy products (NACE 155), performs well throughout the period. Technical progress of 4 per cent per annum is evident in the first half settling to a more moderate growth rate of 1 per cent per annum for later time periods. A decline in average efficiency levels in first half can be explained by difficulties experienced by firms performing at the average keeping up with the rapid pace of technical progress. With a more moderate pace of technical progress in the last 4 years of the sample, average efficiency levels stabilise. Overall, the outlook appears good for this sector with average growth of almost 2.5 per cent per annum in total factor productivity terms.

The sector incorporating grain mill products, starch, starch products and animal feed (NACE 156/7) experiences the fastest rate of productivity growth over time of 4 per cent per annum between 1995 and 2003. This is attributable to a very impressive rate of technical progress of 6 per cent per annum, accelerating over time. A notable feature of this sector's performance, however, is that while the cutting edge or 'frontier' technology improves at a very fast pace the average firm in the sector finds it difficult to keep up as reflected in the falling average efficiency levels of 2.5 per cent per annum.[16]

[14] Since for sub-sectors 151 to 155 the inefficiency effects are restricted to being time invariant, changes in average efficiency levels are caused by firms leaving and entering the sub-sector.

[15] While it is difficult to pinpoint the factors that caused such a collapse in technological progress in the sector, one hypothesis that could be advanced is that the sector was still feeling the effects of the collapse in the Irish sea trout industry experienced in the early 1990s due to a sea lice infestation believed to be caused by salmon farms (see http://www.seaweb.org/resources/aquaculturecenter).

[16] Some caution is needed in interpreting the results for this sub-sector given the diversity of the group of firms, and as such technologies, included in this sub-sector.

The final sub-sector considered is the manufacture of other food products (NACE 158). After a slow start with virtually no technological improvements coupled with a fall in average efficiency levels, the sector experienced impressive technical progress at a rate of over 5 per cent per annum in the second half of sample. While average efficiency levels continued to decline, this occurred at a slower pace in the latter years of the sample. The more recent performance of the sector is encouraging given that the group includes high growth sectors such as prepared foods (Teagasc, 2001).[17]

Overall, an important finding revealed by these results is that for most sub-sectors, productivity growth declines remarkably between 1999 and 2003 relative to growth rates experienced between 1995 and 1999.[18] Given the rising cost environment in Ireland during this period it is not surprising that productivity growth rates have suffered.

4.4 Indicators of globalisation and productivity results

A key aim of this paper is to analyse the impact of increased international integration on the productivity performance of the food manufacturing sector in Ireland. By separating the results for each 3-digit sub-sector by ownership (foreign vs. domestic) and export status (exporting vs. non-exporting) a picture of the effect of globalisation on productivity in the sector can be established. Table 7 presents the results.

It is clear from the above table that trade and origin of ownership impact on sub-sectors in different ways. In general, as might be expected, exporting firms perform better than non-exporting firms with the exception of the manufacture of other food products (NACE 158) where exporting firms experience a slightly slower pace of growth than non-exporting. Overall, foreign-owned firms make up a very small proportion of firms in the sector. Nevertheless, in some sub-sectors they experience a far superior productivity performance over the sample period. A more detailed analysis of each of the sub-sectors is presented below.

For the production, processing and preserving of meat and meat products (NACE 151), exporters outperform non-exporting firms due to a faster pace of technical progress, particularly in first half of the sample period. While they are also more efficient in that on average they are closer to the ‘best practice’ frontier, non-exporting firms experience a faster pace of growth in overall efficiency levels over the sample period. It is difficult to ascertain the impact of foreign ownership on productivity performance in this sector as it is primarily an indigenous sector. The small number of foreign-owned firms that are present perform poorly relative to domestic producers.

For the processing and preserving of fish and fish products (NACE 152) the extent of globalisation is highly correlated with productivity improvements. Exporters significantly outperform non-exporters due to the complete collapse in productivity of

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[17] As for NACE 156/7, some caution is required in interpreting these results given the diversity of firms included in this sub-sector.

[18] This is not the case for two sub-sectors, NACE 156/7 and NACE 158, who perform better in the later period.

non-exporters post 1999. In addition foreign-owned firms perform better than indigenous enterprises on the basis of every component of productivity.

Table 7: Productivity change decomposed by ownership and export status

	NACE 151	NACE 152	NACE 153	NACE 155	NACE 156/7	NACE 158
Foreign-owned	n=52	n=25	n=45	n=119	n=44	n=187
Index 2003 [a]	93.47	183.70	102.33	152.07	108.76	107.97
			% Growth Rate			
1995-2003	-1.01	14.69	0.54	8.18	0.70	0.96
1995-1999	-0.60	10.52	-0.24	2.73	2.85	-3.02
1999-2003	-1.15	9.12	0.87	13.89	-0.92	4.55
Domestic-owned	n=1,456	n=788	n=300	n=774	n=846	n=2,051
Index 2003 [a]	106.70	104.22	97.77	111.86	133.48	117.39
			% Growth Rate			
1995-2003	1.00	2.15	0.01	1.49	4.29	2.05
1995-1999	1.82	0.66	0.33	3.73	3.74	-0.85
1999-2003	0.00	-0.54	-0.69	-0.56	4.66	5.05
Exporting	n=1,020	n=647	n=152	n=463	n=460	n=870
Index 2003 [a]	108.76	124.26	97.11	126.35	133.59	113.75
			% Growth Rate			
1995-2003	1.04	6.66	0.34	2.94	4.12	1.39
1995-1999	2.35	0.32	-0.31	5.65	3.78	-1.25
1999-2003	-0.06	6.09	-0.34	0.36	5.01	4.82
Non-exporting	n=488	n=166	n=193	n=362	n=379	n=1,368
Index 2003 [a]	103.34	60.64	98.40	119.43	128.47	117.72
			% Growth Rate			
1995-2003	0.78	-4.42	-0.08	2.74	3.74	2.14
1995-1999	1.05	0.07	0.57	2.70	3.52	-0.79
1999-2003	-0.04	-14.13	-0.52	3.37	3.13	4.97

[a] *Index in 2003 presented relative to base year 1995 (100.00)*

The poor performance of the fruit and vegetable sector (NACE 153) in the aggregate data is evident in both exporting and non-exporting firms with no obvious distinctions. Decomposition by ownership reveals that foreign firms perform better in relation to technical change while indigenous firms perform better in relation to efficiency improvements.

For the manufacture of dairy products (NACE 155), firms serving the domestic market only are more efficient and more technologically progressive, however, exporting firms are better able to adapt their input mix to benefit from returns to scale. Overall this leads to a superior performance by exporting firms in this sector. Foreign-owned firms perform much better than domestic firms. They are more efficient than domestic-owned counterparts who experience a decline in average efficiency levels over the sample period. They also experience a much faster pace of technical progress.

The fast pace of productivity growth experienced in the sector producing grain mill products, starch, starch products and animal feed (NACE 156/7) is primarily due to exporting firms who perform better in terms of faster rates of technical progress and higher average efficiency levels. Indigenous firms perform better in this sector but there are very few foreign-owned enterprises making it difficult for any conclusions to be drawn.

Finally, in relation to the production of other foods (NACE 158), exporters have higher average efficiency levels which improve significantly over time but, in contrast to what might be expected, non-exporters experience a faster pace of technical progress leading to a better overall productivity performance. Foreign-owned firms have a higher average level of efficiency and perform better over time on this measure however indigenous firms are the forerunners in technological progress experiencing a faster rate of technical change and faster rates productivity growth overall.

Given the indigenous nature of the Irish food sector and its success on world markets over the course of the 1990s, it might be expected that domestic firms out-perform their foreign-owned counterparts. However, this is only the case in three out of the six sub-sectors analysed. Despite this fact, in most cases, Irish owned-firms are the fore-runners in technological advancements in the sector with foreign-owned firms in general performing better on efficiency measures. This is particularly evident on the scale efficiency measure.[19] This might suggest the presence of a group of inefficient Irish-owned companies unable to keep up with the pace of technical progress in the sector thus dragging down the average efficiency performance of the domestic-owned group. This latter finding could be explained by the fact that the Irish food industry has tended to under-invest in training potentially leading to lower average efficiency levels and un-yielded potential for greater economies of scale in domestic firms.[20] In contrast, as expected, the evidence suggests that for the most part exporting firms are both more technologically progressive and efficient than those serving the domestic market only. Two exceptions exist: the manufacture of dairy products (NACE 155) and the manufacture of other products (NACE 158).

5 Conclusions

This paper addresses two important issues in relation to the food industry in Ireland. Firstly, to what extent has the sector has remained productive in the face of new constraints facing the sector in Ireland in the late 1990s and early 2000s, namely, rising cost pressures, structural changes in consumers' tastes and preferences and increased exposure to external pressures due to an increasingly more liberal trade environment. Secondly, this paper examines the impact of globalisation on productivity by comparing the performance of indigenous firms with their foreign-owned counterparts and exporting firms with those who solely rely on the domestic market.

In relation to the first issue, an important finding revealed by the results presented in this paper is that the pace of productivity growth slows, and in some cases productivity itself even declines, between 1999 and 2003 when compared with productivity growth rates experienced between 1995 and 1999. This is a worrying trend particularly given the importance of this sector to indigenous industry in Ireland. A positive finding in this context however, is the fact that the opposite trend is observed for two sub-sectors,

[19] In support of this result, the report of the Food Industry Development Group (1998) highlighted the fact that the Irish food industry suffers from scale related difficulties

[20] A report of the Expert Group on Future Skills Needs (2003) relating to the food processing sector highlighted a range of employer focussed initiatives in this area that need to be adhered to moving forward.

NACE 156/7 (the sector producing grain mill products, starch, starch products and animal feed) and NACE 158 (the sector producing other food products), the latter of which includes the sector with the greatest growth potential in the industry: prepared meals (Teagasc, 2001).

In relation to the second issue, it has long been hypothesized that globalisation and international integration can yield substantial efficiency gains through the promotion of competition and trade in markets for internationally traded goods and services. At the firm level, exposure to competitive pressures creates a necessity for firms to operate as close as possible to the technology frontier in order to survive. The evidence presented in this paper supports this hypothesis with exporting firms out-performing non-exporting firms in most sub-sectors and foreign-owned firms producing more efficiently than their domestic counterparts, particularly in relation to the exploitation of scale efficiencies. The strong position of domestic firms at the forefront of technological innovation is re-assuring but the inability of firms on average to keep up in terms of efficiency improvements or by exploiting scale economies suggests that the government and interest groups on-going concerns in relation to the competitiveness of the sector is warranted and worthy of continued attention.

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