Food Chain Productivity Incorporating External Impacts

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Executive Summary

Objectives of Study

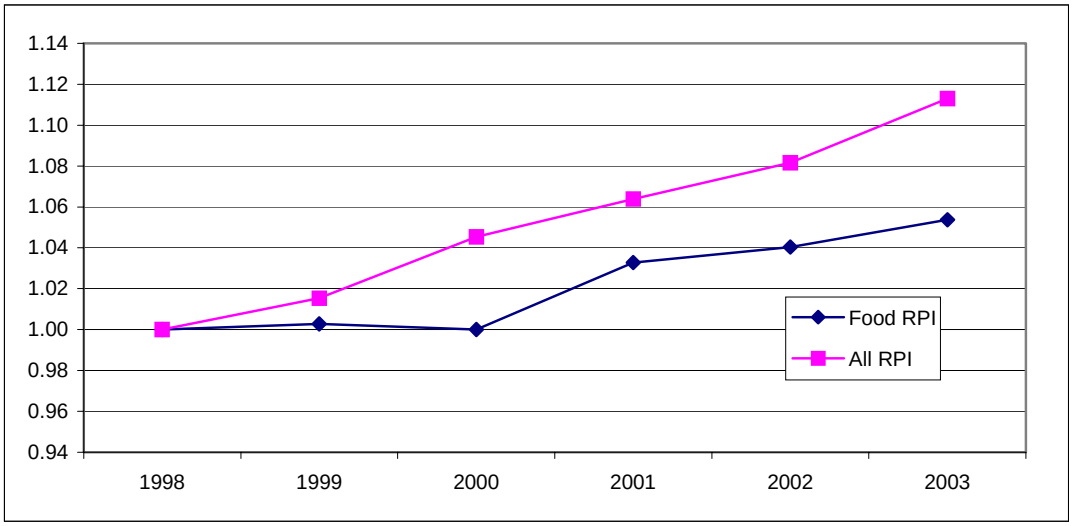
The Food Chain downstream from farming comprises a number of large sectors, namely i) food manufacturing, ii) food wholesaling, iii) food retailing, and iv) non-residential catering. Total gross value added within these sectors has been estimated to be £58 billion (ABI, 2003), employing around 12% of the UK workforce.

Sustainable growth is a key policy concern for this industry. The Sustainable Food and Farming Strategy (SFFS), which was published by Defra in 2002, aimed to bring a 'reconnection' of the food chain with customers, the world economy and the environment. It's central pillars were economic, social and environmental growth. This development would be measured by improvements in indicators of sustainable development. Food Productivity is one of the 11 headline indicators within the SFFS. In addition, Defra's proposed Food Industry Sustainability Strategy (FISS), which is directed at these four sectors, aims to encourage the adoption of best practice to help achieve sustainable development. Productivity, which measures the efficiency at which inputs are converted into outputs, is an underlying indicator of sustainable resource use.

Productivity can be measured partially or totally. The most common partial indicator is labour productivity, which can be measured as either output per annual hours worked, or by full-time employee. It is a relatively simple indicator to construct and allows comparison with international performance. Total Factor Productivity (TFP), which accounts for all the major inputs within the production process, such as capital, labour and intermediate purchases, offers a more comprehensive picture of growth. TFP is effectively a 'residual' effect which encapsulates factors which are difficult to quantify, such as technological development, management expertise and statistical noise. Constructing a TFP index is more complex than a partial productivity index and requires more assumptions to be made. Government has tended to favour partial measures over total measures. However, the imperative of constructing an accurate indicator of sustainable growth means that labour productivity has to be rejected in favour of an index which represents resource use for most factors of production. Hence, Total Factor Productivity (TFP) has been adopted within this report as the principal measure of growth.

Productivity growth leads to greater quality of life. There are benefits to society from a rise in productivity. Figure E1 charts the general retail price index (RPI) with the retail price index for food products over this period. It is quite clear that during this period prices for food are below general retail prices. This tends to indicate some benefit to the consumer.

Figure E1. Food RPI against RPI



However, TFP does not encapsulate sustainable growth alone. A fuller picture emerges when it is complemented by other indicators, such as trends in energy and waste usage. Ultimately, these indicators can be aggregated into a single indicator, known as Total Social Factor Productivity (TSFP).

This report presents measures of TFP growth within the four sectors downstream from farming, and for the food chain as whole. It then adjusts this productivity growth for a number of social and environmental factors which affect resource usage. Specifically, this report has a number of objectives:

1) to construct TFP indexes for the food manufacturing, retailing, wholesaling and catering sectors;

2) to aggregate these indexes into a single TFP index for the Food Chain downstream from farming;

3) to present information regarding the environmental impact of activity within the food chain; and

4) to adjust TFP to include these environmental impacts.

Methodology

The first part of the report is concerned with some of the methodological issues involved with constructing a TFP index. There are four main methodological issues when attempting to produce a TFP index, namely i) data sources used, ii) construction of a capital stock series, iii) accurate estimates of labour hours worked, and iv) application of appropriate deflators.

Data sources

Table E1 shows the details and sources of the data used. The main data source for inputs and outputs was the Annual Business Inquiry (*ABI*), which provides data from 1998 onwards at Standard Industrial Classification[1]. This was complemented by the ONS Capital Stock Series (*Cs*) and the Annual Survey of Hours and Earnings (*ASHE*), also collected by the ONS, to measure total hours worked for full-time and part-time workers for each industry sector. Deflation occurred from specific ONS time series (See table E2 below) It therefore provides a data set at sufficient detail to examine the four sectors downstream from farming.

Table E1. Data Sources Used

	Price Series	Quantity Series	Description	Data Source
Output				
Turnover	£		Sales of Products	ABI
		£(2000)	Deflated to 2000 prices	ONS
Inputs				
Labour	£		Labour Costs	ABI
		Hrs Wrk	Annual Hours Worked adjusted by industry estimates for fulltime and part-time hours	ASHE
Capital	£		Capital Expenditure	ABI
		Cap. Stk*	A 20 year 'sudden death' depreciation rate begun in 1995 from an estimate of capital stock from the ONS 1994	ONS *(Cs)*
Intermediate Purchases	£		Intermediate Purchases**	ABI
		£(2000)	Deflated to 2000 prices	ONS

*'*Capital stock series'* **These comprise energy and raw materials.

Capital Stock Series

A firm will have a stock of capital at any one time which will be composed of assets of differing ages. However, this is not a direct input into the production process, it is the 'flow of physical capital services' which should be included into the TFP measure. This is not directly observable but is usually considered as directly proportional to the stock of physical capital. Consequently, to understand how capital affects production, a series for capital stock was constructed which accounts for the loss in relative efficiency from older stock compared to fresher stock. This was done using the 'perpetual inventory model' (PIM) which allows for this service charge to be computed each year.

Labour Series

Within most production related data sets, a labour expenditure series, usually labour employment numbers, exist. However, a much more accurate indicator is total hours worked, which accounts for actual effort per worker, e.g. no distortion from overtime payments, part-time work etc.

[1] http://www.statistics.gov.uk/abi/quality_measures.asp

In order to gather data on hours per sector the Annual Survey of Hours and Earnings (ASHE) was used, which charts back to 1998. The advantage of using the ASHE is that it gives median rates for total hours worked by industry (SIC) code and hence obviates the problem of using economy wide rates. Furthermore, it gives an estimate of weekly hours worked both full-time and part-time. The ASHE gives estimates of numbers of jobs within each SIC. A drawback is that median rates are a weekly average and therefore assumptions need to be made on the number of weeks worked per year to provide an annual series. As industry specific estimates could not be gathered, the legal minimal number of weeks allowed for paid leave was used, which at present is four weeks including public holidays.

Application of Deflators

Generally, all indexes need a price and a quantity series. However, for most applications physical quantity data do not exist, at least in a form suitable for analysing all inputs and outputs within a TFP index. Table E1 illustrates the price and quantity series for each factor. Where physical data are not available, the usual procedure is to take the constant price series as the quantity index and the current price series to determine the weights for each year (e.g. Thirtle *et al.,* 2003). As the constant price series is effectively free of price changes it can be used as a quantity series.

In order to produce a constant price series some deflation needs to occur. Whereas labour has a physical quantity series, the others do not. The capital stock series used a single deflator across all four sector, namely the producer price index for mechanical goods bought for food and beverages. However, for turnover and purchases, two deflators had to be used to encompass the inputs and outputs within the production process. Where more than one deflator is used moving weights were adopted. The choice of deflator and weights used are outlined in Table E2 below.

Whilst able to encompass most of the price changes prevalent to these series, they are not ideal. Several issues occur with the retailing deflators as they do not cover the divide between domestic and foreign produced raw materials, which would have different price movements. In addition, the retail deflators only reflect changes in the prices of food and beveradge inputs outputs. They do not account for the inreassing proportion of non-food items tha are sold by food retailers, such as clothing and entertainment products. However, whilst some distortion occurs with applying this deflator, it cannot be corrected due to lack of sectoral level information on quantities purchased from abroad.

Table E2. Deflators Used for Turnover and Purchases Series

	Purchases	Turnover
Manufacturing	PPI for food and drink purchases (RABF) and the Agricultural Price Index (API) were used. The weights are determined by the share of fresh food and processed foods purchased.	Output of food products and beverages including duty (RPUN).
Retailing	Output of food products and beverages including duty (RPUN) and the Agricultural Price Index was adopted. Their shares are weighted by the proportion of fresh and processed food sold within the ABI retail classification.2	RPI Food & RPI Beverages. These are weighted by the split in food and beverages sold in the ABI
Wholesaling	Geometric mean of retail and manufacturing sectors.	Geometric mean of retail and manufacturing sectors.
NRC	GDP deflator	RPI catering and RPI alcoholic drinks were used, but weighted by their split within the sale of retail food and beverages.

Source. ONS

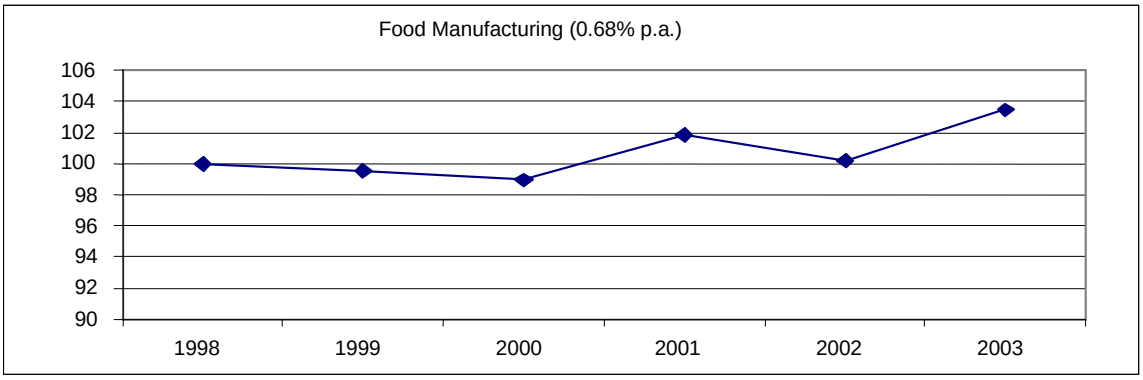
General Findings
TFP Growth Rates for the Four Sectors

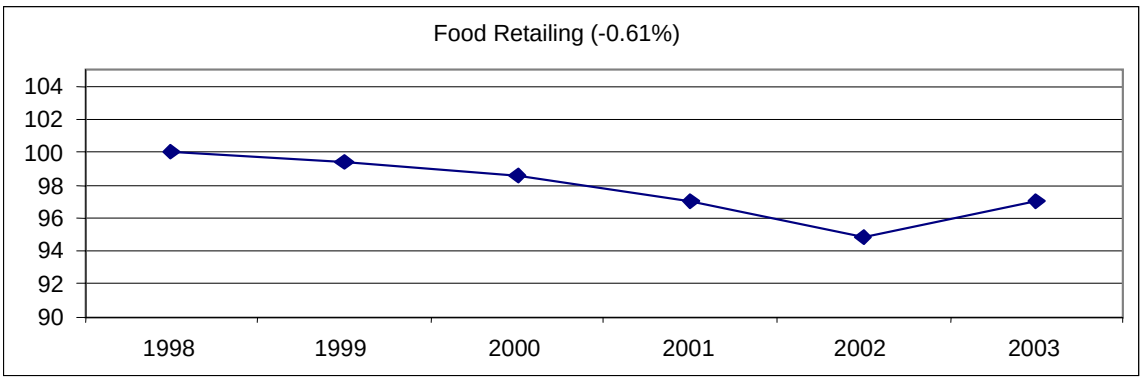
Figures E2 to E5 show the Fisher derived indexes of TFP growth for the four sectors in the Food Chain. Rates of growth for the period 1998 to 2003 are:-

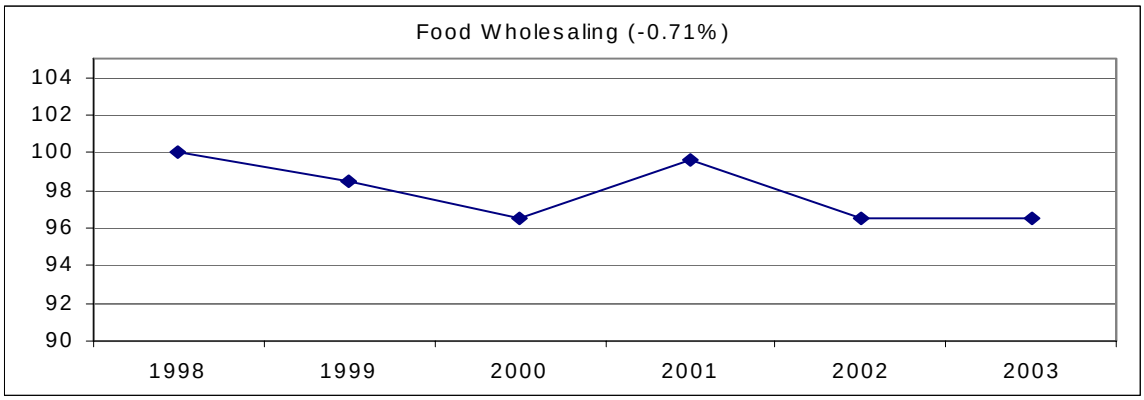
- Food manufacturing TFP is 0.68% per annum;
- Food Wholesaling TFP is –0.71% per annum;
- Food Retailing is –0.61% per annum;
- Non-Residential Catering is –0.10% per annum.

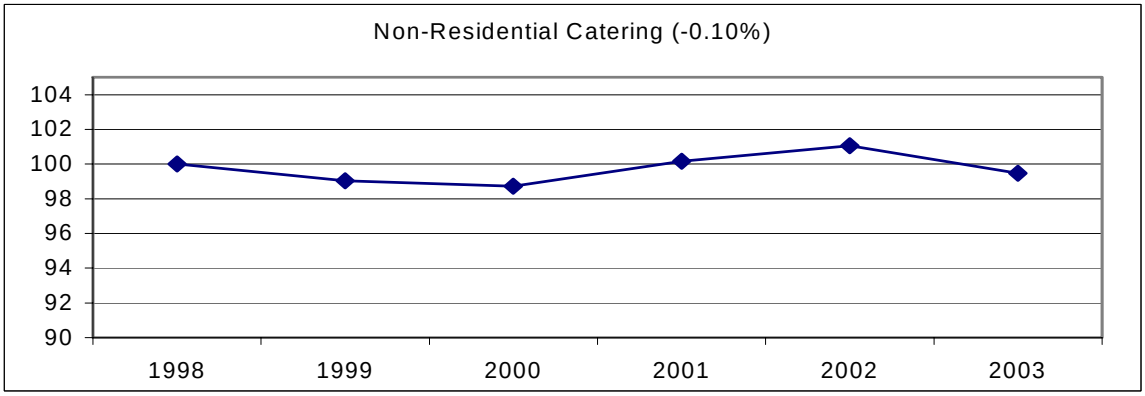
[2] For example the Constant (£2000) Retail Price in 1998 = (Processed Foods (0.38)*RPUN)+(Raw Materials (0.62)*API).

Figures E2 - E5. TFP Growth Rates for Four Food Sectors









TFP Growth Rates for the Food Chain

The indexes for the four sectors were aggregated to provide a picture of growth within the food chain downstream from the farming sector. Figure E3 and Table E5 show partial and total factor productivity indexes for the food chain.

Figure E3. Growth Rates in Input Productivity and TFP for the Food Chain

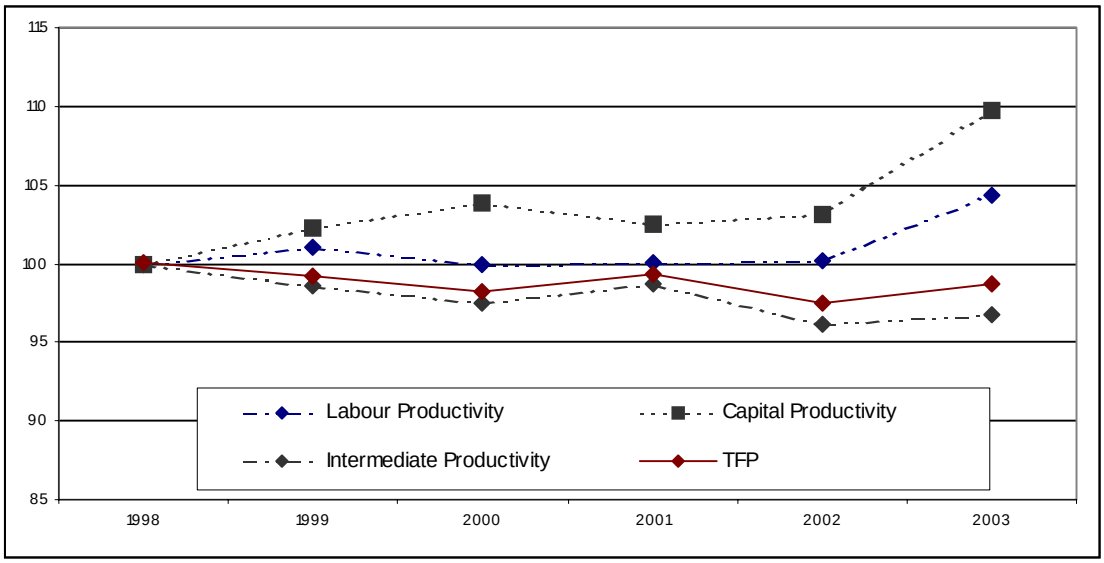


Table E5. TFP Growth Rates for the Food Chain, percent

	Labour Productivity	Capital Productivity	Intermediate Productivity	Inputs	Output	TFP
1998	100.00	100.00	100.00	100.00	100.00	100.00
1999	101.10	102.32	98.63	102.19	101.35	99.18
2000	99.96	103.89	97.46	105.26	103.38	98.21
2001	100.07	102.47	98.67	103.51	102.73	99.30
2002	100.24	103.17	96.14	107.91	105.11	97.47
2003	104.39	109.69	96.73	111.27	109.74	98.77
Average	0.86%	1.87%	-0.66%	2.16%	1.88%	-0.25%

For the food chain as a whole there is positive growth in labour productivity and capital productivity. However, intermediate purchases show a strong negative trend. As these purchases make up around 80% of all inputs they have a strong depressing effect on the input index. This has served to depress growth rates to below zero. The average TFP growth rate for the food chain is –0.25% per annum. This is lower than an estimate of whole economy TFP growth (using the same method and data sources) of 0.57%.

Possible Causes

TFP growth rates within most sectors of the food chain are downward. Consequently, the question of what has caused these negative rates has to be addressed. There are a number of possible causes.

1) **Measurement Errors** - Most data sets contain errors, through measurement and response bias. The Annual Business Inquiry is a fairly robust data set collected by the ONS. Nevertheless some statistical errors may exist. Furthermore, some of this distortion is applicable to the choice of deflators. As far as possible the best deflators have been used, however these are not perfect and may be a source of some bias.

2) **Intermediate Purchases -** The major cause of downward growth rates is lack of efficiency in purchasing intermediates. Some of these inefficiencies may be caused by purchasing perishable products, which could also be affected by blockages in the supply chain for raw materials, for example rising traffic congestion. However, to some degree, it may be reflected in ineffective purchasing behaviour of management and management systems adopted.

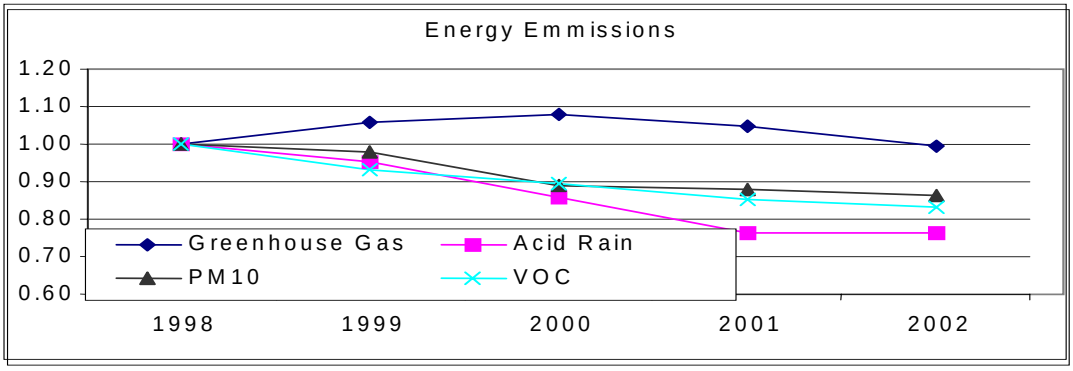
3) **Low R&D Investment** - Few analyses of food sector R&D have been made. However, the DTI (2005) present a scoreboard of R&D intensities, measured in terms of R&D expenditure as a percentage of sales. The only sector which appears in the top 700 companies are food producers and processors as the 11th most intensive sector. Other sectors within the food chain do not appear. Consequently, this may be some indication towards the cause of TFP decline.

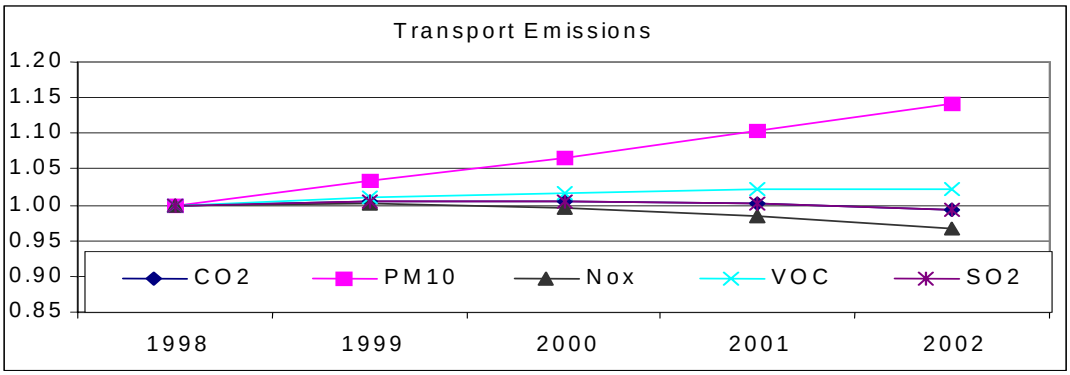
4) **Non-Market Effects** - The marketable outputs of the food chain have been measured. However, a number of non-market effects occur, which may affect TFP performance but have not been quantitatively measured. The benefits occur mostly at the retail end of the food chain, reflecting longer opening hours or increased diversification of activities. Productivity growth would be dampened by these effects, due to losses in labour efficiency, but they add to the quality of life of consumers.

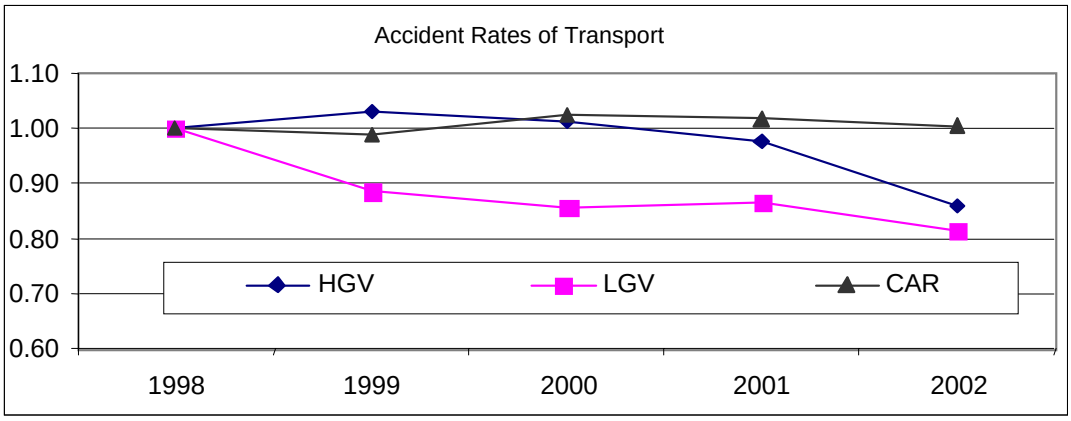
Externalities within the Post-Farmgate Food Chain

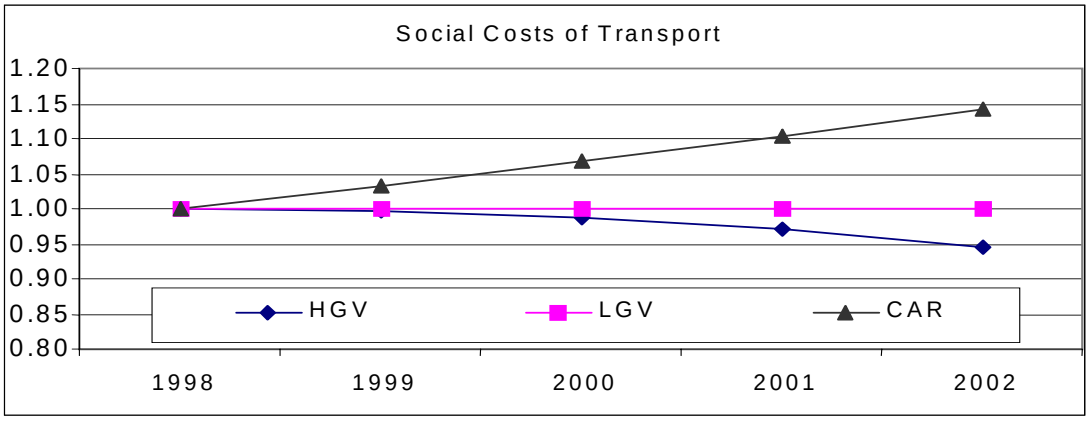
The second section of this report examines the data available for measuring some of the 'non-market' effects involved with food production, these include transportation and contribution to greenhouse gases. **Unfortunately, for several of these areas there is a paucity of data, especially for waste and water usage**. However, detailed information at the industry level exist for five groups of negative externalities; i) energy use and emissions from the food chain; ii) emissions from transport within the food chain; iii) the social costs of transport, i.e. noise, congestion and infrastructure, iv) accidents rates from transport in the food chain; and v) social costs of the food chain, which comprise accidents at work and food poisoning. Figures E4 to E7 shows the majority of their trends over the 6-year period as Fisher indices.

Figures E4 to E7. Trends of Resource Usage within the Food Sector (1998=100)









Emissions from energy use have been declining over the 1998 to 2002 period, an initial increase in greenhouse gas emissions was also later reversed to show a small overall decline. A slightly different picture emerges with respect to emission to air from food chain related road transport. Most emission types have shown small declines, but there was a small increase in volatile organic compounds and large increase in the levels of particulates.

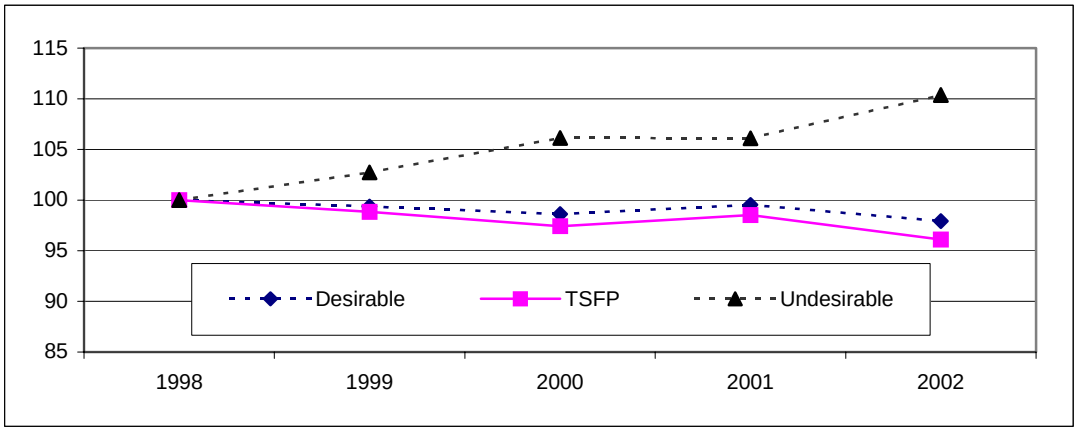
In addition to the emissions from road transport a number of other externalities also arise from transport. These are primarily related to the costs imposed on society by congestion, but to a lesser extent also include costs due to noise and wear and tear of infrastructure. For light goods vehicles these external costs have remained constant (due to data indicating constant distances travelled by LGVs). Externalities due to heavy goods vehicles have fallen due to decreasing mileages, this indicates greater efficiency in the use of such vehicles, which have become larger and have achieved higher load factors. More efficient distribution networks will also contribute to lower external costs from HGVs. However, the decrease in external costs due to transport by food chain industries has been more than offset by increasing externalities resulting from the use of cars for food shopping. Although the average number of food shopping trips has decreased, the number of households making such trips and the distances travelled have both increased.

Further transport related external costs arise due to road accidents. These arise from costs to the health service, police, insurance, lost output, damage to property and pain and suffering. Accident rates, and hence costs, have fallen for both LGVs and HGVs, and despite increased mileage have remained constant for cars.

Total Social Factor Productivity Index

An attempt was made to adjust the TFP index into a Total Social Factor Productivity Index. Effectively, given the quantity series outlined above, and where shadow prices existed over time, these could be used to construct a separate TFP index of 'undesirables'. Furthermore, the shares between 'desirable' output, e.g. gross value added, and 'undesirable' output could be used to weight the two indexes into a single index. However, only limited data were available and this ignores all of the positive externalities of the food chain. Their ommission is likely to have biased the growth rate of TFP downward. Figure E8 shows the desirable, undesirable TFP indexes alongside the TSFP index.

Figure E8. Desirable, Undesirable TFP Indexes and TSFP Index



Generally, it finds that undesirable TFP has increased substantially over the period by around 2.5% per annum. This has the effect of reducing TFP growth from –0.64% per annum to –1.13% over the period 1998-2002. **However, this ignores some of the positive externalities of the food chain, which have not been quantified and priced, and may raise the growth rate of TFP. Nevertheless, two large negative externalities, waste and water, also have sparse data and could not be included. The effect of their inclusion may be to push TFP growth rates even further downwards.**

Main Conclusions

- Food Manufacturing has a positive rate of TFP growth of 0.68% per annum, which is above the whole economy average of 0.57%.

- The remaining three sectors have negative growth rates. Food Wholesaling has the lowest growth rate of –0.71%, this is followed by food retailing of –0.61% and non-residential catering of –0.10%. As this reflects resource usage this is not sustainable in the long-term. Whole economy TFP during this period was 0.57%.

- Most sectors have positive growth rates in labour and capital productivity. However, input productivity is dampened by a high reliance on intermediate purchases, such as raw materials and energy use. Some of this can be negated through greater efficiency of purchasing control mechanisms. However, some may be outwith the control of the business.

- Retail productivity is possibly depressed by the ommission of the non-market benefits offered by supermarkets, such as longer opening hours, and a greater product mix offered within stores.

- **The major cost to the food chain in terms of externalities are the social costs of transport, i.e. the congestion, noise and infrastructure related to food transportation.**

- **The main negative externality originates from the use of cars**, which has increased substantially from 1998 onward. Predominantly, this is due to increased distances travelled to supermarkets for food shopping (the number of shopping trips per household has decreased).

- However, **whereas these external costs are around £8 Billion, desirable benefits (through gross value added) accrue to £58 Billion**.

- **A Total Social Factor Productivity Index was constructed composed of desirable and undesirable outputs, which reduced growth rates from –0.64% per annum to –1.13% for the food chain over 1998-2002**.

- A Total Social Factor Productivity index, whilst desirable as a single indicator, is unable to fully capture the intricacies of sustainable development because of data collection issues. Accordingly, until appropriate time series data can be collected, Total Factor Productivity should be considered as one of a suite of major indicators for sustainable growth.

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1.0. Introduction

Economists usually regard productivity as a residual term. Under the assumption of constant returns to scale, a doubling of inputs should double the level of output. However, what is usually observed is the growth in output exceeds the growth in inputs.. A measure which takes account of all inputs and compares them to outputs should identify this residual. Total Factor Productivity (TFP), unlike labour productivity, attempts to account for all these inputs[1] and relate them to outputs. Consequently, it aims to accurately measure this residual term.

TFP is an aggregate measure directed at a particular industry or a national assessment of performance. Dragun *et al.* (2004) have criticised aggregate approaches to productivity measurement because of the fragility of the data used. They argue that whilst methodologies are both 'careful and meticulous' calculation of input data is susceptible to variation (e.g. in terms of hours worked etc.). Essentially, they argued for measurement at the micro-level to accommodate some of the specific differences which occur between retailing and other sectors. A suite of key performance indicators (KPI), such as overall labour costs and ratios of selling to non-selling space, would improve measurement of performance. However, whilst this may increase accuracy of measurement it suffers from three main problems. Firstly, there are very practical difficulties in collecting micro-level data to construct a set of KPI's for policy-level analysis. This is compounded by the concentrated nature of some of the food sectors and may lead to concerns over disclosure of firm level identifiers. Secondly, whilst a mix of indicators are useful for understanding the specifics of the retailing sector they provide conflicting evidence of performance. Thus there is a real concern over how to correctly weight the importance of one indicator over another. Finally, the real benefit of an aggregate measure is the appropriate removal of distortions from prices (as deflators are collected at a macro, not a micro level). Accordingly, this research develops an aggregate measure of productivity, precisely because it obviates some of these problems.

Accurate measurement of TFP is therefore crucial to understanding changes in sectoral productivity growth. However, whilst most developed and developing countries use indicators of productivity it is less clear what the true purpose of measuring productivity is. This is an important point as, whilst the bulk of the effort is aimed at producing better and more accurate indexes of productivity, little work has concentrated on its uses in a policy context. Consequently, this section aims to focus on the true nature and purpose of a TFP index and some of the arguments for its adoption. A recent study on the measurement and purpose of productivity outlines a number of reasons why measuring productivity is important (OECD, 2001), predominantly;

i) Living Standards

Growth in income per person within an economy can be directly related to labour productivity growth. This increase in productivity also enhances qualitative effects, in terms of improvement of working environment. In addition, a long-term trend in Total Factor Productivity gives an indication of an economy's underlying productive capacity. It can therefore be used as a measure of potential growth and possible inflationary pressure. Consequently, as TFP includes most inputs into the production

[1] Multi-Factor Productivity, a term used by US and Australian Governments, is more appropriate as only some factors can be properly accounted for.

system, it can offer indications of long-term sustainability within an industry or economy.

This argument is also echoed by the HM Treasury (2000) as the central objective of Government is to promote high and stable levels of economic growth and employment. Thus the focus is on increasing the trend in growth to enable sustainable increases in income per head and 'is central to raising the prosperity of the country' (ibid., pp. 3).

ii) Real cost savings

Productivity is generally seen as a residual effect. This differential between rates of input and output growth is composed of a number of phenomena important for business. Aside from measurement error, this residual captures increasing economies of scale, technical and cost efficiencies, and capacity utilisation. Consequently, Harberger (1998) identified that measuring productivity is an indicator of the potential real cost savings that can be achieved over time.

A number of countries, including the UK have favoured labour productivity, usually output per worker, as the key indicator of progress. This is for two reasons, namely i) it is a fairly straightforward measure which requires minimal data requirements and therefore can offer little ambiguity in application[2], and ii) it can be immediately linked to the overall objective of raising employment growth in the long-term (HM Treasury, 2000). However, this is only seen as a starting point to the analysis because using labour productivity as a single indicator is somewhat problematic. Principally, labour can be substituted with capital and, hence, whilst labour is perceived as improving productivity it may be to the detriment of future employment opportunities within the industry.

Consequently, there are strong arguments for adopting a Total Factor Productivity index to understand the full growth potential of an industry. However, in order to produce a TFP a capital stock series needs to be constructed, which requires greater data requirements, along with certain assumptions to be imposed on the series. Nevertheless, it provides an understanding of the relationship between labour, capital, purchased materials and energy within production. This is useful as the substitution of one factor for another would offer greater insights into the way an industry is developing.

2.0. Methodology for Constructing a TFP Index for the Food Sector

This section aims to outline the methodology adopted for measuring Total Factor Productivity within the food supply chain. The rationale for the project is to provide a practical method for use within Defra, as well as a simple and transparent procedure for constructing a set of TFP indexes. This can then be linked to an assessment of the sustainability of the food chain.

Ultimately, discussion of TFP construction focuses on a number of important factors which need to be addressed, these are, namely i) choice of indexing procedure, ii) application of appropriate deflators, and iii) treatment of capital and labour inputs. These are discussed in detail below.

[2] Though see Dragun et al. (2004) for discussion of the limitations of labour productivity measurement.

Choice of Indexing Procedure

As a TFP index is a measure of growth the choice of index is important, as it will affect growth rates if the wrong procedure is chosen. Ultimately, an indexing procedure mimics the underlying production, cost or profit functional forms of a firm's behaviour. A number of indexing procedures exist which aim to mimic the function of how inputs are converted to outputs.

A Laspeyres index is a popular form of index number procedure, which mimics a linear production relationship between inputs and outputs. A Laspeyres quantity index is illustrated in equation 1 below.

$$x_1 / x_0 = \sum p_{i0} x_{i1} / \sum p_{i0} x_{i0} \qquad (1)$$

where (x_1/x_0) is the relative change in output (input) between the periods t_1 and t_2, and the sum of output (input) prices (p) times output (input) quantities (x) in a particular year (i) is measured over the cumulative value of output (input) in a base year (0). This procedure has interpretative qualities, as its reliance on a base year allows for measuring changes in the value of total inputs resulting from pure quantity changes (Christensen, 1975).

An alternative is the Paasche index which can be defined as:-

$$x_1 / x_0 = \sum p_{i1} x_{i1} / \sum p_{i1} x_{i0} \qquad (2)$$

A Paasche quantity index uses period t prices as weights, in contrast to the Laspeyres which uses base year prices as weights.

When the underlying production function is non-linear, more complex indexing numbers can be applied, namely the Fisher index and the Tornqvist-Theil index. The Fisher index is appropriate for a quadratic functional form and is the geometric mean of the Laspeyres and Paasche quantity Indexes and can be specified as:-

$$x_t / x_0 = \left[X^L \cdot X^P \right]^{0.5} \qquad (3)$$

Where X^L is the Laspeyres index and X^P is a Paasche index.

The Tornqvist-Theil (T-T) index is appropriate for a translog function and relies on a system of both factor shares and on smoothing a previous year's prices and quantities, rather than relying on a base period. The T-T index is thus written as;

$$\log(x_t / x_0) = \sum \overline{w}_i (x_{i1} / x_{i0}) \qquad (4)$$

where (x_t/x_0) is the relative change in output (input) between two time periods, and $\overline{w}_i$ is the weight allocated to each factor of production (i).

These latter two have proved the most popular within productivity analysis principally because they are flexible functional forms and make no prior assumptions over the relationship between inputs and outputs. For this research the Fisher index will be

used and was chosen for three main reasons. Firstly, the Fisher index is composed of two simple indexing procedures which are easily understandable and hence can be applied practically. Secondly, from an axiomatic point of view, the Fisher index passes a number of statistical tests and therefore offers something that is more robust statistically than the Tornqvist-Theil index (Diewart, 1976). Finally, it makes no prior assumptions over the relationship between inputs and outputs. These relationships across the supply chain are difficult to model and hence this is an important property of the Fisher index.

A further issue emerges after choosing a particular indexing procedure over whether it is appropriate to use a base weighted index or a chained index. In a review of indexing methods, the OECD (2001a) strongly supported the chaining of indexes. This is principally because chaining avoids 'substitution bias'. This is because fixing measurements of growth against a particular year will increasingly bias the index away from actual labour and capital substitution as the index moves away from the base year. An extreme example of this would be with comparing agriculture in 1948, which was heavily labour intensive, with agriculture in the present day, which has history of heavy capital investment. Chaining obviates this problem by comparing a year's performance against the previous year. Consequently, this study chooses to adopt chaining as the appropriate procedure.

Aggregating Productivity Growth across Sectors

The food supply chain consists of a number of integrated sectors. Thus, most outputs from one sector will become inputs to the next sector downstream. Consequently, some account needs to be made of the contribution of productivity gains in one sector which would also benefit the sectors downstream. Accordingly, not only would total food sector productivity aggregate the four separate indexes produced, but would also 'integrate' the growth in productivity of each sector. Most studies adopt 'Domar' weights which aims to incorporate these integrative effects. Oulton (2004) specified that the aggregate TFP index should be the weighted average in TFP growth rates where the weights are each sector's shares in final output. This is the form of Domar aggregation adopted here.

Definitions of Sectors in the Food Chain

Table 2.1. shows the composition of the food chain be standard industrial classification.

Table 2.1. Composition of the Food Chain by Standard Industrial Classification

Sector	I-O INDUSTRY GROUP	STANDARD INDUSTRIAL CLASSIFICATION
Manufacturing	Manufacture of Food Products and beveradges	15
Wholesaling	Wholesale of food, beverages and tobacco	51.3
Retailing	Retail sale of food, beverages and tobacco in specialised stores MINUS Retail Sale of tobacco products PLUS Retail sale in non-specialised stores with food, beverages or tobacco predominating MINUS Other retail sale in non-specialised stores	52.2 52.26 52.11 52.12
NRC	Restaurants Bars Canteens and catering	55.3 55.4 55.5

Data Sources

The main data source for inputs and outputs was the Annual Business Inquiry (*ABI*), which provides data from 1998 onwards of Standard Industrial Classifications[3]. The ABI collects data on 13 variables, including turnover, gross value added, and major inputs such as labour employed and cost, capital expenditure and purchases of materials. Data are collected through the ONS to provide a representative sample of UK businesses and offers a robust data set. Applications of ABI data include production of annual employment estimates, calculation of gross value added for the measurement of GDP, productivity estimates, input-output tables and other national accounts applications. However, given the survey nature of data collection there are both non-response errors and sampling errors. These are discussed in some depth within the quality control section of the ABI website[4].

This was complemented by the ONS Capital Stock Series (*CS*) and the Annual Survey of Hours and Earnings (*ASHE*), also collected by the ONS, to measure total hours worked for full-time and part-time workers for each industry sector. Deflation occurred from specific ONS time series (See table 2.3 below) It therefore provides a data set at sufficient detail to examine the four sectors downstream from farming.

[3] http://www.statistics.gov.uk/abi/
[4] http://www.statistics.gov.uk/abi/quality_measures.asp

Table 2.2. Data Sources Used

	Price / Quantity	Description	Source
Output			
Turnover	£ / £ (2000)	Sales of Products Deflated to 2000 prices	ABI ONS
Inputs			
Labour	£ / Annual Hours Worked	Labour Costs Annual Hours Worked adjusted by industry estimates for fulltime and part-time hours	ABI/ ASHE
Capital	£ / Perpetual Inventory Method*	Capital Expenditure A 20 year 'sudden death' depreciation rate begun in 1995 and continued from an estimate of capital stock from the ONS 1994	ABI/ ONS CS
Intermediate Purchases	£ / £(2000)	Intermediate Purchases** Deflated to 2000 prices	ABI ONS

*See '*Treatment of Inputs*' section below.
**These comprise energy and raw materials.

Generally, all indexes need a price and a quantity series. Ratio measures of quantities over two time periods are weighted by their prices when aggregating. However, for most applications physical quantity data do not exist, at least in a form suitable for analysing all inputs and outputs within a TFP index. The above table illustrates the price and quantity series for each factor. Where physical data are not available, the usual procedure is to take the constant price series as the quantity index and the current price series to determine the weights for each year (e.g. Thirtle et al., 2003). As the constant price series is effectively free of price changes it can be used as a quantity series.

In order to produce a constant price series some deflation needs to occur. Whereas labour has a physical quantity series, the others do not. The capital stock series used a single deflator, namely the producer price index for mechanical goods bought for food and beverages. However, for turnover and purchases, two deflators had to be used to encompass the inputs and outputs within the production process. Where more than one deflator is used the issue of weighting needs to be addressed. Fixed weights would provide a distorted view of price changes, as the quantities of inputs change over time, hence moving weights are adopted here. The choice of deflator and choice of weights are outlined in Table 2.3 below.

Table 2.3 Deflators Used within Analysis

	Purchases	Turnover
Manufacturing	PPI for food and drink purchases (RABF) and the Agricultural Price Index (API) were used. The weights are determined by the share of fresh food and processed foods purchased.	Output of food products and beverages including duty (RPUN).
Retailing	Output of food products and beverages including duty (RPUN) and the Agricultural Price Index was adopted. Their shares are weighted by the proportion of fresh and processed food sold within the ABI retail classification.[5]	RPI Food & RPI Beverages. These are weighted by the split in food and beverages sold in the ABI
Wholesaling	Geometric mean of retail and manufacturing sectors.	Geometric mean of retail and manufacturing sectors.
NRC	GDP deflator	RPI catering and RPI alcoholic drinks were used, but weighted by their split within the sale of retail food and beverages.

Whilst able to encompass most of the price changes prevalent to these series, they are not ideal. Several issues occur with the retailing deflators as they do not cover the divide between domestic and foreign produced raw materials, which would have different price movements[6]. However, whilst Economic Trends (2003) have provided an indication of the split between home produced and foreign goods it was only at the level of the total food chain. Accordingly, whilst some distortion occurs from applying this deflator, it cannot be corrected due to lack of sectoral level information due to lack of information on quantities purchased from abroad.

Price Changes

Producer Price Indices (PPI) emerge from a monthly survey that measures the price changes of goods bought and sold by UK manufacturers. PPIs work on the 'basket of goods' concept. A wide collection of representative products is selected and the prices of these fixed sets of goods are collected each month. The movements in these prices are weighted to reflect the relative importance of the products. Basic trends in the deflator used are outlined in Table 2.4 below.

[5] For example the retail price in 1998 = (Processed Foods (0.38)*RPUN)+(Raw Materials (0.62)*API).

[6] Work is being conducted by the ONS on this see: http://www.statistics.gov.uk/abi/retail_commodities.xls

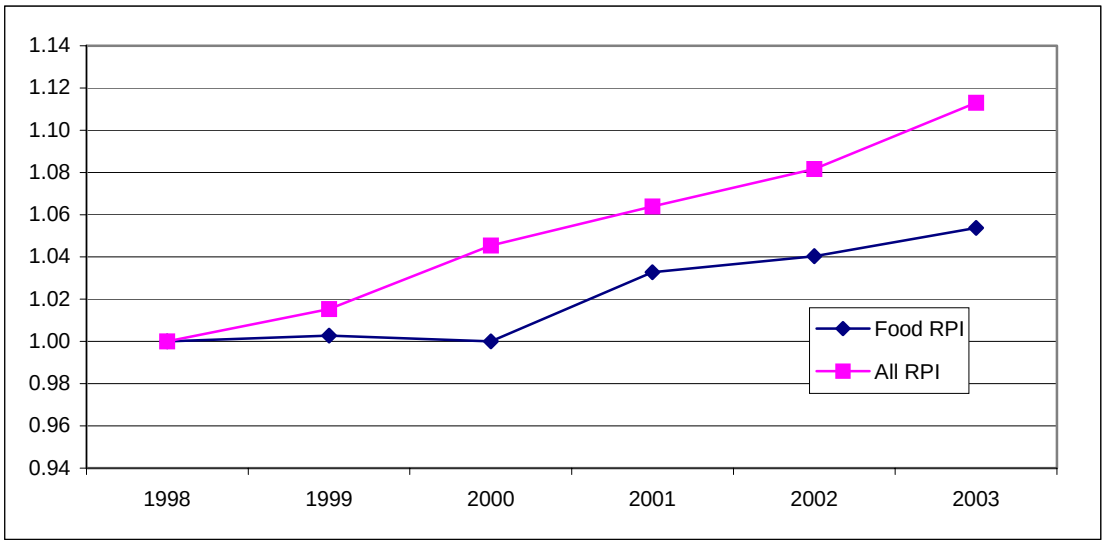
Table 2.4. Price Changes in the Food Chain and the Wider Economy

	Prices changes in the food chain and the wider economy (average annual change from 1998 to 2003)				
	Manufacturing	Retail	Wholesale	NRC	Wider Economy
outputs	+0.6%	+1.4%	+1.0%	+3.2%	+2.2%
inputs	+1.0%	+1.0%	+1.0%	+2.7%	+2.7%
labour	+4.6%	+3.8%	+8.4%	+5.3%	+4.9%
capital	+1.3%	+1.3%	+1.3%	+1.3%	+0.7%
purchases	+0.5%	+0.8%	+0.7%	+2.4%	+2.4%

Source: ONS

This is better summarised in Figure 2.1 which shows a positive picture of food price growth by comparing the general retail price index (RPI) with the retail price index for food products. It is quite clear that during this period prices for food are below general retail prices. This tends to indicate some benefit to the consumer.

Figure 2.1. Food RPI against RPI



Source. ONS

Treatment of Outputs

An OECD (2001a) review of productivity measures found that, whilst labour productivity is the most frequently calculated index of performance, this is followed by TFP measures using both value-added or total turnover. The advantage of using total turnover is that it includes most factors of production, such as labour, capital, materials and energy, which can be examined as separate factors of production, something the value added approach does not offer.

Within the aggregate series total turnover can be used as the single output measure. These exist within the Annual Business Inquiry for each sector over the time period of study. Generally, these would be adjusted for stocks and work in progress as some degree of input effort has been directed towards goods which have not been sold in the same year. Goods that cross over this temporal boundary cause some concern for economists when trying to accurately measure annual growth within a sector. However, whilst work in progress within agriculture needs to be accounted for, due to

the long production cycles, for the downstream food chain production periods are relatively short. Consequently, adjustment for work in progress will be ignored.

Treatment of Inputs

1) Physical Capital Stock

A firm will have a stock of capital at any one time which will be composed of assets of differing ages. However, this is not a direct input into the production process, it is the 'flow of physical capital services' which should be included into the TFP measure. This is not directly observable but is usually considered as directly proportional to the stock of physical capital. Consequently, to understand how capital affects production, a series for capital stock needs to be constructed which takes into account the loss in relative efficiency from older stock compared to fresher stock. This can be done using the 'perpetual inventory model' (PIM) which allows for this service charge to be computed each year. A PIM can be constructed from:-

$$K_t = \sum_{s=0}^{s} \phi_s I_{t-s} \qquad (5)$$

where K_t is the sum of capital stock for a particular asset in period t, which is composed of a number of assets of s vintages (where s=0,…,S); I is the investment in that particular asset in periods *t-s* and ϕ is the relative efficiency of an s-vintage asset to a new asset. Essentially this model sums an asset's efficiency at a particular point in time, taking into account past investments which will be increasingly less efficient than new investments in that asset and which, at a particular point in time, will be removed from the capital stock series. Consequently, in order to use the PIM several pieces of information need to be obtained, namely:

1) an initial estimate of capital stock (e.g. in 1994) needs to be made. As the industry has been in existence for a number of years before the series begins assets have been invested into and exist at the beginning of the study period. This will be added to annually by net capital expenditures (given in the ABI). Fortunately, the ONS have calculated capital stock series for a number of industries from 1948 onwards. The advantage of this series is that it uses the PIM method. Such a series exists for the food and drink manufacturing of £47.2 billion. However, this does not exist for other sectors within the food chain. Consequently, a general assumption is made where the figure for food manufacturing is weighted by the cost share of capital expenditure in 1995 for a sector compared to that for food manufacturing. This makes the assumption that expenditure on capital in 1995 is indicative of capital throughout all sectors in the food chain. Nevertheless, it does provide a reasonable start figure for the PIM.

2) some assumption needs to be made of the service life of the asset to dictate the depreciation rates used within the capital stock series and, also, to reflect the relative shares of efficiency within the age profile of the stock. Estimates can be made from a review of the literature (e.g. OECD (2001b) estimated the average service lives of a number of assets for four countries, namely, the US, Canada, Netherlands and Czech Republic. These categories are quite general and offer rates which run from 11 years for machinery within food manufacturing, to 27 years for buildings involved with wholesaling.

Unfortunately, within the ABI series, no split between the type of asset exists. Estimates of capital stock by plant and machinery, buildings and ICM do exist for the food and drink industry offered by the ONS. However, generalisations would have to be made by fixing the asset mix within each industry to use this. Consequently, this study adopts all assets as one series and takes a rather arbitrary service life for all assets at 20 years.

3) an age structure of the stock. Depreciation can be modelled in one of three ways: Diminishing balance (usually used for machinery); fixed line depreciation (usually used for buildings), and; sudden death depreciation, where an asset maintains its productivity throughout its life (by regular maintenance and monitoring) and is then taken out of the system at the end of the asset's life. Sudden death (sometimes know as 'lightbulb efficiency') may be the most realistic schedule to adopt for the food chain as it assumes that both machinery and buildings are maintained to an optimum until they are disposed of. This must be true for a number of sectors within the food chain as plant and machinery, such as refrigeration devices and transportation have to be kept to their optimal efficiency otherwise this would result in food spoilage. The only sector where this may not apply is the food manufacturing sector. However, for the sake of consistency sudden death depreciation will be adopted for all sectors.

The PIM offers a quantity series to input into the series. These can be deflated by the PPI for machinery for food and beverages offered by the ONS. The price weights to use within the TFP series, as for other inputs, would be the current price series on capital expenditure.

2) Labour Inputs

Within most production related data sets, a labour expenditure series, usually labour employment numbers, exist. Compared to capital, labour productivity is usually the most common indicator of progress used at a sectoral level. However, whilst numbers exist, a much more accurate indicator is total hours worked, which accounts for actual effort per worker, e.g. no distortion from overtime payments, part-time work etc. The Defra labour series takes a standard economy wide estimate of annual labour hours worked by sex and multiplies by numbers in the workforce. This is then split by the ratio of males to females within the UK. This adjustment by sex is an attempt to adjust for quality in the workforce, however most research finds that gender differences have little effect on productivity, the biggest effect on labour quality is usually educational levels, which tends to be seen as a proxy for skills.

The whole area of quality adjustment is complicated, especially at this level of aggregation. Consequently, this study chooses to dispense with the split by sex and concentrate on more accurate estimates of labour hours worked. There are two reasons for this, namely i) the data are not industry specific enough to understand the relationship between explanatory factors, such as age and gender, on performance and, ii) the majority of jobs within the food chain are mostly prescribed and, hence little variation may exist across skill, gender or age levels.

In order to gather data on hours per sector the Annual Survey of Hours and Earnings (ASHE) exists, which charts back to 1998. The advantage of using the ASHE is that it gives median rates for total hours worked by industry (SIC) code and hence

obviates the problem of using economy wide rates. Furthermore, it gives an estimate of weekly hours worked both full-time and part-time. The ASHE gives estimates of numbers of jobs within each SIC. However, due to differences in sampling techniques, these do not match those of the ABI. In order to reduce measurement bias the total numbers of employed will be taken from the ABI, however the ratio of full-time to part-time workers will be taken from the ASHE. A drawback is that median rates are a weekly average and therefore assumptions need to be made on the number of weeks worked per year to provide an annual series. As industry specific estimates could not be gathered, the legal minimal number of weeks allowed for paid leave would be used, which at present is four weeks including public holidays. However, it does offer the advantage of using weekly hour estimates specific to the industry of study as opposed to that from an economy-wide estimate.

Again, hours worked would offer the quantity series, the price series would be the current expenditure on labour costs also offered within the Annual Business Inquiry for each sector.

3) Purchased Inputs

In the food supply chain purchased inputs compose the bulk of total inputs within the production process. The series directly reflects prices and quantities used as an input and little needs to be done before it is applied to the TFP series. The series needs to be deflated using an appropriate deflator to provide a quantity series (see above). The current prices will provide weights for the price series.

Summary

Within the study of productivity analysis a number of key factors have to be considered to construct an accurate indicator of total factor productivity. These and their appropriate treatment have been discussed above. Accordingly, the next section discusses the application of this methodology to the separate sectors for the food chain, outlining particular facets important to the each industry sector of study.

3.0. Productivity Analysis of the Food Chain

3.1. Sectoral Analysis

Within this section the four sectors that make up the food chain are examined individually to understand the underlying patterns of productivity growth in the food chain. The methodology outlined above has been applied and, where appropriate, some key constraints within the methodology for a particular sector are highlighted.

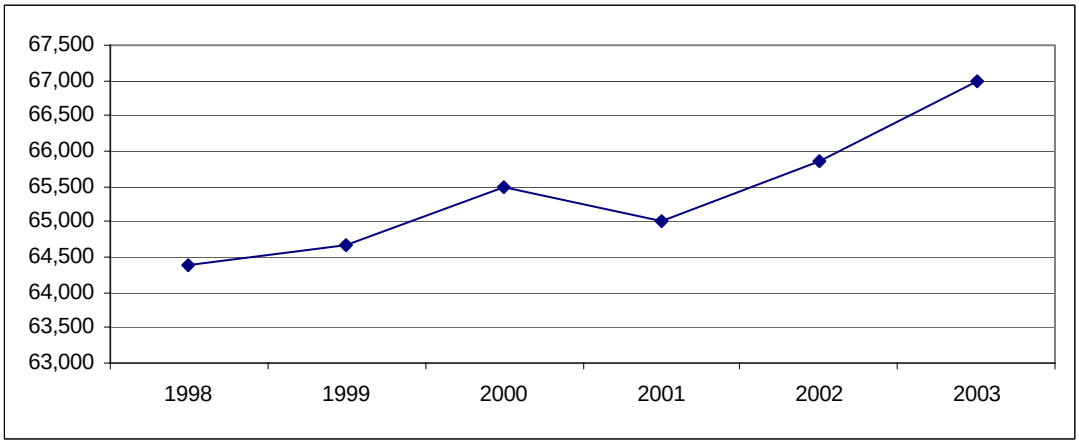
3.1.1. Manufacturing

The UK Food Manufacturing sector consists of a number of different operations, namely processing and preserving of meat and dairy products, along with fruit and vegetables.

Output Growth

Figure 3.1 shows the turnover of food manufacturing in constant (2000) prices from the Annual Business Inquiry.

Figure 3.1. UK Food Manufacturing Turnover, 1998 to 2003 (£m 2000)



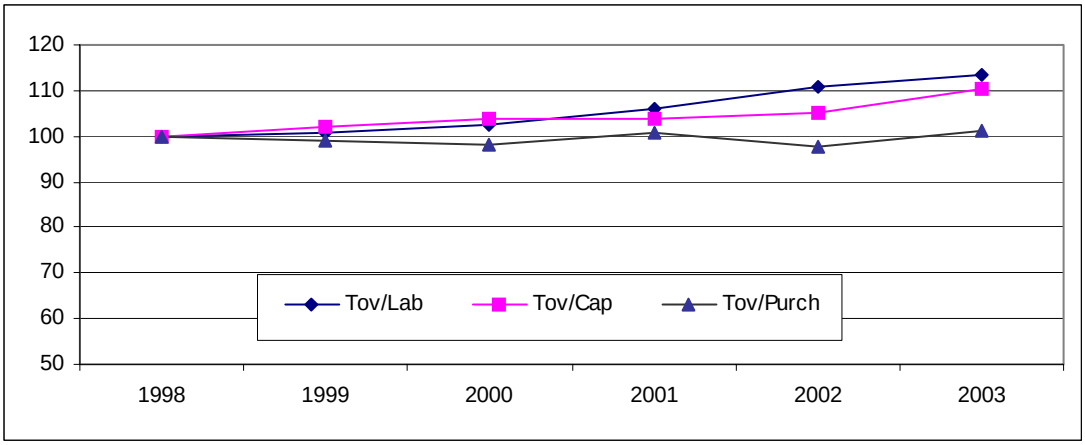
Source: Annual Business Inquiry (Various Years)

Generally, a strong pattern of growth in turnover over the 6-year period has occurred from £64 billion in 1998 to £67 billion in 2003. However, a dip can be seen between the years 2000 to 2001, where turnover fell by over £500 million. Nevertheless, the general trend has been upward.

Input Productivity

The major inputs into the production process are purchases of goods and materials, labour inputs and additions to the stock of capital. By far the greatest input within food manufacturing is purchases of materials, which accounts for around 70% of all input expenditure. Figure 3.2 shows the partial productivity indexes of these three inputs over time. Labour is measured by the ratio of turnover to annual hours worked, the capital series is measured by turnover to the accumulation of capital stock deflated into 2000 prices, and the ratio of turnover to expenditure on purchases.

Figure 3.2. UK Food Manufacturing Index of Input to Output Use (1998 = 100)

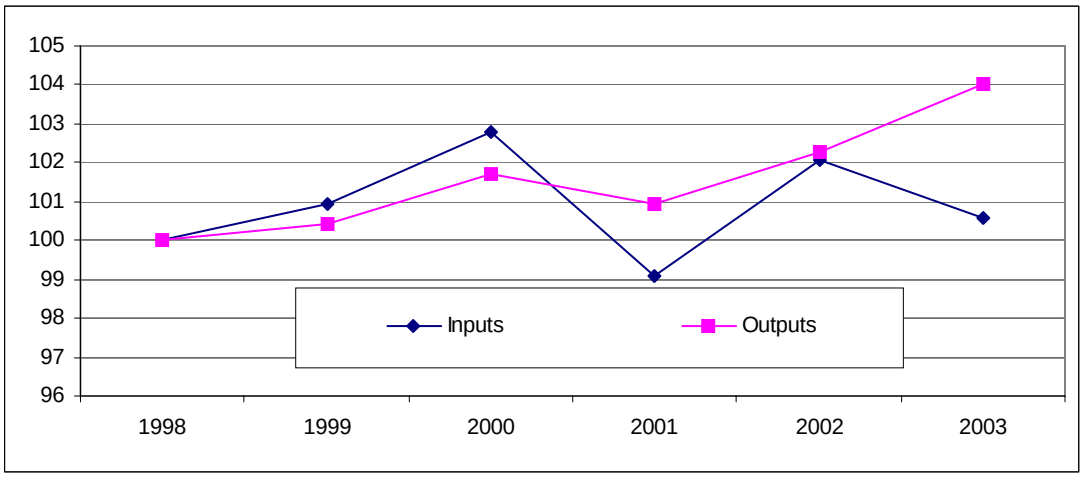


The highest performing input seems to be labour, which increases from the base year to around 115 in 2002. Purchases, seem to fluctuate around the base year value, perhaps demonstrating the difficulty in controlling purchases of adequate levels of raw materials and energy. Turnover to capital stock also rises from the base year to 110 at the end of the period.

TFP Growth

Figure 3.3 shows the turnover series, indexed and chained from 1998, compared with an aggregate input index, also chained, and weighted by the factor share of each input's current prices.

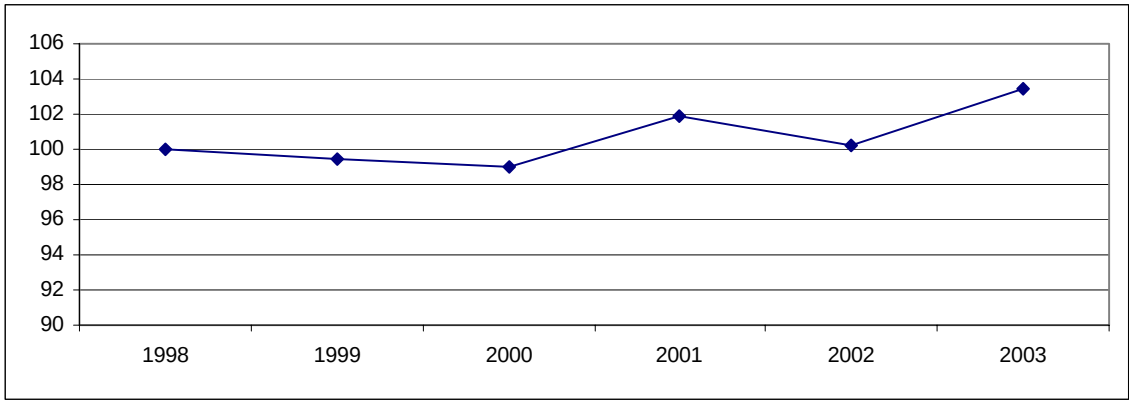
Figure 3.3. UK Food Manufacturing Index of Inputs and Output (1998=100)



The above figure shows that inputs generally mimic the changes in turnover, with the noticeable dip in turnover in the period 2000 to 2001. However, the input series seems more volatile, reflecting the fluctuations in the purchases series, which for its later years is below output growth and would be reflected in positive TFP growth.

Once these indexes have been constructed, it is a simple matter of deriving a total factor productivity index for the food manufacturing sector by dividing the output series by the input series. The final series is shown in Figure 3.4 below.

Figure 3.4. UK Food Manufacturing TFP Index (1998=100)



TFP growth within this sector is relatively smooth, showing a positive growth over the length of the period, with a rise in 2000-2001 from the pronounced fall in input growth shown in Figure 3.3. Table 3.1 shows the indexes discussed within this section and their average (compound) growth rates.

Table 3.1. TFP Growth Rates for the Food Manufacturing Sector (Fisher Chained Index)

	Tov/Lab	Tov/Cap	Tov/Purch	Inputs	Outputs	TFP
1998	100.00	100.00	100.00	100.00	100.00	100.00
1999	100.81	101.92	99.08	100.93	100.43	99.50
2000	102.49	103.94	97.95	102.78	101.69	98.94
2001	106.11	103.70	100.88	99.11	100.95	101.86
2002	110.68	104.96	97.86	102.06	102.28	100.22
2003	113.60	110.17	101.05	100.57	104.02	103.43
Average	2.58%	1.96%	0.21%	0.11%	0.79%	0.68%

TFP growth shows a positive rise of 0.68% over the period and is generally smooth, evidenced by the slight increase in weighted inputs and the substantial rise in outputs. The major reason for this seems to be a strong rise in both the capital and labour productivity series. The only input which shows slower growth is the purchases series. As with all sectors, purchases has a large share of weighted inputs and any positive growth would generally be reflected in positive TFP growth.

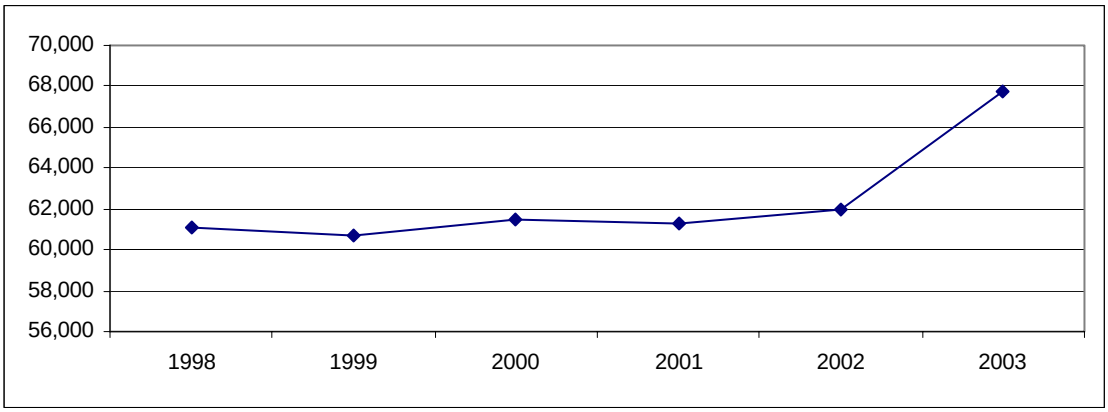
3.1.2. Food Wholesaling

Food Wholesaling consists of the buying, storage and reselling of food materials, some manufactured and some freshly produced.

Output Growth

Figure 3.5 shows the turnover of the food wholesale sector in constant 2000 prices.

Figure 3.5. UK Food Wholesaling Turnover, 1998 to 2003 (£m 2000)



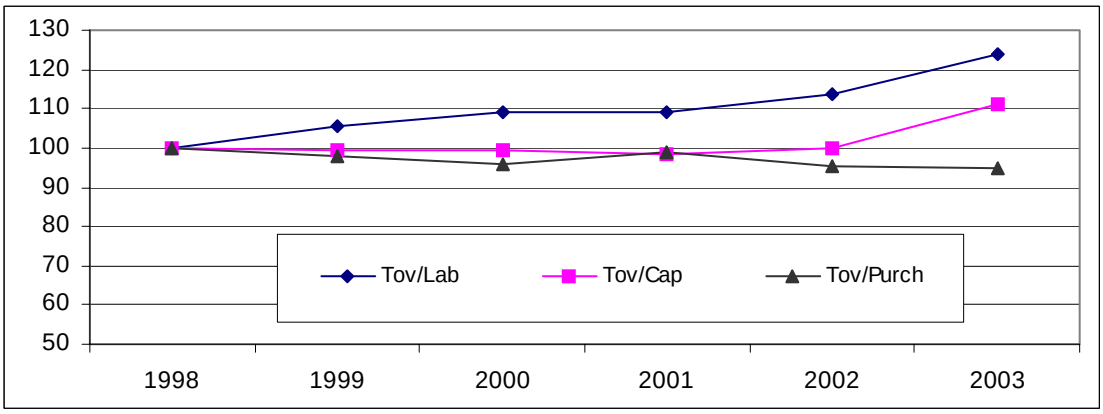
Source: Annual Business Inquiry (Various Years)

Figure 3.5 shows a steady growth in turnover over the period 1998 to 2002, where output rises by £2 billion. However, a steep rise occurs in 2002/3 of around £4 billion. Whilst some of this rise is conceivable it may reflect a reclassification issue in the latest ABI data set (ONS, 2005).

Input Productivity

Figure 3.6 shows the indexes of productivity of the three inputs used. The ratios of turnover to labour, capital stock and purchases are presented.

Figure 3.6. UK Food Wholesaling Index of Input Use (1998 = 100)



Labour productivity seems to be a high performer with strong upward growth over the whole of the period, even in the final year where turnover increases rapidly. Purchases shows a slight decline over the period, whereas capital stock seems to remain constant and only shows a steeper growth in the final year.

TFP Growth

Figure 3.7. UK Food Wholesaling Index of Inputs and Output (1998=100)

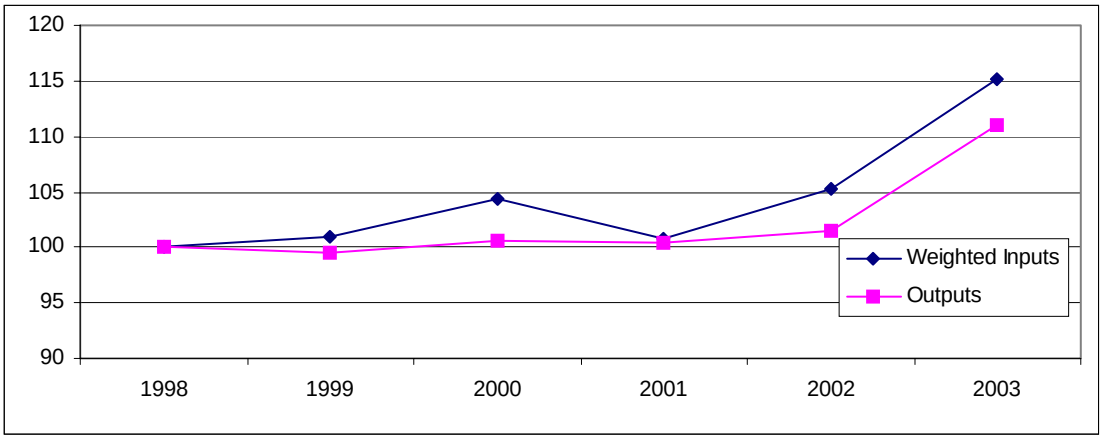
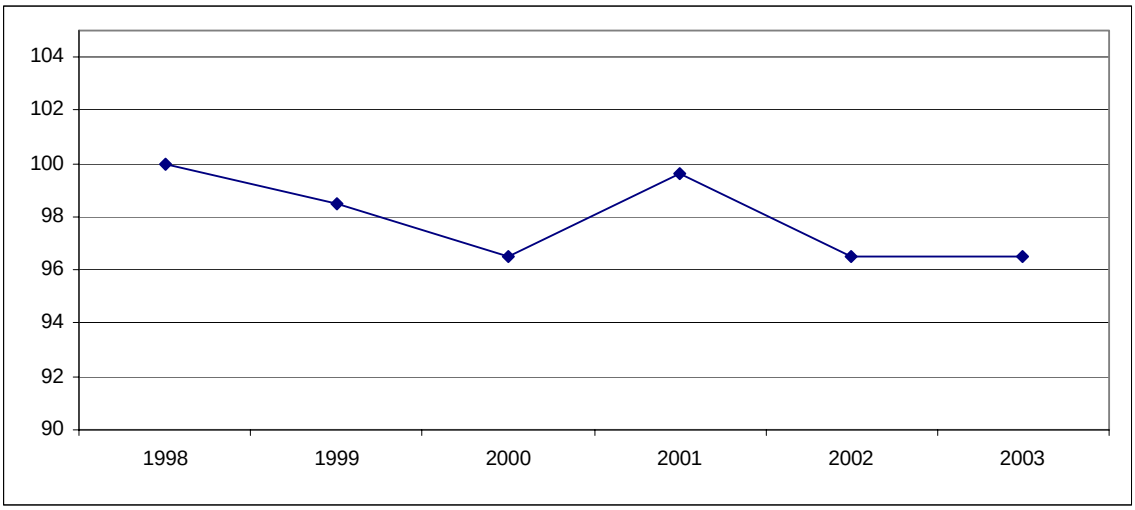


Figure 3.7 shows the inputs weighted by their current price share compared to turnover. It is immediately obvious that the large increase in turnover in the final year is reflected in input growth, indicating that the possible reclassification is consistent over outputs and inputs. However, whilst output is relatively smooth (for the first five years) inputs are more volatile and has a higher rate of growth, which would lead to a negative effect on TFP growth.

Figure 3.8. UK Food Wholesaling TFP Index (1998=100)



The volatility of weighted inputs is shown quite clearly in the TFP series for wholesaling which has a noticeable kink in 2001. However, this is a rise of only 2-points, which then flattens out. Also, the high growth of turnover in the final year is flattened by similar high growth rates in input. This is perhaps more evident when Table 3.2 is examined, which shows the input, output and TFP indexes, alongside average (compound) growth rates.

Table 3.2. TFP Growth Rates for the Food Wholesaling Sector (Fisher Chained Index)

	Tov/Lab	Tov/Cap	Tov/Purch	Weighted Inputs	Outputs	TFP
1998	100.00	100.00	100.00	100.00	100.00	100.00
1999	105.42	99.52	98.04	101.00	99.47	98.49
2000	108.96	99.31	95.68	104.35	100.68	96.48
2001	109.22	98.41	99.08	100.77	100.43	99.66
2002	113.56	99.73	95.39	105.20	101.50	96.48
2003	124.13	111.03	94.69	115.06	111.01	96.48
Average	4.42%	2.11%	-1.08%	2.85%	2.11%	-0.71%

On average growth over the period is –0.71%, with a generally downward trend over the period. This is explained by strong falls in purchases, which, given the contribution to total inputs, easily negates the high growth in both labour and capital over the same period. Consequently, this leads weighted input growth to be higher than output growth, and has negative TFP growth.

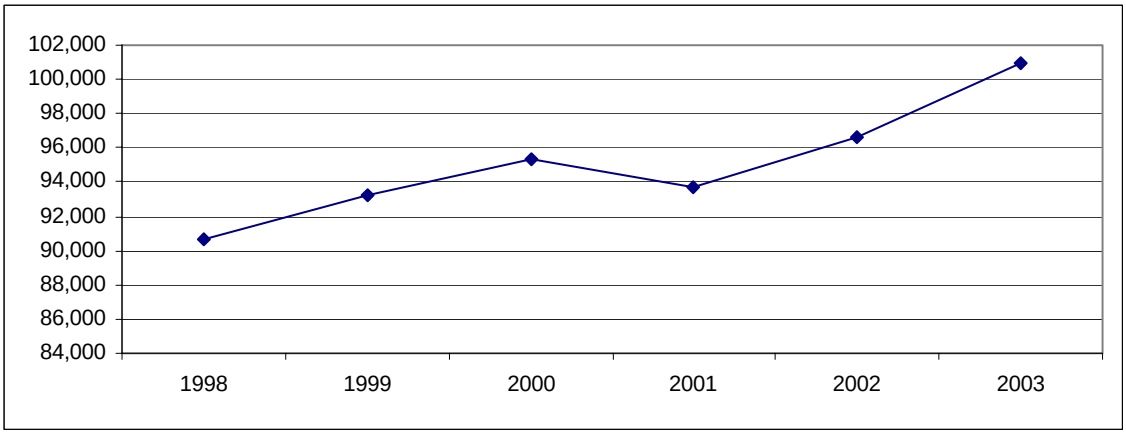
3.1.3. Food Retailing

Food retailing consists of sales of food within both non-specialised stores, of which the supermarkets are the predominant source, and specialised stores, such as health food outlets.

Output Growth

Figure 3.9 shows the turnover of the UK food retailing sector over the 6-year period. This has grown from over £90 Billion in 1998 to over £100 Billion in 2003.

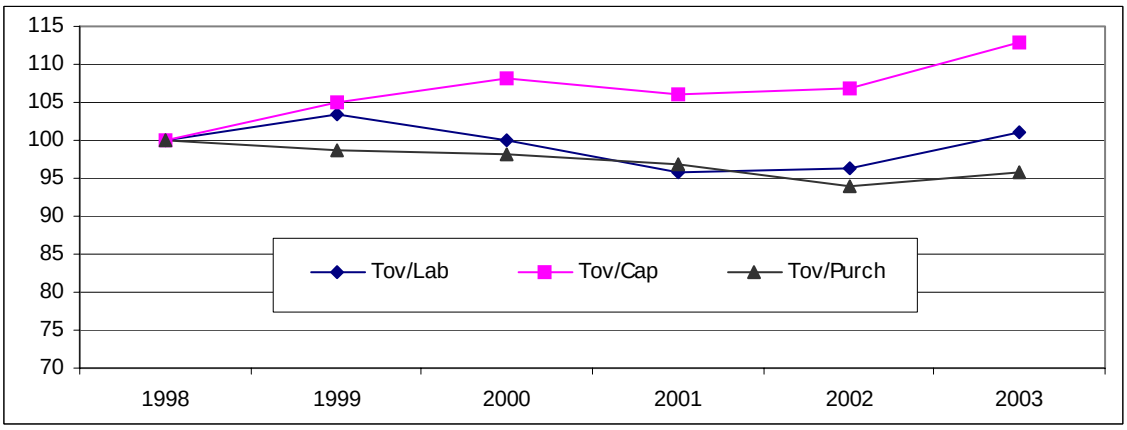
Figure 3.9. UK Food Retailing Turnover, 1998 to 2003 (£m 2000)



Input Productivity

Unlike the previous two sectors labour productivity is less distinctly upward in the retail sector. There is a fall from 1999 for several years but then an increase in the last year. Capital stock grows quite substantially over this period. Purchases seems to stay below the baseline throughout the period and generally fluctuates downwards.

Figure 3.10. UK Food Retailing Index of Input Use (1998 = 100)

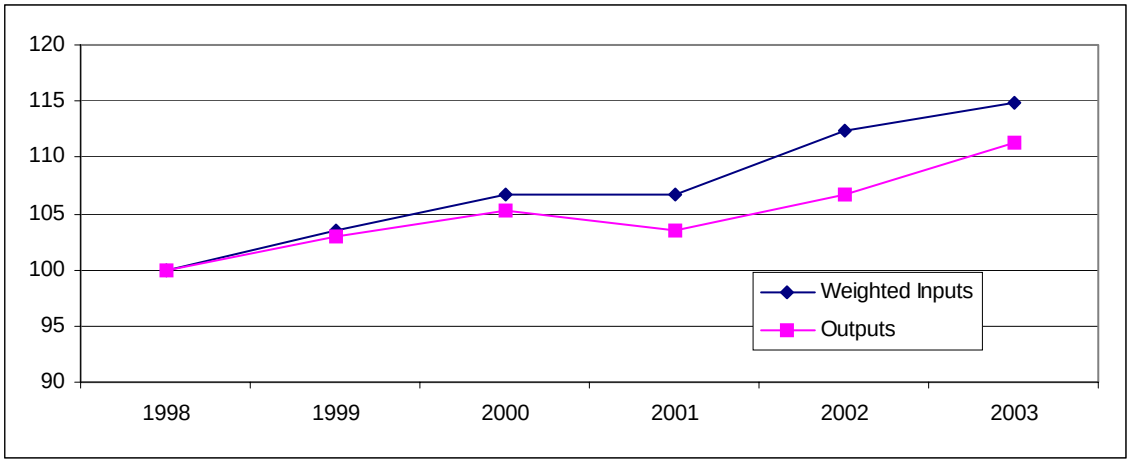


Within the retail sector, purchases account for around 90%. Similarly, an average of around 47% of the workforce is part-time labour and hence offers more flexibility in working hours which may explain some of the volatility of the labour series.

TFP Growth

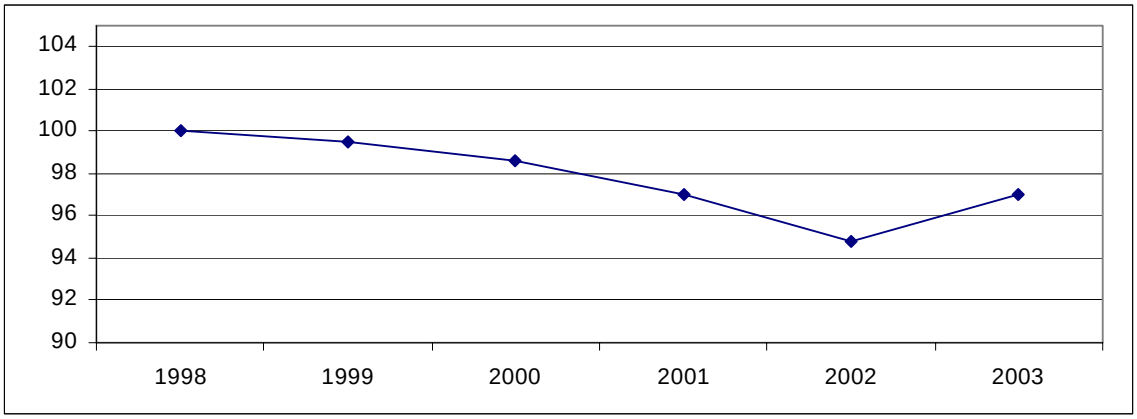
Figure 3.11 shows the indexes of growth of turnover and inputs weighted by their factor share.

Figure 3.11 . UK Food Retailing Index of Inputs and Output (1998=100)



Noticeably input growth is higher than turnover growth throughout the period, mostly through the low purchases productivity series. However, both series show an upward movement in the latter half of the period. Figure 3.12 shows the TFP index for the retail sector.

Figure 3.12. UK Food Retailing TFP Index (1998=100)



It is quite evident that the dominant growth in inputs tend to depress TFP growth during this period. At its lowest point TFP falls by more than 5-points in 2002. These growth rates are illustrated in Table 3.3 below.

Table 3.3. TFP Growth Rates for Food Retailing (Fisher Chained Index)

	Tov/Lab	Tov/Cap	Tov/Purch	Weighted Inputs	Outputs	TFP
1998	100.00	100.00	100.00	100.00	100.00	100.00
1999	103.55	105.07	98.75	103.43	102.87	99.46
2000	99.90	108.16	98.11	106.64	105.19	98.63
2001	95.89	105.97	96.73	106.64	103.43	96.99
2002	96.37	106.80	94.07	112.45	106.62	94.82
2003	100.99	112.81	95.82	114.81	111.36	96.99
Average	0.20%	2.44%	-0.85%	2.80%	2.17%	-0.61%

Labour and capital have shown slight upward growth over the period, however this is negated by the strong fall in purchases of –0.85%. This has a large impact on TFP which is –0.61% over this period. Whilst labour productivity is low, again perhaps reflecting the use of part-time labour and flexible working hours, capital productivity shows a strong growth of over 2% per annum. This reflects more efficient use investment in both land and machinery.

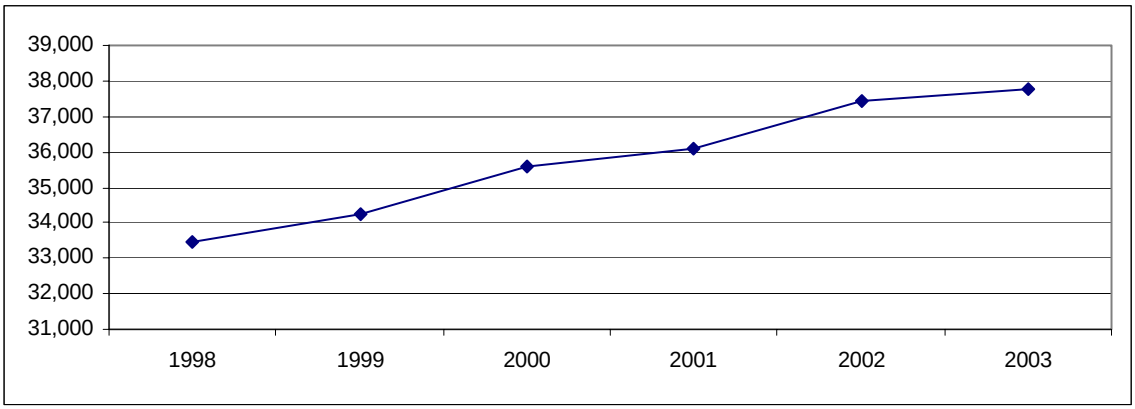
3.1.4. Non-Residential Catering

Non-Residential Catering (NRC) consists of restaurants and bars involved in the preparation and serving of food, alongside canteens and catering services.

Output Growth

Figure 3.13 shows the turnover over the period in constant (2000) prices.

Figure 3.13. UK Food NRC Turnover, 1998 to 2003 (£m 2000)

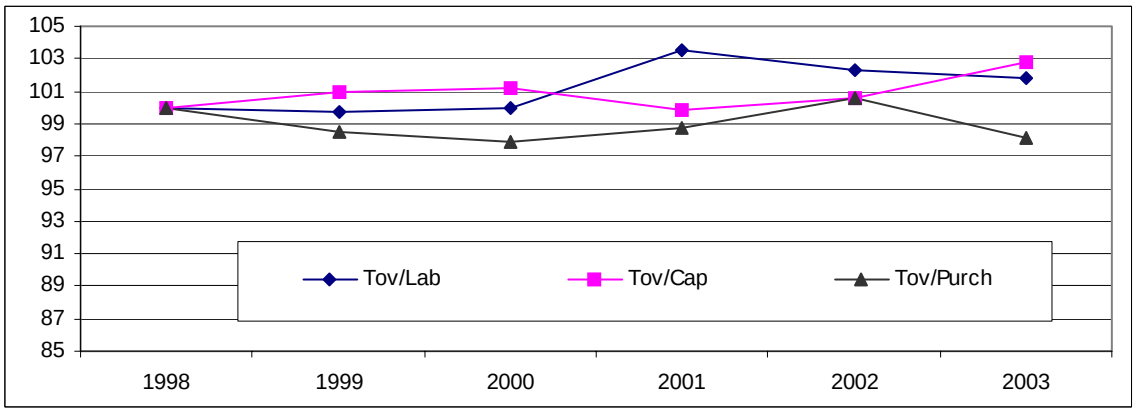


This figure shows a smooth increase in NRC turnover from around £33,500 Billion in 1998 to just under £38 Billion in 2003.

Input Productivity

Figure 3.14 shows that productivity growth of the three major inputs involved in the production process have remained relatively constant.

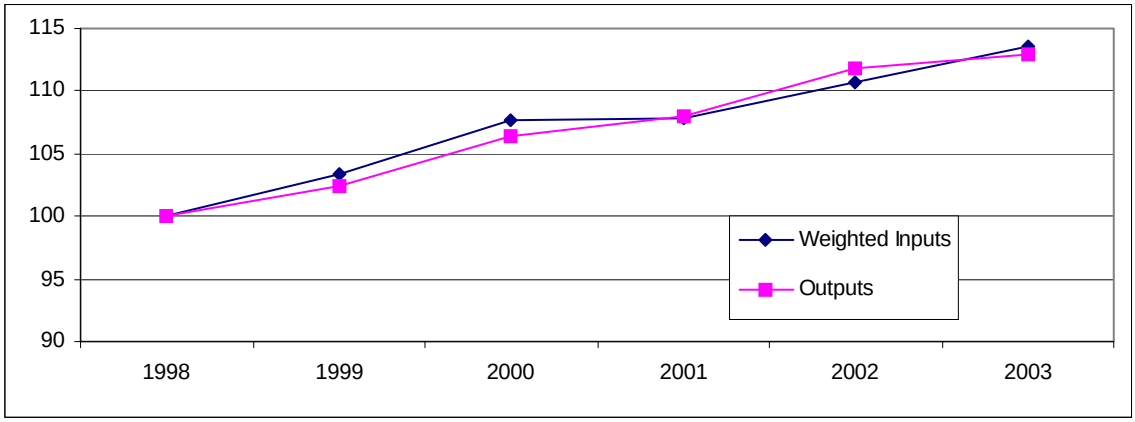
Figure 3.14. UK Food NRC Index of Input Use (1998 = 100)



TFP Growth

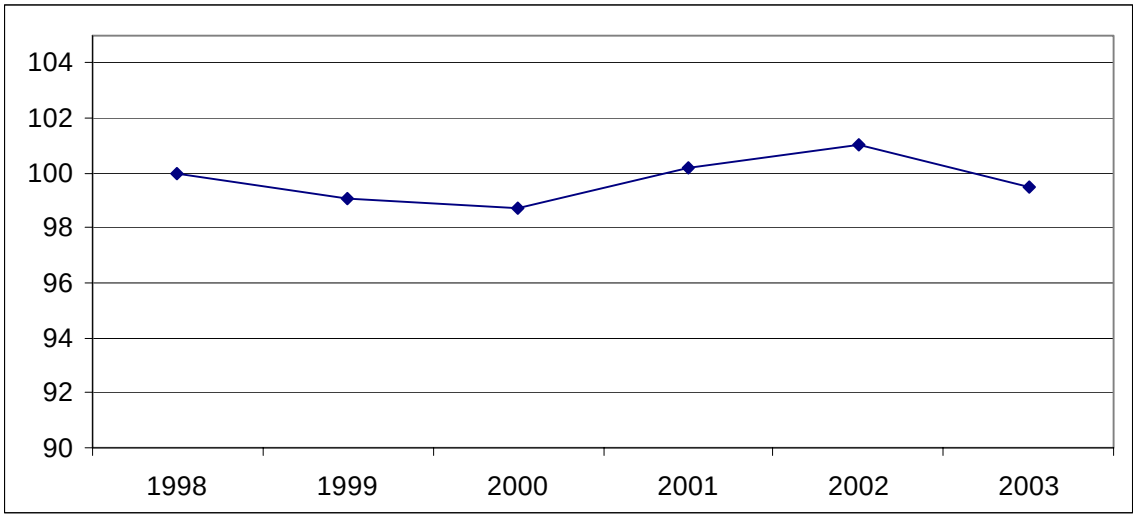
Figure 3.15 shows the growth in weighted inputs relative to turnover for the NRC sector and shows relatively smooth upward growth.

Figure 3.15. UK Food NRC Index of Inputs and Output (1998=100)



When comparing inputs to outputs a fairly clear distinction emerges as growth in inputs exceeds growth in output use. This smooth growth is reflected in the TFP index presented in Figure 3.16 below.

Figure 3.16. UK Food NRC TFP Index (1998=100)



TFP has fallen over the period by 2.3% mostly due to the higher growth in inputs. These growth rates are outlined in Table 3.4 below.

Table 3.4. TFP Growth Rates for the NRC Sector (Fisher Chained Index) (1998=100)

	Tov/Lab	Tov/Cap	Tov/Purch	Weighted Inputs	Outputs	TFP
1998	100.00	100.00	100.00	100.00	100.00	100.00
1999	99.75	100.89	98.48	103.34	102.34	99.04
2000	100.00	101.22	97.84	107.71	106.33	98.72
2001	103.48	99.79	98.80	107.77	107.94	100.16
2002	102.27	100.64	100.58	110.72	111.88	101.05
2003	101.85	102.78	98.08	113.55	112.95	99.48
Average	0.37%	0.55%	-0.39%	2.57%	2.47%	-0.10%

Labour and capital productivity show a rise over this period, however there are slight falls in purchases within this sector. This is reflected in slightly higher input growth to output and is reflected in a fall in TFP of around –0.10%.

Summary
This section has presented each sector's contribution to output growth. These rates of growth are generally downward. Food manufacturing seems to be by far the best performer with a positive growth rate, indicating control over an appropriate level of use of its inputs to outputs.

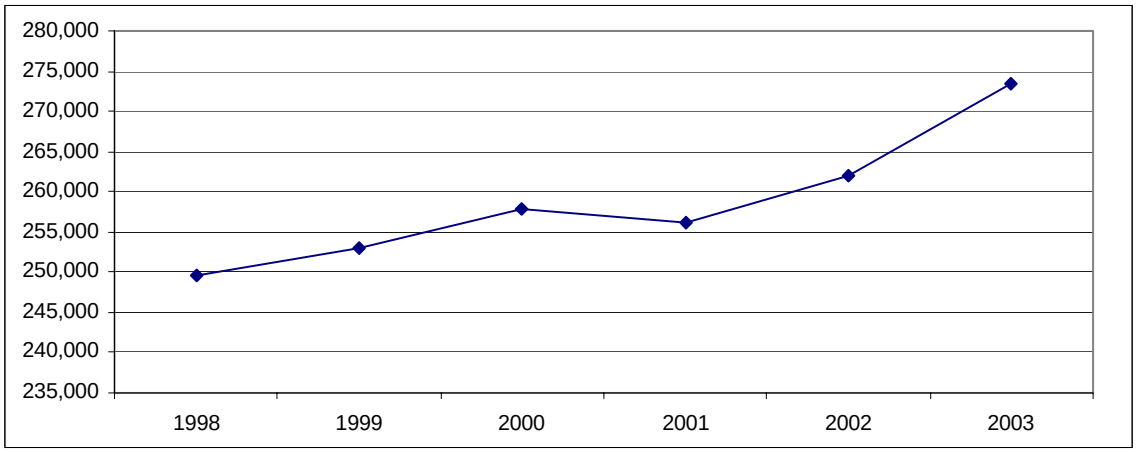
However, what is most prevalent is that the greatest contributor to productivity growth within any sector is purchases. Management control over the quantity of purchases on a monthly, and sometimes with fresh fruit and vegetables, weekly basis has led to a set of rather fluctuating series but not been demonstrated with improvements in productivity.

Accordingly, given the sectoral productivity series, the next stage is to provide an aggregated Total Factor Productivity series for the whole of the food chain. This is discussed in the next section.

3.1.5. Total Factor Productivity Index for the Food Chain

Output Growth
The sectoral analysis above has provided the basis for constructing a TFP index for the food chain downstream from farming. Figure 3.17 shows total turnover for the UK food chain in constant prices. Turnover increased from £245 billion in 1998 to over £270 billion in 2003, showing a reasonable smooth growth over the period, with only the period 2000 to 2001 showing any decline in turnover.

Figure 3.17. UK Food Chain Total Turnover, 1998 to 2003 (£m 2000)

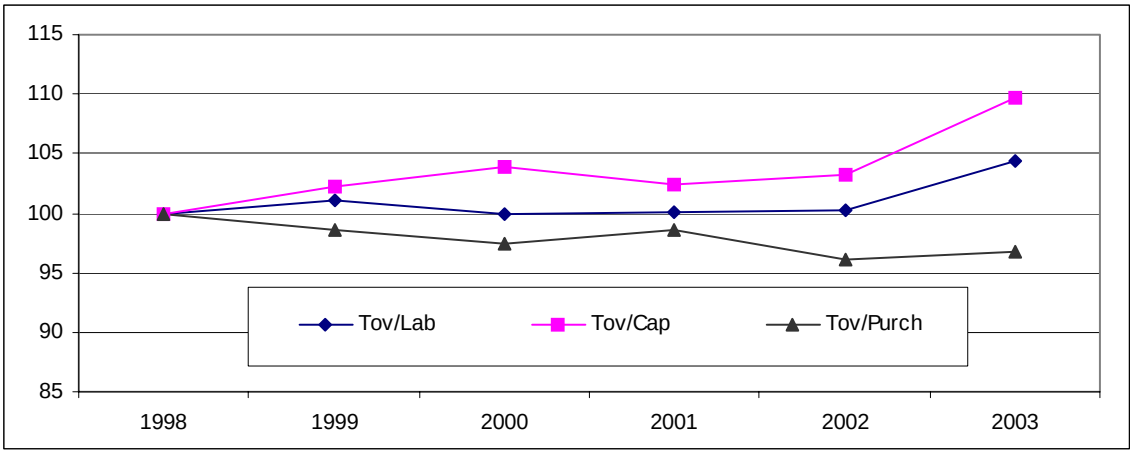


Retailing contributes the most to turnover, with an average of 36% of total turnover, this is followed by manufacturing (26%) and wholesaling (25%). The smallest sector, with an average of 13%, is non-residential catering.

Input Productivity
Figure 3.18 shows the indexes of input productivity growth over the 6-year period, with inputs weighted by contribution to total food chain turnover. Whilst some

volatility occurs, it is fairly evident that labour and capital productivity have risen over this period, whereas productivity of purchases has fallen.

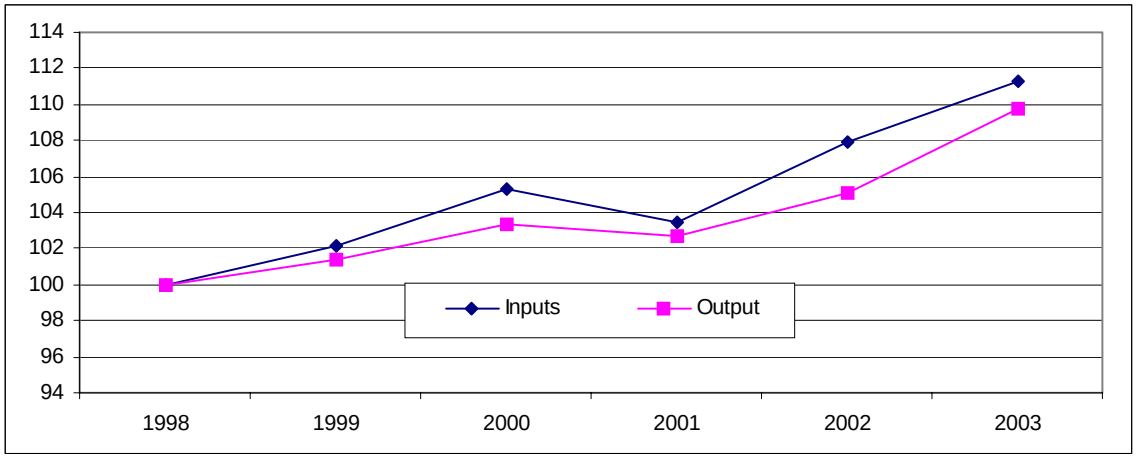
Figure 3.18. UK Food Chain Index of Input Use, weighted by turnover (1998 = 100)



TFP Growth

Figure 3.19 shows that input growth exceeded growth in output throughout this period. This seems to reflect the depressive effects of retailing and wholesaling, which both experienced strong input growth.

Figure 3.19. UK Food Chain Index of Inputs and Output, weighted by turnover (1998=100)



The ratio of outputs to inputs gives the total factor productivity series for the food chain downstream from farming. Figure 3.20 shows this as an index of growth from 1998 onwards. The high input growth throughout the series compared to output growth has forced the TFP rate downwards. However, these fluctuations only vary by around 2 points below the baseline.

Figure 3.20. UK Food Chain TFP Index, weighted by turnover (1998=100)

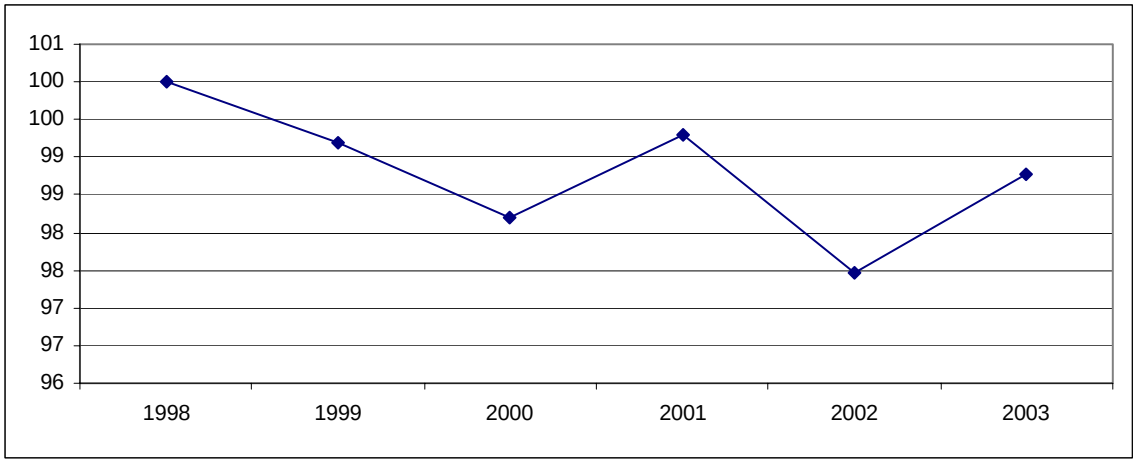


Table 3.5 shows the annual average growth rates of the productivity indexes presented above. It shows an average rate of growth of -0.25% which reflects the negative rates embodied in the three sectors; wholesale, retail and non-residential catering.

Table 3.5. TFP Growth Rates for the Food Chain, percent

	Tov/Lab	Tov/Cap	Tov/Purch	Inputs	Output	TFP
1998	100.00	100.00	100.00	100.00	100.00	100.00
1999	101.10	102.32	98.63	102.19	101.35	99.18
2000	99.96	103.89	97.46	105.26	103.38	98.21
2001	100.07	102.47	98.67	103.51	102.73	99.30
2002	100.24	103.17	96.14	107.91	105.11	97.47
2003	104.39	109.69	96.73	111.27	109.74	98.77
Average	0.86%	1.87%	-0.66%	2.16%	1.88%	-0.25%

Labour productivity shows positive growth over the period of 0.3% per annum. The highest growth rate has been in capital stock which shows an average increase of 0.57% per annum. However, this is negated by strong falls in the purchases productivity series of over –2% p.a. This has depressed TFP which has fallen over the 6-year period by an average of 0.25% per annum.

Comparative Analysis

A small number of academics have sought to measure productivity within specific sectors of the food chain away from agriculture, however, as evidenced by Table 3.6 below, these are of minimal use to this study as they relate to previous periods and economic climates and also only focus on specific sectors within different countries.

Table 3.6: Previous Studies on the Productivity of the Food Sector

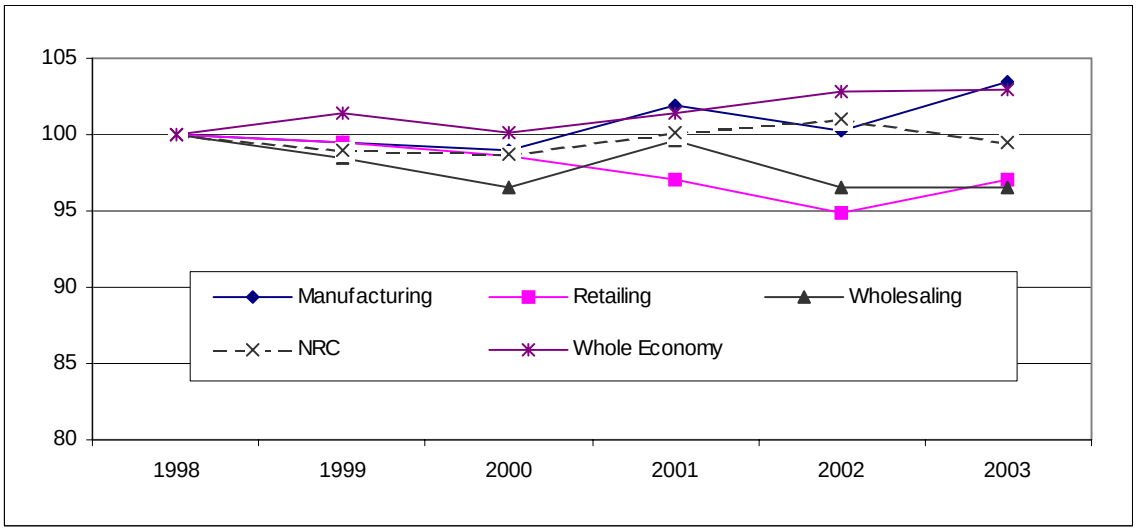
Country	*Industry*	Period	*Annual Growth Rates*
UK (MRB)	Manufacturing	1954-84	'lower than other UK manufacturing'
US (JS)	Processing	1958-96	0.60%
US (GRS)	Processing	1959-91	0.41%
US (H)	Manufacturing	1975-97	0.32%

In fact the only UK study previous to this is by Macdonald, Rayner and Bates (MRB) (1992) who used input-output analysis to asses the productivity of agriculture and food manufacturing. Whilst vague on specific rates of growth it did find that food manufacturing was lower than other UK manufacturing.

The bulk of research work seems to have occurred in the US and focuses on the food manufacturing or processing industry. Jorgenson and Stiroh (JS) (2000) found that food processing grew by 0.6% between 1958 and 1991. Gopinath, Roe and Shane (GRS) (1996) calculated this sector had a growth rate of 0.41% over the period 1959 to 1991. Huang (H) (2002) reported that food manufacturing grew by 0.32% between 1975 to 1997, but a number of sub-periods showed negative growth. Finally, Hazeldine (HZ) (1991) examined food processing in Canada and found that, dependant on assumptions, growth rates varied from 0% to 0.5%.

Perhaps a more useful indicator is that of comparing over sectors. Unfortunately, few specific TFP indicators exist of the UK economy which are not solely concerned with labour productivity. Given this an economy wide TFP index was constructed using the ABI data for non-public sector industries. The same methodology outlined above was adopted. This index is presented in Figure 3.21 below, alongside the other food chain sectors for comparative analysis.

Figure 3.21: Whole Economy TFP Compared with Food Chain Sectors



Over the period 1998 to 2003 economy wide (non-public sector) TFP growth was 0.57%. Estimates of labour productivity for the whole economy (incl. food sectors) are positive for this period (ONS, 2005)[7], much like the food sector labour indicators. When factoring capital and other inputs into the analysis this growth becomes depressed but remains positive for the whole economy. Nevertheless, this figure is still much higher than growth in food chain TFP.

Summary

This section finds a growth rate of –0.25% p.a. for the food chain. Compared to other parts of the economy the food industry is not showing a sustainable level of growth when resource use is considered. Paradoxically, labour and capital productivity seems to be positive within this industry. This may indicate some level of

[7] http://www.statistics.gov.uk/statbase/tsdtables1.asp?vlnk=prdy

improvement in living standards for those workers within the food chain, but also the replacement of jobs through capital investment. Investment in capital stocks and labour are key indicators of long-term sustainable growth. However, future productivity targets are compromised by lack of efficiency in purchasing of intermediates.

Discussion

TFP growth rates within most sectors of the food chain are downward. Consequently, the question of what has caused these negative rates has to be addressed. There are a number of possible causes.

Measurement Errors

Most data sets contain errors, through measurement and response bias. As these data sets are collected for a wide range of analysis, production economists have to admit that some of this 'residual effect' which is interpreted as TFP growth may be due to this error. Whilst this error is out of the control of the analyst the best he or she can do is to adopt the most robust data sets available. The Annual Business Inquiry, as discussed in the introduction, is a fairly robust data set collected by the ONS. Nevertheless errors, whilst some are corrected, still exist and may be biasing the procedure. Similarly, issues exist over the use of deflation, as no deflator could perfectly reflect price changes from a commodity some distortion may emerge from the deflation process.

Intermediate Purchases

The major cause of downward growth rates is lack of efficiency in purchasing intermediates. These intermediates are outwith the control of the firm hence some volatility may occur in the production process. Some of these inefficiencies may be caused by purchasing perishable products, which could also be affected by blockages in the supply chain for raw materials, e.g. rising congestion. However, to some degree, it may be reflected in ineffective purchasing behaviour of management and management systems adopted.

Low R&D Investment

An argument proposed by Thirtle *et al*. (2004) is that low agricultural TFP is a result of reductions in R&D spending during the late 1980s and 1990s. Similarly an emphasis on near-market (applied) research at the expense of more fundamental long-term basic research funding may have pushed this TFP rate downward. Compared to agriculture, few analyses of food sector R&D have been made. However, the DTI (2005) present a scoreboard of R&D intensities, measured in terms of R&D expenditure as a percentage of sales. The only sector which appears in the top 700 companies are food producers and processors as the 11th most intensive sector. Other sectors within the food chain do not appear. Consequently, this may be some indication towards the cause of TFP decline within the remaining sectors.

Non-Market Effects

The marketable outputs of the food chain have been measured. However, a number of non-market effects occur, which may impinge on TFP performance but have not been quantitatively measured. The benefits occur mostly at the retail end of the food chain, reflecting longer opening hours or increased diversification of activities. Productivity growth would be dampened by these effects, due to losses in labour efficiency, but they add to the quality of life of consumers.

This final point effectively highlights some of the inadequacies of solely using marketable inputs and outputs within TFP as a projection of sustainability. Much discussion recently has sought to consider the non-market effects of production and how they may be equated with TFP growth. The second part of this report focuses on the externalities within the food chain. It therefore puts indicators of resource use within a wider context and, hence, provides a clearer picture of its future prospects for sustainable growth.

3.2. Identification of Externalities

It has long been recognised that an economic activity can create costs and benefits, known as externalities, for entities other than the entity that has made the decision to engage in it. Externalities are not reflected in the price of the activity, as they do not accrue to the decision-maker. As a result, the magnitude of the activity can either be above or below the socially optimal level. In this context, the activity of interest is the functions of the food chain beyond the farm gate

A number of recent studies have focused on the externalities caused by food production (see for example Pretty *et al.,* 2000). However, these have tended to focus only on the agricultural industry, principally due to a number of high profile problems, which have emerged from farming under the Common Agricultural Policy. Little or no consideration has been given in these reports towards the external effects of the food chain after the farm gate – food manufacturing, food wholesaling, food retailing and catering – while the relevant decision-makers are the firms in these sectors. The other economic entities concerned are the members of public and other firms who are affected by their actions. The remainder of this report aims to address this by outlining the externalities that occur within the food chain and providing estimates of their magnitude where available, which are used to update the TFP index.

The food chain consists of four main sectors, namely i) manufacturing, ii) wholesaling, iii) retailing and, iv) catering. To some degree they represent a chain which links activity from the farm-gate to the plate of the consumer, Figure 3.22. Table 3.7 lists the sources of external costs of the food chain according to whether these impact on air, water, land or society. The following section will quantify these external impacts where possible.

Figure 3.22: Schematic representation of the food chain. Area of interest to this study in shaded area.

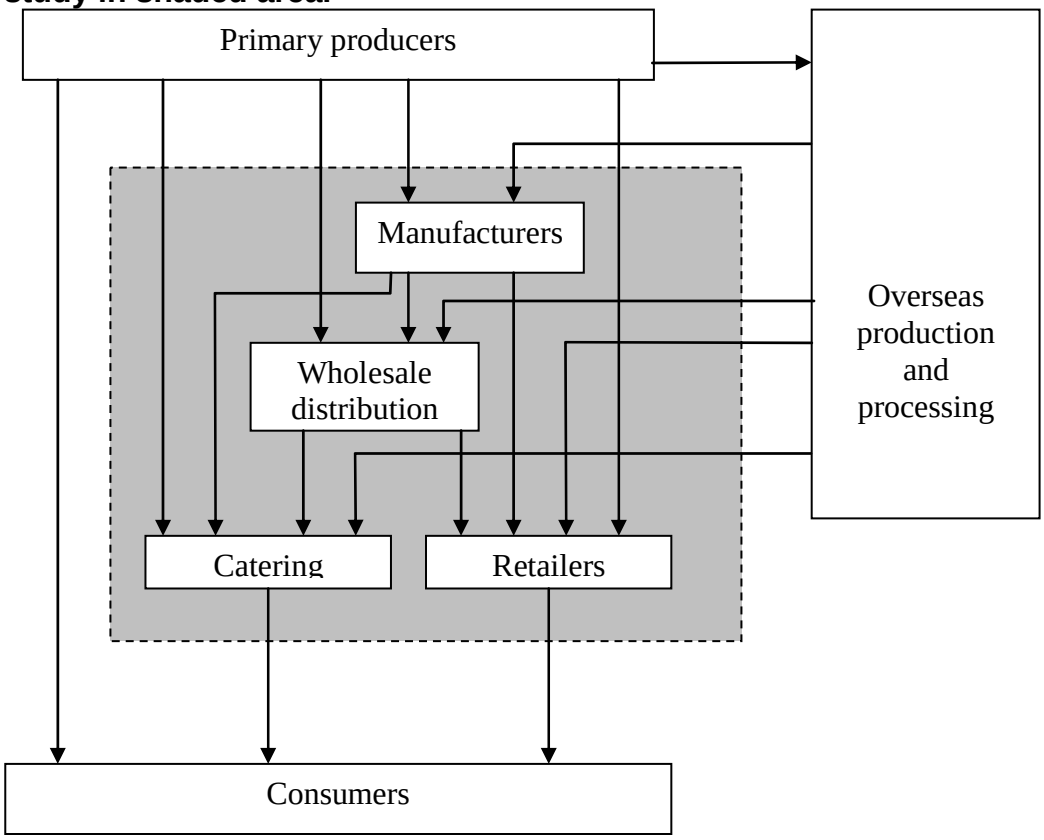


Table 3.7: Externalities by Sector: Post farm-gate Food Chain (incl. Sources*)

	Air	Water	Land	Social
Manufacturing *(production, packing, storage, water use)*	Energy Use (resource, CO_2, NO_2, SO_2) -	Abstraction and discharge (resource use, biodiversity, contamination, transformation) -	Waste -	Odour (operation) -
	Process emissions (GHG, Heavy metals, Particulates) -	Run-off (contamination, flooding) -	Land take (soil, biodiversity) -	Noise (operation) -
			Landscape Effects -	Landscape Effects - Mortality and accidents - Food-borne illness - Landscape Effects - Nutritional Standards ±
Wholesaling (*transportation storage)*	Energy Use (resource, CO_2, NO_2, SO_2) -	Mains abstraction and discharge (resource use) -	Waste -	Congestion and infrastructure -
	Transport (GHG, heavy metals, particulates) -	Run-off (contamination, flooding) -	Land take (soil, biodiversity) -	Odour (operation and transport) -
			Landscape Effects -	Landscape Effects - Noise (operation and transport) - Mortality and accidents -
Retailing *(transportation storage packaging)*	Energy Use (resource, CO_2, NO_2, SO_2) -	Mains abstraction and discharge (resource use) -	Waste -	Macroeconomic (trading position) ±
	Transport (GHG, heavy metals, particulates) -	Run-off (contamination, flooding) -	Land take (soil, biodiversity) -	Food Miles -
			Landscape Effects -	Congestion and infrastructure - Landscape Effects - Consumer Choice (increased choice, food deserts) ± Nutritional Standards ± Mortality and accidents - Food-borne illness -
Catering *(storage preparation)*	Energy Use (resource, CO_2, NO_2, SO_2) -	Mains abstraction and discharge (resource use) -	Waste -	Mortality and accidents -
	Transport (GHG, heavy metals, particulates)			Food-borne illness -

*Drawing on the existing literature, Table 7 lists what are considered to be the most significant externalities from the food chain according to whether the impact is on air, water, land or society.

3.2.1. Air

Energy use: resource use

Energy use by the food chain contributes both to general resource use as an input to production and also as a source of emissions to air. The resource use element of energy use can be considered as an internal cost to industry, whereas emissions contribute to external costs. As such the use of energy by the food chain industries is included in the TFP indices as part of the intermediates productivity series.

AEA Technology (2005) presents data by transport mode (HGV, LGV and car)[8] for 1992, 1998 and 2002 in terms of both tonne kilometres and vehicle kilometres. For indexing purposes it is necessary to estimate annual figures for different vehicle classes. For light goods vehicles (LGV) the reported data did not vary across the years presented, and were consequently assumed to be constant. For cars and heavy goods vehicles (HGV) a trend line was estimated using the three data points. For both modes, a polynomial trend line was found to have the best fit, however caution should be taken due to the small number of actual data points.

The AEA Technology data can be used to estimate transport fuel use by the entire food chain, from farm gate to consumer's homes. Although the brief for this study is to consider only externalities arising from manufacturing, wholesaling, retailing and catering, it may be informative to also consider the whole food chain. This may serve to highlight instances where resource use and externalities have been "displaced". For example, the trend towards larger out of town supermarkets may allow efficiencies to be made in the retail and wholesale sector, however, the external costs may still arise from households making longer journeys to such sites. Table 3.8 presents distance travelled and fuel use by transport mode, the series for light goods vehicle is constant as there was no variation across the years reported by AEA Technology.

Table 3.8: Distance travelled and fuel use in the food chain by transport mode. (Source: AEA Technology, 2005).

	HGV		LGV		Car	
	Vehicle km(m) [a]	Fuel ('000 tonnes) [b]	Vehicle km(m)	Fuel ('000 tonnes)	Vehicle km(m)	Fuel ('000 tonnes)
1996	6060.80	2081.44	4743.00	355.00	11817.80	628.80
1997	6123.79	2103.08	4743.00	355.00	12174.71	647.79
1998	6145.00	2110.36	4743.00	355.00	12557.00	668.13
1999	6124.41	2103.29	4743.00	355.00	12964.69	689.82
2000	6062.05	2081.87	4743.00	355.00	13397.75	712.87
2001	5957.90	2046.11	4743.00	355.00	13856.20	737.26
2002	5812.00	1996.00	4743.00	355.00	14340.00	763.00

[a] Vehicle kilometres estimated from data for 1992, 1998 and 2002 using fitted values for remaining years.
[b] Fuel use estimated from consumption per kilometre derived from 2002 data

The data in Table 3.8 do show that total HGV distance travelled and fuel use has declined, whereas these have increased for car use. The extent to which this is the

[8] Data are also supplied for import and export modes of transport, however as the externalities arising from these aspects of transport fall without the UK these are omitted from this study. Cars have been included as they form the final link in the food chain with respect to transport, however, where possible data are presented by mode.

result of transference of resource use towards the household sector or increased efficiencies in HGV usage is not clear.

Energy use: emissions to air

In addition to the resource use and efficiency element of energy use there is the also the externality issues that arise from emissions to air. The Environmental Accounts 2004 (ONS, 2004) provide data for data for different types of emissions to air from the food chain, however, as with energy use these data are only food chain specific for the manufacturing sector. AEA Technology (2005) provides transport related data for the food chain as a whole, including agricultural products and the transport of food from supermarket to home by private car, together with estimates of the external costs of these emissions.

Table 3.9 to Table 3.12 presents the emissions by sector for selected air pollutants as published in the Environmental Accounts. Unit prices were derived by dividing external (social) costs of each pollutant by the figures for total emissions, to give a constant price series AEA Technology (2005). The data is based on emissions from total energy use (including road transport), it is important to note that the actual external costs for some pollutants will vary depending on the site of the emission. For example, emissions of some pollutants in rural areas will have a lower impact than those in urban areas due to the lower concentrations of people affected. Furthermore, in the case of road transport, emissions factors (as measured by g/km travelled) vary depending on the type of road (urban, rural or motorway).

As with energy consumption as a resource use issue it is also possible to consider emissions to air from the transport of food within the food chain. Table 3.13 presents the transport related emissions and externality costs. As with fuel consumption as a resource use, there has been a reduction in the externality costs related to HGV use and an increase in externalities from car use. With the exception of emissions of PM_{10} and NO_x the reduction in external costs from HGVs has been offset by increased external costs from cars.

Table 3.9: Greenhouse gas emissions and external costs. (Sources: ONS, 2004; AEA Technology, 2005)

		Food and drink manufacturing	Wholesale distribution	Retail distribution	Hotels, catering, pubs etc
Emissions ('000 tonnes CO2 equivalent)	1996	10059.53	8437.36	3613.75	3495.16
	1997	9618.25	8042.34	4111.46	3213.03
	1998	9452.88	8253.96	4790.46	3465.74
	1999	10244.90	8300.79	5330.54	3633.72
	2000	9895.81	8679.94	5648.04	3772.04
	2001	9602.42	7540.74	6263.26	3819.30
	2002	9405.68	6902.14	6540.18	3033.64
Cost per tonne (2000 £)		19.10	19.10	19.10	19.10
External costs (2000 £M)	1996	192.09	161.12	69.01	66.74
	1997	183.67	153.57	78.51	61.35
	1998	180.51	157.61	91.48	66.18
	1999	195.63	158.51	101.79	69.39
	2000	188.97	165.75	107.85	72.03
	2001	183.36	143.99	119.60	72.93
	2002	179.61	131.80	124.89	57.93

Table 3.10: Acid rain precursor emissions and external costs. (Sources: ONS, 2004; AEA Technology, 2005)

		Food and drink manufacturing	Wholesale distribution	Retail distribution	Hotels, catering, pubs etc
Emissions ('000 tonnes SO2 equivalent)	1996	54.34	45.53	11.63	4.87
	1997	48.84	40.85	12.42	4.76
	1998	43.10	39.55	14.06	4.74
	1999	42.17	35.98	14.03	4.34
	2000	33.69	35.54	13.18	4.50
	2001	30.23	28.00	14.51	4.44
	2002	30.45	28.61	14.46	3.79
Cost per tonne (2000 £)		1219.51	1219.51	1219.51	1219.51
External costs (2000 £)	1996	66270	55527	14178	5933
	1997	59556	49811	15148	5806
	1998	52564	48226	17145	5781
	1999	51426	43882	17116	5288
	2000	41084	43340	16074	5490
	2001	36865	34148	17699	5414
	2002	37130	34892	17639	4617

Table 3.11: PM_{10} emissions and external costs. (Sources: ONS, 2004; AEA Technology, 2005)

		Food and drink manufacturing	Wholesale distribution	Retail distribution	Hotels, catering, pubs etc
Emissions ('000 tonnes)	1996	3.11	4.02	1.26	0.51
	1997	2.83	3.71	1.29	0.50
	1998	2.72	3.62	1.37	0.52
	1999	2.60	3.52	1.40	0.53
	2000	2.18	3.31	1.30	0.54
	2001	2.48	2.93	1.33	0.51
	2002	2.33	2.97	1.34	0.48
Cost per tonne (2000 £)		49400.00	49400.00	49400.00	49400.00
External costs (2000 £)	1996	153445	198766	62454	25323
	1997	139706	183327	63885	24597
	1998	134601	178638	67609	25621
	1999	128582	173957	69025	26341
	2000	107933	163469	64417	26729
	2001	122599	144816	65609	25063
	2002	114945	146730	66352	23605

Table 3.12: Volatile organic compound emissions and external costs. (Sources: ONS, 2004; AEA Technology, 2005)

		Food and drink manufacturing	Wholesale distribution	Retail distribution	Hotels, catering, pubs etc
Emissions ('000 tonnes)	1996	83.82	38.29	9.13	2.33
	1997	84.21	35.10	8.66	2.01
	1998	84.73	27.37	8.44	1.82
	1999	84.59	19.65	8.31	1.52
	2000	82.88	17.18	7.96	1.33
	2001	83.12	12.03	8.05	1.12
	2002	82.78	10.16	7.72	0.94
Cost per tonne (2000 £)		571.43	571.43	571.43	571.43
External costs (2000 £)	1996	47897	21880	5218	1330
	1997	48119	20058	4951	1151
	1998	48415	15640	4823	1039
	1999	48336	11228	4751	870
	2000	47363	9818	4547	761
	2001	47497	6875	4601	637
	2002	47302	5804	4410	535

Table 3.13: Transport related emissions and externality costs. (Source: AEA Technology, 2005).

	CO_2			PM_{10}			NO_x			VOCs			SO_2		
	HGV	LGV	Car	HGV	LGV	Car	HGV	LGV	Car	HGV	LGV	Car	HGV	LGV	Car
Emissions ('000 tonnes)															
1996	6542.58	1076.00	1971.28	1.69	0.71	0.17	62.01	4.77	6.63	4.39	0.98	2.89	0.17	0.03	0.05
1997	6610.57	1076.00	2030.82	1.71	0.71	0.18	62.65	4.77	6.83	4.44	0.98	2.98	0.17	0.03	0.05
1998	6633.47	1076.00	2094.58	1.71	0.71	0.18	62.87	4.77	7.04	4.45	0.98	3.07	0.17	0.03	0.05
1999	6611.25	1076.00	2162.59	1.71	0.71	0.19	62.66	4.77	7.27	4.44	0.98	3.17	0.17	0.03	0.05
2000	6543.92	1076.00	2234.83	1.69	0.71	0.20	62.02	4.77	7.51	4.39	0.98	3.28	0.17	0.03	0.06
2001	6431.50	1076.00	2311.30	1.66	0.71	0.20	60.95	4.77	7.77	4.32	0.98	3.39	0.16	0.03	0.06
2002	6274.00	1076.00	2392.00	1.62	0.71	0.21	59.46	4.77	8.04	4.21	0.98	3.51	0.16	0.03	0.06
Cost/tonne (2000 £)		19.10			49400			841.77			571.43			1219.51	
External cost (2000 £m)															
1996	124.93	20.55	37.64	83.45	35.07	8.55	52.19	4.02	5.58	2.51	0.56	1.65	0.20	0.04	0.06
1997	126.23	20.55	38.78	84.32	35.07	8.81	52.74	4.02	5.75	2.53	0.56	1.70	0.21	0.04	0.06
1998	126.67	20.55	40.00	84.61	35.07	9.08	52.92	4.02	5.93	2.54	0.56	1.76	0.21	0.04	0.06
1999	126.25	20.55	41.30	84.33	35.07	9.38	52.74	4.02	6.12	2.54	0.56	1.81	0.21	0.04	0.07
2000	124.96	20.55	42.68	83.47	35.07	9.69	52.21	4.02	6.32	2.51	0.56	1.87	0.20	0.04	0.07
2001	122.81	20.55	44.14	82.04	35.07	10.02	51.31	4.02	6.54	2.47	0.56	1.94	0.20	0.04	0.07
2002	119.81	20.55	45.68	80.03	35.07	10.37	50.05	4.02	6.77	2.41	0.56	2.01	0.20	0.04	0.07

3.2.2. Water

Table 3.7 identifies a number of impacts on water arising from the food chain. These include the effects of direct abstraction of water and also the discharge of water into watercourses following either contamination or physical transformation.

Data for water use by the food chain has only been collected for single years, 1999 in REWARD (2001) and 1997/98 in ONS (2004). Consequently although absolute estimates of water use can be made by extrapolation from volume/GVA figures, these do not inform us about changes in resource use productivity. Again problems arise due to the resolution of the sectors covered by the data sources. Table 3.14 presents the available water use data. Future estimation of water use by the food chain will be improved as data on water use is due to included in the ABI from 2007.

Table 3.14: Water-use data

	Environmental Accounts 1997/8 (million cubic metres)			REWARD 1999 (Ml/day)[1]
	Public water supply	Direct abstractions from groundwater and non-tidal waters	Total groundwater and non-tidal abstractions	Industrial use of water
Food, drink and tobacco	190	110	300	715.87
Wholesale, hotels and catering	140	-	140	-
Retail	-	-	-	485.87
Hotels	-	-	-	348.70

[1] English regions and Wales only

In addition to the use of water as a resource by the food chain, externality issues such as pollution of watercourses arise. These can impose costs on society directly through clean up costs and indirectly through impairment of ecological functioning and loss of amenity. Data on water pollution incidents are only available in terms of the broad sources of the pollution (industrial; water and sewage; agricultural; and other). Consequently, data on pollution incidents is not sufficiently refined to determine pollution due to the food chain. Other, more diffuse, impacts on water arise from the operation of the food chain (although these are not unique to the food chain). These include run-off from hard surfaces and buildings that can contribute to contamination of watercourses and increase flood risks.

3.2.3. Land

The food chain impacts on land through the use of land for plant and infrastructure and through the generation of waste. These land uses can in turn affect landscapes and natural habitats. There is little information regarding these

impacts. For example data on waste arising is available for two years only, 1998/9 and 2002/3. Table 3.15 presents these figures in for the identifiable food chain sectors broken down by type. As with other data series there is a lack of resolution with respect to wholesaling, retailing and catering as these are not food chain specific. Overall waste generation by manufacturing and wholesaling and retailing remained constant over the period, but with some changes within the particular waste streams. However, hotels and catering did show a reduction of 1 million tonnes of waste, representing a reduction of almost 30%. Industrial and commercial waste as a whole has declined from 83.2 to 79.8 million tonnes between 1999 and 2003. However, this may not be reflected in the food chain, and it should also be noted that municipal waste, including household waste, increased from 31.7 to 35.5 million tonnes over the same period.

Table 3.15: Food chain waste arising 1998/9 and 2002/3. (Source: ONS, 2005)

	Waste arising by type (million tonnes)							
	Inert, construction demolition	Paper, card	Animal and vegetable	General	Metal & scrap equipment	Mineral	Other	All types of waste
Food, drink and tobacco[1]								
1998/9	0.5	0.3	2.3	3.8	0.1	0.0	1.6	8.6
2002/3	0.0	0.3	4.9	2.2	0.1	0.8	0.3	8.6
Wholesale and retail[2]								
1998/9	0.1	0.1	0.0	3.6	0.1	0.0	0.1	3.9
2002/3	0.0	0.2	0.2	3.5	0.0	0.0	0.1	4.0
Hotels and catering[2]								
1998/9	0.0	0.4	0.2	2.1	0.1	0.0	0.6	3.5
2002/3	0.0	0.4	0.1	1.4	0.1	0.0	0.4	2.5

[1] Industry figures based on Environment Agency estimates for England and Wales, controlled to GB total, and grossed to UK total on the basis of estimated manufacturing industry GDP for 1997 and 2002.
[2] Services sector figures based on Environment Agency estimates for England and Wales, controlled to GB service sector total and grossed to UK total on the basis of service sector GDP estimates for 1997 and 2002.

3.2.4. Social externalities

External costs of road transport

In addition to externalities arising from emissions to air, transport of food within the food chain also creates social externalities. These include congestion, noise, infrastructure costs and accidents. AEA Technology (2005) provides estimates for these social costs for 2002. By dividing these total costs by distance travelled a cost per kilometre can be derived for congestion, noise and infrastructure (accident costs are dealt with separately due to better data resolution).

Caution is urged with these costs due to difficulty in obtaining precise values for the costs. In the case of noise, it is recognised that excessive noise levels can have an impact on human health and well-being. However, these impacts have not been directly valued (AEA Technology, 2005). Instead the loss in amenity due to noise has been estimated using hedonic pricing studies of house prices. For example, Bateman *et al*. (2001) found that a 10dB increase in noise level can reduce the value of affected property by 2%. Congestion costs are estimated from the time lost by all vehicles when and additional vehicle joins the traffic flow. The overall figure for the cost of congestion used in this study is by its nature an "average" cost as the true costs will vary according to factors such as road setting (e.g. urban versus rural) and time of day.

Table 3.16 presents the estimated social costs for noise, congestion and infrastucture, the price series is assumed to be constant. As with air emissions it is clear that whilst the social costs arising from HGVs has fallen over the period covered by the data these have been more than offset by increases in the external costs from car use. For example, whilst congestion costs due to HGVs have fallen by £60.2m, they have increased by £468.8m for cars. Overall for the three types of externality considered in Table 3.16 there has been an increase of £395m in social costs between 1996 and 2002.

The external costs to society reported for transport are averaged and are likely to be concentrated around food chain sites such as distribution centres and supermarkets. It is not clear what the actual cost functions look like in terms of the marginal costs faced by affected populations in the vicinity of such sites relative to those further away, or what the sizes of the most affected populations are.

Table 3.16: Social external costs of food chain road transport. (Source: AEA Technology, 2005).

		Noise		Congestion		Infrastructure	
	Vehicle km (m)	Cost (2000 pence/km)	Total cost (2000 £M)	Cost (2000 pence/km)	Total cost (2000 £M)	Cost (2000 pence/km)	Total cost (2000 £M)
HGV							
1996	6060.80	2.19	132.71	24.19	1466.27	6.89	417.55
1997	6123.79		134.09		1481.51		421.89
1998	6145.00		134.55		1486.64		423.35
1999	6124.41		134.10		1481.66		421.93
2000	6062.05		132.74		1466.58		417.63
2001	5957.90		130.46		1441.38		410.46
2002	5812.00		127.26		1406.08		400.41
LGV							
1996	4743.00	0.59	27.94	23.04	1092.58	0.09	4.14
1997	4743.00		27.94		1092.58		4.14
1998	4743.00		27.94		1092.58		4.14
1999	4743.00		27.94		1092.58		4.14
2000	4743.00		27.94		1092.58		4.14
2001	4743.00		27.94		1092.58		4.14
2002	4743.00		27.94		1092.58		4.14
Car							
1996	11817.80	0.30	35.81	18.59	2196.47	0.06	7.67
1997	12174.71		36.89		2262.80		7.91
1998	12557.00		38.05		2333.85		8.15
1999	12964.69		39.29		2409.63		8.42
2000	13397.75		40.60		2490.12		8.70
2001	13856.20		41.99		2575.33		9.00
2002	14340.00		43.46		2665.24		9.31

Road accident figures have been estimated by applying road accident rates by vehicle type and severity (DfT, 2003a) to food chain related distance travelled. The costs of different severities of accident are provided by DfT (2003b) and provide a constant cost series for road accidents[9].

Table 3.17 presents estimated accident rates and costs for the food chain. Between 1996 and 2002 there was a reduction in accident related costs of £86m for the food chain, with the largest decrease arising from reduced HGV accidents. There were, however, increases in the number of fatal and slight accidents involving cars.

[9] Accident costs include casualty related costs (lost output; medical and ambulance; and human costs) and accident related costs (police cost; insurance and administration; and damage to property). The 2003 estimates have been deflated to 2000 prices. These differ from figures published for 2000, however the 2000 data does include accident related costs.

Table 3.17: Food chain road accident rates and costs. (Sources: DfT, 2003a & 2003b; AEA Technology, 2005)

		1996	1997	1998	1999	2000	2001	2002
Million vehicle km								
	HGV	6061	6124	6145	6124	6062	5958	5812
	LGV	4743	4743	4743	4743	4743	4743	4743
	Car	11818	12175	12557	12965	13398	13856	14340
Accidents per million km								
HGV	Fatal	2.26	2.13	2.15	2.19	2.00	2.09	2.01
	Serious	9.70	9.74	8.95	8.77	8.74	8.27	7.49
	Slight	39.81	41.70	41.27	43.04	43.06	42.41	38.06
LGV	Fatal	0.65	0.64	0.57	0.51	0.53	0.56	0.54
	Serious	6.41	5.89	5.56	4.68	4.48	4.40	4.10
	Slight	34.48	34.81	33.41	29.81	28.77	29.18	27.63
Car	Fatal	1.05	1.09	1.00	0.96	0.93	0.95	0.95
	Serious	12.56	12.07	11.23	10.45	10.10	9.69	9.12
	Slight	78.38	79.49	78.91	75.99	76.50	73.46	69.99
Food chain accident rates								
HGV	Fatal	136.77	130.43	131.81	134.34	121.28	124.82	116.88
	Serious	587.96	596.31	549.84	537.35	529.79	492.90	435.11
	Slight	2413.05	2553.51	2536.31	2635.80	2610.52	2526.71	2212.03
LGV	Fatal	30.70	30.18	27.08	24.09	25.30	26.70	25.52
	Serious	304.02	279.18	263.59	221.94	212.26	208.46	194.69
	Slight	1635.20	1651.14	1584.53	1413.66	1364.69	1383.90	1310.69
Car	Fatal	123.82	132.43	125.84	124.82	125.02	132.28	136.05
	Serious	1484.31	1469.83	1410.45	1354.30	1353.66	1342.74	1307.81
	Slight	9263.00	9678.01	9909.19	9851.32	10249.38	10178.15	10036.41
Cost per accident (2000 £)								
Fatal	1402331							
Serious	163941							
Slight	16485							
Accident costs (2000 £m)								
HGV	Fatal	191.79	182.91	184.84	188.39	170.08	175.04	163.90
	Serious	96.39	97.76	90.14	88.09	86.85	80.81	71.33
	Slight	39.78	42.10	41.81	43.45	43.03	41.65	36.47
	Total	327.96	322.77	316.80	319.93	299.97	297.50	271.70
LGV	Fatal	43.05	42.33	37.97	33.78	35.48	37.44	35.79
	Serious	49.84	45.77	43.21	36.39	34.80	34.18	31.92
	Slight	26.96	27.22	26.12	23.30	22.50	22.81	21.61
	Total	119.85	115.32	107.31	93.47	92.77	94.43	89.32
Car	Fatal	173.63	185.71	176.47	175.04	175.31	185.50	190.79
	Serious	243.34	240.96	231.23	222.02	221.92	220.13	214.40
	Slight	152.70	159.54	163.35	162.40	168.96	167.79	165.45
	Total	569.67	586.22	571.06	559.47	566.20	573.42	570.65

Food-borne illness

Food-borne illness can occur due to failures throughout the food chain with initial contamination of food whilst on the farm. This contamination can be exacerbated through poor hygiene and cross-contamination by manufacturers, wholesalers, retailers, caterers and consumers. Inadequate cooking and storage by caterers and consumers further results in food-borne illness risks. The interaction between the different agents in the food chain means that apportioning responsibility for aggregate food-borne illness statistics to different food chain sectors is impossible. Indeed, there is some dispute as to the actual number of cases of food-borne illness in the UK due to widespread underreporting.

There is some variation in published sources for the incidence of food-borne illness in the UK. Adak *et al* (2002) estimate a total of 1,338,772 cases of indigenous (contracted in the UK) food-borne disease in England and Wales in 2000. Of these cases 368,516 were presented to GPs; 20,759 resulted in hospital admissions; 88,545 resulted in hospital occupancy; and there were 480 deaths. It is assumed that all cases resulting in hospitalisation or death had presented to a GP, therefore 970,256 (72.5%) cases did not seek medical attention. These figures compare to a total of 2,365,909 cases in 1995, of which 1,853968 (78%) did not present to a GP. However, other published sources including data collected by the Public Health Laboratory Service (PHLS) suggest a much lower level of illness with figures of 82,041 and 86,528 in England and Wales for 1995 and 2000 respectively.

The data reported by the PHLS and its counterparts in Scotland and Northern Ireland, Health Protection Scotland (HPS) and Communicable Disease Surveillance Centre Northern Ireland (CDSCNI), whilst risking possible underreporting has the advantage of being available as a time series. Consequently, general trends in food-borne illness can be determined. Figure 3.23 illustrates the trends in food-borne illness across the UK from 1995 to 2004. With the exception of Northern Ireland there is downward trend in the incidence of food-borne illness in the UK.

The costs of food-borne illness arise through lost production, health service costs, and pain, grief and suffering. These costs can be categorised as externalities as they do not accrue to the companies within the food chain. Estimates of these costs are provided by FSA (2004) based on the disease incidence estimates reported by Adak *et al* (2002). Total direct costs (2000 prices) from food-borne illness were estimated as £123 million for those who visited a doctor including primary and secondary NHS costs and lost earnings and £41 million for those who did not visit a doctor, based on 1,338,772 cases. These are likely to be an underestimate of total economic costs as lost earnings are used as proxy for lost production, thus value added elements from labour are ignored.

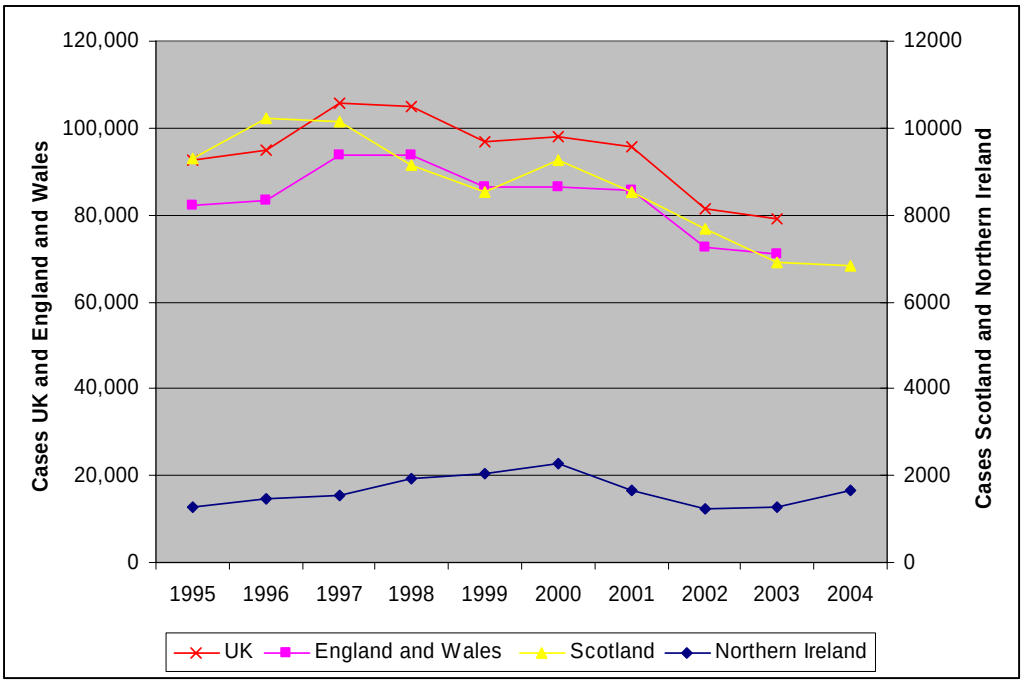
Estimates for the value of pain, grief and suffering are drawn Department for Transport (DfT) and Health and Safety Executive (HSE) estimates of willingness to pay to avoid death and varying severity of injury:

Minor illness of up to 7 days:	£155
Illness lasting more than 7 days:	£1,960
Permanently incapacitating ill health:	£188,870
Death:	£1,065,504

FSA (2004) calculate that the total cost of food-borne illness in England in Wales in 2000 was £1,290 million (£964 per case) and £1,456 million for the whole of the UK.

We will now use these cost estimates to attempt to assess the costs of the food-borne illness time series data provided by PHLS, HPS and CDSCNI. Firstly, we assume that the reported data represents cases presented to GPs, involving hospital treatment and death, and that these represent 25% of total cases (assuming average 75% non-GP cases from Adak *et al*). Total cases are presented in Table 3.18.

Figure 3.23: Incidence of food-borne illness in the UK. Data for Scotland and Northern Ireland plotted on right hand axis.



Sources: PHLS, HPS, CDSCNI.

Table 3.18: Reported and estimated cases and costs of food-borne illness in the UK 1995 to 2000. Sources: PHLS, HPS, CDSCNI.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Reported cases (25% of total)										
England and Wales	82,041	83,233	93,901	93,932	86,316	86,528	85,468	72,649	70,895	70,452
Scotland	9,296	10,234	10,161	9,136	8,517	9,263	8,525	7,682	6,924	6,820
Northern Ireland	1,266	1,456	1,534	1,942	2,033	2,285	1,644	1,220	1,268	1,666
UK	92,603	94,923	105,596	105,010	96,866	98,076	95,637	81,551	79,087	78,938
Unreported cases (75% of total)										
England and Wales	246,123	249,699	281,703	281,796	258,948	259,584	256,404	217,947	212,685	211,356
Scotland	27,888	30,702	30,483	27,408	25,551	27,789	25,575	23,046	20,772	20,460
Northern Ireland	3,798	4,368	4,602	5,826	6,099	6,855	4,932	3,660	3,804	4,998
UK										
Total cases (estimated)										
England and Wales	328,164	332,932	375,604	375,728	345,264	346,112	341,872	290,596	283,580	281,808
Scotland	37,184	40,936	40,644	36,544	34,068	37,052	34,100	30,728	27,696	27,280
Northern Ireland	5,064	5,824	6,136	7,768	8,132	9,140	6,576	4,880	5,072	6,664
UK	370,412	379,692	422,384	420,040	387,464	392,304	382,548	326,204	316,348	315,752
Estimated costs (£m 2000 @ £964 per case)	357	366	407	405	374	378	369	314	305	304

Caution should be taken in attributing these costs entirely to the food industry. Around half of food poisoning incidents are thought to originate outside the home (Parliamentary Office of Science and Technology, 2003). Of the remaining half of incidents, these may result from contamination arising within the food chain, pre-food chain contamination, or poor storage and handling in the home. Increases in food-borne illness have been attributed to changing social patterns including less frequent shopping, hence longer storage periods for food, and increased use of pre-prepared foods, which are inappropriately stored and reheated (Parliamentary Office of Science and Technology, 2003).

Mortality and accidents

The Health and Safety Executive (HSE) collects data on the incidence of deaths and injury to workers in the food chain industries and also members of the public. Table 3.19 gives total numbers of deaths and injuries from 1996/7 to 2003/04, and Table 3.20 gives fatality and injury rates per 100,000 employees for each sector.

Table 3.19: Occupational deaths and injuries in the food chain. (Source: HSE, 2005a).

	1996/97	1997/98	1998/99	1999/00	2000/01	2001/02	2002/03	2003/04
Fatal								
Manufacturing	4	6	7	1	4	7	3	2
Wholesaling	1	1	0	1	1	1	0	1
Retail	0	0	0	0	1	0	0	1
Catering	2	0	1	0	2	1	1	4
Food industry	7	7	8	2	8	9	4	8
Major [a]								
Manufacturing	1478	1541	1500	1519	1331	1397	1293	1196
Wholesaling	164	390	392	287	264	142	118	152
Retail	1188	1078	935	958	946	1044	1176	1215
Catering	608	672	628	579	514	648	686	838
Food industry	3438	3681	3455	3343	3055	3231	3273	3401
Over 3 days [b]								
Manufacturing	9335	9828	9523	9732	9358	8723	8631	7812
Wholesaling	693	2530	2603	1924	2047	785	572	593
Retail	5914	6204	5753	5526	5392	5233	6161	6387
Catering	1936	2283	2431	2425	2335	2265	2410	2870
Food industry	17878	20845	20310	19607	19132	17006	17774	17662
Total								
Manufacturing	10817	11375	11030	11252	10693	10127	9927	9010
Wholesaling	858	2921	2995	2212	2312	928	690	746
Retail	7102	7282	6688	6484	6339	6277	7337	7603
Catering	2546	2955	3060	3004	2851	2914	3097	3712
Food industry	21323	24533	23773	22952	22195	20246	21051	21071

[a] Major injuries include fracture (except to fingers, thumbs and toes); amputation; dislocation (of shoulder, hip, knee or spine); loss of sight (temporary or permanent); chemical or hot metal burn to the eye or any penetrating eye injury; injury from electric shock or burn leading to unconsciousness or requiring resuscitation or admittance to hospital for more than 24 hours; any injury leading to hypothermia, heat-induced illness or unconsciousness, requiring resuscitation, or admittance to hospital for more than 24 hours; loss of consciousness or acute illness caused by asphyxia or exposure to harmful substance or biological agent.

[b] Over 3 day injuries are not major but result in the injured person being away from work or unable to do their normal work for more than 3 days

Table 3.20: Occupational injury rates (per 100,000 employees) in the food industry. (Source: HSE, 2005a)

	1996/97	1997/98	1998/99	1999/00	2000/01	2001/02	2002/03	2003/04
Fatal								
Manufacturing	0.94	1.32	1.55	0.21	0.84	1.60	0.69	0.46
Wholesaling	0.52	0.55	0.00	0.49	0.52	0.53	0.00	0.53
Retail	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.08
Catering	0.21	0.00	0.10	0.00	0.16	0.08	0.07	0.29
Food industry	0.29	0.28	0.31	0.07	0.27	0.29	0.12	0.25
Major								
Manufacturing	345.84	337.84	331.42	316.72	281.16	319.90	297.45	276.79
Wholesaling	85.95	213.85	221.09	139.59	136.43	74.78	63.00	81.02
Retail	136.85	119.89	97.70	90.80	88.62	91.12	94.94	101.34
Catering	64.71	68.82	61.21	45.70	41.12	49.16	50.39	59.95
Food industry	141.73	146.41	132.23	111.17	102.37	104.55	101.58	105.74
Over 3 days								
Manufacturing	2184.33	2154.66	2104.07	2029.19	1976.76	1997.48	1985.51	1807.91
Wholesaling	363.19	1387.29	1468.13	935.80	1057.88	413.38	305.39	316.10
Retail	681.27	689.99	601.15	523.74	505.11	456.75	497.38	532.74
Catering	206.05	233.80	236.96	191.41	186.80	171.84	177.02	205.32
Food industry	736.99	829.11	777.33	652.00	641.07	550.28	551.63	549.12
Total								
Manufacturing	2531.11	2493.82	2437.03	2346.12	2258.77	2318.98	2283.64	2085.17
Wholesaling	449.67	1601.69	1689.23	1075.88	1194.83	488.68	368.39	397.65
Retail	818.13	809.89	698.85	614.54	593.82	547.87	592.31	634.16
Catering	270.98	302.61	298.27	237.11	228.08	221.08	227.49	265.56
Food industry	879.00	975.80	909.87	763.23	743.70	655.13	653.33	655.11

In addition to deaths and injuries suffered by food chain employees, members of the public will also suffer injuries. These are summarised in Table 3.21, however, care should be taken as only the manufacturing figures relate specifically to the food chain. Hotels and restaurants will also include non-catering activities.

Table 3.21: Injuries to members of the public. (Source: HSE, 2005a)

	1998/99	1999/00	2000/01	2001/02	2002/03	2003/04
Fatal						
Manufacturing (food products & beverages)	0	0	0	0	0	0
Wholesale (exc. motor vehicles)	4	1	0	0	0	0
Retail (exc. motor vehicles)			2	3	4	0
Hotels and restaurants	2	6	4	4	3	6
Non-fatal						
Manufacturing (food products & beverages)	31	68	31	11	22	6
Wholesale (exc. motor vehicles)	2098	3457	59	107	86	90
Retail (exc. motor vehicles)			2417	2052	1855	2238
Hotels and restaurants	692	1284	914	783	711	814

The costs of injuries to industry have been estimated by the HSE and are summarised in Table 3.22. These represent direct costs faced by industry and are therefore internal costs. Table 3.23 calculates internal costs to industry for the periods covered above. The HSE categorises these internal costs in two ways:

1. *Financial costs*: those additional costs incurred to achieve the desired output. For example:
   - overtime payments;
   - cost of repairs;
   - cost of extra materials; and
   - fines and penalties.
2. *Opportunity costs*: the costs of labour paid for no production. For example:
   - salary costs of people waiting to work at an idle machine;
   - people at home unable to work through injury; and
   - costs for machinery running idle.

The external costs of injuries include costs to the NHS and those for pain, grief and suffering. Data is not available for the typical costs to the NHS of the different categories of injury reported by the HSE. Directly using the estimates for food-borne illness as these types of illness are often similar in terms of treatment (commonly gastro-intestinal) and duration, whereas workplace injuries may be varied. Costs arising from pain, grief and suffering can be calculated on the same basis as those for food-borne illness (see above) and are presented in Table 3.24.

Table 3.22: Average internal costs of injuries to industry by sector (2000 £). (Source: HSE, 2005b)

Sector	All Injuries (£)	Serious or Major (£)	Over 3 Day (£)	Other Injury (£)	Non Injury (£)
Manufacturing	1372	18725	594	48	181
Distribution and repair	513	17803	482	44	181
Consumer & leisure	1442	17320	502	42	181
Hotels and restaurants	465	18943	313	38	181

Table 3.23: Internal costs of injuries to the food sector (2000 £'000).

	1996/97	1997/98	1998/99	1999/00	2000/01	2001/02	2002/03	2003/04
Fatal								
Manufacturing	75	112	131	19	75	131	56	37
Wholesaling	18	18	0	18	18	18	0	18
Retail	0	0	0	0	17	0	0	17
Catering	38	0	19	0	38	19	19	76
Food industry	131	130	150	37	148	168	75	148
Major								
Manufacturing	27676	28855	28088	28443	24923	26159	24211	22395
Wholesaling	2920	6943	6979	5109	4700	2528	2101	2706
Retail	20576	18671	16194	16593	16385	18082	20368	21044
Catering	11517	12730	11896	10968	9737	12275	12995	15874
Food industry	62689	67199	63157	61113	55744	59044	59675	62019
Over 3 days								
Manufacturing	5545	5838	5657	5781	5559	5181	5127	4640
Wholesaling	334	1219	1255	927	987	378	276	286
Retail	2969	3114	2888	2774	2707	2627	3093	3206
Catering	606	715	761	759	731	709	754	898
Food industry	9454	10886	10560	10241	9983	8896	9250	9031
Total								
Manufacturing	33295	34805	33875	34243	30557	31471	29394	27073
Wholesaling	3272	8180	8233	6055	5704	2924	2376	3010
Retail	23545	21785	19082	19367	19109	20709	23461	24267
Catering	12161	13444	12676	11727	10505	13003	13768	16848
Food industry	72273	78215	73867	71391	65875	68108	69000	71198

Table 3.24: Pain, grief and suffering costs for food chain employee injuries (2000 £'000).

	1996/97	1997/98	1998/99	1999/00	2000/01	2001/02	2002/03	2003/04
Fatal								
Manufacturing	4262	6393	7459	1066	4262	7459	3197	2131
Wholesaling	1066	1066	0	1066	1066	1066	0	1066
Retail	0	0	0	0	1066	0	0	1066
Catering	2131	0	1066	0	2131	1066	1066	4262
Food industry	7459	7459	8524	2131	8524	9590	4262	8524
Major [a]								
Manufacturing	2897	3020	2940	2977	2609	2738	2534	2344
Wholesaling	321	764	768	563	517	278	231	298
Retail	2328	2113	1833	1878	1854	2046	2305	2381
Catering	1192	1317	1231	1135	1007	1270	1345	1642
Food industry	6738	7215	6772	6552	5988	6333	6415	6666
Over 3 days								
Manufacturing	1447	1523	1476	1508	1450	1352	1338	1211
Wholesaling	107	392	403	298	317	122	89	92
Retail	917	962	892	857	836	811	955	990
Catering	300	354	377	376	362	351	374	445
Food industry	2771	3231	3148	3039	2965	2636	2755	2738
Total								
Manufacturing	8606	10937	11875	5551	8321	11549	7069	5686
Wholesaling	1494	2222	1172	1926	1900	1465	320	1455
Retail	3245	3075	2724	2734	3755	2857	3260	4437
Catering	3623	1671	2673	1511	3500	2687	2784	6349
Food industry	16968	17904	18444	11722	17477	18558	13432	17928

[a] These costs are likely to be conservative estimates as they use the figure of £1,960 for illnesses lasting more than 7 days rather than the figure of £188,870 for permanently incapacitating ill health. Major injuries will include both degrees of severity, although it might be assumed that the distribution is skewed towards less severe injuries.

Other social external costs

As with any other economic activity, the operation of the food chain will influence the patterns of land use and development. The siting of food chain production, distribution and retailing sites will have a direct impact on the amenity of such sites through the effect on landscapes (and wildlife habitats). This may be particularly the case where development has occurred in isolation from existing land uses of a similar nature.

Whilst supermarkets offer increased consumer choice within their stores (reflecting increasing choice offered by food producers) it has been claimed that the market power of the large multiples has had deleterious effect on the viability of smaller retailers. This has led to the identification of the issue of food deserts, where there are issues of food availability, variety and price, often in low-income and deprived neighbourhoods (Wrigley, 2002). Such areas typically have lower

levels of car ownership and consequently residents have greater difficulty travelling to large "out-of-town" supermarkets.

Social external benefits of the food chain

The foregoing has concentrated on the negative effects of the food chain on society. This concentration on social costs is due to the availability of suitable data and the need to quantify the impacts of the food chain. However, this is not to say that the food chain does not deliver substantial benefits to society. Competition amongst companies within the food chain has, often controversially, delivered cheap and plentiful food to consumers. This has provided the opportunity for improved diets and also released money that would have been spent on food for spending on other, welfare enhancing activities. In addition, activities of retailers in terms of longer opening hours, internet shopping and a greater product mix within supermarkets have provided benefits of convenience to the consumer.

Summary

A variety of externality data exist for the food chain. However, whilst air emissions are well served, data on waste and water are only collected sporadically. Similarly, whilst some significant social external costs can be collected, the positive externalities from the food chain are absent. Given these constraints the next section aims to adjust the TFP index estimated in the previous section for those externalities where time series are available. Table 3.25 summarises the external costs arising from the food chain downstream from the farm gate for five categories for which there is time series data. Although this is a short time scale it is apparent that overall external costs have remained constant. Externalities arising from transport accidents, food borne illness and accidents at work have shown a strong downward trend. There has also been a more modest decrease in the external costs of emissions, both from energy use and transport. However, these have been offset by continued increases in the social externalities arising from transport.

Table 3.25: Summary of externalities arising from the food chain.

	External costs (2000 £m)					
	Emissions from energy use	Emissions from transport	Social costs of transport [a]	Transport accidents	Other social costs [b]	Total
1998	496.4	384.0	5549.3	995.2	483.2	7908.0
1999	525.9	385.0	5619.7	972.9	447.9	7951.3
2000	535.1	384.2	5681.0	958.9	449.4	8008.7
2001	520.4	381.8	5733.3	965.4	434.9	8035.7
2002	494.7	377.6	5776.4	931.7	382.1	7962.6

[a] Noise, congestion, infrastructure
[b] Accidents at work and food borne illness

3.3 Integrating Externalities within a TFP Index

Lynam and Herdt (1989) have argued that TFP is an appropriate measure of sustainable development, because a non-negative trend in TFP growth implies that outputs are growing at least as fast as inputs. Within the whole schema of sustainability it could be argued that positive TFP growth allows economic and social benefits as well as an indication of greater efficiency of resource use, which ultimately improves environmental quality.

However, this is a somewhat charitable view of the ability of a TFP index to pick up the full consequences of sustainable growth within a relatively simple measure. Sustainable growth comprises a set of complex interactions typified through the physical, natural and social sciences. As a result the relationships between these aspects of sustainability cannot be adequately modelled through a solely market-based measurement instrument. Accordingly, some economists have argued that the non-market costs of production have to be accurately measured and appropriately included within the TFP measure to provide a better measure of sustainable development. This is usually referred to as Total Social Factor Productivity (TSFP).

From a policy making point of view, the environmental and social costs of growth have only become a growing concern. Environmental damage has led to a very real degradation in the quality of life in both rural and urban areas. In essence, awareness has been growing regarding the levels of nitrate within water supplies, the effects of ammonia on the quality of air and the overall effects on human health of chemical application to food products. For the consumer generally, the issue of food miles and congestion seems to be of major importance (AEA technology, 2005). There is, therefore, a growing concern that the full costs have not been accounted for by traditional approaches to measuring growth. Archibald (1988) points out a number of implications that may be relevant to this study:

> ‘‘Firstly, productivity growth may over or understate the gains from technology without the inclusion of externalities, as some resource costs are not included. Secondly, as producers are increasingly required to bear more of the costs of production and to internalise externalities, the total, or social, costs and benefits from technology must be determined. Thirdly, as interest focuses on the long-run profitability of technology, the biological and physical sustainability of technology becomes critical.’’
>
> *Archibald (1988, pg. 366)*

Methodology for Adjusting TFP Growth

Generally, traditional productivity analysis has focused on the ‘desirable’ outputs, i.e. market outputs and positive externalities, within a system, from which producers are rewarded. However, Fare *et al*. (1989) argue that it is reasonable to expect firms to be penalised for their production of ‘undesirable’ outputs, i.e.

negative externalities. Thus, from the early 1980s, with the work of Pittman (1983), there was a growing awareness of the concepts involved in creating a TSFP measure. A number of studies exist which are concerned with the development of a performance measure which accounts for the creation of undesirables within a production economics framework. The majority seem to have focused on agricultural production (Ball *et. al*., 1994; Oskam, 1991; Barnes, 2002) as both a growing policy need for multi-functionality within farming has been coupled with a belief that primary food production has strong environmental and social impacts.

Essentially, adjusting productivity measures relies on the concept of joint outputs. Production of desirables is usually coupled with production of undesirables. Externalities such as air pollution, waste and noise are a consequence of production within the food chain. The implication is that it is impossible to reduce undesirables to zero and still produce desirables, i.e. some cost will always be incurred when producing marketable goods. A way to overcome this problem is to reduce desirable output, hence undesirables would also decrease. However, from a producer point of view this is not acceptable restriction. Hence economists have sought formulations in which producers seek a minimal decrease in desirable outputs at the cost of a minimal increase in undesirable outputs.

Two main approaches have been developed for adjusting productivity measures. The first is based on estimating the technical efficiencies of individual firms. This requires extensive firm level data both on desirable and undesirable output and input quantities. These are not usually available in the UK due to the prohibitive cost of data gathering. However, some work has been conducted in Canada (Hailu and Veeman, 2000) and the US (Ball *et. al.* 1994) using these techniques.

The second approach is to use index numbers. Essentially, aggregate productivity indexes can be adjusted for the non-market costs of production. This approach has advantages as most data are available at an aggregate (rather than at a firm) level. Similarly, it provides macro-level indications of resource use, consistent with other national or industry level indicators. The major disadvantage of the approach is that it requires both quantity and price data over time. Generally, estimates have to be made on sparse data.

Pittman (1983) was the first to adjust indexing techniques on Wisconsin paper mills. He collected quantities of pollutants directly attributable to paper mill outputs and then estimated shadow prices of specific elements of water and air pollution. Several indexes were then constructed to compare solely desirable outputs with components of undesirable outputs to test the differences in growth rates. Other authors have followed this lead with the bulk focusing solely on agricultural productivity adjustment (Archibald, 1988; Oskam, 1991; Repetto *et al.,* 1996; Shaik and Perrin, 2001). Only Barnes (2002) has applied these techniques to UK agriculture. Using quantities of N and P recorded by the ONS

and prices for organic aid schemes, deflated over the period of study, a Total Social Factor Productivity Index was constructed for UK agriculture.

However, the main issue for these authors was not the collection of quantities, which in some countries are considerably detailed, but in the collection of appropriate price estimates to reflect damage.

Pittman (1983) was the first to propose replacing the output revenue shares of an index to non-positive shadow prices. These shadow prices were estimated using optimisation techniques after data were gathered from several surveys. Oskam (1991) estimated prices for a number of agro-chemicals which were either based on unit costs of measures taken in the future, or, the marginal costs of environmental measures taken in other parts of the economy. Barnes (2002) uses prices directly from agricultural pollution abatement schemes, specifically payments made to farmers to reduce applications of either fertilisers or pesticides under the nitrate sensitive area and organic aid scheme. These prices, he argued, reflect the value present society places on past damages. Hence these prices could be used to directly weight the undesirable outputs within an index.

Summary

A number of policy-makers and researchers have criticised the conventional TFP index's ability to capture the full effects of sustainability. Total Social Factor Productivity (TSFP) can be adopted as an alternative which expands a single measure to capture non-market effects of production. From the mid-1980s onwards academics have concentrated on developing approaches to include undesirable outputs within the measurement of productivity. Two issues need to be addressed when constructing a TSFP index. Firstly, there are methodological issues with modelling joint outputs. Ideally a producer would aim to maximise good output and minimise bad outputs. A second problem relates to the availability of data for measurement. Quantity and price data have to be available for inclusion into the series. Since the late 1990s there has been an increase in the collection of quantity data on major externalities. A number of studies have also attempted to estimate prices on these quantity data. These quantities and, where available, prices have been presented in the previous section. Accordingly, the remainder of this section focuses on methodology for constructing a TSFP measure and the results of this procedure.

Methodology

This study adopts the index number approach, predominantly due to its ability to capture industry wide impacts, but also due to the practical problem of restricted access to panel data within the ABI. Similarly, aggregate quantities and prices for the non-market effects of the food chain have been constructed in the previous section. However, this presents problems when constructing TSFP indexes for each of the four sectors in the food chain. Consequently this section only focuses on a TSFP index for the food chain as a whole.

An index is a form of aggregation of series that reflects the underlying production technology inherent within the observed industry. The Fisher index has been adopted due to its ability to capture some of these production processes. Consequently, the central concern of this section is the construction of a Fisher-based indexing procedure which captures the externalities within a system. As the Fisher index is composed of the Laspeyres and the Paasche indexes, these both need to be adjusted for environmental goods and bads. Firstly, given the concept of joint outputs, production can be seen as a function of desirable (y_g) and undesirable (y_b) outputs, as well as conventional inputs (x), namely:-

$$P = f(y_g, y_b, x)$$

Formally then the Fisher index for desirable outputs can be stated as:-

$$y_g = \sqrt{\left(\sum_{i=1}^{M} W_0 \frac{y_{it}}{y_0}\right) \times \left(\sum_{i=1}^{M} W_t \frac{y_{it}}{y_0}\right)}$$

This is simply the index adopted in the previous section, which concentrated on wholly marketable outputs. Essentially, the Laspeyres and Paasche indexes are constructed as the sum of weights, i = 1…M, multiplied by each '*i*-ith' output quantity change in period t compared to the base period. For the desirable outputs weighting is unnecessary as only 1 output exists, i.e. turnover. However, a number of undesirable outputs exist for the undesirable output index.

$$y_b = \sqrt{\left(\sum_{i=M+1}^{Q} W_0 \frac{b_{it}}{b_{i0}}\right) \times \left(\sum_{i=M+1}^{Q} W_t \frac{b_{it}}{b_{i0}}\right)}$$

The indexes are constructed as the sum of the weights i = M+1,…,Q which are the negative revenue shares from the undesirable externality. These are multiplied by the changes in quantities of each externality.

The Fisher input index is not affected, as the externalities are considered as outputs. Accordingly, this can be restated as:-

$$x = \sqrt{\left(\sum_{k=1}^{P} Z_0 \frac{x_{kt}}{x_0}\right) \times \left(\sum_{k=1}^{P} Z_t \frac{x_{kt}}{x_0}\right)}$$

where the weights (Z) are the *k-ith* cost share of each input multiplied by the quantity change of that input relative to the base period.

Accordingly, two TFP indexes can be constructed by dividing each output index by the same input index. A desirable index (TFPg) and an undesirable index (TFPb) which can be stated formally as:-

$TFP^g = y_g / x$

$TFP^b = y_b / x$

Finally, these two TFP indexes need to be aggregated to create a TSFP index. Following Carlson *et al*. (1993) generalised revenue shares can be expressed as :-

$$\text{Revenue Shares} = \frac{P_i Y_i}{\sum_{i=1}^{Q} P_i Y_i}$$

Where desirable outputs, i= 1..M, can be expressed as:-

$$W^g = \sum_{i=1}^{M} W_g$$

Undesirable outputs, i = M+1…Q can be expressed as:-

$$W^b = \sum_{i=M+1}^{Q} W_b$$

Where $W^g > 0$, as it is a desirable output and adds to the growth of the industry, and $W^b < 0$, if it is an undesirable output. This directional measure aims to capture the problem of joint output. These weights ($W^g + W^b$) sum to 1, therefore the adjusted measure (TSFP) can be expressed as:-

$$\text{Total Social Factor Productivity} = W^g (TFP^g) + W^b (TFP^b)$$

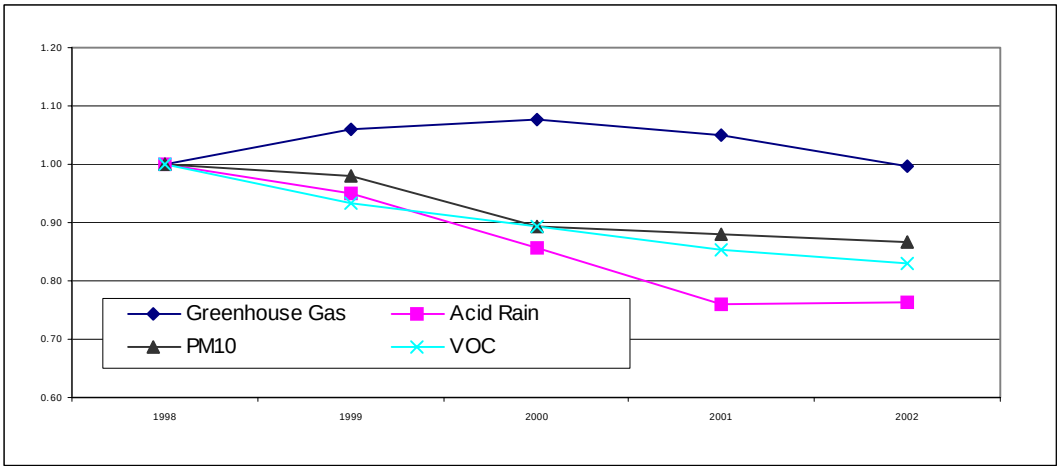
Indexes of Bad Outputs

Byerlee and Murgati (2001) offered a critique of the TSFP measure and its ability to encapsulate the full scientific and social scientific indicators of sustainability. They concluded that TFP is a starting point for measuring sustainability, but has to be interpreted in relation to resource quality trends. Consequently what follows are the outputs of externalities, presented in index form, in order to examine the trends in major externalities over the period of study.

Energy emissions

These consist of greenhouse gas emissions, acid rain precursor emissions, PM10 and volatile organic compound emissions. Figure 3.24 shows these as Laspeyres quantity indexes.

Figure 3.24. Index of Energy Emissions (1998=100)

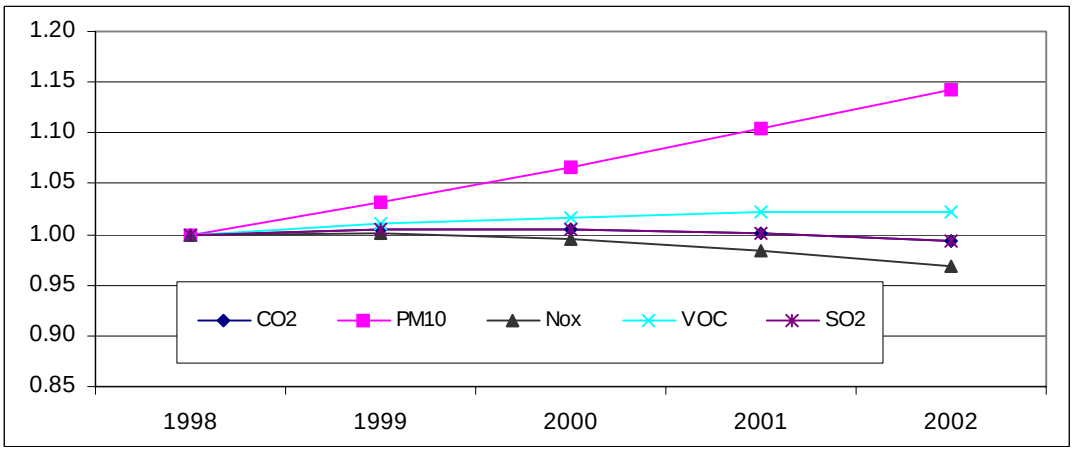


Greenhouse gas emissions show a rise over this period, reaching a peak in 2000, which then arcs downward to 1998 levels. However, the overall trend is downward with the remaining series around 10 points lower in 2002 compared to 1998. However, in terms of negative revenue shares greenhouse gas emissions merits an average of around half the total share for this group.

Transport Emissions

Figure 3.25 shows the emissions for transportation within the food chain.

Figure 3.25. Index of Transport Emissions (1998=100)

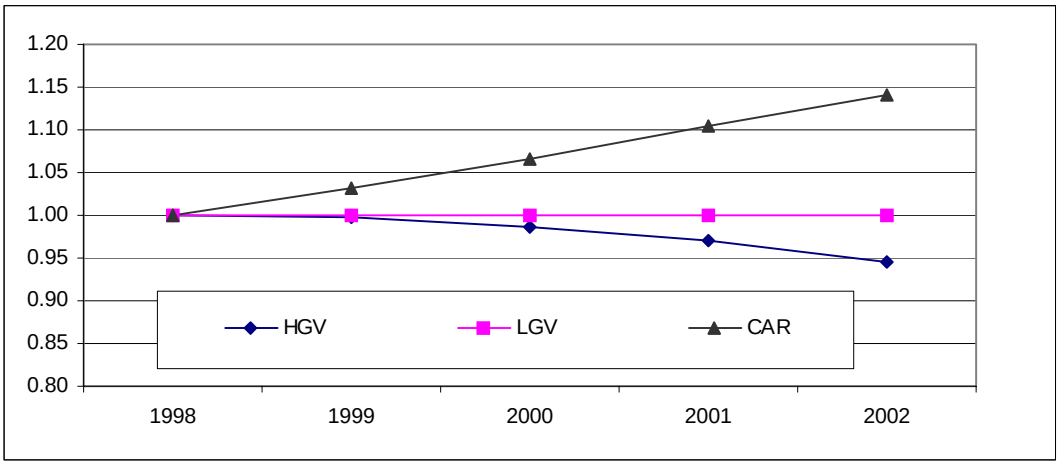


The major rise seems to be in PM10 emissions which increase by around 15 points on the index of the period. Of the remainder volatile organic compounds have remained relatively stable. The others have shown some decrease since 1998. CO2 emissions garner the greatest revenue share of this group with just under 50% of all costs, this is followed by PM10, with a 33% share of costs.

Social Costs of Transport

Noise congestion and infrastructure constitute the social costs of transport. Whilst it seems that LGV's have remained consistent, this is related to an issue of lack of data over the period of study.

Figure 3.26. Social Costs of Transport within the Food Chain (1998=100)



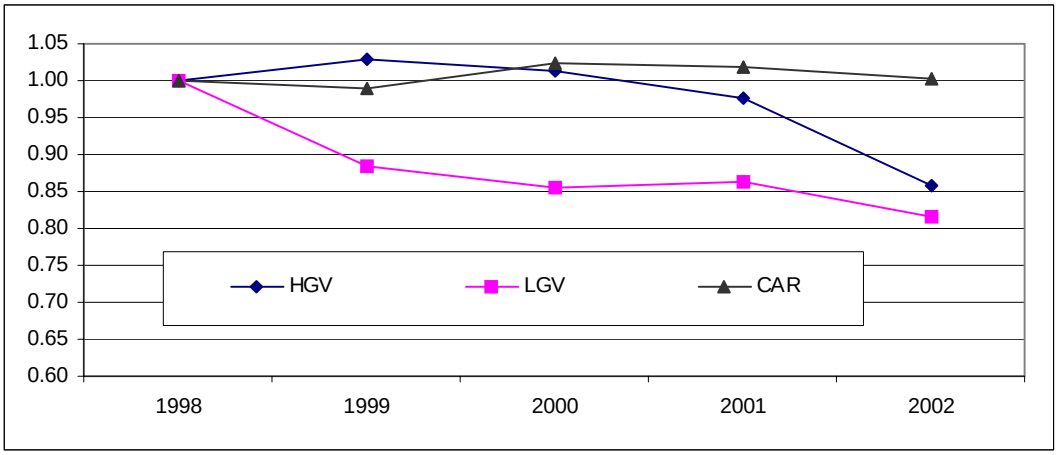
The social costs of HGV use have reduced over the period, which indicates some reduction in the negative effect of the supply chains. This constitutes an average social cost of £2 billion per annum. However, food chain related car usage has substantially increased, predominantly this consists of visits to and from the supermarkets which have increase from over 12 million trips to 14 million over the period. In addition, the negative revenue from car usage constitutes around 45% of total social cost, this is an average of over £2.5 billion.

The inclusion of the external impacts of car use may be questioned in an exercise aimed at determining the social productivity of the food chain industries as these relate to externalities generated by the household sector. However, the increased use of cars in distance terms does represent a transfer of externality generation from the food industry to households. Inclusion of car generated externalities in the TSFP could in the longer term illustrate the benefits of home delivery schemes, which have the potential to reduce car kilometres by up to 70% (Cairns, 2005)

Accident Rates of Transport

Figure 3.27 shows the trend in accident rates for vehicles operating within the food chain.

Figure 3.27. Accident Rates of Transport within the Food Chain (1998=100)

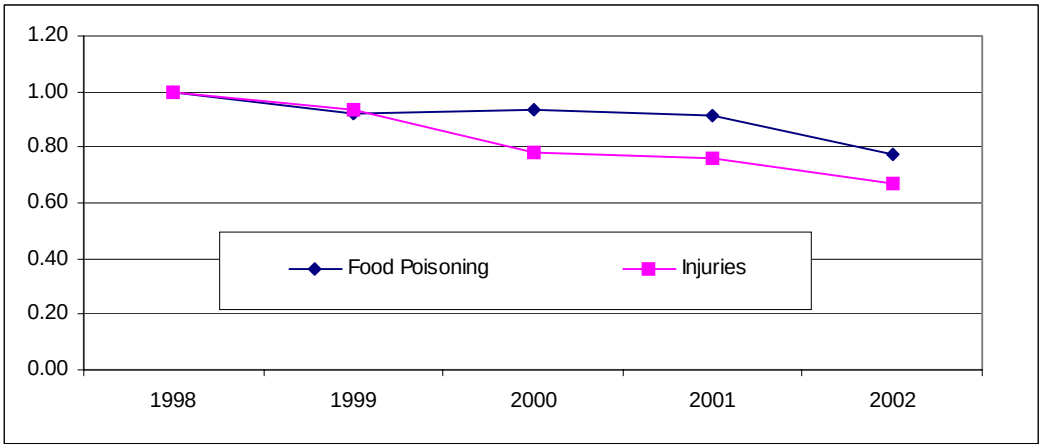


Accident rates for lorries LGV and HGV have reduced over the period where accidents from car usage saw a slight increase over 2000 to 2001 and then returned to 1998 levels. However, around 60% of the negative revenue shares for this group come from car accidents.

Social Costs of the Food Chain

Food poisoning and injuries constitute the social costs of the food chain. Figure 3.28 shows these trends over the period 1998 to 2002.

Figure 3.28. Social Costs of the Food Chain (1998=100)

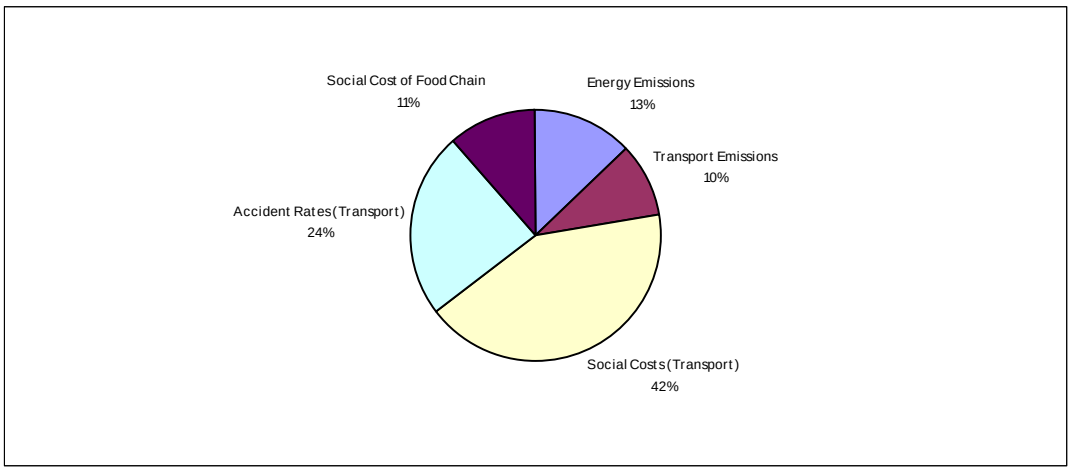


Generally, the number of injuries related to the food chain have declined over the period as have the cases of food poisoning. Both series have reduced by around 20 points. However, injuries are minimal making up only 16% of the external costs of the food chain (referred to here as 'negative revenue shares') of this group. The remaining 84%, around £350 million, emerges from cases of food poisoning.

Negative Revenue Share Weights.

Figure 3.29 shows the relative contributions of each of the five groups of externalities.

Figure 3.29. Negative Revenue Shares of the Externality Groups (percent)

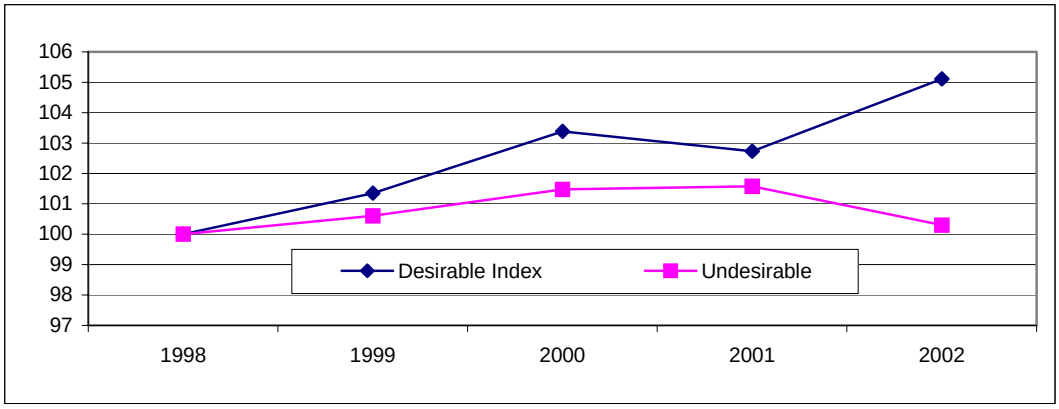


The social costs of transport seem to be the most prominent, with constitutes around 42% of all undesirable outputs. Second to this, with around 25% of the total shares are accident rates within transports. The remaining three externalities are around 10% of all price weights.

Total Social Factor Productivity

The undesirable and the desirable outputs (constructed in stage 1) are presented as chained Fisher indexes below.

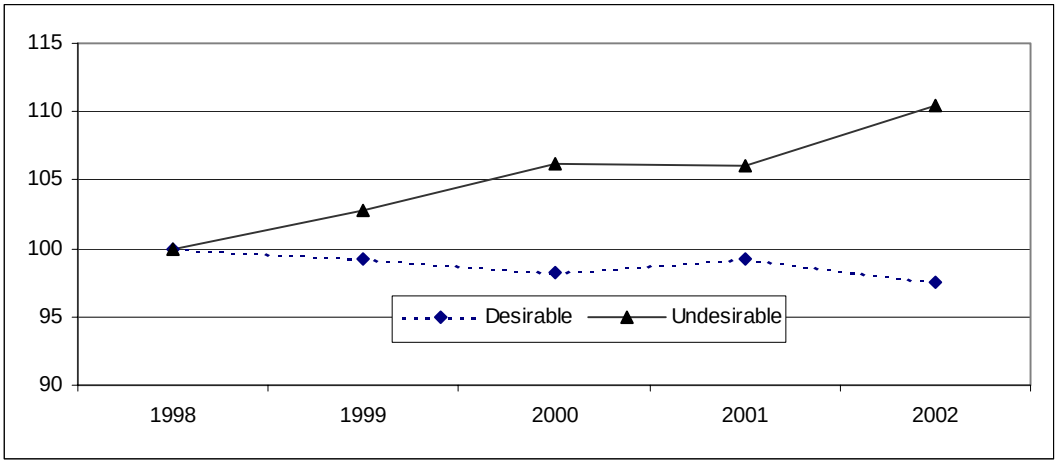
Figure 3.30. Undesirable and Desirable Output Indexes (1998=100)



Considerable growth can be seen in desirable outputs, in this case turnover, which grew rapidly for the food chain over this period. Undesirable outputs tended to rise also, but then fell to 1998 levels at the end of the period.

However, this does not give an indication of resource usage, as inputs need to be equated into these trends. The two Fisher indexes of desirable and undesirable TFP are shown in Figure 3.31 below.

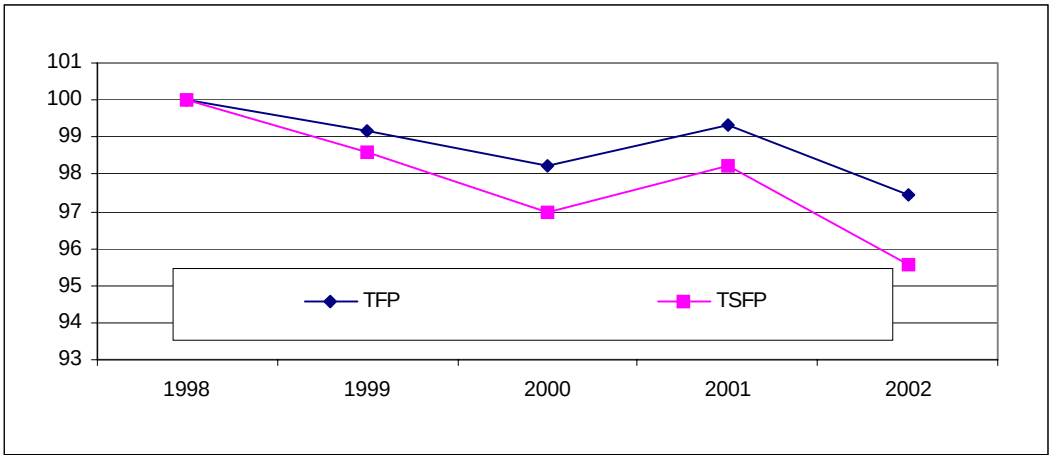
Figure 3.31. TFP Indexes for Desirable and Undesirables (1998=100)



The two indexes seem to reflect some level of similarity in terms of trends, however the bad TFP series is more dramatically downward. Whereas the growth rate of the desirable productivity is –0.64% per annum over the period 1998-2002, undesirable productivity grew by 2.5% per annum. Both results prove problematic for the food chain. Firstly, growing inefficiency is occurring when converting inputs into desirable outputs. However, the food chain is becoming more 'efficient' at producing undesirables. Consequently, whenever there is a growth in bad output, this is exacerbated by the increased efficiency of conversion.

The desirable (TFP) index can now be adjusted to include the undesirables (TSFP), adopting the methodology outlined above. However, imposing the adjusted TFP shows the reliance on share weights within the food sector. In total £58 billion is produced in desirable benefit, i.e. gross value added, whereas only around £8 billion is incurred as a negative revenue share. Consequently, its influence on food chain TFP as a whole is minimal. The adjusted series, whilst slightly downward, strongly mimics the desirable TFP index.

Figure 3.32. TFP and Total Social Factor Productivity Indexes (1998=100)



Nevertheless growth rates are reduced from –0.64% per annum to –1.13% per annum when including undesirables. This is predominately due to the rises in the social costs of car usage, which has the largest negative revenue share of all externalities.

Summary

This section has outlined the major issues involved with developing a total social factor productivity index. Inclusion of externalities within a productivity index measure is a relatively straightforward procedure. However, whilst data for a number of externalities can be collected, it is problematic that no data for positive externalities can be found. As discussed previously, there are positive non-market benefits from the food chain, predominantly from food retailing. If it were possible to value and quantify these effects then the regressive effects on TSFP growth may be dampened.

Conclusions

- Robust measures of productivity are crucial indicators of growth for both policy-makers and industry. Labour productivity, whilst the most popular and simplest measure to construct, is somewhat unidimensional in its capacity to capture economic growth. Total Factor Productivity, whilst having to rely on several assumptions, overcomes this problem by including capital and intermediate inputs, and hence offers a broader perspective on an industry's sustainable development.

- This study has focused on a standard methodology for deriving estimates of TFP for the four major sectors of the food chain, and produced an aggregate TFP index for the industry as a whole for the period 1998 to 2003. Furthermore, it has scoped the externalities prevalent to the food chain's operation and, where possible, quantified and measured their effect on productivity growth.

- **Food Manufacturing** has a positive rate of TFP growth of **0.68% per annum**, which is above the whole economy average of 0.57%.

- The remaining three sectors have negative growth rates, which are not sustainable in the long-term. Average growth rates for the three sectors are:

    - **Food Wholesaling** **–0.71% p.a.**
    - **Food Retailing** **–0.61% p.a.**
    - **Non-Residential Catering** **–0.10% p.a.**

- **Most sectors have positive growth rates in labour and capital productivity**. However, input productivity is dampened by a high reliance on intermediate purchases, such as raw materials and energy use. Some of this can be negated through greater efficiency of purchasing control mechanisms. However, some may be outwith the control of the business.

- **Retail productivity is possibly depressed through the non-market benefits offered by supermarkets**, such as longer opening hours, and a greater product mix offered within stores.

- The crucial argument for concentrating on TFP measurement is because it offers an indication of the future growth potential of that industry and, from a policy making perspective, can be used as a basis to set targets. **It seems that little can be proposed in terms of targets when growth rates are negative, other than seeking reductions in the rates of negative growth or a growth rate which is at least on parity with the remaining sectors**. This latter target seems the most appropriate. However, the maturity of the food industry may restrict growth rates compared to newer sectors.

- **The major cost to the food chain in terms of externalities are the social costs of transport, i.e. the congestion, noise and infrastructure related to food transportation.**

- However, HGV and LGV use has declined over this period. **The main negative impact is with the use of cars**, which has increased substantially from 1998 onward. Predominantly, this is due to increased distances travelled to supermarkets for food shopping (the number of shopping trips has decreased). This is evidence that externality generation has been transferred from the industrial sector to the household sector. Recently, moves have been made by retailers to improve convenience in terms of internet shopping and smaller city centre based retail units. In time these might have the effect of reducing externalities by altering shopping patterns.

- However, **whereas these external costs are around £8 Billion, desirable benefits (through added value) accrue to £58 Billion**.

- Data gaps hinder attempts at providing a fuller picture of sustainable resource use. Waste and Water usage for the food sectors are not, at present, collected on annual basis.

- **A Total Social Factor Productivity Index was constructed composed of desirable and undesirable benefits, which reduced growth rates from –0.64% per annum to –1.13% for the food chain over 1998-2002**.

- Whilst all available data were incorporated into our estimate of the annual growth of TSFP in the food industry, there was a paucity of data on all externalities. Notable gaps included an absence of time series data on waste and water usage, as well as a lack of data on any of the positive externalities. Our estimate is consequently incomplete but it remains the best obtainable measure. The inclusion of data on positive externalities would have likely revised our measure upwards. However, the inclusion of waste and water usage, which, according to AEA technology (2005), may be substantial, would have likely had a significant depressive effect. The net impact of the missing externalities is thus ambiguous.

- A Total Social Factor Productivity index, whilst desirable as a single indicator, is unable to fully capture the intricacies of sustainable development through data collection issues. **Accordingly, until appropriate time series data can be collected, Total Factor Productivity should be considered as one of a suite of major indicators for sustainable growth.**

References

Adak, G.K., Long, S.M., and O'Brien, S.J. (2002). Trends in indigenous foodborne disease and deaths, England and Wales: 1992 to 2000. Gut, 51: 832-841

AEA Technology. (2005). The Validity of Food Miles as an Indicator of Sustainable Development. Final Report produced for Defra

Aghion et al. (2001). Competition, Innovation and Growth with Step by Step Innovation. Review of Economic Studies 68, 467-492

Archibald, S.O. (1988). Incorporating Externalities into Agricultural Productivity Analysis. In: Capalbo, S.M. and Antle, J.M. eds. Agricultural Productivity: Measurement and Explanation. Washington: Resources for the Future, pp. 366-393.

Ball et al (1994) . Incorporating undesirable outputs into models of production: An application to US agriculture. Cahiers d'Economiqueet Sociologie Rurales 31, 59-73.

Barnes, A.P. (2002). Public Agricultural R&D and 'Social' Total Factor Productivity. Agricultural Economics 27 (1), 65:74.

Bateman, I, Day, B., Lake, I., and Lovett, A. (2001). The Effect of Road Traffic on Residential Property Values: A Literature Review and Hedonic Pricing Study. Report to the Scottish Executive Development Department, Edinburgh. www.scotland.gov.uk/library3/housing/ertpv.pdf

Byerlee, D. and Murgai, R. (2001). Sense and Sensibility Revisited. Agricultural Economics 26, 227-236

Carlson, G.A., Zilberman, D. and Miranowski, J.A. (1993) Agricultural and Environmental Resource Economics. OUP, Oxford.

Christensen, L.R. (1975). Concepts and Measurement of Agricultural Productivity. American Journal of Agricultural Economics, 57, 5, pp. 910-15.

Defra (2002). Sustainable Food and Farming Strategy. Defra, London.

Defra (2003). Sustainable farming and food: meeting the new data needs. Defra, London.

Defra (2005). Sustainable Development Indicators. http://www.sustainable-development.gov.uk/performance/18.htm

DETR. (1999). A Better Quality Of Life. DETR, London.

Devine, PJ. et al. (1989). An Introduction to Industrial Economics. 4th Edition. Unwin Hyman, London.

DfT (2003a). Road Casualties in Great Britain 2003: Annual Report. Department for Transport

DfT (2003b). Highways Economics Note No. 1: 2003 Valuation of the Benefits of Prevention of Road Accidents and Casualties. www.dft.gov.uk/stellent/groups/dft_rdsafety/documents/page/dft_rdsafety_033570.pdf

Diewert, W.E. (1976). Exact and Superlative Index Numbers. Journal of Econometrics 4, 115:116.

Dragun, D., Howard,E. and Reynolds, J. (2004). Assessing the productivity of the UK retail sector. Oxford Institute of Retail Management, Templeton College, University of Oxford.

DTI (2005). Quarterly Energy Prices. June 2005. Department for Trade and Industry

DTI (2004) The DTI 2004 R&D Scoreboard: The top 700 UK and 700 International companies by R&D Investment. DTI, London.

DUKES (2005). Digest of United Kingdom Energy Statistics. Department for Trade and Industry

Economic Trends (2003). Food Sector 1992-2001: Extract taken from UK Input-Output Analyses, 2003 Edition. HMSO, London.

Elsayed, M.A., Grant, J.F., and Mortimer, N.D. (2002) Energy Use in the United Kingdom Non-domestic Building Stock: 2002 Catalogue of Results. Resources Research Unit, School of Environment and Development, Sheffield Hallam University. Final report for the Global Atmosphere Division of Defra.

Fare, R.S. et al. (1989) Multiple Productivity Comparisosns when some outputs are undesirable: a non-parametric Approach. Review of Economics and Statistics, 71, 90-98

Food Standards Agency. (2004). Full regulatory impact assessment proposals to consolidate EU food hygiene legislation. www.food.gov.uk/multimedia/pdfs/euhygiene2004riafull.pdf

Gopinath, M., Roe, T.L. and Shane, M.D. (1996). Competitiveness of US Food Processing: Benefits from Primary Agriculture. American Journal of Agricultural Economics 78(4), 1044-55

Hailu, A. and Veeman, T.S. (2000). Alternative Models for Environmentally Sensitive Productivity Analysis, paper presented at the International Association of Agricultural Economists, Humboldty University, Berlin, August 13-19.

Hazledine, T. (1991). Productivity in Canadian Food and Beverage Industries: An Interpretative Survey of methods and results. Canadian Journal of Agricultural Economics, 38(1), 1-34.

HM Treasury (2000). Productivity in the UK: The evidence and the Government's Approach. HMSO, London.

HSE (2005a). Injuries to employees, as reported to HSE & local authorities. Health and Safety Executive, pers comm.

HSE (2005b). Injury costs. Health and Safety Executive. http://www.hse.gov.uk/costs/costs_of_injury/costs_of_injury.asp

Huang, K.S. (2002). Measuring Food Manufacturing Productivity: Gross or Net Output Approach? Paper presented at the American Agricultural Economics Association Annual Meeting, Long Beach, CA, July 28-31.

Jorgenson, D.W. and Stiroh, K. (2000). Raising the Speed Limit: US Economic Growth in the Information Age, forthcoming in Brookings Papers on Economic Activity, 2.

Lynam, J.K., Herdt, R.W., 1989. Sense and sustainability: sustainability as an objective in international agricultural research. Agricultural Economics. 3, 381–398.

Macdonald,J.R.S., Rayner, T.J. and Bates, J.M. (1992). Productivity Growth and the UK Food System 1954-1984. Journal of Agricultural Economics 43(2), 191-204.

Mohnen, P. and Raa, T T. (2003). A General Equilibrium Analysis of Canadian Service Productivity. Structural change and Economic Dynamics 11, 496-506.

Nickell, S. (1996) Competition and Corporate Performance. Journal of Political Economy 104(4), 1996.

Office of National Statistics. (Various Years). Estimates of Capital Stock. http://www.statistics.gov.uk/statbase/TSDtables1.asp

Office of National Statistics (2004).Environmental Accounts: Autumn 2004.

Office of National Statistics. (Various Years). Annual Business Inquiry. http://www.statistics.gov.uk/abi/default.asp.

Office of National Statistics (2004). Transport Statistics Bulletin. Transport of Goods by Road in Great Britain: 2003.

Organisation for Economic Co-operation and Development. (1992). Technology and the Economy: The Key Relationships. Paris: OECD.

Organisation for Economic Co-operation and Development (2001a). Measuring Productivity: Measurement of Aggregate and Industry-Level Productivity Growth. Organisation for Economic Co-Operation and Development, Paris.

Organisation for Economic Co-operation and Development (2001b). Measuring Capital: Measurement of Capital Stocks, Consumption of Fixed Capital and Capital Services. Organisation for Economic Co-Operation and Development, Paris.

Oskam, A. (1991). Productivity Measurement, Incorporating Environmental Effects of Agricultural Production. In. Burger et al. eds. (1991). Agricultural Economics and Policy: International Challenges for the Nineties. Amsterdam: Elsevier, pp. 186-204.

Oulton, N. (2004). Investment Specific Technological Change and Growth Accounting. Working Paper No. 213. HM Treasury, HMSO.

Parliamentary Office of Science and Technology. (2003). Food Poisoning. Postnote Number 193

Paul, C.J.M. (2000). Modeling and measuring Productivity in the Agri-Food Sector: Trends, Causes and Effects. Canadian Journal of Agricultural Economics 48, 217-240.

Pittman, R., 1983. Multilateral productivity comparisons with undesirable outputs. Economic Journal, 93, 883–891.

Pretty J.N., Brett C., Gee D., Hine R.E., Mason C.F., Morison J.I.L, Raven H., Rayment M.D., van der Bijl G. (2000) An assessment of the total external costs of UK agriculture. *Agricultural Systems* 65 (2000) 113 - 136

Repetto, R., Rothman, D., Faeth, P., Austin, D., 1997. Productivity measures miss the value of environmental protection. Choices Fourth Quarter, pp. 16–19.

REWARD (2001)Regional and Welsh Appraisal of Resource Productivity and Development: Key Industrial Environmental Pressures – Water Use. www.reward-uk.org/docs/REWARD_Water.pdf

SAC (2004). Dynamics of Water Use in Scotland. Draft final report to the Scottish Executive. Scottish Agricultural College.

Shaik, S. and Perrin, R.K. (2001). Agricultural Productivity and Environmental Impacts: The Role of Non-Paramteric Analysis. Paper presented at the Annual American Agricultural Economics Association Meeting, Chicago, 5th to 8th August.

Thirtle, C. and Bottomley, P. (1992). Total Factor Productivity in UK Agriculture 1967-1990. Journal of Agricultural Economics, 43 (3) 381:400.

Thirtle et al. (2004). Explaining the Decline in UK Agricultural Productivity Growth. Journal of Agricultural Economics 55 (2), 343:366.

Wrigley, N. (2002) 'Food deserts' in British cities: Policy context and research priorities. Ubrban Studies, 39(11), 2029-2040