

Report to

The National Assembly for Wales

Labour Productivity Growth in Wales 1990-98: Evidence Based on the Annual Respondents Database (ARD):

Stage 2: Detailed Analyses

Submitted by

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Executive Summary

- E.1 Based on the agreed terms of reference, this report considers the following topics:
 - A comparison of total factor productivity (TFP) and labour productivity measures
 - Estimation of the capital stock
 - The role of economies of scale in measuring TFP and (in)efficiency
 - Factor-biased technological change and measuring TFP
 - Regional perspectives on relative merits of various productivity measures
 - Transfer pricing and measuring TFP
 - Gross output versus gross value-added measures of labour productivity and the importance of outsourcing
 - The determinants of TFP in Welsh manufacturing.
- E.2 Section 2 compares labour productivity across the regions of the UK for the 1973-1998 period. Labour productivity was relatively high (and grew fastest) in Wales during the 1980's and early 1990's, but from 1996 onwards there was a sharp downturn in performance (whether labour productivity is measured using a gross output or gross value-added measure). Moreover, the usage of intermediate inputs (which is by definition the difference between gross output and gross value-added) is generally more intensive in Welsh manufacturing when compared to other regions, and this accounts for much of the difference in performance when gross output and gross value-added measures are compared.
- E.3 In Section 3, measures of TFP and labour productivity growth are set out, showing that the former depends on technological change and efficiency while labour productivity also depends on what happens with the other factors of production (i.e. whether intermediate inputs and/or capital are substituted for labour). Thus, the major weakness of using a measure of labour productivity growth, that is primarily intended to capture the impact of improvements in technology and/or efficiency, is that it is also significantly influenced by

- substitution between the factors of production. In contrast, TFP captures the 'pure' impact of shifts in the production possibility curve (due to technical change) or movements towards it (due to improvements in efficiency).
- E.4 With regard to estimating the capital stock, the various assumptions and methods used are set out in detail. Some of the drawbacks of the approach stem from the fact that we do not have direct estimates of depreciation and have instead to rely on length of life assumptions that were collected some time ago (by the ONS). However, it is argued that without better assumptions and data, the methods used are as robust as any available. Clearly, any inaccuracy in the measure of capital stock used when estimating TFP will result in bias, but at present we do not know how inaccurate our measure is (except to say it is probably as accurate as any other that has been constructed). It is expected that the degree of bias is probably small and in any event is not sufficient to abandon the use of TFP measures vis-à-vis labour productivity measures, given that the latter are 'biased' through increases in factor substitution.
- E.5 The impact of economies-of-scale are not reflected in measures of TFP, and thus the latter is not biased if large plants benefit from scale economies. But, it is possible to consider the importance of plant size on TFP through the impact of size on efficiency levels (and thus TFP). In Welsh manufacturing, the use of relatively large plants (having controlled for certain other characteristics such as ownership and industry composition) does mitigate against other factors that would otherwise result in a significantly lower level of efficiency in Wales visà-vis many other UK regions.
- E.6 In terms of the impact of factor-biased (or scale-biased) technological change and the measurement of TFP, the measurement of factor inputs used in this study do not adjust for the skill composition of the workforce and with respect to the capital stock (probably) imprecisely take account of obsolescence due to technical change and quality-enhancement through the use of appropriate price indices. Thus, TFP as measured here probably does pick up most of the embodiment effects of technological change. In terms of the potential that innovation (technological change) may be associated with scale, this should not matter in terms of the measurement of TFP as carried out here, since such innovations (whatever the size of plants) should result in increases in output not

accounted for by increases in factor inputs, and should thus be captured by our measure of TFP.

- E.7 As to whether a labour productivity measure is more 'relevant' than TFP, given that much of manufacturing is externally-owned and thus profits are repatriated elsewhere, it is argued that we need to concentrate on improving technology and efficiency in Welsh manufacturing, since this will ultimately improve regional competitiveness and thus current and future job creation in the Principality. The most appropriate measure of such improvements is TFP, rather than labour productivity.
- E.8 With respect to transfer pricing, it is recognised that if intra-firm trade does not reflect equivalent transactions that take place in the market between independent enterprises, the result will be biased estimates of productivity. However, insufficient data is available to be able to judge whether transfer prices are biased (what we do show in the report is that foreign-owned plants use more intermediate inputs which may in part reflect some inflation of the transfer prices of such inputs but they are also more productive).
- E.9 As to whether a gross output or a gross value-added measure of productivity is valid, this depends on the technical condition of whether the production function is separable (i.e. can we separate out the production of value-added using labour and capital from the production of gross output using value-added and intermediate inputs). This is a statistical issue and evidence is presented that firmly rejects the notion that separability is valid.
- E.10 As to what factors are most important in explaining differences in the use of intermediate inputs per employee (given that the latter is the difference between a gross output and a gross value-added measure of labour productivity), as expected foreign-owned plants have much higher levels of intermediate inputs per employee, while on average over the period some 11% of Welsh manufacturing plants were foreign-owned compared to less than 8.5% of all plants operating in the UK. This helps to explain the high levels of outsourcing that are a feature in the Principality. There are also certain industries that are more intermediate intensive; such as metal manufacturing, non-metallic minerals, chemicals, man-made fibres, and the drink and tobacco industries have high usage of intermediate products. Wales tends to specialise in many of these

industries, and has lower specialisation in industries where outsourcing is relatively lower (e.g., metal goods not-elsewhere-specified, mechanical engineering, and paper and products). After controlling for size, and other relevant factors, it is calculated that the South East and East Anglia are particularly intermediate intensive, with Wales and the North West coming next in UK terms. In terms of sub-regions of Wales, plants operating in the eastern M4 corridor *cet. par.* engage in more outsourcing, while the rest of South Wales (including the Upper Valleys) is the least intermediate intensive. Lastly, we find that there has been a clear increase in the importance of intermediate inputs, with average growth rates of about $3\frac{1}{2}$ % p.a. over the 1974-1998 period in both Wales and the UK.

- E.11 Finally, this report looks at the determinants of TFP in UK manufacturing, *inter alia* to show if Welsh manufacturing performs better or worse than the average. Using manufacturing data from the ARD and SAMIS covering all UK plants operating during 1988-1998 that did not close before 1990, we find that manufacturing operated with increasing returns-to-scale. It is also clear that greater use of intermediate inputs is associated with higher levels of output. In addition, US- and other foreign-owned plants are more productive as are certain industries such as the extraction of minerals and office machinery. Other industries (particularly, those using older technologies) such as food, textiles, leather goods, footwear and clothing, have lower TFP. Plants located in East Anglia, the South West and Scotland (*cet. par.*) operate with higher levels of TFP while Northern Ireland has TFP levels that were 2.2% below the average. Wales as a location neither resulted in a higher or lower TFP.
- E.12 After allowing for the impact of whether plants were located in Assisted Areas, and/or received Regional Selective Assistance (RSA), and/or were single plant enterprises, it is found that these additional characteristics, rather than being located in Wales *per se*, have more of an impact on TFP. In fact, single-plant enterprises had TFP levels that were 6.5% lower than the average, while Assisted Area and RSA plants operated with TFP levels that were 2.3% and 2.5% lower, respectively. Only when Wales is sub-divided into different areas is it possible to show that plants located in South Wales excluding the eastern M4 corridor and the Upper Valleys had lower TFP (of around 2.9%). Indeed, the most extensive model estimated suggests that plants located in the eastern

M4 corridor (and the Upper Valleys and North East Wales) actually benefit from their location, having controlled for the negative impact on TFP of Assisted Area status, whether they received RSA or operated as a single plant.

E.13 In summary, the major result obtained with respect to the determinants of TFP shows that location *per se* does not suggest that Wales has a productivity problem (when compared to most UK regions). Rather where there is poorer productivity in Wales, it is usually linked to plants being located in Assisted Areas or having received RSA (or being single-plant enterprises).

1. Introduction

- 1.1 This Report outlines the analysis that has been carried out on the linked datasets (comprising plant level data on production activities and which plants received RSA) that have been developed for the Department of Trade and Industry. Following this earlier work by Harris and Robinson (2002a) for the DTI, and a presentation in May 2002 of the main results and findings as they relate to plant opening and closures in Wales, the Economic Research Unit of the Welsh Assembly Government requested two further set of analysis to extend the previous work.
- 1.2 Stage 1 has already been carried out and a report submitted (see Harris, 2003). The terms of reference for Stage 2 (comprising a more detailed analysis of productivity growth) are as follows:

(i) Discussion of the following agreed issues:

- under TFP (total factor productivity) how are capital stock values estimated, and what implications does this have for the robustness of the TFP results?
- what is the extent of the gain from economies of scale (which underlie the production function estimates of TFP), which represents an efficiency improvement not reflected in TFP?
- whether the TFP methodology might be underestimating the contribution of innovation (in the broadest sense) because such innovation may be embodied in capital equipment (or associated with changes in scale)?
- what are the implications of taking a regional perspective on the relative merits of TFP and labour productivity (taking particular account of likelihood that the returns to capital are taken disproportionately outside Wales, and the importance of job creation)?
- an assessment of whether transfer pricing raises any significant difficulties

(ii) In addition, several issues have arisen from the results provided in Stage 1:

• The different results obtained for Wales when labour productivity is measured on the basis of gross output compared with gross value-added. Further investigation of plant-level data to be undertaken in Stage 2 to discover whether this is due to certain (large) outlier plants; or certain industries (where the level of use of intermediate inputs is greater); or whether ownership and/or plant size contribute to the differences reported on in Stage 1.

• More importantly, there is a need to consider other approaches to measuring plant-level performance in both Wales and other regions, to corroborate the results obtained in Stage 1, and to help explain the large variation across UK regions and thus why Wales' performance is relatively poor. Thus, in Stage 2 it is proposed to use an augmented production function approach that measures gross output and gross value added as determined by labour, capital and (where appropriate) intermediate inputs, as well as include other determinants such as industry, ownership (including foreign and single plant enterprises), the age of the plant, whether the plant received RSA, and location as factors that determine output levels (in particular a sub-regional analysis of Wales will be undertaken). The methodological approach to be taken will be similar to that used in Harris (2002) and Harris and Robinson (2002b, 2002c).

2. Productivity Growth: Background Analysis

- 2.1 The data used in this study comprises merged data that links the DTI's SAMIS database on firms that received RSA during the 1990-1998 period with the ONS's ARD database comprising plant level production information for the period 1973-1998.² A discussion of the data, the methods used to merge the datasets, and how capital stocks are estimated, is summarised in Appendix 1.
- 2.2 To provide some background details, this section compares labour productivity (both the levels and growth) across the regions of the UK. Measures based on (real) gross output and (real) gross value-added are computed, with the basic difference between the two series being (real) intermediate inputs (i.e., purchases of materials, energy, and other business services see Figure 2.1).

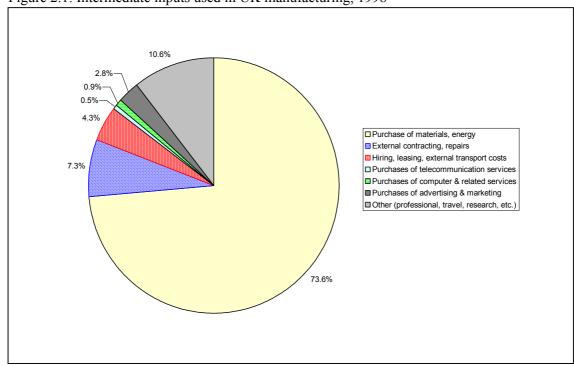


Figure 2.1: Intermediate inputs used in UK manufacturing, 1998

Source: calculations based on ARD

2.3 Using data from the ARD, aggregate labour productivity levels for UK manufacturing are shown in Figure 2.2 for the 1974-1998 period. There was a substantial increase in labour productivity from the early 1980's, especially when gross output per worker is considered. Gross value-added is more cyclically sensitive, and declined substantially in the 1997-1998 period relative to gross output.³

100.000 29,000 90,000 27,000 (left-hand scale) 25,000 80,000 E per employee 1990 prices gross output per employee 23,000 70.000 21.000 E per 60,000 19.000 50,000 17,000 15,000 40,000

1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

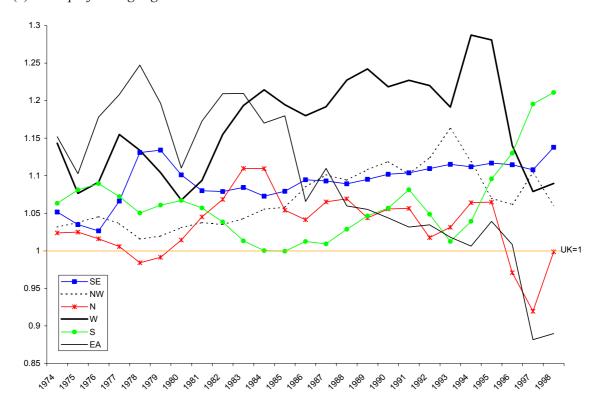
Figure 2.2: (Real) labour productivity UK manufacturing, 1974-1998

Source: calculations based on ARD

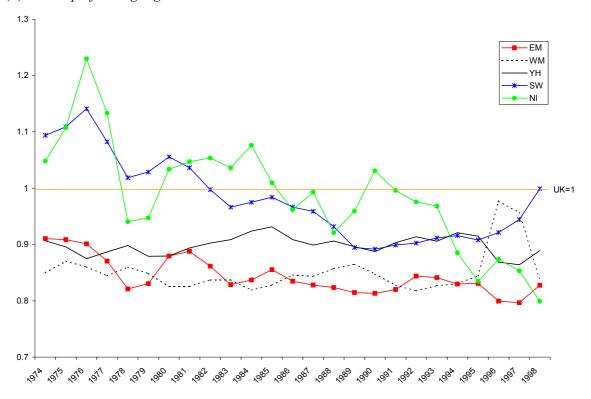
- 2.4 Figures 2.3-2.4 present data for the UK regions covering the same period, expressed relative to the UK average (i.e. the data in Figure 2.2). In terms of gross output, Wales had the highest productivity levels throughout the 1984-1996 period, with a major decline at the end of the period. Other regions traditionally associated as being on the periphery (the North West, the North and Scotland) also performed relatively well (although productivity in the north fell sharply after 1995 while Scotland experienced substantial relative increases in the mid- to late 1990's).
- 2.5 In comparison, Welsh labour productivity was relatively low when we use a measure of gross value-added. This indicates that manufacturing in the Principality is much more intermediate intensive (and this is often associated with plants being relatively larger and/or foreign-owned). However, relative productivity increased substantially during the period up to 1994 before declining significantly in the late 1990's.
- 2.6 Regions that generally featured in the 'best' performing category when a gross output measure is used were also those that did well using a gross value-added measure; Wales was the major exception and this highlights the importance of the point already made that Welsh manufacturing is particularly intermediate intensive.

Figure 2.3: Relative gross output based labour productivity UK manufacturing, 1974-1998

(a) 'best' performing regions



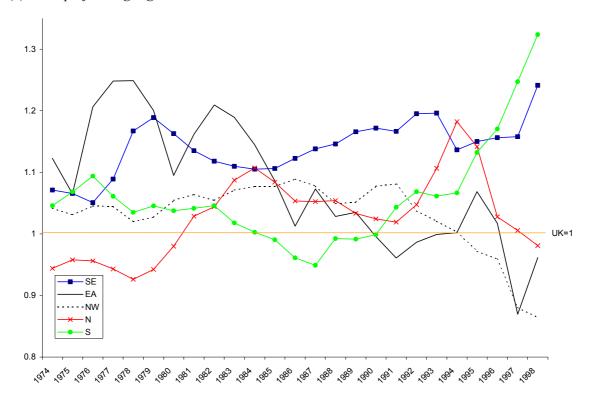
(b) 'worst' performing regions



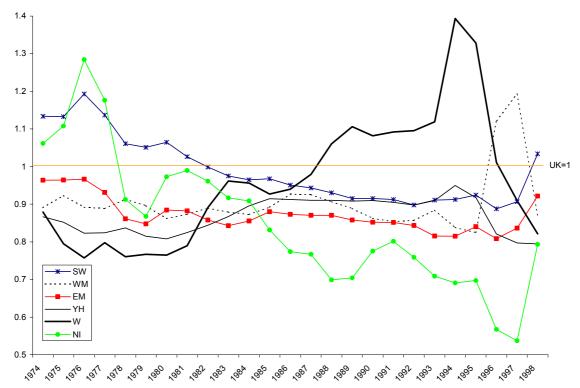
Source: own calculations based on ARD

Figure~2.4:~Relative~gross~value-added~based~labour~productivity~UK~manufacturing,~1974-1998

(a) 'best' performing regions



(b) 'worst' performing regions



Source: own calculations based on ARD

Table 2.1: Growth in (real) labour productivity in manufacturing, UK regions, 1974-1998 (figures are per cent per annum)

	SE	EA	SW	WM	EM	YH	NW	N	W	S	NI	UK
Gross outp	ut per worl	cer										
1974-79	2.23	1.48	-0.51	0.68	-1.12	0.11	0.49	0.07	0.02	0.68	-1.31	0.72
1979-84	3.36	4.02	3.40	3.77	4.63	5.46	5.16	6.72	6.38	3.29	7.03	4.47
1984-89	4.71	2.23	2.58	5.39	3.76	3.69	5.27	3.08	4.75	5.20	1.99	4.30
1989-94	4.06	2.81	4.23	2.93	4.12	4.30	3.94	4.14	4.47	3.61	2.15	3.76
1994-98	2.11	-1.54	3.71	1.72	1.48	0.65	0.20	-0.05	-2.63	5.36	-1.02	1.53
1990-98	3.30	0.90	4.32	2.73	3.12	2.92	2.22	2.20	1.50	4.60	-0.29	2.89
1974-98	3.34	1.94	2.64	2.95	2.62	2.93	3.13	2.91	2.81	3.56	1.89	3.01
Gross valu	Gross value-added per worker											
1974-79	1.18	0.44	-2.41	-0.78	-3.47	-2.13	-1.18	-0.93	-3.62	-0.91	-4.93	-0.90
1979-84	2.15	2.66	1.90	3.07	3.79	5.50	4.56	6.84	8.02	2.78	4.54	3.62
1984-89	3.24	0.16	1.12	2.54	2.23	2.44	1.69	0.79	5.09	1.95	-2.94	2.17
1989-94	0.53	0.38	0.97	-0.13	0.00	1.93	0.10	3.73	5.66	2.49	0.66	1.04
1994-98	-3.07	-6.31	-2.15	-4.35	-2.19	-9.75	-9.01	-9.95	-18.50	0.12	-1.82	-5.28
1990-98	-1.14	-2.30	-0.34	-1.75	-0.88	-3.57	-4.62	-2.41	-5.31	1.66	-1.57	-1.86
1974-98	0.97	-0.29	-0.03	0.25	0.17	-0.01	-0.42	0.51	0.07	1.33	-0.86	0.35

Source: calculations based on ARD

- 2.1. Lastly, the growth of labour productivity (using both measures) is presented in Table 2.1. This shows that for Wales, after below average performance in the 1970's, growth was particularly strong in the 1980's and early 1990's, relative to the UK. However, during the 1994-1998 period the annual percentage growth of labour productivity was –2.6% p.a. when considering gross output and –18.5% p.a. on the basis of gross value-added per worker. During this period, Wales was the worst performing UK region in terms of productivity growth. Overall, for the whole period 1974-1998, Welsh manufacturing achieved 2.8% p.a. growth in terms of (real) gross output per employee (and only 0.1% p.a. based on the real gross value-added measure).
- 2.8 In summary, labour productivity was relatively high (and grew fastest) in Wales during the 1980's and early 1990's, but from 1996 onwards there was a sharp downturn in performance (whichever measure of labour productivity is used). Moreover, the usage of intermediate inputs is generally more intensive in Welsh manufacturing when compared to other regions, and this accounts for much of the difference in performance when gross output and gross value-added measures are compared.

3. Total Factor and Labour Productivity Measures

3.1 It is useful to start with a simple Cobb-Douglas⁵ production function:

$$y = \alpha_0 + \alpha_E e + \alpha_M m + \alpha_K k + \alpha_T t \tag{3.1}$$

where y refers to the logarithm of real gross output; e refers to the logarithm of employment (with α_E measuring the elasticity of output with respect to employment – i.e. $\partial y/\partial e$); m refers to the logarithm of real intermediate inputs (with corresponding elasticity of output, α_M); and k refers to the logarithm of capital stock (with corresponding elasticity of output, α_K). Totally differentiating this function with respect to time to obtain rates of change (and expressing terms such as dy/dt as \dot{y}), a measure of total factor productivity growth can be obtained as:

$$T\dot{F}P = \alpha_T = \dot{y} - \alpha_E \dot{e} - \alpha_M \dot{m} - \alpha_K \dot{k} \tag{3.2}$$

Note, this measures the increase in output that is not attributable to increases in e, m, or k; rather it measures the contribution to growth of all influences other than the factors of production, capturing such determinants as technological progress and/or increases in efficiency (note, inefficiency also captures any under-utilising of factor inputs). Thus, if any factor input increases, then via (3.1) output increases by a value depending on the elasticity of output with respect to the factor increasing, and the impact on TFP in (3.2) is zero.

3.2 In terms of labour productivity growth, a relationship can be obtained by subtracting the logarithm of employment from both sides of (3.1) and expressing the result in terms of rates of change with respect to time:

$$\dot{y} - \dot{e} = (\alpha_E - 1)\dot{e} + \alpha_M \dot{m} + \alpha_K \dot{k} + T\dot{F}P \tag{3.3}$$

This shows that increases in labour productivity $(\dot{y} - \dot{e})$ are negatively related to increases in employment [since $(\alpha_E-1)<0$], and positively related to increases in intermediate inputs, capital stock and TFP. Indeed, if over time there is an increase in capital deepening (*cet. par.* the K/E ratio rises as capital is substituted for labour perhaps due to greater automation) or outsourcing (*cet. par* the M/E ratio rises as less is made internally and more semi-finished and finished products, and services, are bought from suppliers), then labour productivity will increase as relatively less labour is used to produce output.⁶ Thus, increases in labour productivity do not depend on just technological progress and/or gains in efficiency, since what happens with the other factors of production is also important.

3.3 Figure 3.1 provides some insights with regard to what has been happening in UK manufacturing in recent decades. As has already been seen (Figure 2.2), labour productivity (based on the gross output measure) rose fairly constantly throughout the 1973-1998 period; however, this was likely to have been at least in part due to capital deepening (increases in K/E), particularly in the 1970's and early 1980's, and outsourcing (increases in M/E), which seems to have increased at a more significant pace from the mid-1980's onwards.

Figure 3.1: Real outputs and inputs in UK manufacturing, 1973-1998

Source: based on own calculations using the ARD

- 3.4 Thus, the major weakness of using a measure of labour productivity growth that is primarily intended to capture the impact of improvements in technology and/or efficiency is that it is also significantly influenced by substitution between the factors of production. In contrast, TFP measures capture the 'pure' impact of shifts in the production possibility curve (due to technical change) or movements towards it (due to improvements in efficiency).
- 3.5 It can also be seen that there is an issue of which labour productivity measure should be used (based on gross output or gross value-added). This will be discussed in detail in the next section, but it is useful to note here that the answer depends on whether the production function is separable or not (i.e., whether intermediate inputs be separated from K and E in the formulation of the function) and the empirical evidence strongly suggests not while the literature on outsourcing suggests that the gross output approach captures more exactly measures of efficiency while value-added functions are more closely related to profitability (Gorzig and Stephen, 2002).

3.6 This section concludes with a discussion of the various agreed issues relating to TFP that arose from the Stage 1 (Initial Analysis) report, as set out in the introduction (Section 1). The first relates to how capital stock is estimated (since this is necessary for the calculation of TFP) and whether the estimates are robust with regard to the accuracy of measuring TFP.

Estimating the capital stock⁸

3.7 An accurate measure of the capital stock that is intended for use in estimating production relations should represent the total amount of capital services available for producing output. This means taking into account efficiency losses due to deterioration (including obsolescence). This requires the use of an appropriate rate of deterioration of capital goods that reduces their efficiency through time as they are used to provide capital services and as they age. Essentially, we define the net stock of capital as:

$$K(t) = \int_{-\infty}^{L} \frac{E(\upsilon)}{E(t)} . D(t - \upsilon) . I(\upsilon) . d\upsilon$$
(3.4)

where I(v) is constant price gross investment of year v, weighted by both physical decay D between time v and t, and by accumulated embodied technical progress (obsolescence) E between time v and t. Therefore, vintages installed in year v provide less capital services as the age of I(v), i.e., t-v, becomes sufficiently large due to (i) wear and tear, resulting in D \rightarrow 0,¹⁰ and (ii) accumulated technical progress means that the newest vintages in time t embody more capital services than do older fixed assets, thus over time $E(v)/E(t) \rightarrow 0$. Physical decay and obsolescence combine to produce deterioration. Therefore, information is required on the rate of deterioration that reduces the capital services available from any vintage and eventually removes the ageing asset from the remaining capital stock.

3.8 Ideally, we require empirical estimates of the level of known deterioration to enable us to calculate both the rate (or pattern) of deterioration and the value of the actual length of life of a capital good. Unfortunately, this information is not available and therefore some other technique must be used to estimate the expected life of a capital good, which provides an indication of the period over which deterioration must take place. The perpetual inventory method is typically adopted for this purpose, with the rate of deterioration assumed to follow some simple pattern such as straight-line or exponential decline. If rates of physical decay and embodied technical progress are assumed to be stable over long periods of time, then the expected length of life will remain the same and using expected length of life is an accurate indication of how long deteriorating capital goods remain in a net stock measure. However, these assumptions appear more appropriate for physical decay, and not technical progress, and this is presumably the

major reason why the ONS adopt the procedure of shortening asset lives every five years for plant and machinery expenditure undertaken since 1950.¹¹ The length of life assumptions do not take account of premature scrapping, which is mainly caused by obsolescence. This occurs when a capital good ceases to earn a positive quasi-rent, often caused by a lack of demand for the firm's product or a sharp change in relative factor prices, and is scrapped in advance of the period when repairs to combat physical decay become too great. The issue of premature scrapping due to plant closures is taken on board since the data used (based on the ARD) identifies those plants that close, such that we can remove their capital stock from any aggregate measure following closure.

- 3.9 As to the appropriate rate of deterioration, it was argued by Denison (1972) that the expected time pattern of deterioration of a capital good is expected to exhibit a slow rate of deterioration at the beginning, becoming more rapid as the expected length of life of the good approaches. The reasons for this are that firms typically undertake maintenance and repair in order to maintain the same performance level as when the machine was new (Jefferson, 1971), with this activity increasing with the age of the capital goods, while the effect of obsolescence on the *rate* of deterioration is probably small (Barna, 1962). This assumption is more applicable when the rate of capital-embodied technical progress is low over time since equation (3.4) shows that obsolescence not only affects the length of life of an asset but it also makes older vintages less productive than newer ones. Thus lowering the length of life of assets, on the assumption that technical change has increased in more recent years is presumed to reduce any impact of obsolescence on the rate of deterioration.
- 3.10 Given the above discussion, gross and net (of straight-line deterioration) plant and machinery capital stock figures are calculated for eighteen groups of industries, using the perpetual inventory method and the expected length of life of capital goods adopted by the ONS since 1983.¹⁴ As set out in Hulten and Wykoff (1996 p.15), if φ_s represents the efficiency (or remaining capital services) of an *s*-year-old asset as a function of the productive capacity of a newly produced asset, then the deterioration pattern for the gross stock measure is:

$$\varphi_0 = \varphi_1 = \dots = \varphi_{T-1} = 1, \ \varphi_{T+t} = 0 \qquad t = 0, 1, 2 \dots$$
(3.5)

That is, assets retain full efficiency until retirement at time T, the service life of the asset. If straight-line deterioration is adopted then the pattern for the net stock is:

$$\varphi_0 = 1, \varphi_1 = 1 - (1/T), \varphi_2 = 1 - (2/T), \dots \varphi_{T-1} = 1 - [(T-1)/T], \varphi_{T+\tau} = 0 \qquad \tau = 0, 1, 2$$
 (3.6)

For completeness, choosing the exponential distribution, deterioration (and in this instance depreciation) would occur at a constant rate $\delta = (\phi_{t-1} - \phi_t)/\phi_{t-1}$ so that:

$$\varphi_0 = 1, \ \varphi_1 = (1 - \delta), \ \varphi_2 = (1 - \delta)^2, \ \dots \ \varphi_t = (1 - \delta)^t$$
 (3.7)

Note, the exponential distribution is not (directly) determined by the service life of the asset, and only asymptotically declines to zero. Thus under the exponential distribution the efficiency function and the age-price function are identical and deterioration and depreciation are equal.

3.11 Once gross and net stock figures have been calculated, the approach used by Denison (1972) of weighting these in the ratio of three to one was adopted to obtain net stock figures K(t), which incorporate the desired pattern of deterioration, at first slow, followed by more rapid deterioration.¹⁵ Other authors have advocated different deterioration and/or depreciation patterns or an alternative approach to the perpetual inventory method used in this paper. ¹⁶ For instance, Oulton and O'Mahony (1994) use an exponential rate of depreciation (which is equivalent to exponential deterioration) together with the ONS length of life assumptions. They justify the use of the exponential distribution with reference to Hulten and Wykoff (1981), in which the prices of second-hand assets were found to decline geometrically with an asset's age in the US. 17 Oulton and O'Mahony (1994) nevertheless argue that the rise in efficiency of new assets (or equivalently the increased obsolescence of older ones) leads to an overall geometrically declining deterioration pattern even though they accept that for plant and machinery, physical deterioration is unlikely to follow such a pattern (the 'light bulb' or one-hoss shay pattern being more likely). Advocates of the exponential distribution usually favour its use for reasons other than just to take account of obsolescence; e.g., because its is consistent with the economic accounts definition of the capital stock; it is implied by second-hand US capital price data; and it also incorporates various factors that can lead to a wide-band distribution of retirements in practice (e.g., the loss of assets due to fires, explosions, pre-mature scrapping). Hulten and Wykoff (1996) state:

...it may well be true that every single asset in a group of 1000 assets depreciates as a one-hoss shay, but that the group as a whole experiences near-geometric depreciation. This fallacy of composition arises from the fact that different assets in the group are retired at different dates; some may last only a year or two, others ten to fifteen years. When the experience of short-lived assets is averaged against the experience of long-lived assets, and the average cohort experience is graphed, it will look nearly geometric (p. 18).

However, this implies that a number of assets are pre-maturely scrapped, destroyed or 'lost'. That is, many assets have to be short-lived in order to produce an exponential deterioration rate, especially if (as in this paper) pre-mature scrapping due to closure is accounted for separately.

3.12 A simple example demonstrates the implications of using the exponential distribution. If an asset has an average service life of 20 years, then after five years it will typically offer only 33 per cent of the capital services that would be available from a new asset.

After ten years, only 11 per cent of the asset's initial services are available, falling to 3 per cent in year 15. In other words, when deterioration is assumed to be very high in the first few years after installation, a new asset is three times more productive than an asset that is one-quarter of the way through its life. This implies a far higher rate of capitalembodied technical progress than those typically found in the empirical literature (e.g., Kalt, 1978, estimated capital-embodied technical progress at 0.01 per cent per annum for the USA over the 1929-67 period, while Hulten, 1992, reports a figure of 0.3 per cent per annum for 1949-83).

3.13 An alternative approach to the perpetual inventory method that has been suggested is one that centres on the use of a putty-clay model of production (e.g., Coen, 1980; and Anderson and Rigby, 1989). Basically this means using an investment model to impute the 'best' rate of depreciation and service life that fits gross investment data matched to employment levels through time. Besides the untested hypothesis that once installed a capital good requires a fixed amount of labour to operate it, the approach is also subject to other theoretical and empirical limitations (see Fabricant, 1980 for a discussion). 18

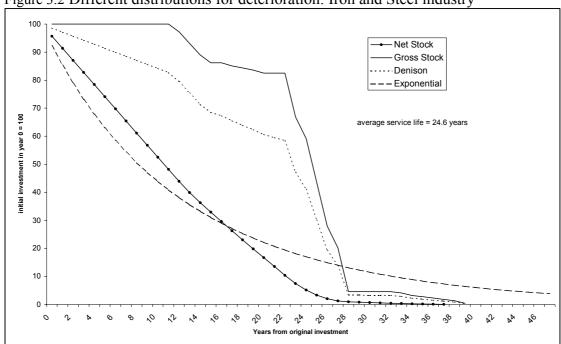


Figure 3.2 Different distributions for deterioration: Iron and Steel industry

Source: Harris and Drinkwater (2000)

To illustrate the use of the Denison deterioration pattern instead of the more frequently 3.14 used exponential pattern, Figure 3.2 shows various outcomes for the Iron and Steel industry following the purchase of a single capital good (costing £100 in real terms). The ONS assumes that investment in any year is sub-divided (in this industry) into 4 sub-groups, each accounting for a different proportion of the total investment and each with a different service life (see Table A1 in the Stage 1 report for details). 19 For

example, 77.9 per cent of the investment is presumed to belong to an asset class where the length of life is 26 years. For Iron and Steel, the average length of life when combining all four sub-groups is 24.6 years. For the net and gross (and thus Denison) stock, assets are assumed to be retired 10 per cent either side of the average length of life of each sub-group. The exponential pattern is based on the ONS length of life of each sub-group and the declining balance rate (*DBR*) derived from Hulten and Wykoff (1981) with $\delta = DBR \div T$.²⁰

- 3.15 Figure 3.2 shows that when the asset is 6 years old (approximately one-quarter of the way through its average length of life), none of the gross stock has deteriorated, 89.9 per cent of the Denison stock remains, 69.8 per cent of the net stock is intact, but only 58.5 per cent of the asset's capital services remain in the exponential measure. At the other extreme, when the asset is 28 years old only 4.6 per cent of the gross stock, 3.4 per cent of the Denison stock, and 1 per cent of the net stock remains; however, 13.1 per cent of the asset is still in place under the exponential distribution. Hence, for an industry like Iron and Steel, where a large amount of investment took place in the 1950-1980 period, if the exponential distribution is used a significant amount of old, non-depreciated capital stock will still remain in place in the post-1980 period.
- 3.16 Thus, this sub-section has presented in some detail how (plant and machinery) capital stock is estimated. Some of the drawbacks of the approach stem from the fact that we do not have direct estimates of depreciation and have instead to rely on length of life assumptions that were collected some time ago (by the ONS). However, it is argued here that without better assumptions and data, the methods used are as robust as any available. Clearly, we use plant level estimates and therefore can take account of scrapping; however, prior to 1970 we have no plant level measures of gross investment to use in the perpetual inventory measure and our disaggregation of industry level estimates of investment for the 1949-1969 period will clearly bias the plant level estimates we use (particularly in the earlier years post-1969, but much less so for estimates for the 1980's and onwards).
- 3.17 Any inaccuracy in the measure of capital stock used when estimating equation (3.1) will result in bias when calculating measures of TFP (cf. equation 3.2). At present we do not know how inaccurate our measure of K_t is (except to say it is probably as accurate as any other that has been constructed, and likely better than most). However, the degree of bias is probably small and in any event is not sufficient to abandon the use of TFP measures vis-à-vis labour productivity measures, given that the latter are 'biased' through increases in factor substitution (see equation 3.3 and the discussion in par. 3.2-3.4).

3.18 Manufacturing industries in the UK generally operate under increasing returns-to-scale. Table 3.1 (taken from Harris, 1999, Table 3)²¹ reports that the mean (median) estimate of the returns-to-scale across 202 4-digit manufacturing industries in the UK was 1.19 (1.17). Thus, larger plants produce more output than do smaller plants.²²

Table 3.1: Elasticities of Output, Returns-to-Scale and Technical Progress in 202 UK Manufacturing industries, 1974-1994

	∂lnY/∂lnK	∂lnY/∂lnE	∂lnY/∂lnE ÷ ∂lnY/∂lnK	RTS	TC	$\beta_{ET} \div \beta_{KT}$
Mean	0.284	0.910	4.143	1.194	0.027	-0.577
Median	0.255	0.896	3.247	1.170	0.021	-1.198
σ	0.183	0.223	2.830	0.236	0.031	78.941
Percentiles						
10	0.102	0.661	1.588	0.917	-0.003	-3.554
20	0.148	0.755	2.088	1.017	0.004	-2.199
30	0.183	0.830	2.327	1.074	0.008	-1.686
40	0.221	0.856	2.758	1.125	0.016	-1.409
50	0.255	0.896	3.247	1.170	0.021	-1.198
60	0.292	0.942	3.949	1.223	0.030	-1.030
70	0.336	0.985	4.760	1.284	0.038	-0.855
80	0.393	1.045	5.799	1.372	0.050	-0.564
90	0.506	1.145	8.113	1.472	0.065	0.337

Source: Harris (1999, Table 3). Based on a value-added frontier translog production function

- 3.19 However, the existence of returns-to-scale (*per se*) as measured through estimating the production function are not necessarily linked to differences in technical efficiency (as conventionally defined by economists see below). If all plants operate efficiently (i.e. with the same knowledge of how to produce using 'best practice' methods) then any increased levels of output produced would reflect the fact that larger plants take advantage of scale economies, rather than they are more efficient. Furthermore, this larger output, which is associated with the exploitation of economies-of-scale, is not reflected in the measurement of TFP, since greater use of factor inputs (resulting in relatively higher levels of output when returns-to-scale are greater than 1) do not feature as a determinant of TFP in equation (3.2).
- 3.20 When plants operate with different levels of efficiency, this is incorporated into the regression error term that needs to be added to equation (3.1) in order to obtain estimates of the parameters of the production function. Thus, measures of TFP do include the impact of (in)efficiency since (3.2) includes all factors affecting output that cannot be attributed to increases in factor inputs (and this includes the regression error

term from (3.1)). But as has already been stated, this is not directly related to the parameters of the production function that measure economies-of-scale (i.e. $\alpha_E + \alpha_M + \alpha_K$). Instead, the link between the size of a plant and TFP can be established through measuring differences in efficiency.

3.21 One method of measuring efficiency (which is included as part of the error term in the production function) is to estimate a frontier production function. That is, the following stochastic translog production function frontier can be estimated for each industry:²³

$$\ln Y_{it} = \beta_0 + \sum_{j=1}^4 \beta_j x_{jit} + \sum_{j\leq k=1}^4 \beta_{jk} x_{jit} x_{kit} + \upsilon_{it} - \varepsilon_{it}$$

$$\upsilon_{it} \sim N(0, \sigma_{\nu}^2)......(3.8)$$

where the subscripts i and t represent the i-th plant and the t-th year of observation, respectively; Y_{it} represents (constant-price) gross output; x_1 represents the logarithm of (constant-price) intermediate inputs; x_2 represents the logarithm of total employment; x_3 represents the logarithm of constant-price plant and machinery capital stock; x_4 represents a time trend to take account of technical progress; and ε_{it} are non-negative unobservable random variables associated with the technical inefficiency of production such that for the given technology and levels of inputs, the observed output falls short of its potential output.

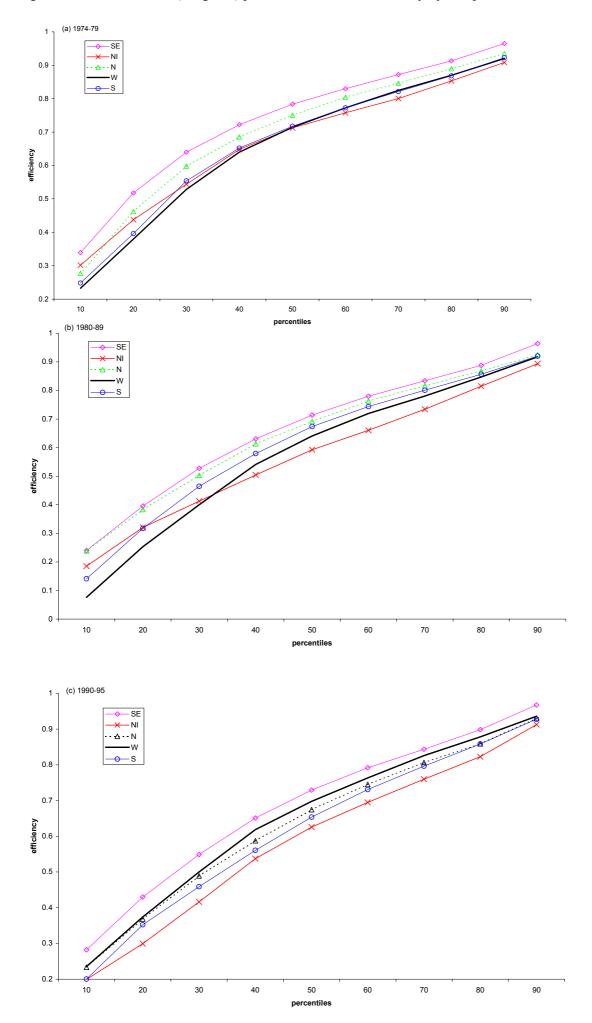
3.22 It is now necessary to set out the determinants of inefficiency, ε_{it} ; in Harris (1999) this was defined as:

$$\varepsilon_{it} = \delta_0 + \sum_{l=1}^6 \delta_l z_{lit} + \omega_{it} \tag{3.9}$$

where z_1 is the logarithm of proportion of workers who are non-manual; z_2 is the logarithm of capital-to-labour ratio; z_3 is the logarithm of age of the plant; z_4 is the logarithm of plant's percentage share in industry output; z_5 is logarithm of population density (persons per hectare) of the Local Authority District in which the plant is located at time t; z_6 is a dummy variable coded 1 if the plant is foreign-owned (where appropriate, this variable is subdivided into different foreign ownership sub-groups); and ω_{it} are unobservable independently distributed random variables.

3.23 Thus, the relative size of the plant (as measured by the variable z₄) is included as a determinant of inefficiency, and the results reported in Harris (1999, Table 4) show that this was indeed a major positive determinant of efficiency levels (a one standard deviation increase in a plant's share in industry output increased efficiency on average by some 25%). However, it is important to note that this is not a 'pure' economies-of-

Figure 3.3: Distribution of (weighted) plant-level technical efficiency by sub-period and certain regions



- scale effect linked to the underlying technology as represented in the production function.
- 3.24 Using data for 1974-1995, Harris (2001) has considered differences in efficiency across the regions of the UK (including the important of plant size). Firstly, Figure 3.3 plots the distribution of (weighted) plant-level technical efficiency by sub-period and certain regions (including Wales); in the 1970's Welsh manufacturing had both a long-tail of plants with low efficiency levels and its best plants performed less well than those in other peripheral regions. However, over time efficiency has improved (see Figure 3.3(b) and (c).
- 3.25 In terms of the relative importance of the various determinants of (in)efficiency (cf. equation 3.9), Harris (2001) estimated a simple model that disaggregates differences between Welsh manufacturing efficiency and that pertaining to the South East of England (details are provided in Appendix 3). A summary of the results are presented in Figure 3.4.

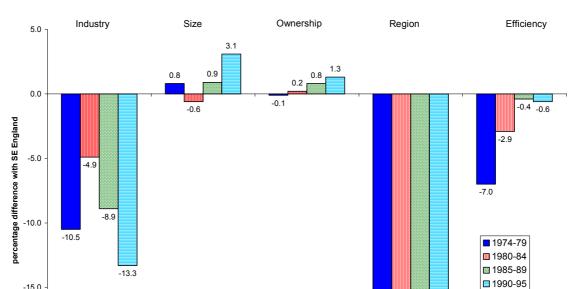


Figure 3.4: Difference in Welsh relative efficiency attributable to various factors

Source: based on Harris (2001)

-19.3-19.3-19.3

3.26 The gap in aggregate efficiency levels between Wales and the South East during the 1974-1979 period was -7 per cent, which was mainly due to the adverse effect of being located in the region (-19.3%) followed by a difference in the Principality's industrial structure when compared with the South East (the latter specialised more in industries

-20.0

with higher average efficiency levels). *Ceteris paribus*, this difference in industrial structures would have resulted in a 10.5 per cent lower level of efficiency, but within Wales inter-industry differences in efficiency (and the negative impact of location) are less important than size in determining aggregate efficiency (hence the overall effect was a gap of only –7 per cent); indeed, size differences and ownership composition actually benefited (or had little impact in) Wales.

- 3.27 Over time, Wales has tended to increase specialisation more in those industries with higher average efficiency levels (although there was a major decline in the early 1990's in this respect), and this in part helps to account for the narrowing of the overall gap in aggregate efficiency between the Principality and the South East. By 1990-95, the major reason for the gap of only -0.6 per cent was the positive effect attributable to plant size, together with an increase that is positively associated with ownership characteristics²⁴ (cf. Figure 3.4).
- 3.28 In summary, the impact of economies-of-scale (in terms of the elasticities that underlie the production function) are not reflected in measures of TFP. But, it is possible to consider the importance of plant size on TFP through the former's impact on efficiency levels. In Welsh manufacturing, the use of relatively large plants (having controlled for certain other characteristics such as ownership and industry composition) does mitigate against other factors that would otherwise result in a significantly lower level of efficiency in Wales vis-à-vis many other UK regions.

Other issues: (b) Impact of factor-biased or (scale-biased) technological change

3.29 There are generally two approaches to measuring whether technological change is embodied in one or other of the various factors of production. The first is to adjust each factor input measure directly for quality enhancing change over time. For instance, in the case of the capital input, the calculation of the quantity of capital services used in the TFP calculation can be based on a price index that reflects quality changes in capital goods. In principle, some effort is made by the ONS to do this; in practice it is unlikely that all the quality enhancing effects are adequately captured (using the aggregate price indices produced by the ONS, and the information available with which to make quality adjustments). The second approach to capturing embodied technological change is to link the time trend included in the production function directly to the various factors of production and thus test whether there is any bias (i.e. differences in the values for these time trends) that would then suggest factor-augmenting technical change.

- 3.30 In both approaches, embodied technological change would be captured by the growth contribution of the factor concerned (e.g., capital) and not by the TFP term (in equation 3.2). The latter would only measure disembodied technical change. However, when quality-enhancement is not taken into account when measuring the factors of production (or if it is imperfectly measured), or when the time trend enters in its disembodied Hicks-neutral form (as in equation 3.1), then both embodied and disembodied technological change will be included in the calculation of TFP.
- 3.31 The measurement of factor inputs used in this study (and in Stage 1) do not adjust for the skill composition of the workforce and (probably) imprecisely take account of obsolescence due to technical change and quality-enhancement through the use of appropriate price indices. Moreover, technological change is represented in equation (3.1) through a time trend not linked directly to any single factor(s) of production. Thus, TFP as measured here probably does pick up most of the embodiment effects of technological change.²⁵
- 3.32 In terms of the potential that innovation (technological change) may be associated with scale, it is generally found that most innovations are introduced into the largest (but also the smallest) plants (see Harris, 1988, for regional evidence for the UK). However, this should not matter in terms of the measurement of TFP as carried out here, since such innovations (whatever the size of plants) should result in increases in output not accounted for by increases in factor inputs, and should thus be captured by equation (3.2).

Other issues: (c) Regional perspective on relative merits of various productivity measures

- 3.33 It might be argued that since profits (and thus the returns to capital) are expatriated back to the controlling company, and since Wales (in common with most RSA-assisted regions of the UK) has a relatively large proportion of its manufacturing base owned from outside the region, it is more appropriate to concentrate on the returns to labour (wages paid and spent locally) rather than the returns to capital. Thus, a labour productivity measure is more 'relevant' than TFP.
- 3.34 However, par. 3.2 has shown that labour productivity is not a straight-forward indicator of improvements in technological change or efficiency. It will increase when the other factors of production increase. Thus, when capital- or intermediate input substitution (away from labour) occurs, labour productivity will increase.
- 3.35 What seems more relevant is to concentrate on improving technology and efficiency in Welsh manufacturing, since this will ultimately improve regional competitiveness and

thus current and future job creation in the Principality. The most appropriate measure of such improvements is TFP, rather than labour productivity (indeed TFP is the major driver of labour productivity that does not necessarily involve reductions in employment – see equation 3.3).

Other issues: (d) Transfer pricing

- 3.36 When independent enterprises trade with each other, market forces determine their commercial and financial relations. When plants or sub-divisions of the same enterprise engage in intra-firm buying and selling of goods and services there is no necessity for the price of these goods and services to mirror what would have been charged if transactions had of been between firms. For multi-national enterprises (MNE's) in particular, there is a presumption that 'transfer' prices may be manipulated upwards in order to reduce profits, and thus tax liabilities.
- 3.37 If transfer prices do not accurately measure the market price for goods and services traded internally within an organisation, then this will impact on our ability to measure the volume of (in particular) intermediate goods and services used in production. Therefore, productivity measures are biased.
- 3.38 The OECD publish guidelines for measuring transfer prices (see OECD, 2001), setting out the procedures for calculating such prices using the 'arm's length principle' of pricing whereby firms (and tax authorities) can adjust prices and profits "...by reference to the conditions which would have obtained between independent enterprises in comparable transactions and comparable circumstances" (OECD, *op. cit.*, par. 1.6).
- 3.39 However, it is recognised that MNE's often produce highly specialised goods and services that often use intangible assets that are difficult (if not impossible) to price. In addition, the joint economies-of-scale enjoyed by the enterprise and the interrelation of diverse activities cannot be easily attributed to sub-divisions and plants (often located in different countries). Indeed, the OECD recognise that such enterprises "...may engage in transactions that independent enterprises would not undertake." (OECD, *op. cit.*, par. 1.10).
- 3.40 In short, accurately measuring transfer prices is difficult in practice (see also Buckley and Frecknall-Hughes, 2000) and discrepancies between such prices and the economic prices that would exist in the market place are hard to detect. Certainly, the data used here (the ARD) offers little information on such issues of measurement. What is determined in the present analysis is that foreign-owned plants are more intermediate intensive when compared to UK-owned plants (see Table 4.2 below), but they also have

higher TFP (see Tables 5.1 and 5.4 below). Thus, if the nominal price of intermediate inputs is inflated through transfer pricing, this does not seem to reduce productivity in foreign-owned plants.

3.41 Conversely, and working against the transfer pricing problem, foreign plants may be purely production platforms whereas domestic plants will often include the overheads associated with the firm (and thus all indirect costs of production). This may impact on our ability to accurately measure productivity (although it is likely that only data for the ARD is collected for all plants that relates to the direct costs of production and neither domestic or FDI plants are asked to supply data not directly related to output and costs associated with manufacturing) but in any case we have no further information on outputs and costs other than that provided in the Annual Business Inquiry

4. Gross Output and Gross Value-added Labour Productivity

- 4.1 The first major issue when considering whether a gross output or gross value-added function should be used, when measuring either TFP or labour productivity, is the appropriate form of the production function. A value-added production function (where intermediate inputs are netted out through subtracting them from gross output) requires the existence of 'separability'. Jorgenson, Gollop and Fraumeni (1987, Chapter 7) show that for US manufacturing, separability is not consistent with the empirical evidence.
- 4.2 A gross output formulation of the production function is specified in equation (3.8), rather than one based on value-added. If this were to be re-formulated as a value-added specification, it would be necessary to test if strong partial separability of capital and labour from intermediate inputs holds. Chambers (1988, section 1c) discusses the properties of separability, while Norsworthy and Malmquist (1983) show that within the context of the translog production function, strong separability involving intermediate inputs (x_1) requires that $\beta_{12} = \beta_{13} = 0$.

Table 4.1: Tests for separability of the translog production function, Welsh manufacturing 1973-1998

Based on equation (3.8) with $\varepsilon_{it} = 0$	H_0 : $\beta_{12} = \beta_{13} = 0$ $\sim F(2, n-1)$	Significance level
Metal manufacturing	15.78	0.000
Extraction of minerals	6.63	0.002
Non-metallic mineral products	29.07	0.000
Chemicals	6.52	0.001
Metal goods nes	14.73	0.000
Mechanical engineering	11.55	0.000
Office machinery & data processing equipment	3.34	0.038
Electrical & electronic engineering	25.35	0.000
Motor vehicles	10.36	0.000
Other transport	11.38	0.000
Instrumental engineering	5.89	0.003
Food	12.66	0.000
Drink & tobacco	3.63	0.027
Textiles	3.56	0.030
Leather & leather goods	1.19	0.317
Footwear & clothing	18.90	0.000
Timber & wooden products	1.28	0.278
Paper & paper products	4.52	0.011
Rubber & plastics	4.51	0.011
Other manufacturing	4.12	0.017

Source: calculations based on the ARD

- 4.3 Using data from the ARD, the translog function (equation 3.8) has been estimated for twenty 2-digit manufacturing sectors using (weighted)²⁶ data for Wales. Note, a non-frontier model was estimated (since this was simpler to estimate and the purpose of the exercise is to test for separability, not a full model of (in)efficiency) with the results relating to the test that $\beta_{12} = \beta_{13} = 0$ given in Table 4.1. These show that only in the leather and leather goods sector, and timber and wooden products, is separability (and thus a value-added function) supported by the data. Thus, a gross value-added function is generally not applicable when considering productivity, since the GVA production function is mis-specified.
- 4.4 The difference between gross output and gross value-added measures of labour productivity is simply (constant-price) intermediate inputs per employee. The greater are intermediate inputs, the greater is outsourcing (see Figure 2.1). Basically, we can identify two major categories of outsourcing: (i) material inputs (reflecting the make-or-buy decision made by the plant, such that the greater the outsourcing of internal production to external suppliers, the greater will be material inputs relative to the internal use of the other factors of production labour and capital); and (ii) external contracting of goods and services (including repairs, hiring and leasing equipment, transport costs, purchases of telecommunication, computer and advertising services, and consultancy, R&D, cleansing, security services etc.).
- 4.5 The question of why firms outsource will be considered below; clearly Figure 3.1 shows that such outsourcing has been increasing steadily in recent decades. However, it should be noted that we have insufficient information to be able to separate out whether increased intermediate inputs into manufacturing have been due strictly to outsourcing (i.e. substitution of externally produced output for internally produced goods and services) and/or whether increasing intermediate usage is a more general trend towards greater use of services and enhancements to the basic product, that increase the overall quality of (and consumer choice for) manufactured goods. Probably both substitution and increasing intermediate inputs have been a feature of the period considered here.
- 4.6 Firms will outsource if there are performance gains to be achieved from saving resources in terms of the internal use of capital and labour, i.e. when the market price for an outsourced activity is lower than the internal marginal cost for that activity. This includes the situation where outside producers are able to produce intermediate products either more cheaply and/or with a higher quality, so enhancing the quality of the final product produced by the firm engaged in outsourcing.²⁷ In short, by outsourcing, firms concentrate on 'core competencies', allowing outside contractors to supply goods that benefit from specialised knowledge and/or economies of scale that are not available to the firm (cf. Heshmati, 2002). Large firms/plants are perhaps more likely to engage in

- this type of activity, and this presumably helps to explain the sharp decline in the average size of plants in manufacturing since the 1970's.
- 4.7 However, the decision to outsource is not only dependent on a narrow consideration of the internal versus external short-run marginal costs of production (i.e. there are transaction costs that also need to be taken into account). Firms prefer to maintain a vertically integrated approach (where they internalise production and decide to 'make' rather than 'buy') when there is a need to closely co-ordinate several (potentially complicated) processes and/or when they wish to maintain greater control over their economic environment (to ensure the supply of goods and services needed when producing their own final product). Essentially, the primary reason for internalising is the absence of competitive markets for products and services needed by the firm (Anderton and Weitz, 1986). If outsourcing requires other firms to invest in specific assets with a large sunk cost element, then there is always a tendency for these firms to act in an opportunistic fashion once they become the source of supply (since they need to cover the sunk cost of their own investments). Conversely, if the firm outsourcing has previously invested in sunk cost assets to produce (internally) the goods and services being considered for outsourcing, there is often a tendency to (erroneously) add some element of these sunk costs to the decision of whether to 'make' or 'buy'. Thus, Roodhooft and Warlop (1999) state that "..."Good" outsourcing decisions require that decision makers are appropriately sensitive to asset specific investments, and appropriately insensitive to sunk costs" (p. 364).
- 4.8 Finally, Gorzig and Stephan (2002) found that outsourcing of internal production was significantly positively related to firm performance when this was measured by a gross output type measure of labour productivity. That is, they found such plants became relatively more efficient over time. However, they also found that such firms also experienced lower profit margins as a result of outsourcing. Since gross value-added is gross output minus intermediate inputs, and is thus more closely related to profitability (i.e. returns to labour and capital), it is likely that the two measures of productivity will provide different results in terms of firm/plant level performance (see section 2).
- 4.9 Turning now to the factors that are associated with the greater use of (constant-price) intermediate inputs per employee (i.e., the difference between gross output and gross value-added productivity measures), Table 4.2 reports the results from regressing log (M/E) on certain characteristics using ARD (weighted) plant level data covering the 1973-1998 period. Separate results are reported for Wales and the UK. Note, the intention is not to produce a model of the determinants of outsourcing, based on theoretical arguments, but rather to summarise the differences in intermediate input intensity across certain variables such as plant size, the age of the plant, ownership

- characteristics, industrial breakdown, and location. Table 4.3 provides the means of the variables, to see if these are different for Welsh manufacturing vis-à-vis the UK.
- 4.10 As expected, foreign-owned plants are more likely to have high levels of intermediate inputs per employee for EU-owned plants, this is on average 69% per cent higher in Wales (compared to UK-owned plants), after controlling for all other factors such as size and age. EU-owned plants in the UK as a whole are also more intermediate intensive, although the effect is slightly lower at 53.7%. (Note, Table 4.3 shows that Wales has proportionately more EU-owned plants compared to the UK average). SE Asian plants operating in Wales are very heavy users of intermediate inputs, although in the UK as a whole such plants have 93% higher intensity compared to UK-owned plants. In summary, foreign-owned plants have much higher levels of intermediate inputs per employee, while on average over the period some 11% of Welsh manufacturing plants were foreign-owned compared to less than 8.5% of all plants operating in the UK. This helps to explain the high levels of outsourcing that are a feature in the Principality.
- 4.11 There are also certain industries that are more intermediate intensive; clearly the benchmark industry (metal manufacturing) is, since most of the parameter estimates for the industries included in Table 4.2 are negative. In addition, non-metallic minerals, chemicals, man-made fibres, and the drink and tobacco industries have high usage of intermediate products. Wales tends to specialise in many of these industries, and has lower specialisation in industries where outsourcing is relatively lower (e.g., metal goods not-elsewhere-specified, mechanical engineering, and paper and products).
- 4.12 The inclusion of regional dummies in the UK regression shows that after controlling for size, etc., the South East (the benchmark region) and East Anglia are particularly intermediate intensive, with Wales and the North West coming next. In terms of subregions of Wales, plants operating in the benchmark area (the eastern M4 corridor) *cet. par.* engage in more outsourcing, while the rest of South Wales (including the Upper Valleys) is the least intermediate intensive. The time trend shows a clear increase in the importance of intermediate inputs, with average growth rates of about 3½% p.a. over the 1974-1998 period in both Wales and the UK.

Table 4.2: Factors determining differences in (constant-price) intermediate inputs per employee, Welsh and UK manufacturing plants, 1973-1998

Dependent variable: log (M/E) β t-value β t-value Constant 10.126 302.3 10.126 1304.8 log Employment 0.009 2.5 -0.008 -10.9 log Age 0.011 1.8 0.005 3.7 Single plant ^a -0.243 -19.8 -0.220 -93.6 SE Asian owned 2.120 14.6 0.930 29.7 EU owned 0.690 18.5 0.537 71.6 US owned 0.261 10.3 0.366 64.7 Commonwealth owned 0.341 8.5 0.594 51.4 Rest of World owned 0.826 3.6 0.316 5.2 Extraction of minerals -0.376 -7.2 -0.143 -11.1 Non-metallic mineral products 0.162 5.4 0.1166 20.2 Metal goods nes -0.458 -20.1 -0.505 -96.1 Mechanical engineering -0.482 -22.9 -0.457 -88.2 Of		Wales		UK	
log Employment 0.009 2.5 -0.008 -10.9 log Age 0.011 1.8 0.005 3.7 Single plant ^a -0.243 -19.8 -0.220 -93.6 SE Asian owned 2.120 14.6 0.930 29.7 EU owned 0.690 18.5 0.537 71.6 US owned 0.261 10.3 0.366 64.7 Commonwealth owned 0.341 8.5 0.594 51.4 Rest of World owned 0.826 3.6 0.316 5.2 Extraction of minerals -0.376 -7.2 -0.143 -11.1 Non-metallic mineral products 0.162 5.4 0.116 15.3 Chemicals 0.217 6.2 0.166 20.2 Man-made fibres 0.041 0.2 0.082 2.6 Metal goods nes -0.458 -20.1 -0.505 -96.1 Metal goods nes -0.482 -22.9 -0.457 -88.2 Office machinery & data proces	Dependent variable: log (M/E)	\hat{eta}	<i>t</i> -value	\hat{eta}	<i>t</i> -value
log Age 0.011 1.8 0.005 3.7 Single plant ^a -0.243 -19.8 -0.220 -93.6 SE Asian owned 2.120 14.6 0.930 29.7 EU owned 0.690 18.5 0.537 71.6 US owned 0.261 10.3 0.366 64.7 Commonwealth owned 0.341 8.5 0.594 51.4 Rest of World owned 0.826 3.6 0.316 5.2 Extraction of minerals -0.376 -7.2 -0.143 -11.1 Non-metallic mineral products 0.162 5.4 0.116 15.3 Chemicals 0.217 6.2 0.166 20.2 Man-made fibres 0.041 0.2 0.082 2.6 Metal goods nes -0.458 -20.1 -0.505 -96.1 Metal goods nes -0.482 -22.9 -0.457 -88.2 Office machinery & data processing equip. -0.482 -22.9 -0.457 -88.2	Constant	10.126	302.3	10.126	1304.8
Single plant ^a -0.243 -19.8 -0.220 -93.6 SE Asian owned 2.120 14.6 0.930 29.7 EU owned 0.690 18.5 0.537 71.6 US owned 0.261 10.3 0.366 64.7 Commonwealth owned 0.826 3.6 0.316 5.2 Extraction of minerals -0.376 -7.2 -0.143 -11.1 Non-metallic mineral products 0.162 5.4 0.116 15.3 Chemicals 0.217 6.2 0.166 20.2 Man-made fibres 0.041 0.2 0.082 2.6 Metal goods nes -0.458 -20.1 -0.505 -96.1 Mechanical engineering -0.482 -22.9 -0.457 -88.2 Office machinery & data processing equip. -0.244 -3.6 -0.251 -21.8 Electrical & electronic engineering -0.560 -27.6 -0.485 -90.4 Motor vehicles -0.391 -13.9 -0.322 -4	log Employment	0.009	2.5	-0.008	-10.9
SE Asian owned 2.120 14.6 0.930 29.7 EU owned 0.690 18.5 0.537 71.6 US owned 0.261 10.3 0.366 64.7 Commonwealth owned 0.341 8.5 0.594 51.4 Rest of World owned 0.826 3.6 0.316 5.2 Extraction of minerals -0.376 -7.2 -0.143 -11.1 Non-metallic mineral products 0.162 5.4 0.116 15.3 Chemicals 0.217 6.2 0.166 20.2 Man-made fibres 0.041 0.2 0.082 2.6 Metal goods nes -0.458 -20.1 -0.505 -96.1 Mechanical engineering -0.482 -22.9 -0.457 -88.2 Office machinery & data processing equip. -0.482 -22.9 -0.457 -88.2 Office machinery & data processing equip. -0.244 -3.6 -0.251 -21.8 Electrical & electronic engineering -0.560 -27.6	log Age	0.011	1.8	0.005	3.7
EU owned 0.690 18.5 0.537 71.6 US owned 0.261 10.3 0.366 64.7 Commonwealth owned 0.341 8.5 0.594 51.4 Rest of World owned 0.826 3.6 0.316 5.2 Extraction of minerals -0.376 -7.2 -0.143 -11.1 Non-metallic mineral products 0.162 5.4 0.116 15.3 Chemicals 0.217 6.2 0.166 20.2 Man-made fibres 0.041 0.2 0.082 2.6 Metal goods nes -0.458 -20.1 -0.505 -96.1 Mechanical engineering -0.482 -22.9 -0.457 -88.2 Office machinery & data processing equip. -0.244 -3.6 -0.251 -21.8 Electrical & electronic engineering -0.560 -27.6 -0.485 -90.4 Motor vehicles -0.391 -13.9 -0.322 -45.8 Other transport -0.521 -15.5 -0.631 <t< td=""><td>Single plant^a</td><td>-0.243</td><td>-19.8</td><td>-0.220</td><td>-93.6</td></t<>	Single plant ^a	-0.243	-19.8	-0.220	-93.6
US owned 0.261 10.3 0.366 64.7 Commonwealth owned 0.341 8.5 0.594 51.4 Rest of World owned 0.826 3.6 0.316 5.2 Extraction of minerals -0.376 -7.2 -0.143 -11.1 Non-metallic mineral products 0.162 5.4 0.116 15.3 Chemicals 0.217 6.2 0.166 20.2 Man-made fibres 0.041 0.2 0.082 2.6 Metal goods nes -0.458 -20.1 -0.505 -96.1 Mechanical engineering -0.482 -22.9 -0.457 -88.2 Office machinery & data processing equip. -0.244 -3.6 -0.251 -21.8 Electrical & electronic engineering -0.560 -27.6 -0.485 -90.4 Motor vehicles -0.391 -13.9 -0.322 -45.8 Other transport -0.521 -15.5 -0.531 -77.6 Instrumental engineering -0.655 -26.0 -0	SE Asian owned	2.120	14.6	0.930	29.7
Commonwealth owned 0.341 8.5 0.594 51.4 Rest of World owned 0.826 3.6 0.316 5.2 Extraction of minerals -0.376 -7.2 -0.143 -11.1 Non-metallic mineral products 0.162 5.4 0.116 15.3 Chemicals 0.217 6.2 0.166 20.2 Man-made fibres 0.041 0.2 0.082 2.6 Metal goods nes -0.458 -20.1 -0.505 -96.1 Mechanical engineering -0.482 -22.9 -0.457 -88.2 Office machinery & data processing equip. -0.244 -3.6 -0.251 -21.8 Office machinery & data processing equip. -0.244 -3.6 -0.251 -21.8 Office machinery & data processing equip. -0.560 -27.6 -0.485 -90.4 Motor vehicles -0.391 -13.9 -0.322 -45.8 Office machinery & data processing equip. -0.560 -27.6 -0.485 -90.4 Motor vehicles	EU owned	0.690	18.5	0.537	71.6
Rest of World owned 0.826 3.6 0.316 5.2 Extraction of minerals -0.376 -7.2 -0.143 -11.1 Non-metallic mineral products 0.162 5.4 0.116 15.3 Chemicals 0.217 6.2 0.166 20.2 Man-made fibres 0.041 0.2 0.082 2.6 Metal goods nes -0.458 -20.1 -0.505 -96.1 Mechanical engineering -0.482 -22.9 -0.457 -88.2 Office machinery & data processing equip. -0.244 -3.6 -0.251 -21.8 Electrical & electronic engineering -0.560 -27.6 -0.485 -90.4 Motor vehicles -0.391 -13.9 -0.322 -45.8 Other transport -0.521 -15.5 -0.531 -77.6 Instrumental engineering -0.655 -26.0 -0.623 -102.2 Food -0.366 -15.6 -0.329 -54.4 Drink & tobacco 0.180 5.0 0.	US owned	0.261	10.3	0.366	64.7
Extraction of minerals -0.376 -7.2 -0.143 -11.1 Non-metallic mineral products 0.162 5.4 0.116 15.3 Chemicals 0.217 6.2 0.166 20.2 Man-made fibres 0.041 0.2 0.082 2.6 Metal goods nes -0.458 -20.1 -0.505 -96.1 Mechanical engineering -0.482 -22.9 -0.457 -88.2 Office machinery & data processing equip. -0.244 -3.6 -0.251 -21.8 Electrical & electronic engineering -0.560 -27.6 -0.485 -90.4 Motor vehicles -0.391 -13.9 -0.322 -45.8 Other transport -0.521 -15.5 -0.531 -77.6 Instrumental engineering -0.655 -26.0 -0.623 -102.2 Food -0.366 -15.6 -0.329 -54.4 Drink & tobacco 0.180 5.0 0.491 51.6 Textiles -0.413 -11.7 -0.534 <td>Commonwealth owned</td> <td>0.341</td> <td>8.5</td> <td>0.594</td> <td>51.4</td>	Commonwealth owned	0.341	8.5	0.594	51.4
Non-metallic mineral products 0.162 5.4 0.116 15.3 Chemicals 0.217 6.2 0.166 20.2 Man-made fibres 0.041 0.2 0.082 2.6 Metal goods nes -0.458 -20.1 -0.505 -96.1 Mechanical engineering -0.482 -22.9 -0.457 -88.2 Office machinery & data processing equip. -0.244 -3.6 -0.251 -21.8 Electrical & electronic engineering -0.560 -27.6 -0.485 -90.4 Motor vehicles -0.391 -13.9 -0.322 -45.8 Other transport -0.521 -15.5 -0.531 -77.6 Instrumental engineering -0.655 -26.0 -0.623 -102.2 Food -0.366 -15.6 -0.329 -54.4 Drink & tobacco 0.180 5.0 0.491 51.6 Textiles -0.413 -11.7 -0.534 -99.6 Leather & leather goods -0.587 -9.4 -0.264 </td <td>Rest of World owned</td> <td>0.826</td> <td>3.6</td> <td>0.316</td> <td>5.2</td>	Rest of World owned	0.826	3.6	0.316	5.2
Chemicals 0.217 6.2 0.166 20.2 Man-made fibres 0.041 0.2 0.082 2.6 Metal goods nes -0.458 -20.1 -0.505 -96.1 Mechanical engineering -0.482 -22.9 -0.457 -88.2 Office machinery & data processing equip. -0.244 -3.6 -0.251 -21.8 Electrical & electronic engineering -0.560 -27.6 -0.485 -90.4 Motor vehicles -0.391 -13.9 -0.322 -45.8 Other transport -0.521 -15.5 -0.531 -77.6 Instrumental engineering -0.655 -26.0 -0.623 -102.2 Food -0.366 -15.6 -0.329 -54.4 Drink & tobacco 0.180 5.0 0.491 51.6 Textiles -0.413 -11.7 -0.534 -99.6 Leather & leather goods -0.587 -9.4 -0.264 -22.4 Footwear & clothing -0.726 -41.5 -0.667	Extraction of minerals	-0.376	-7.2	-0.143	-11.1
Man-made fibres 0.041 0.2 0.082 2.6 Metal goods nes -0.458 -20.1 -0.505 -96.1 Mechanical engineering -0.482 -22.9 -0.457 -88.2 Office machinery & data processing equip. -0.244 -3.6 -0.251 -21.8 Electrical & electronic engineering -0.560 -27.6 -0.485 -90.4 Motor vehicles -0.391 -13.9 -0.322 -45.8 Other transport -0.521 -15.5 -0.531 -77.6 Instrumental engineering -0.655 -26.0 -0.623 -102.2 Food -0.366 -15.6 -0.329 -54.4 Drink & tobacco 0.180 5.0 0.491 51.6 Textiles -0.413 -11.7 -0.534 -99.6 Leather & leather goods -0.587 -9.4 -0.264 -22.4 Footwear & clothing -0.726 -41.5 -0.667 -149.7 Timber & wooden products -0.215 -7.7	Non-metallic mineral products	0.162	5.4	0.116	15.3
Metal goods nes -0.458 -20.1 -0.505 -96.1 Mechanical engineering -0.482 -22.9 -0.457 -88.2 Office machinery & data processing equip. -0.244 -3.6 -0.251 -21.8 Electrical & electronic engineering -0.560 -27.6 -0.485 -90.4 Motor vehicles -0.391 -13.9 -0.322 -45.8 Other transport -0.521 -15.5 -0.531 -77.6 Instrumental engineering -0.655 -26.0 -0.623 -102.2 Food -0.366 -15.6 -0.329 -54.4 Drink & tobacco 0.180 5.0 0.491 51.6 Textiles -0.413 -11.7 -0.534 -99.6 Leather & leather goods -0.587 -9.4 -0.264 -22.4 Footwear & clothing -0.726 -41.5 -0.667 -149.7 Timber & wooden products -0.215 -7.7 -0.289 -44.4 Paper & paper products -0.544 -21	Chemicals	0.217	6.2	0.166	20.2
Mechanical engineering -0.482 -22.9 -0.457 -88.2 Office machinery & data processing equip. -0.244 -3.6 -0.251 -21.8 Electrical & electronic engineering -0.560 -27.6 -0.485 -90.4 Motor vehicles -0.391 -13.9 -0.322 -45.8 Other transport -0.521 -15.5 -0.531 -77.6 Instrumental engineering -0.655 -26.0 -0.623 -102.2 Food -0.366 -15.6 -0.329 -54.4 Drink & tobacco 0.180 5.0 0.491 51.6 Textiles -0.413 -11.7 -0.534 -99.6 Leather & leather goods -0.587 -9.4 -0.264 -22.4 Footwear & clothing -0.726 -41.5 -0.667 -149.7 Timber & wooden products -0.215 -7.7 -0.289 -44.4 Paper & paper products -0.534 -25.9 -0.510 -10.4 Rubber & plastics -0.484 -21.6 -0.379 -61.1 Other manufacturing -0.566 <td>Man-made fibres</td> <td>0.041</td> <td>0.2</td> <td>0.082</td> <td>2.6</td>	Man-made fibres	0.041	0.2	0.082	2.6
Office machinery & data processing equip. -0.244 -3.6 -0.251 -21.8 Electrical & electronic engineering -0.560 -27.6 -0.485 -90.4 Motor vehicles -0.391 -13.9 -0.322 -45.8 Other transport -0.521 -15.5 -0.531 -77.6 Instrumental engineering -0.655 -26.0 -0.623 -102.2 Food -0.366 -15.6 -0.329 -54.4 Drink & tobacco 0.180 5.0 0.491 51.6 Textiles -0.413 -11.7 -0.534 -99.6 Leather & leather goods -0.587 -9.4 -0.264 -22.4 Footwear & clothing -0.726 -41.5 -0.667 -149.7 Timber & wooden products -0.215 -7.7 -0.289 -44.4 Paper & paper products -0.534 -25.9 -0.510 -10.4 Rubber & plastics -0.484 -21.6 -0.379 -61.1 Other manufacturing -0.566 -17.	Metal goods nes	-0.458	-20.1	-0.505	-96.1
Electrical & electronic engineering -0.560 -27.6 -0.485 -90.4 Motor vehicles -0.391 -13.9 -0.322 -45.8 Other transport -0.521 -15.5 -0.531 -77.6 Instrumental engineering -0.655 -26.0 -0.623 -102.2 Food -0.366 -15.6 -0.329 -54.4 Drink & tobacco 0.180 5.0 0.491 51.6 Textiles -0.413 -11.7 -0.534 -99.6 Leather & leather goods -0.587 -9.4 -0.264 -22.4 Footwear & clothing -0.726 -41.5 -0.667 -149.7 Timber & wooden products -0.215 -7.7 -0.289 -44.4 Paper & paper products -0.534 -25.9 -0.510 -101.4 Rubber & plastics -0.484 -21.6 -0.379 -61.1 Other manufacturing -0.566 -17.9 -0.542 -82.5 Rest of S Wales (ex Upper Valleys) -0.110 -8.7	Mechanical engineering	-0.482	-22.9	-0.457	-88.2
Motor vehicles -0.391 -13.9 -0.322 -45.8 Other transport -0.521 -15.5 -0.531 -77.6 Instrumental engineering -0.655 -26.0 -0.623 -102.2 Food -0.366 -15.6 -0.329 -54.4 Drink & tobacco 0.180 5.0 0.491 51.6 Textiles -0.413 -11.7 -0.534 -99.6 Leather & leather goods -0.587 -9.4 -0.264 -22.4 Footwear & clothing -0.726 -41.5 -0.667 -149.7 Timber & wooden products -0.215 -7.7 -0.289 -44.4 Paper & paper products -0.534 -25.9 -0.510 -101.4 Rubber & plastics -0.484 -21.6 -0.379 -61.1 Other manufacturing -0.566 -17.9 -0.542 -82.5 Rest of S Wales (ex Upper Valleys) -0.110 -8.7 - Upper Valleys -0.113 -6.1 -	Office machinery & data processing equip.	-0.244	-3.6	-0.251	-21.8
Other transport -0.521 -15.5 -0.531 -77.6 Instrumental engineering -0.655 -26.0 -0.623 -102.2 Food -0.366 -15.6 -0.329 -54.4 Drink & tobacco 0.180 5.0 0.491 51.6 Textiles -0.413 -11.7 -0.534 -99.6 Leather & leather goods -0.587 -9.4 -0.264 -22.4 Footwear & clothing -0.726 -41.5 -0.667 -149.7 Timber & wooden products -0.215 -7.7 -0.289 -44.4 Paper & paper products -0.534 -25.9 -0.510 -101.4 Rubber & plastics -0.484 -21.6 -0.379 -61.1 Other manufacturing -0.566 -17.9 -0.542 -82.5 Rest of S Wales (ex Upper Valleys) -0.113 -6.1 - Upper Valleys -0.026 -1.6 - Rural -0.075 -5.3 - East Anglia -	Electrical & electronic engineering	-0.560	-27.6	-0.485	-90.4
Instrumental engineering	Motor vehicles	-0.391	-13.9	-0.322	-45.8
Food -0.366 -15.6 -0.329 -54.4 Drink & tobacco 0.180 5.0 0.491 51.6 Textiles -0.413 -11.7 -0.534 -99.6 Leather & leather goods -0.587 -9.4 -0.264 -22.4 Footwear & clothing -0.726 -41.5 -0.667 -149.7 Timber & wooden products -0.215 -7.7 -0.289 -44.4 Paper & paper products -0.534 -25.9 -0.510 -101.4 Rubber & plastics -0.484 -21.6 -0.379 -61.1 Other manufacturing -0.566 -17.9 -0.542 -82.5 Rest of S Wales (ex Upper Valleys) -0.110 -8.7 - Upper Valleys -0.113 -6.1 - North East -0.026 -1.6 - Rural -0.075 -5.3 - East Anglia - -0.056 -14.4 West Midlands - -0.058 -15.6	Other transport	-0.521	-15.5	-0.531	-77.6
Drink & tobacco 0.180 5.0 0.491 51.6 Textiles -0.413 -11.7 -0.534 -99.6 Leather & leather goods -0.587 -9.4 -0.264 -22.4 Footwear & clothing -0.726 -41.5 -0.667 -149.7 Timber & wooden products -0.215 -7.7 -0.289 -44.4 Paper & paper products -0.534 -25.9 -0.510 -101.4 Rubber & plastics -0.484 -21.6 -0.379 -61.1 Other manufacturing -0.566 -17.9 -0.542 -82.5 Rest of S Wales (ex Upper Valleys) -0.110 -8.7 - Upper Valleys -0.113 -6.1 - North East -0.026 -1.6 - Rural -0.075 -5.3 - East Anglia - -0.056 -14.4 West Midlands - -0.056 -15.6 East Midlands - -0.058 -15.6	Instrumental engineering	-0.655	-26.0	-0.623	-102.2
Textiles -0.413 -11.7 -0.534 -99.6 Leather & leather goods -0.587 -9.4 -0.264 -22.4 Footwear & clothing -0.726 -41.5 -0.667 -149.7 Timber & wooden products -0.215 -7.7 -0.289 -44.4 Paper & paper products -0.534 -25.9 -0.510 -101.4 Rubber & plastics -0.484 -21.6 -0.379 -61.1 Other manufacturing -0.566 -17.9 -0.542 -82.5 Rest of S Wales (ex Upper Valleys) -0.110 -8.7 - Upper Valleys -0.113 -6.1 - North East -0.026 -1.6 - Rural -0.075 -5.3 - East Anglia - 0.028 5.0 South West - -0.056 -14.4 West Midlands - -0.058 -15.6	Food	-0.366	-15.6	-0.329	-54.4
Leather & leather goods -0.587 -9.4 -0.264 -22.4 Footwear & clothing -0.726 -41.5 -0.667 -149.7 Timber & wooden products -0.215 -7.7 -0.289 -44.4 Paper & paper products -0.534 -25.9 -0.510 -101.4 Rubber & plastics -0.484 -21.6 -0.379 -61.1 Other manufacturing -0.566 -17.9 -0.542 -82.5 Rest of S Wales (ex Upper Valleys) -0.110 -8.7 - Upper Valleys -0.113 -6.1 - North East -0.026 -1.6 - Rural -0.075 -5.3 - East Anglia - 0.028 5.0 South West - -0.056 -14.4 West Midlands - -0.058 -15.6	Drink & tobacco	0.180	5.0	0.491	51.6
Footwear & clothing	Textiles	-0.413	-11.7	-0.534	-99.6
Timber & wooden products -0.215 -7.7 -0.289 -44.4 Paper & paper products -0.534 -25.9 -0.510 -101.4 Rubber & plastics -0.484 -21.6 -0.379 -61.1 Other manufacturing -0.566 -17.9 -0.542 -82.5 Rest of S Wales (ex Upper Valleys) -0.110 -8.7 - Upper Valleys -0.113 -6.1 - North East -0.026 -1.6 - Rural -0.075 -5.3 - East Anglia - 0.028 5.0 South West - 0.056 -14.4 West Midlands - 0.058 -15.6	Leather & leather goods	-0.587	-9.4	-0.264	-22.4
Paper & paper products -0.534 -25.9 -0.510 -101.4 Rubber & plastics -0.484 -21.6 -0.379 -61.1 Other manufacturing -0.566 -17.9 -0.542 -82.5 Rest of S Wales (ex Upper Valleys) -0.110 -8.7 - Upper Valleys -0.113 -6.1 - North East -0.026 -1.6 - Rural -0.075 -5.3 - East Anglia - 0.028 5.0 South West - 0.056 -14.4 West Midlands0.056 -15.6	Footwear & clothing	-0.726	-41.5	-0.667	-149.7
Rubber & plastics -0.484 -21.6 -0.379 -61.1 Other manufacturing -0.566 -17.9 -0.542 -82.5 Rest of S Wales (ex Upper Valleys) -0.110 -8.7 - Upper Valleys -0.113 -6.1 - North East -0.026 -1.6 - Rural -0.075 -5.3 - East Anglia - 0.028 5.0 South West - -0.056 -14.4 West Midlands - -0.058 -15.6 East Midlands - -0.058 -15.6	Timber & wooden products	-0.215	-7.7	-0.289	-44.4
Other manufacturing -0.566 -17.9 -0.542 -82.5 Rest of S Wales (ex Upper Valleys) -0.110 -8.7 - Upper Valleys -0.113 -6.1 - North East -0.026 -1.6 - Rural -0.075 -5.3 - East Anglia - 0.028 5.0 South West - -0.056 -14.4 West Midlands - -0.058 -37.5 East Midlands - -0.058 -15.6	Paper & paper products	-0.534	-25.9	-0.510	-101.4
Rest of S Wales (ex Upper Valleys) -0.110 -8.7 - Upper Valleys -0.113 -6.1 - North East -0.026 -1.6 - Rural -0.075 -5.3 - East Anglia - 0.028 5.0 South West - -0.056 -14.4 West Midlands - -0.125 -37.5 East Midlands - -0.058 -15.6	Rubber & plastics	-0.484	-21.6	-0.379	-61.1
Upper Valleys -0.113 -6.1 - North East -0.026 -1.6 - Rural -0.075 -5.3 - East Anglia - 0.028 5.0 South West - -0.056 -14.4 West Midlands - -0.125 -37.5 East Midlands - -0.058 -15.6	Other manufacturing	-0.566	-17.9	-0.542	-82.5
North East -0.026 -1.6 - Rural -0.075 -5.3 - East Anglia - 0.028 5.0 South West - -0.056 -14.4 West Midlands - -0.125 -37.5 East Midlands - -0.058 -15.6	Rest of S Wales (ex Upper Valleys)	-0.110	-8.7	_	
Rural -0.075 -5.3 - East Anglia - 0.028 5.0 South West - -0.056 -14.4 West Midlands - -0.125 -37.5 East Midlands - -0.058 -15.6	Upper Valleys	-0.113	-6.1	_	
East Anglia - 0.028 5.0 South West - -0.056 -14.4 West Midlands - -0.125 -37.5 East Midlands - -0.058 -15.6	North East	-0.026	-1.6	_	
South West - -0.056 -14.4 West Midlands - -0.125 -37.5 East Midlands - -0.058 -15.6	Rural	-0.075	-5.3	_	
West Midlands - -0.125 -37.5 East Midlands - -0.058 -15.6	East Anglia	_		0.028	5.0
East Midlands – -0.058 -15.6	South West	_		-0.056	-14.4
East Midlands – -0.058 -15.6	West Midlands	_		-0.125	-37.5
	East Midlands	_		-0.058	
		_			
North West0.034 -10.1		_			

North	_		-0.131	-28.6
Wales	_		-0.036	-7.1
Scotland	_		-0.057	-15.8
Northern Ireland	_		-0.059	-9.5
T (time)	0.036	49.3	0.035	246.1
\overline{R}^2 no. of observations	0.30 29,092		0.30 693,363	

^a Parameter estimates on dummy variables are calculated as e^{β} –1. The benchmark group is UK-owned plants operating in metal manufacturing located in the east M4 corridor sub-region (for Wales) or the South East (for the UK results).

- 4.13 Older plants are more intermediate intensive although the relationship (with an elasticity of 0.011 or 1.1% in Wales) is not very strong (and even weaker in the UK as a whole). A major difference between the Welsh and UK results is that in the former outsourcing increases with the size of the plant (measured in terms of employment), but decreases in the UK. However, the elasticities involved are again rather small, and in general employment size has a small impact in terms of explaining differences in outsourcing. Lastly, plants that do not belong to a larger enterprise are significantly less likely to outsource (intermediate inputs are on average 22-24% lower relative to multiplant enterprises).
- 4.14 In the next section an attempt is made to measure plant-level performance through estimating gross output and gross value-added production functions (using appropriate econometric techniques). This will allow an assessment of whether greater use of intermediate inputs (outsourcing) is associated with higher levels of output.

Table 4.3: Weighted mean values, Welsh and UK manufacturing plants, 1973-1998

	Wales		UK	
	mean	SD	mean	SD
log intermediate inputs per worker	10.164	0.994	10.031	0.969
log Employment	2.831	1.539	2.929	1.466
log Age	2.330	0.895	2.397	0.878
Single plant	0.156	0.363	0.177	0.381
SE Asian owned	0.004	0.064	0.002	0.044
EU owned	0.031	0.173	0.027	0.162
US owned	0.052	0.222	0.043	0.204
Commonwealth owned	0.021	0.143	0.012	0.107
Rest of World owned	0.001	0.029	0.000	0.018
Extraction of minerals	0.006	0.079	0.006	0.078
Non-metallic mineral products	0.139	0.346	0.092	0.289
Chemicals	0.056	0.231	0.056	0.230
Man-made fibres	0.001	0.027	0.001	0.033
Metal goods nes	0.067	0.250	0.071	0.257
Mechanical engineering	0.097	0.296	0.125	0.330
Office machinery & data processing equip.	0.004	0.067	0.007	0.084
Electrical & electronic engineering	0.078	0.268	0.072	0.258
Motor vehicles	0.034	0.180	0.029	0.169
Other transport	0.014	0.118	0.017	0.130
Instrumental engineering	0.022	0.146	0.019	0.135
Food	0.087	0.282	0.072	0.258
Drink & tobacco	0.046	0.209	0.049	0.217
Textiles	0.016	0.125	0.054	0.226
Leather & leather goods	0.003	0.053	0.006	0.080
Footwear & clothing	0.059	0.236	0.072	0.259
Timber & wooden products	0.061	0.239	0.052	0.222
Paper & paper products	0.087	0.282	0.109	0.312
Rubber & plastics	0.066	0.248	0.047	0.212
Other manufacturing	0.015	0.121	0.019	0.138
Rest of S Wales (ex Upper Valleys)	0.319	0.466	_	
Upper Valleys	0.082	0.275	_	
North East	0.138	0.345	_	
Rural	0.216	0.414	_	
	29,092			
no. of observations		69	3,363	

Source: based on calculations using the ARD

5. Determinants of TFP in Welsh Manufacturing

As set-out in the Stage 1 report (and par. 3.1), plant-level total factor productivity for plant *i* in period *t* can be measured using a standard production function approach. If we take a Cobb-Douglas specification, then:

$$y_{it} = \alpha_0 + \alpha_E e_{it} + \alpha_M m_{it} + \alpha_K k_{it} + \alpha_T t + \varepsilon_{it}$$
(5.1)

where y refers to the logarithm of real gross output (in 1990 prices)²⁸ in plant i in time t; e refers to the logarithm of average employment in plant i in time t; m refers to the logarithm of real intermediate inputs²⁹ in plant i in time t; and k refers to the logarithm of plant and machinery capital stock³⁰ in plant i in time t. In order to calculate TFP, a common approach is to obtain estimates of the elasticities of output with respect to inputs (α_E , α_M , and α_K) and then treat TFP as a combination of the residual ϵ_{it} from (5.1) and the time trend, t, which represents technological change Hence, TFP is obtained from:

$$\ln TFP_{it} = y_{it} - \alpha_E e_{it} - \alpha_M m_{it} - \alpha_K k_{it}$$
(5.2)

- 5.2 The usual approach to obtain estimates of α_E , α_M , and α_K is not to estimate the production function but to use cost shares for each factor input (i.e. the ratio of the cost of each input such as the total wage bill to total costs). There are two major difficulties with the cost share approach: (i) data are needed on capital costs (the 'user' cost of capital) and this is not generally available; and (ii) the approach usually implies that the sum of factor input shares in total revenue generated equals 1 (the so-called 'adding-up' condition), which is only consistent with constant returns-to-scale technology and perfect competition in factor and output markets. Thus a less restrictive approach is to estimate (5.1) directly and directly use the estimated output-elasticities in (5.2). This methodology was applied in Harris and Robinson (2002a) using an appropriate GMM methodology.
- 5.3 A problem with estimating (5.1), and using output-elasticities to obtain TFP using (5.2), is that we would then need to model the determinants of TFP in order to answer questions such as whether Welsh manufacturing performs better or worse when compared to other regions. That is, the TFP estimates from equation (5.2) would need to be regressed against a set of determinants (such as locational factors) which do not feature when estimating (5.1) and yet which clearly are not random (even though they are captured in the random term ε_{it} in equation (5.1), where $\varepsilon_{it} \sim \text{n.i.d}(0, \sigma^2)$ is required for efficient and unbiased estimation of the model). Thus, the preferred approach is to directly include the determinants of output (and thus TFP) into equation (5.1), since this

also allows us to test whether such determinants (such as location) are statistically significant. The augmented production function estimated is therefore:

$$y_{it} = \alpha_0 + \alpha_1 m_{it} + \alpha_2 e_{it} + \alpha_3 k_{it} + \alpha_4 t + \beta_1 \ln Ag e_{it} + \beta_2 U S_{it} + \beta_3 E U_{it} + \beta_4 O T H_{it} + \sum_{i=1}^{21} \delta_k I N D_{it} + \sum_{i=1}^{21} \varphi_k R E G_{it} + \gamma_k \mathbf{X}_{it} + \varepsilon_{it}$$

$$(5.3)$$

where the new variables are: the age of the plant (in years)³¹; whether the plant is US, EU or other foreign-owned (coded 1 if true; 0 otherwise); 21 dummy variables covering the (2-digit 1980 SIC) industry sector to which the plant belongs; the standard region where the plant is located; and finally, X_{it} is a vector of any other effects introduced to capture impacts on TFP. Initially, X_{it} is omitted from the baseline specification of (5.3).

- When estimating equation (5.3) based on a gross output specification the variable representing the age of the plant was never statistically significant. In addition, the EU-owned dummy was insignificant, as were a number of industry and region dummy variables. These were therefore omitted from the estimated model (after checking that jointly they were statistically equal to zero).
- 5.5 Equation (5.3) was estimated using panel data methods. That is, the error term in equation (5.3) comprises three elements:

$$\varepsilon_{ii} = \eta_i + t_i + e_{ii} \tag{5.4}$$

with η_i affecting all observations for cross-section unit i; t_t affects all units for time period t; and e_{it} affects only unit i during period t. If e_{it} is serially correlated such that:

$$e_{it} = \rho e_{it-1} + u_{it} \tag{5.5}$$

where u_{it} is uncorrelated with any other part of the model, and $|\rho| < 1$, then equation (5.3) can be transformed into a dynamic form involving first-order lags of the variables and a well behaved error term (see Griffith, 1999, equations 6-8). To allow for potential endogeneity of capital, employment and intermediate inputs, it is appropriate to use the General Method of Moments (GMM) systems approach available in DPD98 (Arellano and Bond, 1998)³², since this is sufficiently flexible to allow for both endogenous regressors (through the use of appropriate instruments) and a first-order autoregressive error term.³³ All data need also to be weighted to ensure that the samples are representative of the population of UK manufacturing plants under consideration.³⁴ The main reason for weighting is the problem of endogenous sampling (see the appendix in Harris, 2002), since stratification in the ARD is based upon employment size and this means that it is likely that the probability of being in the sample is correlated with the

- variables in the model (particularly whether the plant received government assistance and ownership attributes, and thus productivity) and thus correlated with the model's error term (i.e., $E(z|e) \neq 0$, where z is the complete vector of regressors in the model).
- 5.6 The results obtained from estimating (5.3), using manufacturing data from the ARD covering all UK plants operating during 1988-1998 that did not close before 1990, are presented as Model 1 in Table 5.1.35 The sum of the output elasticities on factor inputs (m, e and k) indicate that manufacturing operated with increasing returns-to-scale. It is also clear that the elasticity of output with respect to m is greater than that for e and k. Thus, we can conclude that (with respect to par. 4.14) greater use of intermediate inputs is associated with higher levels of TFP. In addition, US- and other foreign-owned plants were more productive (7.7% in the case of US-owned, and 8.8% for other foreignowned), 36 as were certain industries such as the extraction of minerals and office machinery. Other industries (particularly, those using older technologies) such as food, textiles, leather goods, footwear and clothing, had lower TFP. Plants located in East Anglia, the South West and Scotland (cet. par.) operated with higher levels of TFP (some 6% higher in the case of East Anglia) vis-à-vis other regions not included in (5.2), while Northern Ireland had TFP levels that were 2.2% below the average. Wales had neither higher or lower TFP based on the results shown in Model 1 (Table 5.1).³⁷
- 5.7 Model 2 (Table 5.1) extends Model 1 by including such characteristics as to whether the plant was a single-plant enterprise, and/or operated in an Assisted Area, and/or was in receipt of RSA at any time during the 1990-1998 period. The major differences in these new results is that TFP in Wales is now 1.8% *above* average while Northern Ireland is no longer (statistically) below average. The model 2 results therefore show that it is whether a plant in Wales or Northern Ireland had these additional characteristics, rather than its regional location, that impacts on TFP, given that single-plant enterprises had TFP levels that were 6.5% lower, while Assisted Area and RSA plants operated with TFP levels that were 2.3% and 2.5% lower, respectively.
- In order to help in interpreting the importance of these factors (such as whether a plant was located in an Assisted Area), Table 5.2 reports the share of manufacturing (gross output) that is located in plants operating in Assisted Areas and/or that were in receipt of RSA and/or were single plants. Clearly the majority of (gross) output produced by Welsh manufacturing is located in Assisted Areas, and a relatively high proportion is produced in plants that received RSA (although Scottish and Northern Irish plants were more 'dependent' on RSA).

Table 5.1 Long-run^a weighted system estimates of gross output Cobb-Douglas production function, 1988-1998: UK manufacturing (dependent variable is the natural log of real gross output)

	Mod	lel 1	Mod	el 2	Mod	lel 3	Mod	lel 4	Mod	lel 5
	\hat{eta}	<i>t</i> -value								
<i>In</i> intermediate inputs	0.648	30.08	0.670	26.38	0.648	30.09	0.670	26.36	0.670	26.30
<i>ln</i> employment	0.330	6.14	0.330	3.96	0.330	6.11	0.332	3.85	0.333	3.85
<i>ln</i> capital stock (P&M)	0.140	2.90	0.123	1.69	0.140	2.88	0.121	1.85	0.121	1.86
Гіте	0.001	1.60	0.002	1.56	0.001	1.58	0.002	1.49	0.002	1.49
Country of ownership										
US-owned	0.074	9.68	0.066	8.40	0.074	9.72	0.066	8.46	0.066	8.41
Other FO	0.084	7.63	0.073	6.47	0.084	7.63	0.073	6.46	0.076	6.52
Industry (1980 SIC)										
Extraction of minerals	0.345	4.79	0.361	3.39	0.345	4.78	0.363	3.31	0.364	3.30
Non-metallic mineral products	0.084	1.38	0.092	1.76	0.084	1.38	0.094	1.70	0.095	1.59
Metal goods nes	-0.061	-2.58	-0.050	-1.67	-0.061	-2.58	-0.051	-1.70	-0.051	-1.70
Office machinery & data processing equip.	0.248	8.49	0.235	6.91	0.248	8.48	0.235	6.80	0.234	6.78
Motor vehicles	-0.064	-4.93	-0.065	-3.41	-0.064	-4.93	-0.066	-3.34	-0.066	-3.33
Food	-0.136	-3.40	-0.147	-2.38	-0.136	-3.39	-0.149	-2.32	-0.149	-2.32
Textiles	-0.174	-14.52	-0.162	-12.60	-0.174	-14.52	-0.162	-12.59	-0.016	-1.62
Leather & leather goods	-0.156	-3.48	-0.160	-2.61	-0.157	-3.47	-0.162	-2.55	-0.161	-2.55
Footwear & clothing	-0.172	-2.63	-0.182	-1.81	-0.172	-2.62	-0.184	-1.77	-0.185	-1.78
Timber & wooden products	-0.084	-2.01	-0.090	-1.76	-0.084	-2.01	-0.092	-1.53	-0.092	-1.53
	0.034	4.04	0.039	4.21	0.034	4.03	0.039	4.20	0.039	4.18

Region of UK	Mode	el <u>1</u>	Mod	el 2	Mod	<u>el 3</u>	Mod	<u>el 4</u>	Mod	el <u>5</u>
East Anglia	0.058	7.32	0.052	5.91	0.058	7.32	0.052	5.82	0.052	5.84
South West	0.026	5.57	0.022	4.56	0.026	5.58	0.022	4.59	0.021	4.54
Wales	0.004	0.56	0.018	1.93	_		_		_	
Scotland	0.034	4.68	0.039	4.20	0.034	4.67	0.040	4.14	0.040	4.12
Northern Ireland	-0.022	-2.05	-0.008	-0.74	-0.022	-2.04	-0.009	-0.75	-0.009	-0.78
Other characteristics										
Single plant enterprise	_		-0.063	-2.22	_		-0.064	-2.18	-0.064	-2.18
Assisted Area	_		-0.023	-7.10	_		-0.022	-7.13	-0.023	-7.22
RSA	_		-0.025	-1.87	_		-0.024	-1.73	-0.023	-1.64
Sub-regions of Wales										
M4 corridor east	_		_		0.025	1.37	0.041	1.60	0.042	1.66
Rest of S Wales – excl. Upper Valleys	_		_		-0.029	-2.45	-0.014	-1.01		
Upper Valleys	_		_		0.020	0.68	0.041	1.35	0.052	1.75
North East Wales	_		_		0.011	0.64	0.025	1.43	0.033	1.75
Rural Wales	_		_		0.022	1.20	0.028	1.23		
Rural × US-owned	_		_		_		_		-0.102	-1.57
Rest of S. Wales × EU-owned	_		_		_		_		0.077	2.31
Upper Valleys × EU-owned	_		_		_		_		-0.095	-2.27
Rural × EU-owned	_		_		_		_		-0.052	-1.81
North East Wales × Other FO	_		_		_		_		-0.155	-2.08
Upper Valleys \times RSA	_		_		-		_		-0.109	-2.50

^a Based on a dynamic specification of the production function where y_{t-1} and m_{t-1} were statistically significantly different from zero.

Table 5.2: Shares of manufacturing output in certain sub-groups and UK regions, 1988-1998 (figures are percentages)

(figures are percentages)		East Anglia	South West	Wales	Scotland	N. Ireland	UK
Assisted Area	GO	2.2	11.5	89.5	72.2	100.0	41.6
	GVA	2.1	12.5	89.3	72.3	100.0	39.7
Received RSA	GO	0.4	1.8	12.2	15.3	55.7	6.4
	GVA	0.4	1.7	11.2	15.2	52.9	5.4
Single plant enterprise	GO	15.9	15.3	17.0	19.5	30.4	15.7
	GVA	16.8	16.9	16.3	20.5	36.1	16.6
Extraction of minerals	GO	0.2	0.0	0.1	0.2	0.2	0.2
	GVA	0.4	0.1	0.1	0.3	0.3	0.3
Non-metallic mineral products	GO	3.1	4.2	3.2	2.8	3.6	3.6
•	GVA	4.0	5.2	4.4	3.5	5.1	4.7
Metal goods nes	GO	3.0	3.0	4.7	2.4	2.0	4.1
	GVA	3.2	3.5	4.7	2.9	2.5	4.8
Office machinery & data							
processing equip.	GO	1.4	1.2	1.1	15.1	0.6	3.0
	GVA	1.8	1.8	1.1	13.4	1.2	3.4
Motor vehicles	GO	2.5	3.9	5.7	1.5	2.1	7.7
	GVA	2.9	3.4	5.8	1.2	2.4	6.1
Food	GO	18.1	11.6	5.4	9.3	18.3	8.5
	GVA	13.3	8.0	4.5	7.7	13.1	6.2
Textiles	GO	0.4	1.2	1.0	3.7	7.3	2.9
	GVA	0.5	1.4	1.0	4.4	10.1	3.2
Leather & leather goods	GO	0.2	0.4	0.1	0.5	0.4	0.3
	GVA	0.1	0.4	0.1	0.1	0.1	0.1
Footwear & clothing	GO	1.2	2.5	1.8	2.5	5.7	2.3
	GVA	1.7	2.7	2.4	3.2	9.0	2.8
Timber & wooden products	GO	2.8	2.8	2.3	2.3	3.4	2.3
	GVA	3.3	2.9	2.4	2.1	3.7	2.4
Paper & paper products	GO	8.4	7.8	6.2	7.4	4.6	7.7
	GVA	10.1	8.8	7.0	8.0	6.7	8.6
US-owned	GO	12.0	8.9	13.8	24.5	19.2	15.3
	GVA	12.0	9.6	14.5	24.0	11.8	13.8
EU-owned	GO	9.7	6.4	8.2	7.1	6.5	8.5
	GVA	8.8	5.5	7.8	6.5	6.7	7.3
Other foreign-owned	GO	4.6	3.8	11.6	5.4	4.9	4.3
	GVA	4.9	3.6	9.1	5.8	8.0	3.9

GO= gross output; GVA= gross value-added.

Source: calculations based on the ARD

Table 5.3: Shares of Welsh manufacturing output in certain sub-groups, 1988-1998 (figures are

percentages) Rest of South Wales M4 corridor (excl. upper Upper east North East valleys) Valleys Rural Wales Assisted Area GO 83.2 97.9 99.7 92.7 58.6 89.5 **GVA** 81.2 99.7 93.6 57.8 89.3 97.8 4.9 Received RSA GO 22.9 4.7 11.3 9.1 12.2 5.1 **GVA** 5.1 19.7 9.5 11.5 11.2 US-owned GO 8.9 21.9 11.1 14.2 3.7 13.8 GVA8.5 22.8 10.6 17.0 3.9 14.5 EU-owned GO 3.9 3.4 6.7 8.2 11.9 12.1 2.9 **GVA** 3.2 11.8 10.7 7.1 7.8 Other foreign-owned GO 14.4 19.3 5.4 5.5 2.5 11.6 **GVA** 15.6 12.4 3.7 3.6 2.7 9.1 Single plant enterprise GO 10.6 12.1 22.0 12.0 17.0 22.7 **GVA** 10.1 21.4 10.1 21.3 14.3 16.3

GO= gross output; GVA= gross value-added.

Source: calculations based on the ARD

- 5.9 Model 3 in Table 5.1 drops the dummy for Wales (and omits the additional characteristics just considered) and instead introduces location dummies based on 5 sub-regions of Wales (these are explained in Appendix 1). The only statistically significant effect relates to lower TFP (of 2.9%) for plants located in South Wales excluding the eastern M4 corridor and the Upper Valleys.
- 5.10 Model 4 includes sub-regional dummy variables and controls for whether a plant operated as a single plant, and/or in an Assisted Area and/or was in receipt of RSA. The results confirm that it is generally these characteristics that account for the poorer performance of Welsh manufacturing (and manufacturing in other regions), rather than location itself. (Table 5.3 shows how important such characteristics are across the sub-regions of Wales.) There is some weak evidence that plants located in the eastern M4 corridor (and possibly the Upper Valleys and North East Wales) actually benefit from their location, having controlled for Assisted Area status, whether they received RSA or operated as a single plant.
- 5.11 Finally, Model 5 initially included composite dummy variables that linked the subregion dummies for Wales with foreign ownership, RSA, and single plant status, in order to measure how (and where) these characteristics affected Welsh manufacturing. Only those composite dummy variables that were significant (e.g., EU-owned plants operating in the Upper Valleys) were retained in the model.

- 5.12 There are a number of significant composite dummy variables that were retained in Model 5 (Table 5.1), and these will be discussed presently. However, it is initially worth noting that Model 5 confirms the results reported on in par. 5.10, that plants located in the eastern M4 corridor (and the Upper Valleys and North East Wales) actually benefited from their location, having controlled for Assisted Area status, whether they received RSA or operated as a single plant. However, Table 5.3 shows that there were few plants (producing significant levels of gross output) in the Upper Valleys and North East Wales that were not located in an Assisted Area (and more than 4/5th's of output produced in the eastern M4 corridor was also located in an Assisted Area), and thus the negative impact of being in an Assisted Area (i.e., 2.3% lower TFP) needs to be balanced against the higher TFP due to location in these various sub-regions of Wales.
- 5.13 Model 5 in Table 5.1 shows that plants located in South Wales (excluding the M4 eastern corridor and the Upper Valleys) that were also EU-owned were some 8% more productive, although Table 5.3 indicates that they only accounted for (on average) less than 12% of gross output during the period. Plants located in rural Wales that were US and EU-owned under-performed (in the case of US-owned plants, wiping out the 6.8% advantage that being US-owned provided to UK manufacturing plants; while EU-owned plants in rural Wales were 5.3% less productive). And while being located in the Upper Valleys sub-region was generally beneficial, even after taking into account the negative impact of being in an Assisted Area, plants in this sub-region that were EU-owned and/or received RSA had significantly lower levels of TFP (between 9.1 and 10.3% lower, respectively). Lastly, plants that were owned by other foreign countries (rather than the US or EU) and located in North East Wales had 14.4% lower TFP (although this reduces to lower TFP of around 11% if the overall benefit of being located in North East Wales is also taken into account).
- In general, these results based on estimating TFP using a gross output formulation of the production function show that location *per se* does not suggest that Wales has a productivity problem (when compared to most UK regions). Rather where there is poorer productivity in Wales, it is usually linked to plants being located in Assisted Areas or having received RSA (or being single-plant enterprises). A more detailed model (Model 5) shows that there are some exceptions that point to perhaps greater reasons for concern for, say, the Upper Valleys of South Wales and rural Wales, especially as foreign-owned plants located in such areas have tended to under-perform (when presumably the expectation has been that they will help to improve such areas).

Table 5.4 Long-run^a weighted system estimates of gross value-added Cobb-Douglas production function, 1988-1998: UK manufacturing (dependent variable is the natural log of real gross output)

	Mod	lel 1	Mod	lel 2	Mod	lel 3	Mod	lel 4	Mod	lel 5
	β	<i>t</i> -value	\hat{eta}	<i>t</i> -value						
<i>ln</i> employment	0.776	9.70	0.798	4.87	0.776	9.66	0.800	4.85	0.772	9.70
<i>ln</i> capital stock (P&M)	0.247	3.76	0.235	1.81	0.246	3.74	0.234	1.79	0.251	3.85
In Age	-0.282	-4.72	-0.273	-2.22	-0.282	-4.69	-0.272	-2.19	-0.286	-4.80
Country of ownership										
US-owned	0.193	11.54	0.188	8.15	0.193	11.55	0.187	8.10	0.194	11.68
Other FO	0.152	4.36	0.149	3.33	0.152	4.34	0.150	3.30	0.156	4.37
Industry (1980 SIC)										
Extraction of minerals	0.583	6.42	0.599	3.79	0.582	6.42	0.600	3.80	0.575	6.38
Office machinery & data processing equip.	0.630	8.91	0.624	8.46	0.630	8.90	0.625	8.45	0.627	8.91
Food	-0.391	-9.45	-0.401	-4.94	-0.391	-9.44	-0.401	-4.93	-0.389	-9.47
Drink & tobacco	0.104	2.23	0.106	1.72	0.104	2.23	0.107	1.73	0.100	2.18
Textiles	-0.384	-11.08	-0.389	-7.07	-0.384	-11.06	-0.389	-7.06	-0.381	-11.02
Leather & leather goods	-0.320	-3.08	-0.326	-2.19	-0.320	-3.08	-0.327	-2.19	-0.315	-3.06
Footwear & clothing	-0.259	-2.48	-0.278	-1.36	-0.259	-2.48	-0.280	-1.40	-0.253	-2.45
Paper & paper products	0.021	1.44	0.018	1.72	0.021	1.44	0.018	1.70	0.019	1.62
<u>Region of UK</u>										
East Anglia	0.069	3.47	0.068	3.11	0.069	3.48	0.068	3.12	0.065	3.33
West Midlands	-0.056	-2.47	-0.044	-1.82	-0.056	-2.45	-0.044	-1.79	-0.039	-1.94
Yorks-Humberside	-0.043	-3.21	-0.034	-2.47	-0.043	-3.19	-0.033	-2.44	-0.032	-2.35
North West	-0.040	-2.94	-0.027	-1.85	-0.040	-2.92	-0.027	-1.82	-0.026	-1.79
North	-0.086	-4.33	-0.063	-2.41	-0.086	-4.32	-0.062	-2.41	-0.066	-3.30
Wales	-0.072	-3.83	-0.047	-1.72	_		_		_	
Northern Ireland	-0.149	-6.01	-0.125	-5.11	-0.148	-5.99	-0.125	-5.12	-0.136	-5.58

	Model 1	Mod	<u>el 2</u>	Mod	<u>el 3</u>	Mod	<u>el 4</u>	Mod	<u>el 5</u>
Other characteristics									
Assisted Area	_	-0.029	-3.17	_		-0.029	-3.21	-0.030	-3.42
RSA	_	-0.059	-1.66	-		-0.058	-1.78	-0.048	-1.64
Sub-regions of Wales									
M4 corridor east	_	_		-0.047	-1.21	-0.019	-0.31	_	
Rest of S Wales – excl. Upper Valleys	_	_		-0.098	-3.16	-0.074	-2.06	-0.084	-2.42
Upper Valleys	-	_		-0.050	-0.77	-0.018	-0.28	_	
North East Wales	_	_		-0.068	-1.43	-0.040	-0.57	_	
Rural Wales	-	_		-0.059	-1.73	-0.042	-1.10	_	
Rest of S Wales × EU-owned	-	_		_		_		0.158	2.39
North East Wales × other FO	_	_		_		_		-0.346	-2.74
North East Wales × RSA		_		_		_		0.195	2.44
$Rural \times RSA$	_	_		_		_		-0.423	-2.33
Upper Valleys × single plant	-	_		_		-		-0.343	-2.01

^a Based on a dynamic specification of the production function where y_{t-1} , e_{t-1} and k_{t-1} were statistically significantly different from zero.

- 5.15 While it has been argued that the gross output production function is more applicable when considering such issues as TFP (and the results in Table 4.1 clearly indicate that the gross value-added specification is likely to be mis-specified), equation (5.3) has also been estimated with intermediate inputs netted out. The results are set out in Table 5.4.³⁸
- 5.16 Again, the production function exhibits increasing returns-to-scale and US- and other foreign-owned plants are significantly more productive than UK- or EU-owned plants. Differences across industries are not dissimilar to the gross output results (Table 5.1), but a different regional pattern emerges when (constant-price) gross value-added data is used. Many of the regions associated with development area status under-perform (with Scotland being the exception), and in particular the results for Model 1 (Table 5.4) show that Welsh manufacturing had TFP levels some 7% lower than (for example) the South East and Scotland, with only the North and Northern Ireland performing less well.
- 5.17 Again, when we include whether the plant was located in an Assisted Area or whether it received RSA, regional location itself becomes less important. However, in general Wales still has below average TFP (about 4.6% lower) while plants in Assisted Areas and those that received RSA *additionally* had lower TFP levels of some 2.8% and 5.7%, respectively.
- As to which sub-regions of Wales were the worst performers, Model 3 (Table 5.4) 5.18 shows that South Wales (excluding the eastern M4 corridor and the Upper Valleys) had the lowest TFP levels. When we allow for Assisted Area and RSA status (Model 4), this sub-region still had lower TFP of some 7.1%. Similarly, when various composite dummy variable effects are included (Model 5), this part of South Wales continues to under-perform, except for (cet. par.) EU-owned plants located in the sub-region. Plants that operated in North East Wales that belonged to other foreign-owned companies significantly did worse (29% lower TFP, although this reduces to just over 12% lower TFP if the positive effects on UK manufacturing plants of being other foreign-owned are also included). In contrast, plants that operated in North East Wales that also received RSA did much better. This might suggest that RSA 'leaked' into higher profits, given that the gross value-added measure is more closely linked to profitability than is the gross output measure. Lastly, the results for Model 5 in Table 5.4 show that single-plant enterprises operating in the Upper Valleys were some 29% less productive (cet. par.).

6. Summary and Conclusions

- Based on the agreed terms of reference, after providing some initial background analysis of productivity growth in the regions of the UK, this report considered the following topics:
 - A comparison of total factor and labour productivity measures
 - Estimation of the capital stock
 - The role of economies of scale in measuring TFP and (in)efficiency
 - Factor-biased technological change and measuring TFP
 - Regional perspectives on relative merits of various productivity measures
 - Transfer pricing and measuring TFP
 - Gross output versus gross value-added measures of labour productivity and the importance of outsourcing
 - The determinants of TFP in Welsh manufacturing.
- 6.2 With regard to the background analysis, labour productivity was relatively high (and grew fastest) in Wales during the 1980's and early 1990's, but from 1996 onwards there was a sharp downturn in performance (whichever measure of labour productivity is used). Moreover, the usage of intermediate inputs is generally more intensive in Welsh manufacturing when compared to other regions, and this accounts for much of the difference in performance when gross output and gross value-added measures are compared.
- In Section 3, measures of TFP and labour productivity growth were set out, showing that the former depends on technological change and efficiency while labour productivity also depends on what happens with the other factors of production (i.e. whether intermediate inputs and/or capital are substituted for labour). Thus, the major weakness of using a measure of labour productivity growth, that is primarily intended to capture the impact of improvements in technology and/or efficiency, is that it is also significantly influenced by substitution between the factors of production. In contrast, TFP measures capture the 'pure' impact of shifts in the production possibility curve (due to technical change) or movements towards it (due to improvements in efficiency).
- With regard to estimating the capital stock, the various assumptions and methods used were set out in detail. Some of the drawbacks of the approach stem from the fact that we

do not have direct estimates of depreciation and have instead to rely on length of life assumptions that were collected some time ago (by the ONS). However, it is argued here that without better assumptions and data, the methods used are as robust as any available. Clearly, any inaccuracy in the measure of capital stock used when estimating TFP will result in bias, but at present we do not know how inaccurate our measure of K_t is (except to say it is probably as accurate as any other that has been constructed, and likely better than most). However, the degree of bias is probably small and in any event is not sufficient to abandon the use of TFP measures vis-à-vis labour productivity measures, given that the latter are 'biased' through increases in factor substitution.

- 6.5 When considering economies-of-scale and TFP, it was argued that the impact of economies-of-scale (in terms of the elasticities that underlie the production function) are not reflected in measures of TFP. But, it is possible to consider the importance of plant size on TFP through the impact of size on efficiency levels (and thus TFP). In Welsh manufacturing, the use of relatively large plants (having controlled for certain other characteristics such as ownership and industry composition) does mitigate against other factors that would otherwise result in a significantly lower level of efficiency in Wales vis-à-vis many other UK regions.
- In terms of the impact of factor-biased (or scale-biased) technological change and the measurement of TFP, the measurement of factor inputs used in this study do not adjust for the skill composition of the workforce and with respect to the capital stock (probably) imprecisely take account of obsolescence due to technical change and quality-enhancement through the use of appropriate price indices. Thus, TFP as measured here probably does pick up most of the embodiment effects of technological change. In terms of the potential that innovation (technological change) may be associated with scale, this should not matter in terms of the measurement of TFP as carried out here, since such innovations (whatever the size of plants) should result in increases in output not accounted for by increases in factor inputs, and should thus be captured by our measure of TFP.
- As to whether a labour productivity measure is more 'relevant' than TFP given that much of manufacturing is externally-owned and thus profits are repatriated elsewhere, it is argued that we need to concentrate on improving technology and efficiency in Welsh manufacturing, since this will ultimately improve regional competitiveness and thus current and future job creation in the Principality. The most appropriate measure of such improvements is TFP, rather than labour productivity.
- 6.8 With respect to transfer pricing, it is recognised that if intra-firm trade does not reflect equivalent transactions that take place in the market between independent enterprises,

the result will be biased estimates of productivity. However, insufficient data is available to be able to judge whether transfer prices are biased (what we do show in the report is that foreign-owned plants use more intermediate inputs – which may in part reflect some inflation of the transfer prices of such inputs – but they are also more productive).

- As to whether a gross output or a gross value-added measure of productivity is valid, this depends on whether the production function is separable (i.e. can we separate out the production of value-added using labour and capital from the production of gross output using value-added and intermediate inputs). This is a statistical issue and evidence is presented that firmly rejects the notion that separability is valid.
- 6.10 As to what factors are most important in explaining differences in the use of intermediate inputs per employee (given that the latter is the difference between a gross output and a gross value-added measure of labour productivity), as expected foreignowned plants have much higher levels of intermediate inputs per employee, while on average over the period some 11% of Welsh manufacturing plants were foreign-owned compared to less than 8.5% of all plants operating in the UK. This helps to explain the high levels of outsourcing that are a feature in the Principality. There are also certain industries that are more intermediate intensive; such as metal manufacturing, nonmetallic minerals, chemicals, man-made fibres, and the drink and tobacco industries have high usage of intermediate products. Wales tends to specialise in many of these industries, and has lower specialisation in industries where outsourcing is relatively lower (e.g., metal goods not-elsewhere-specified, mechanical engineering, and paper and products). After controlling for size, etc., the South East and East Anglia are particularly intermediate intensive, with Wales and the North West coming next. In terms of sub-regions of Wales, plants operating in the eastern M4 corridor cet. par. engage in more outsourcing, while the rest of South Wales (including the Upper Valleys) is the least intermediate intensive. Lastly, there has been a clear increase in the importance of intermediate inputs, with average growth rates of about 31/2% p.a. over the 1974-1998 period in both Wales and the UK.
- 6.11 Finally, this report looks at the determinants of TFP in UK manufacturing, *inter alia* to show if Welsh manufacturing performs better or worse than the average. Using manufacturing data from the ARD and SAMIS covering all UK plants operating during 1988-1998 that did not close before 1990, we find that manufacturing operated with increasing returns-to-scale. It is also clear that greater use of intermediate inputs is associated with higher levels of output. In addition, US- and other foreign-owned plants were more productive as were certain industries such as the extraction of minerals and office machinery. Other industries (particularly, those using older technologies) such as

food, textiles, leather goods, footwear and clothing, had lower TFP. Plants located in East Anglia, the South West and Scotland (*cet. par.*) operated with higher levels of TFP while Northern Ireland had TFP levels that were 2.2% below the average. Wales as a location neither resulted in a higher or lower TFP.

- After allowing for the impact of whether plants were located in Assisted Areas, and/or received RSA, and/or were single plant enterprises, it was found that these additional characteristics, rather than being located in Wales *per se*, had more of an impact on TFP. In fact, single-plant enterprises had TFP levels that were 6.5% lower than the average, while Assisted Area and RSA plants operated with TFP levels that were 2.3% and 2.5% lower, respectively. Only when Wales is sub-divided into different areas was it possible to show that plants located in South Wales excluding the eastern M4 corridor and the Upper Valleys had lower TFP (of around 2.9%). Indeed, the most extensive model estimated suggests that plants located in the eastern M4 corridor (and the Upper Valleys and North East Wales) actually benefited from their location, having controlled for the negative impact on TFP of Assisted Area status, whether they received RSA or operated as a single plant.
- 6.13 In summary, the major result obtained with respect to the determinants of TFP shows that location *per se* does not suggest that Wales had a productivity problem (when compared to most UK regions). Rather where there was poorer productivity in Wales, it was usually linked to plants being located in Assisted Areas or having received RSA (or being single-plant enterprises).

Appendix 1

(a) Data Matching

- A1.1 The data used in this study comes from two primary sources: the DTI's SAMIS database and the ARD. The ARD has been discussed extensively elsewhere³⁹ and basically comprises (mainly financial) information⁴⁰ collected from some 14-19,000 establishments (or reporting units) each year, based on a stratified sampling frame that is heavily biased towards the largest establishments. Establishments (and the plants comprising such establishments) can be linked through time to form a panel, and information on the population of establishments (or plants) can be used to weight the data to obtain population estimates.
- A1.2 The DTI's Selective Assistance Management Information System (SAMIS) database for 1990-2000 has records on enterprises that received Regional Selective Assistance and SMART/SPUR grants. In January 2001, the DTI conducted an internal exercise that resulted in them being able to match a large proportion of these records with the Inter-Departmental Business Register (the IDBR), which then allows a link to be established with the ARD. With this IDBR information, we have been able to locate 7,737 observations in SAMIS⁴² for RSA projects that are also uniquely matched to plant-level information in the ARD. In terms of linking SAMIS with the ARD for the various SMART and SPUR schemes, we were able to locate 1,778 unique plants that match in both the datasets. 44
- A1.3 Having matched what we could of the RSA and SMART/SPUR records in the SAMIS database with the ARD, it is possible to look in more detail at the characteristics of the plants that received government assistance. Overall, RSA accounted for about 8.4 percent of average manufacturing employment during 1990-1998, with particular concentrations in Office Machinery, Electrical and Electronic Engineering and Motor Vehicles and Parts. Our combined data shows that RSA plants were considerably larger than non-assisted plants, based on either mean or median plant size (but more particularly the latter, since mean values are skewed by the existence of a small number of big plants in most industries).

(b) Plant-Level Capital Stock

A1.4 Details on the underlying rationale used in calculating economic measures of the capital stock are provided in the text. Using a measure based on the perpetual inventory method, and depreciation rates as specified by the ONS, gross investment data is needed at plant level for every year the plant is in production. Data from the ARD is available

from 1970 (and this is matched to 4-digit estimates of capital stock based on gross investment data provided by the NIESR), although there are problems with tracking plants through time as a result primarily of changes to the business register used by the ONS. The largest problem relates to the change to the IDBR in 1994. The ONS only constructed a partial look-up table to link the old local unit identifiers (known as CSO_REF) to the new local unit identifiers (IDBR_REF). This has resulted in the need to (often manually) match plants using industry SIC and postcode information. The move to the IDBR has resulted in 'new' plants being added to the population of production units in each of the years since 1994, and when updating the database to 1996-98 we still have found it necessary to match plants where the CSO_REF and IDBR_REF codes did not initially link-up.

- A1.5 Only when we had constructed a panel of plants linking data across the 1970-1998 period, covering some 4.5 million units, was it possible to estimate the plant and machinery capital stock for each local unit. This is based on splitting gross investment⁴⁶ for each plant into asset classes (as defined by the ONS), each accounting for a proportion of total gross investment in that year, and then using the perpetual inventory approach and ONS estimated length-of-life for each asset. The length-of-life assumptions and asset classes used are set-out in Table A.1 (taken from Harris and Drinkwater, 2000).
- A1.6 In conclusion, plant level capital stocks were calculated using the method described in this section. This was necessary in order to calculate total factor productivity and the various indices involving the capital stock used throughout this report.

Table A1.1: Definitions of the 18 industries

Industry	Name	SIC80 codes	SIC80 codes Asset class (and %							
			A	В	С	D	Е	F		
1	Iron and steel	221 - 223			13.8	3.7	77.9	4.6		
2	Other metal	210, 224		1.4	10.0	20.0	56.5	12.1		
3	Extraction, bricks,	231-239, 241		3.0	15.0	31.0	28.0	23.0		
	asbestos	-246								
4	Glass, pottery	247, 248		5.0	24.0	19.0	14.0	38.0		
5	Chemicals	251 - 259		3.4	2.7	6.8	56.9	30.2		
6	Man-made fibres	260				2.6	89.7	7.7		
7	Other metal products	311 - 316		1.1	10.9	16.3	61.4	10.3		
8	Electrical engineering	320 - 348		1.4	10.0	20.0	56.5	12.1		
9	Motor vehicles	351 - 353	25.0	2.0		10.0	52.0	11.0		
10	Shipbuilding	361		1.4	10.0	20.0	56.5	12.1		
11	Other vehicles	362 - 365		3.0		13.0	69.0	15.0		
12	Instrumental Engineering	371 - 374		1.4	10.0	20.0	56.5	12.1		
13	Food, drink, tobacco	411 - 429			2.0	22.0	68.0	8.0		
14	Textiles	431 - 442				2.6	89.7	7.7		
15	Clothing, footwear, leather	451 - 456				73.0	4.0	23.0		
16	Timber products	461 - 467				76.0	5.0	19.0		
17	Paper, publishing	471 - 475				4.5	54.5	41.0		
18	Other manufacturing	481 - 495				73.0	4.0	23.0		
Average	Average length of life for asset (in years): $A=5$: $B=12$: $C=14$: $D=10$: $E=26$: $E=27$ Source: ONS									

Average length of life for asset (in years): A=5; B=12; C=14; D=19; E=26; F=37.

(c) Sub-areas of Wales

A1.7 The local-authority codes available in the ARD were used to obtain the sub-regional classification of Wales used in this report. Table A1.2 maps out the local authorities to each sub-region.

Table A1.2 Sub-regions of Wales

Sub-region	Local authorities	LA-codes in ARD
M4 corridor east	Newport, Cardiff, Vale of Glamorgan, Monmouthshire	6220, 6605, 6610, 6215
Upper Valleys	Neath Port Talbot, Merthyr Tydfil, Blaenau Gwent	6715, 6705, 6410, 6205
Rest of South Wales	Swansea, Bridgend, Rhondda Cynon Taff, Torfaen, Caerphilly	6720, 6710, 6415, 6420, 6430, 6405, 6225, 6210, 6425
North East	Flintshire, Wrexham, Denbighshire	6005, 6015, 6030, 6025, 6020
Rural	Pembrokeshire, Ceredigion, Carmarthenshire, Powys, Gwynedd, Conwy, Anglesey	6125, 6130, 6110, 6105, 6115, 6120, 6505, 6510, 6515, 6310, 6315, 6320, 6010, 6305, 6325

A1.8 The major problem when creating these sub-areas was the change in 1994 to the new local authorities (as featured in Table A1.2), while the ARD uses the old local authority areas. However, using data on the populations contained in both the old and the new LA's (taken from various Regional Trends), it was possible to obtain a mapping that was almost one-to-one with respect to the sub-regions. That is, while the old and new LA's did not necessarily match to each other, there was almost no splitting of LA's needed to obtain the sub-regional classification.

Appendix 2

Table A2.1: Comparison of productivity indices used

	Aggreg	ate data ^a	Plant-le	vel data ^b
	Gross output per worker	Gross value-added per worker	Gross output per worker	Gross value-added per worker
South East	3.30	-1.14	2.03	-0.83
East Anglia	0.90	-2.30	0.18	-2.39
South West	4.32	-0.34	2.79	-0.03
West Midlands	2.73	-1.75	1.90	-0.45
East Midlands	3.12	-0.88	1.55	-1.05
Yorks-Humberside	2.92	-3.57	1.33	-2.17
North West	2.22	-4.62	-0.06	-3.24
North West	2.20	-2.41	0.50	-2.66
Wales	1.50	-5.31	1.35	-1.56
Scotland	4.60	1.66	1.07	-0.62
Northern Ireland	-0.29	-1.57	0.88	-0.16

^a Based on (100/8)×
$$\left(\ln \frac{\sum_{i} Y_{i,98}}{\sum_{i} L_{i,98}} - \ln \frac{\sum_{i} Y_{i,90}}{\sum_{i} L_{i,90}}\right)$$
 where *i* refers to plant *i*. See Table 2.1

a Based on
$$(100/8) \times \left(\ln \frac{\sum_{i} Y_{i,98}}{\sum_{i} L_{i,98}} - \ln \frac{\sum_{i} Y_{i,90}}{\sum_{i} L_{i,90}} \right)$$
 where i refers to plant i . See Table 2.1

b Based on $(100/8) \times \left[\sum_{i} \left(\frac{L_{i,98}}{\sum_{i} L_{i,98}} \right) \ln \frac{Y_{i,98}}{L_{i,98}} \right] - \left[\sum_{i} \left(\frac{L_{i,90}}{\sum_{i} L_{i,90}} \right) \ln \frac{Y_{i,90}}{L_{i,90}} \right]$. See Tables 3.2 and 3.3 of

Stage 1 report (Harris, 2003).

Appendix 3: Interregional Differences in Efficiency

- A3.1 A common way to analyse interregional differences in economic conditions is to use 'shift-share' analysis, whereby differences between the region and some 'benchmark' (e.g. the national average) are decomposed into that part that can be explained by differences in industrial structure (or ownership structure, or size, etc.) and the 'residual' that captures all other influences specific to a region. Thus, 'shift-share' analysis is a simple weighting procedure, but one that does not capture the multivariate influence of several factors at once. A better approach would to use analysis of variance, but this can be computationally difficult if there are several covariates (since analysis of variance typically captures all the cross-product variation between the categorical variables, as well as the separate influence of each variable on a single variable of particular importance). An intermediate method (between 'shift-share' and a full analysis of variance) is to estimate a regression model and then to use the predicted values of the variables to compare differences across regions.
- A3.1 That is, the following (weighted) regression equation has been estimated, with the log of efficiency in each plant i in period t (obtained from Harris, 1999) as the dependent variable:

$$\ln e_{i,t} = \alpha + \sum_{s=2}^{103} \beta_s SIC_s + \sum_{r=2}^{11} \delta_r REG_r + \sum_{o=2}^{4} \gamma_o OWNER_o + \sum_{e=2}^{10} \lambda_e SIZE_e + \rho.time$$
 (A3.1)

and where SIC is a vector of 2-digit dummy variables covering 103 (3-digit) industries in manufacturing; REG is a vector of dummy variables for each of the standard UK regions; OWNER is a vector of dummy variables for each of the ownership groups comprising multiplants only operating in the region, plants belonging to enterprises that operated in more than 1 region, and foreign-owned plants; SIZE is a vector of dummies constructed by dividing UK manufacturing plants into 10 equal-sized sub-groups based upon their employment size; and *time* is a simple time trend variable (taking on a value of 1 in 1974). The benchmark group in (A3.1) comprises single enterprise plants in metal manufacturing operating in the South East employing up to 4 workers.

References

- Anderson, J. and B. Weitz (1986) Make-or-buy Decisions: Vertical Integration and Marketing Productivity, *Sloan Management School*, Spring, 3-19.
- Anderson, W. P. and D. L. Rigby (1989) Estimating Capital Stocks and Capital Ages in Canada's Regions: 1961-1981, *Regional Studies*, 23, 117-126.
- Arellano, M. and S. R. Bond (1998) *Dynamic Panel Data Estimation using DPD98 for GAUSS*, mimeo.
- Bahk, B.H., and M. Gort (1993) Decomposing Learning by Doing in New Plants, *Journal of Political Economy*, 101, 561-83.
- Bartelsman, E.J., and P.J. Dhrymes (1998) Productivity Dynamics: U.S. Manufacturing Plants, 1972-1986, *Journal of Productivity Analysis*, 9, 5-34.
- Barna, T. (1962) Investment and Growth Policies in British Industrial Firms, Occasional Paper No. 20, National Institute of Economic and Social Research, Cambridge University Press, Cambridge.
- Buckley, P.J. and J Frecknall-Hughes (2000) Transfer Pricing and Economic Functions Analysis: The Japanese Paradigm, in *Multinational Firms, Cooperation and Competition in the World Economy* by P.J. Buckley (ed.), Macmillan Press, London.
- Chambers, R.G (1988) *Applied Production Analysis: A Dual Approach*, Cambridge University Press, Cambridge.
- Coen, R. M. (1980) Alternative Measures of Capital and its Rate of Return in United States Manufacturing, in Usher D (ed.) *The Measurement of Capital*, 121-48, National Bureau of Economic Research, Studies in Income and Wealth, Vol. 45, University of Chicago Press, Chicago.
- Denison, E. F. (1972) Final Comments, Survey of Current Business, 52, 95-110.
- Disney, R., J. Haskel and Y. Heden, (2000) 'Restructuring and Productivity Growth in UK Manufacturing', mimeo.
- Dhrymes, P.J.(1991) The Structure of Production Technology, Productivity and Aggregation Effects, Center for Economic Studies Paper 91-5, Bureau of the Census, Washington D.C.
- Doms, M.E. (1996) Estimating Capital Efficiency Schedules within Production Functions, *Economic Inquiry*; 34, 78-92.

- Doms, M., T. Dunne and M. J. Roberts, (1995) The Role of Technology use in the Survival and Growth of Manufacturing Industries, *Rand Journal of Economics*, 19, 495-515.
- Fabricant, S. (1980) Comment, in Usher D (ed.) *The Measurement of Capital*, 149-52, National Bureau of Economic Research, Studies in Income and Wealth, Vol. 45, University of Chicago Press, Chicago.
- Gorzig, B. and A. Stephan (2002) Outsourcing and Firm-level Performance, German Institute for Economic Research, Discussion paper 309, DIW Berlin.
- Griffith, R (1999) Using the ARD Establishment Level Data to Look at Foreign Ownership and Productivity in the United Kingdom, the *Economic Journal*, 109, F416-F442.
- Harris, R.I.D. (1988) Technological Change and Regional Development: Evidence from the SPRU Database on Innovations, *Regional Studies*, 22.5, 361-374
- Harris, R.I.D. (1999) Efficiency in UK Manufacturing 1974-1994, mimeographed and http://www.dur.ac.uk/richard.harris/UKeff.pdf
- Harris, R.I.D. (2001) Comparing Regional Technical Efficiency in UK Manufacturing Plants: The Case of Northern Ireland 1974-1995, *Regional Studies*, vol. 35, pp. 519-354
- Harris, R. I. D. and S. Drinkwater (2000) UK Plant and Machinery Capital Stocks and Plant Closures, *Oxford Bulletin of Economics and Statistics*, 62, 239-261.
- Harris, R. I. D. and P. Hassaszadeh (2002) The Impact of Ownership Changes and Age Effects on Plant Exits in UK Manufacturing, 1974-1995, *Economics Letters*, 75, 309-317.
- Harris, R. I. D. and C. Robinson (2001) Research Project on DTI Industrial Support Policies.

 Contract A: An Analysis of Current DTI Industry Support Patterns, mimeo (http://www.dur.ac.uk/richard.harris/DTI A.pdf)
- Harris, R.I.D and C. Robinson (2002a) Evaluation of RSA in Great Britain (see http://www.dur.ac.uk/richard.harris/DTI_Final_Report.pdf)
- Harris, R.I.D (2002) Foreign Ownership and Productivity in the United Kingdom Some IssuesWhen Using the ARD Establishment Level Data, Scottish Journal of Political Economy, 49, 318-335
- Harris, R.I.D and C. Robinson (2002b) Industrial Policy and its effect on Total Factor Productivity in UK Manufacturing: the impact of RSA 1990-1998, mimeo (see http://www.dur.ac.uk/richard.harris/RSA.pdf).
- Harris, R.I.D and C. Robinson (2002c) The Impact of Foreign Acquisitions on Total Factor Productivity: Plant-level Evidence from UK Manufacturing, 1987-1992, *Review of*

- Economics and Statistics, vol. 84, August 2002, pp. 562-568 (see http://www.dur.ac.uk/richard.harris/fo.pdf)
- Harris, R.I.D. (2003) Labour Productivity Growth in Wales 1990-98: Evidence Based on the Annual Respondents Database (ARD): Stage 1: Initial Analyses. Report to the National Assembly for Wales.
- Heshmati, A. (2003) Productivity Growth, Efficiency and Outsourcing in Manufacturing and Service Industries, *Journal of Economic Surveys*, 17, 79-112.
- Hulten, C. R. and F. C. Wykoff (1981) The Estimation of Economic Depreciation Using Vintage Asset Prices: An Application of the Box-Cox Transformation, *Journal of Econometrics*, 15, 367-396.
- Hulten, C. R. (1992) Growth Accounting When Technical Change is Embodied in Capital, *American Economic Review*, 82, 964-980.
- Hulten, C. R. and F. C. Wykoff (1996) Issues in the Measurement of Economic Depreciation: Introductory Remarks, *Economic Inquiry*, 34, 10-23.
- Jefferson, C. W. (1971) Capital Statistics for Irish Manufacturing Industry, Paper No. 60, Economic and Social Research Institute, Dublin.
- Jorgenson, D.W., Gollop, F., and B. Fraumeni (1987) *Productivity and US Economic Growth*, Harvard University Press, Cambridge, MA.
- Kalt, J. P. (1978) Technological Change and Factor Substitution in the United States, 1929-67, International Economic Review, 19, 761-775.
- Kovenock, D. and G.M. Phillips (1997) Capital Structure and Product Market Behaviour: An Examination of Plant Exit and Investment Decisions, *The Review of Financial Studies*, 10, 767-803.
- McGuckin, R.H. and S.V. Nguyen (1995) On the Productivity and Plant Ownership Change: New Evidence from the Longitudinal Research Database, *Rand Journal of Economics*, 26, 257-76.
- McGuckin, R.H. and S.V. Nguyen (2001) The Impact of Ownership Changes: A View from Labor Markets, *International Journal of Industrial Organization*, 19, 739-762.
- Norsworthy, J.R. and D. Malmquist (1983) Input Measurement and Productivity Growth in Japanese and US Manufacturing, *American Economic Review*, 73, 947-967.
- OECD (2001) Transfer Pricing Guidelines for Multinational Enterprises and Tax Administrations, OECD, Paris.

- Olley, G. S. and A. Pakes (1996) The Dynamics of Productivity in the Telecommunications Equipment Industry, *Econometrica*, 64, 1263-97.
- Oulton, N. (1997) The ABI Respondents Database: A New Resource for Industrial Economics Research, *Economic Trends*, 528, 46-57.
- Oulton, N. and M. O'Mahony (1994) *Productivity and Growth: A Study of British Industry,* 1954-1986, The National Institute of Economic and Social research Occasional Papers 47, Cambridge University Press, Cambridge.
- Roodhooft, F. and L. Warlop (1999) On the Role of Sunk Cost and Asset Specificity in Outsourcing Decisions: A Research Note, *Accounting, Organization and Society*, 24, 363-369.
- Triplett, J.E. (1996) Depreciation in Production Analysis and in Income Wealth Accounts: Resolution of an Old Debate, *Economic Inquiry*, 34, 93-115.

Endnotes

⁵ Other forms of the production function (e.g. CES or translog), or indeed a general function, could be used, and the points to be illustrated will not alter in any significant way.

⁶ If a value-added production function were used instead of a gross output function (with VA=Y-M), and constant returns-to-scale imposed with perfect competition in factor and output markets, then (3.3) simplifies to:

$$\dot{y} - \dot{e} = (1 - \alpha_E)(\dot{k} - \dot{e}) + T\dot{F}P \tag{3.3a}$$

which shows that labour productivity growth depends positively on capital deepening and TFP growth.

Of course, this same question arises when calculating TFP - should a gross output or value added production function be used?

The material used here draws heavily on Harris and Drinkwater (2000). It should also be read in conjunction with the Appendix in the Stage 1 report.

⁹ Note, deterioration is not the same as depreciation (the latter measuring capital that is 'used up' in production). As Triplett (1996) shows, deterioration measures the current services lost from using the capital stock in any one period, and thus the loss in potential for next period's production; depreciation measures (in value terms) the lifetime deterioration in the capital stock that reduces the long run income flow from that stock. That is, deterioration refers: "... to the loss of capital services in the following period that arise from the use of the capital good in any period, $t + i^{"}$ while depreciation is "... the diminution of the total stock of services embodied in a capital good because it has been used in production for one period" (p. 100, italics from original). Triplett notes that:

"Capital used up is not the appropriate concept for production analysis... deterioration is not the appropriate definition for the purposes of economic accounts... These are not mere semantic differences, or issues that arise from differences in the use of language; they are conceptual distinctions that arise because the production function use of capital and the economic accounts use are different purposes" (p.

 $^{10}D(t-v)$ can be thought of as an index of decay equal to 1 when t=v, but becoming equal to 0 when t=vv becomes sufficiently large.

¹¹Asset lives decline depending on which 5-year period the asset was purchased between 1950 and 1970 (assets bought since 1970 are assumed to have the same lengths of lives as 1970 assets). For example, the average life assumption for all manufacturing plant and machinery declined from around 29 years in 1949 to 22 years by 1970.

Note, Denison referred to depreciation rather than deterioration, but failed to distinguish between the production analysis use of capital stock and the economic accounts measure.

13 Barna (1962) is concerned with capital stocks in the 1950s, when there was a large amount of heavy

¹⁴Note, there are up to 6 different classes of assets covering plant and machinery capital goods purchased by each of the 18 industries, each with a different average length of life (which also changes over time although post-1970 lives are used throughout in this study). Table A1 in the appendix to the Stage 1 report presents the lengths of life assumptions used since 1970. Gross investment figures by industry were available for the 1948 to 1969 period and individual plant level estimates were available from 1970; see the discussion in the Appendix to the Stage 1 report for details (and/or the appendix to Harris and Drinkwater, 2000).

¹⁵ It is possible to use weighting ratios other than the preferred 3:1 ratio. However, other ratios would move the distribution closer to the distribution for the gross stock or closer to straight-line deterioration, while it is argued here that the Denison approach is more appropriate. Figure 3.2 illustrates this point.

¹⁶ Those interested in an economic accounts measure of capital stock need to measure depreciation. As pointed out in the text, only when the exponential distribution is used do depreciation and deterioration coincide. Thus using the exponential distribution results in an internally consistent measure of capital

Specifically, a report for the DTI entitled Evaluation of RSA in Great Britain (this is available at the following location: http://www.dur.ac.uk/richard.harris/DTI Final Report.pdf)

² The Annual Respondents Database is a panel comprising the production sector of the Annual Business Inquiry (formally the Annual Census of Production).

³ Disaggregating the figures by (2-digit) industry shows that most industries experienced substantial declines in (real) GAV per worker (although in some instances this was because value-added grew by less than employment; in the majority of cases GVA declined faster than employment levels).

⁴ Note, these figures are not the same as those reported in Tables 3.2 and 3.3 from the Stage 1 analysis (see Harris, 2003). The differences reported are set-out in Appendix 2, and essentially relate to the fact that the figures in the Stage 1 report are geometrically weighted averages of plant-level data; the figures reported in this section are aggregate figures for all manufacturing (by region where appropriate).

stock in that the two concepts are then the same (see Jorgenson, 1996, who gives this argument in favour of using the exponential distribution).

- ¹⁷ Such data is not available for the UK, and we would argue that it would not necessarily reflect accurately both wear and tear and obsolescence. This is because second-hand asset price data reflects the impact of depreciation and not just deterioration (the former taking account of deterioration over the entire life of an asset), and it has been argued that using used-asset market price data as an indicator of inuse asset values is problematic if the relatively small number of assets resold in second-hand markets are not of as 'good quality' as those assets that remain with the plants that undertook the initial investment.
- ¹⁸Note, the assumption of 'putty-clay' technology is not essential for this type of approach. For instance, Nadiri and Prucha (1996) jointly estimate a labour-demand equation, based on a normalised variable cost function in which K_t is a determinant, with the following identity: $K_t \equiv I_t + (1 \delta)K_{t-1}$, where I_t denotes gross investment and δ the depreciation rate of capital. The authors found that δ took a value of 0.059 using data on US manufacturing plant and machinery gross investment for 1960-88 (and an initial benchmark estimate of the capital stock).
- ¹⁹ In theory, it is possible to use different lengths of life assumptions (and thus different rates of deterioration). However, we only have information collected by the ONS on which to base asset lives, with no evidence that alternative estimates should be used in their place.
- ²⁰ Oulton and O'Mahony (1994, Table 3.4) provide the estimates of δ employed here. See also Fraumeni (1997) for an explanation of how DBR is combined with asset life to produce rates of deterioration/depreciation.
- ²¹ See http://www.dur.ac.uk/richard.harris/UKeff.pdf
- ²² Note, comparing average plant sizes across the regions of the UK using the data from the ARD does not suggest that Welsh plants are overall larger or smaller in certain industries and certain years there is some limited evidence of a larger scale of production, but overall no clear evidence to show Welsh manufacturing operates with larger plants.
- Note the cross-product terms involving j = k are multiplied by $\frac{1}{2}$ (although not shown in equation 3.8 for convenience).
- ²⁴ In the other major development areas, size and ownership (which have a relatively higher weight in determining aggregate efficiency) tended to have positive impacts by 1990-95.
- ²⁵ It is worth noting that the results reported in the last column of Table 3.1 from Harris (1999) show that, in the majority of cases, technological change is labour-saving, and capital-augmenting.
- ²⁶ Weighted to ensure the data is representative of the underlying population of plants in operation (see Harris, 2002, for a discussion of weighting using the ARD).
- Outsourcing has also been used to explain why manufacturing in developed countries has tended to shift some of its low-skill-intensive parts of production to low-wage cost, labour-abundant countries. Once the low-skill activities have been undertaken in such countries, they are often imported back as intermediate inputs (see Anderton and Brenton, 1999).
- ²⁸ We use 4-digit 1980 SIC price deflators for outputs to obtain real values for gross output.
- ²⁹ We use 4-digit 1980 SIC price deflators for inputs in this instance.
- ³⁰ Updated from Harris and Drinkwater (2000); see also the appendix.
- ³¹ We only have data back to 1970, thus plants predating this base year are given 1970 as their year of opening for the purposes of calculating the age of the plant.
- Note, we use the DPD sub-routine available in PcGive (v10) since it is an updated version of the original DPD programme written by Arellano and Bond.
- ³³ Using the GMM systems approach the model is estimated in both levels and first-differences. This is important, since Blundell and Bond (1999) argue that including both lagged levels and lagged first-differenced instruments leads to significant reductions in finite sample bias as a result of exploiting the additional moment conditions inherent from taking their system approach.
- ³⁴ Note the data had to be weighted prior to use in PcGive (and thus any constant terms were suppressed).
- ³⁵ In terms of model diagnostics, the results (not produced here) show that the instruments used are appropriate (cf. the Sargan (χ^2) test of over-identifying restrictions), and there is no evidence of second-order autocorrelation.
- ³⁶ Note, since the dependent variable is logged, parameter estimates for dummy variables need to be converted into $e^{\hat{\beta}} 1$.
- ³⁷ Note, these results are not strictly comparable to those produced in Table 3.1 in the Stage 1 report, since here we have controlled for industry differences directly and (more importantly) we use data covering the operation of plants (that did not close before 1990) in every year from 1988-1990 (while Table 3.1 in the Stage 1 report only uses data for two years, 1990 and 1998, as well as being aggregated based on equation 1 in the earlier report).

³⁸ Note, in the gross value-added production function, the age of the plant was significant (and negatively related to output – such that doubling the age of the plant reduced TFP by about 14%) but the time trend

(representing technological change) was always insignificant.

39 For a description of the ARD see Oulton (1997), Griffith (1999), and Harris (2002). Analysis using the database covers a range of areas; cf. Disney, Haskel and Heden (2000), Harris and Drinkwater (2000), Harris (2001), Harris and Robinson (2002b), and Harris and Hassaszadeh (2002). The counterpart to the ARD in the US is the Longitudinal Research Database - or LRD - for US manufacturing provided through the US Bureau of Census. This has been analysed fairly extensively in recent years, covering various areas linked to productivity (e.g., Dhrymes, 1991; Bahk and Gort, 1993; and Bartelsman and Dhrymes, 1998); the impact of ownership change on productivity (McGuckin and Nguyen, 1995; McGuckin and Nguyen, 2001); capital efficiency (e.g., Doms, 1996) and entry and exit (e.g., Doms, et. al, 1995; Olley and Pakes, 1996; Kovenock and Phillips, 1997)

⁴⁰ Such as sales, purchases of inputs, as well as the characteristics of respondents in terms of ownership and location.

⁴¹ It covers all the major schemes where expenditure was incurred in the form of financial aid, but in terms of expenditure RSA and SMART/SPUR account for a large proportion of the total.

⁴² These 7,737 observations comprise some 72 percent of the observations that were both linked with the IDBR and belonged to manufacturing. Note, we only had access to the ARD up to 1998 and therefore plants opened after this date (but provided with RSA after 1998) are by definition excluded.

Full details are provided in Harris and Robinson (2001).

- This is consistent with a 62.2 percent success rate in terms of those SAMIS records that were linked to the IDBR and which are in the manufacturing sector.
- ⁴⁵ A more detailed analysis is provided in Chapter 6.1 in Harris and Robinson (op. cit.).

⁴⁶ Including pre-production expenditure.