The Economic Journal, **109** (*June*), F416–F442. Published by Blackwell Publishers, 108 Cowley Road, Oxford OX4 1JF, UK and 350 Main Street, Malden, MA 02148, USA.

USING THE ARD ESTABLISHMENT LEVEL DATA TO LOOK AT FOREIGN OWNERSHIP AND PRODUCTIVITY IN THE UNITED KINGDOM*

Rachel Griffith

Recently the data underlying the Annual Census of Production has been made available to academic economists in the United Kingdom. The data provide information on production activity in the United Kingdom at the plant level. This paper provides some preliminary description of the data and discusses a few of its advantages and some of the problems associated with using it. A brief review of current empirical work using the ARD data is given. A particular application, looking at differences between foreign and domestic-owned establishments, is described in more detail.

The micro data that underlies the Annual Census of Production has recently been made available to academic economists in the United Kingdom. It provides information on the vast majority of production activity undertaken in the United Kingdom at a very disaggregated level. Historically there has been a lack of this type of data in the United Kingdom. This is unlike the United States, where the LRD has been available for quite a while, and countries like Norway where equivalent plant level data has been available.

This paper provides some preliminary description of the data and discusses a few of its advantages and problems associated with using it. A brief review of current empirical work using the ARD data is given. The main section summarises the results from Griffith (1999) which analysing the differences between foreign and domestic-owned establishments production behaviour in the car industry. A final section summarises.

1. The ARD Dataset

The data are from the Annual Census of Production (ACOP) or Annual Business Inquiry (ABI) Respondents Database (ARD) which is held at the ONS office in Newport.[1] The ARD data includes information on output, employment, investment and expenditure on intermediate goods plus a range of other interesting information (see the Appendix for a list of some of the variables). There are three main output variables: gross output, net output and gross valued added. The data on employment include the average number

* I would like to thank Jonathan Haskel, Stephen Machin and an anonymous referee for helpful comments and Ylva Heden, Richard Harris, Isabel Reduto dos Reis and staff at the ONS office in Newport for help in interpreting and using the data. All errors and omission remain the responsibility of the author. For enquiries about access to the ARD data contact the ONS, Room 1.301, Government Buildings, Cardiff Road, Newport South Wales NP9 1XG.

[1] See Oulton (1997) for a description of how the ARD was set up. ARD is similar to the Longitudinal Research Database (LRD) in the United States, see McGuckin (1995) for a description of the LRD, or *http://www.census.gov/ces/data/lrddb.html.*

employed and wages and salaries for two categories of worker – administrative, technical and clerical (ATC) and operatives (Ops). Capital investment is split into three types up until 1992 – plant and machinery, buildings and land, and vehicles. In later years total investment is available. Both acquisitions and disposals of physical equipment are reported, although there is no information on either scrapping or on the stock of capital.[2] The ARD also contains the postcode and local authority within the United Kingdom in which the establishment is located and the nationality of the ultimate owner of the establishment. Some of the ARD data are published in aggregate form (at the 3-digit industry level) in ONS *Business Monitor PA1002* and recent years of the industry level data are available on CD with limited historical information.[3]

The surveys which collect the data are sent out under the Statistics and Trade Act, 1947 and it is a legal requirement that businesses fill them in and return them to the ONS. This survey has been carried out since 1912, and has been conducted annually since 1970. Unfortunately the establishment level data for years prior to 1968 were destroyed. The data from 1970 onwards are available in electronic form.

An establishment is defined as the smallest unit which can provide the full range of data required for the survey. An establishment can consist of several local units. A local unit is a plant at a single geographic location and is said to no longer exist if there is no longer production at that address. Establishments themselves are local units but can also be parents of other local units on whose behalf they report. Both local units and establishments have unique reference numbers which are not meant to change over the period 1970–93 (see Section 2 for some problems with this). Changes in ownership do not result in a change in the establishment or local unit reference number. If a local unit dismantles all of its machinery and moves to a different address this will result in a change of local unit reference number. There is also an enterprise reference which links establishments that are under common ownership or control. Only production establishment are included in the ARD and establishments are asked to exclude any non-production activities.

Establishments include not only privately owned businesses but also some government bodies and other types of institution. The distribution by establishment type over years is shown in Table 1. The vast majority of entries are for companies. The numbers of sole proprietors and partnerships are higher in the years when smaller firms were explicitly sampled more (these were 1984, 1989 and after 1993, see sampling frame below), although there is also a large increase in 1995. The number of public corporations has fallen, although for some reason larger numbers reported in 1987 and 1989. The number of government bodies included in the data is very small over the mid to late

[2] See Oulton and O'Mahony (1994) for a detailed discussion of the issues involved in constructing capital stocks with the aggregated form of the ARD data.

[3] The PACSTAT data is available from HMSO. The ONS will also supply tailor made aggregate data sets for a charge.

Table 1

Number of Establishments by Type

Year	incorporated or company	sole proprietor	partnership	public corporation	central government body	local authority	other or non-profit making body	Total
1980	14,451	–	–	141	40	91	269	15,108*
1981	14,269	–	–	143	38	88	293	14,922*
1982	14,003	–	–	135	38	44	302	14,620*
1983	13,610	–	–	119	40	55	303	14,204*
1984	17,623	116	248	93	1	53	29	18,163
1985	13,561	70	137	98	4	40	26	13,936
1986	13,037	42	123	66	4	46	17	13,335
1987	13,045	28	147	159	6	46	19	13,450
1988	13,245	40	123	82	42	38	17	13,587
1989	18,536	86	288	132	4	46	21	19,113
1990	13,789	49	200	37	46	45	17	14,183
1991	13,702	60	176	25	51	35	16	14,065
1992	13,279	54	168	21	48	29	16	13,615
1993	15,714	255	494	23	51	389	13	16,939
1994	14,835	191	504	23	33	392	15	15,993
1995	14,086	910	1,006	16	8	307	17	16,350

Source: Author's calculations using ARD, the variable is ACP_STAT.

* There are 22 unclassified and 94 co-operative establishments in 1980, 5 unclassified and 86 co-operative in 1981, 15 unclassified and 83 co-operative in 1982 and 77 co-operative establishments in 1983.

1980s, and the number of non-profit making and other bodies declines markedly after 1993.

1.1. *Sampling Frame*

The sampling frame has changed over the years in a number of ways. The ONS send out forms to a sample of establishments on their register, so despite its name this is not really a Census. In 1984 and 1989 there were changes to the way the register was constructed. In 1984 the register was updated to make more use of the VAT registration list held by HM Customs and Excise. This lead to a large increase in numbers sampled (1.3% overall, up by as much as 38% for some groups). The coverage was also extended to include three new SIC codes. The way the register was constructed was changed in 1992 and now the ONS uses the inter-departmental business register (IDBR).[4] The sampling frame and how it has changed is summarised in Table 2.

The concept of the reporting unit for the ARD data has changed over time. Up until 1986 it was the establishment. In 1987 the system of reporting was changed with a shift towards reporting at the enterprise level. In practice, however, companies were given some discretion, and this change does not appear to have made that big of a difference to the size of reporting unit (see Section 2 and also ONS BM1002, para 10). However, the 1993 change in reporting unit seems to have had some impact on the average size of reporting unit (see Section 2).

Table 2
Sampling Frame

Establishment size (number of employees)	1–19	20–49	50–99	100+
1970–1	0 (cut off 11 in some industries)	all above 25	all	all
1972–7	0	all	all	all
1978–9	0	1 in 2	all	all
1980–4	0	1 in 4	1 in 2	all
1984	0	1 in 2 (England) all elsewhere		all
1985–8	0	1 in 4	1 in 2	all
1989	0	1 in 2 (England) all elsewhere		all
1990–2	0	1 in 4	1 in 2	all
1993–5	some	1 in 5	1 in 2	all

Source: ONS documentation on ACOP Respondents Database (ARD) and Oulton (1997).

[4] See Perry (1995) for a description of the IDBR.

The actual distribution of establishments that have reported is not the same as the sampling frame for many reasons. The actual distribution of establishments by size is shown in Table 3. Up until 1993 establishments with 100 or more employees accounted for over half of selected establishments except in the two years 1984 and 1989 when a larger number of smaller establishments were sampled. Prior to 1993 the small number of establishments with fewer than 20 employees arose largely because sampling is based on selected (last year's) employment while the reported data is based on reported (this year's) employment. After 1993 a larger number of small establishments were sampled and establishments with 100 or more employees account for around 40–45% of the selected data. This increase is largely in incorporated establishments but in 1995 also represents a very large increase in the number of sole proprietors and partnerships.

Local units on the register are classified as either selected or non-selected. Selected local units are called establishments, these are the ones sent the forms. Non-selected units consist of those not in the sampling frame, and the children of establishments which will be reported on by their parent. Limited information is available on non-selected units.

Fig. 1 depicts an example of a UK-based multinational with both production and non-production facilities in the United Kingdom and abroad. Data on the two UK-based production establishments would be included in the ARD selected data. The two local units that are part of the first UK-based production establishment would be recorded in the non-selected file. A common code would link the two UK-based production establishments as being owned by the

Table 3

Actual Distribution of Selected Establishments by Number of Employees

Establishment size (number of employees)	1–19	20–49	50–99	100+	Total
1980	198	2,791	3,211	8,908	15,108
1981	276	2,940	3,331	8,375	14,922
1982	267	3,165	3,276	7,912	14,620
1983	308	2,992	3,165	7,739	14,204
1984	512	5,606	4,587	7,806	18,511
1985	150	3,271	2,956	7,559	13,936
1986	220	2,978	2,681	7,456	13,335
1987	235	3,004	2,714	7,497	13,450
1988	134	2,872	2,988	7,593	13,587
1989	285	5,980	5,041	7,807	19,113
1990	201	3,309	3,116	7,557	14,183
1991	265	3,411	3,151	7,238	14,065
1992	440	3,243	2,966	6,966	13,615
1993	2,052	3,917	3,314	7,588	16,871
1994	2,032	3,532	3,173	7,208	15,945
1995	4,263	3,378	2,457	6,246	16,344

Source: Author's calculations using ARD.

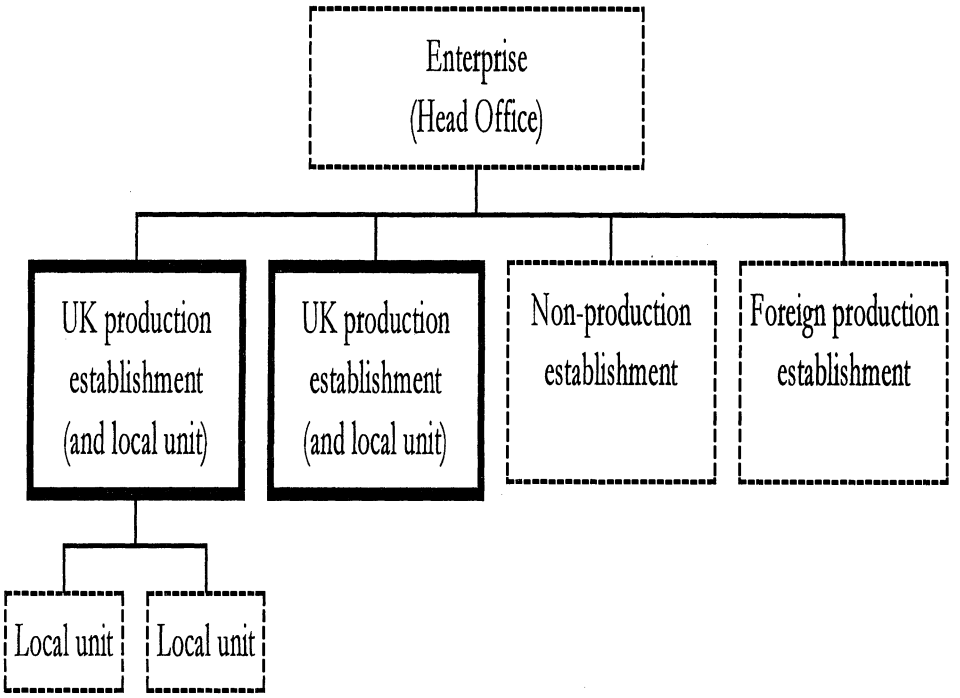

Fig. 1. *Example of Reporting for UK-based Multinational*

same parent enterprise. No information would be contained on any other part of the enterprise.

1.2. *Foreign Ownership*

One particularly interesting feature of the ARD data is the information on nationality of the ultimate parent. This information is collected as part of a separate enquiry and is linked through the inter-departmental business register (IDBR). The ownership data is updated using information the ONS obtains from establishments directly, and through a regular enquiry using information from Dun & Bradstreet's Who Owns Whom database.

Fig. 2 shows the proportion of establishments, output, employment and investment in the selected ARD data on incorporated establishments that is accounted for by foreign-owned establishments. The proportion of foreign-owned establishments remains fairly constant around 10%, employment rises slightly from 20% to 22% and value added rises from 24% to 27%. Investment is more variable and ranges between 21% and 35%.

Most empirical work that has addressed the issues of where firms locate production and how multinational investment affects economic conditions has used data on the flows or stocks of foreign direct investment. However, foreign

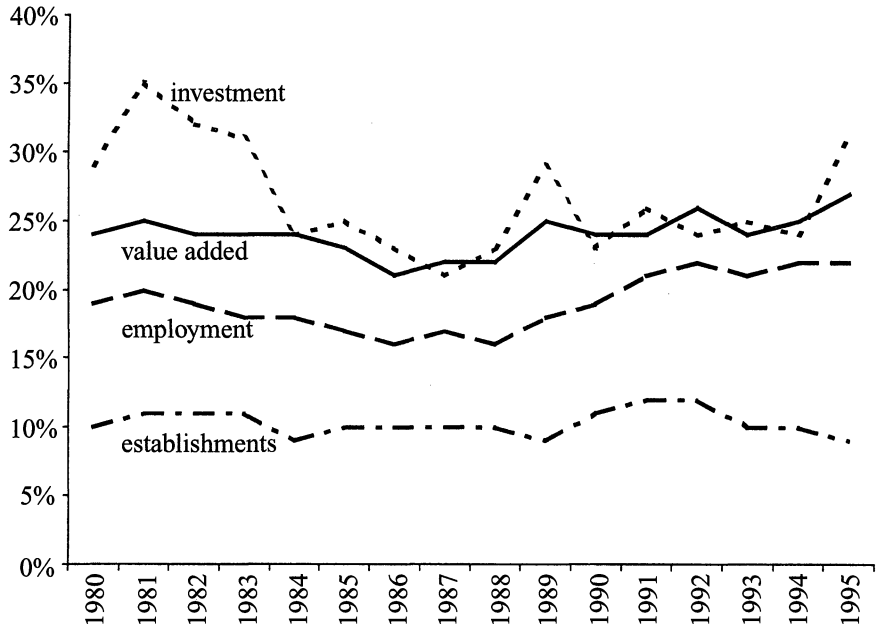

Fig. 2. *Foreign-owned Establishments % of Selected Data*

production (or even investment by foreign-owned firms) and foreign direct investment are not the same thing. The former is a measure of the amount of real activity that is undertaken by a firm that is resident in another country, while the latter is a measure of the flow of financial capital. They will differ to the extent that foreign-owned establishments finance expenditure from local capital markets and repatriate profits to the parent country. This difference is pointed out by Auerbach and Hassett (1993) and Grubert and Mutti (1991) show that the two series are unrelated using data on US firms investment in Canada. Griffith (1999) illustrates this point by comparing foreign direct investment (FDI) into the United Kingdom to expenditure on physical capital by foreign-owned establishments (ForCapEx) in the United Kingdom.

Table 4 shows how output is broken down between different nationalities of ownership in four years. While the proportion of output by foreign-owned establishments has remained fairly constant (rising slightly) the composition has changed somewhat. US-owned establishments accounts for by far the largest proportion throughout the period. Dutch-owned declines from just over 3% to around 1% while French and Japanese-owned both increase by over one percentage point. Employment shows a similar pattern, while net capital expenditure by US-owned establishments falls from around 20% to around 12% while the domestic-owned proportion rises. The striking feature of Table 4 is how little change there is in the proportion of economic activity accounted for by foreign-owned establishments.

Table 4

Proportion of Output in ARD Selected Data by Nationality of Owner

	1980	1984	1988	1992
Domestic	0.721	0.730	0.740	0.697
US	0.190	0.194	0.177	0.178
Canadian	0.017	0.017	0.013	0.015
Dutch	0.032	0.008	0.006	0.010
Swiss	0.010	0.009	0.009	0.013
French	0.009	0.008	0.011	0.025
Japanese	0.001	0.002	0.007	0.019
Other foreign	0.021	0.034	0.037	0.042

Note: The proportions are of output in the selected ARD data, it is the non-grossed up Census of Production data (since grossing up factors are not available by ownership).
Source: Author's calculations using ARD.

2. Some Problems with the Data

The ARD is one of the most disaggregated panel data sources available on company behaviour in the United Kingdom, and it is because of this that it is so useful. However, as with all data sources, there are some problems with the ARD data. Some of these are related to the coding of variables and the longitudinal nature of the data, while others are related to how the data are interpreted. A few of the problems that have come to light as empirical researchers have started using the micro data are discussed here. This is not an exhaustive list but is simply meant to illustrate some of the difficulties that have arisen. Researchers using the data should be wary of these and other potential problems that will arise.

The annual returns of establishments have been linked across years so that there is a panel for over 20 years for some variables. The fact that these data are longitudinal – that we have information on a large number of individual establishments over a large number of years – means that many economic issues can be investigated using the latest econometric methods. However, when the ONS collected the data it was not with the intention of constructing a longitudinal panel. Because of this continuity of establishment and enterprise identifiers has not always been maintained.

Examples of this sort of problem include the fact that establishment codes where changed in 1993 and the mapping between 1993 and 1994 is far from perfect. In 1984 a large number of enterprise group numbers were changed, and it appears that no record linking 1983 codes to 1984 codes was kept. This means that it is very difficult to identify changes in ownership in 1984 or the following two years as it seems that the recoding happened with a time lag for some enterprises. Table 5 shows the extent of this problem.

Another example is the fact that many non-selected establishments identi-

Table 5

Proportion of Establishments with Enterprise Reference Different from Previous Year's

Year	% of selected establishments
1981	3.3
1982	4.6
1983	5.8
1984	58.3
1985	35.7
1986	18.4
1987	12.4
1988	11.0
1989	9.8
1990	10.1
1991	10.9
1991	8.6

Source: Author's calculations using ARD.

fiers were recoded in 1984 and 1992. The data from 1980 to 1993 are reasonably straightforward to use as a panel.[5]

Several additional problems arise when the ARD data are matched with other data sets. One straight forward problem is timing, the ARD data do not always correspond to a calendar year, and even some information given in the ARD data does not correspond to the same time period as the other data. For example, the information on ownership is not collected at the same time as the Census information. There is some information on the period to which the data apply given in the ARD.

Changes in industry coding also present a challenge for researchers who either want to aggregate the data themselves or who want to matching in industry level data from other sources. The ARD data spans two major revisions in industry classification in 1980 and 1992. Establishments in the transition years have both classifications and it is possible to use this information to construct smooth transitions but it takes some effort.

An issue of interpretation arises over whether the aggregation of information from the plant to the establishment level is meaningful. Table 6 shows the average number of local units accounted for by establishments of different size (an establishment reporting only on its own activities will have a value of 1). It is clear that larger establishments are made up of a greater number of local units. In this sense it is not clear that the distinction between establishments of different sizes is meaningful as an indicator of the size of the production

[5] Although some minor problems arise, such as data for 1993 being in £1,000 while for all other years in pounds.

Table 6

Average Number of Local Units per Selected Establishment

Establishment size (number of employees):	<100	100–199	200–299	300–499	>500	Total
1980	1.3	1.5	1.8	2.0	3.7	1.8
1981	1.3	1.6	1.8	2.2	3.7	1.8
1982	1.3	1.5	1.8	2.3	3.7	1.8
1983	1.3	1.6	1.8	2.4	3.8	1.8
1984	1.2	1.5	1.9	2.2	3.8	1.6
1985	1.3	1.6	1.9	2.2	3.7	1.8
1986	1.2	1.5	1.9	2.2	3.7	1.7
1987	1.2	1.6	2.1	2.3	4.0	1.8
1988	1.2	1.7	2.1	2.3	4.3	1.9
1989	1.2	1.7	2.1	2.4	4.4	1.7
1990	1.2	1.7	2.1	2.5	4.6	1.9
1991	1.2	1.7	2.0	2.6	4.8	1.9
1992	1.3	1.7	2.0	2.4	5.1	1.9
1993	1.2	1.6	1.9	2.2	4.5	1.7
1994	1.3	2.0	2.7	3.1	8.9	2.4
1995	1.3	2.1	2.8	3.3	9.1	2.4

facility, it appears to represent a difference in the level of aggregation at which firms choose to report. On the other hand, it could be that the decision (by the firm) at what level to report represents the level at which decisions are taken. More worryingly perhaps is the fact that the numbers vary over time and jump up in 1994, particularly for larger establishments. This appears to be due to change in the level of reporting from the establishment to the enterprise (or company) level. This will be an issue of more or less concern depending on the empirical application.

3. Current Work Using the ARD Data

Several researchers are currently using the ARD data to look at a range of issues. There is not scope in this short article to provide a comprehensive survey but in order to give a flavour of the type of work that is possible a few are described here.

Oulton (1998*a*) examines the role that plant closure and down-sizing during two cycles, 1973–79 and 1979–89, had on productivity levels. He finds that plant closures did not play a big role in productivity growth – while firms that closed were low productivity they were replaced by low productivity entrants. Most productivity growth occurred in a small number of large establishments that downsized employment.

Oulton (1998*b*) examines investment and productivity patterns in 1,752 establishments that were in existence for the entire 21 year period 1973–93. He finds that capital intensities vary widely across establishments, and that the

neo-classical view that the elasticity of output with respect to capital is equal to capital's share cannot be rejected. He finds that foreign-owned establishments have higher value-added per worker and that this can be partly explained by higher levels of human capital.

Haskel and Heden (1999) have used the ARD to investigate skill upgrading. Using the information on manual (operatives) and non-manual (administrative, technical and clerical) workers they calculate the extent to which the increased use of skilled (non-manual) labour is due to skill upgrading within firms, movements of skilled labour between firms and entry and exit of firms. They find that around half of aggregate skill upgrading can be explained by increased employment of skilled workers within firms (the rest is due to changes between firms and the entry of new firms, who were predominantly more skilled than average). To investigate the within-firm effects, they use the information that is available on computerisation in 1986 and 1988. They find that skill upgrading was faster in more computer-intensive industries, supporting the idea that computers are complementary to skilled labour.

Disney *et al.* (1999) are also using the data set to analyse the impact of entry and exit of firms. They are combining the selected and non-selected data to calculate entry and exit over the 1970s and 1980s. Changes in the local unit and establishment identifiers and in the sampling frame make this difficult. They are able to document entry by new firms, expansion by existing firms, and switches by firms into a new industry. They document that industries with large entry rates also have large exit rates, as has been found for the United States. They are also able to document the behaviour of cohorts of entrants. About 50% of the cohort of new entrants exits within the first three years. But, not surprisingly, the survivors grow disproportionately large. They are also looking in more detail at the impact of entry and exit on skill upgrading and skilled-unskilled wage differentials.

Harris and Drinkwater (1998) use the ARD data to examine how important plant closures are in constructing industry level capital stock series. They construct capital stocks at the establishment level and use this data to construct adjusted capital stock series that account for plant closures by removing their capital stock from the aggregate. They find that using the perpetual inventory method from 1974 to 1993 the unadjusted capital stock series is around 44% higher than the stock adjusted for closures. They then look at how this affects the measurement of total factor productivity at the industry level and show that it will lead to significant bias. This work is part of a larger research project looking at efficiency, profitability and pollution control.

Hildreth and Pudney (1998) consider the statistical problems involved in the econometric analysis of data formed by linking the UK New Earnings Survey (which surveys workers) and the ARD data (which has information on employers). In a separate paper Hildreth and Pudney (1999) describe the composition of newly-hired workers by age, sex and previous labour market status.

My own work is summarised in the next section.

4. Analysing Differences in the Production Behaviour of Foreign and Domestic-owned Establishments in the Car Industry

Griffith (1999) analyses differences in the production behaviour of domestic and foreign-owned establishments by estimating production functions at the establishment level using the ARD data. The ARD data shows, as many other data sources do, that the 1980s were a time of rapid growth in labour and total factor productivity in many industries in the United Kingdom.[6]

This period of productivity growth coincided with many changes to the UK economy – the weakening of labour unions, rapid shakeouts of firms in the early 1980s recession, computerisation and increases in the quality of the labour force. Rapid productivity growth also coincided with an increase in the inward flow of foreign investment. One of the main strands of the theoretical literature in this area predicts that multinational firms will be more productive and concentrated in knowledge-intensive industries.

Differences in technological knowledge and ability across countries have been seen as a possible source of differences in productivity levels since at least the work of Gerschenkron (1962) and Nelson and Phelps (1966). Empirical support for this hypothesis has been found looking at aggregate country and industry level data. The endogenous growth[7] and new trade literatures[8] focus on the role multinational firms play in transferring technology from the frontier to technologically more backward economies. Alternatively, Nickell (1995) and others have argued that the productivity increase over the 1980s was due to management innovation and the reorganisation of production and not to a surge in the rate of technological or scientific advance.[9]

Dougherty and Jorgenson (1997) and others argue that output growth in most of the G7 countries can almost entirely be explained by differences in the level and growth rate of investment, where investment is defined as the commitment of resources in the expectation of future returns to the investor.[10] This encompasses investment in physical, human and intangible capital.

Griffith (1999) addresses the question of whether multinational firms played a role in United Kingdom productivity growth by looking at whether foreign-owned establishments have higher productivity levels than domestic-owned establishments and whether an increase in the proportion of foreign-owned establishments could thus account for some of the increase in the average level of productivity.

Looking across all manufacturing establishments we see that foreign-owned establishments are larger and produce more per worker than domestic-owned establishments. Table 7 shows the proportional differences between the

[6] See Mayes (1996) and Oulton (1998*a*,*b*) on the ARD data and Nickell (1996), Layard and Nickell (1989), Oulton and O'Mahony (1994) and Cameron *et al.* (1998) using other data sources.

[7] See, *inter alia*, Aghion and Howitt (1998), Grossman and Helpman (1991).

[8] See, *inter alia*, Krugman (1991*a*,*b*, 1994) Venables (1994) and Smith (1994).

[9] Nickell (1995) Layard and Nickell (1989), Bean and Symons (1989) and Bean and Crafts (1995).

[10] See, *inter alia*, Oulton (1997), Oulton and O'Mahony (1994) and O'Mahony (1998).

Table 7

Percentage Difference between Domestic and Foreign-owned Establishments in Full ARD Sample

Characteristic:	French		German		Japanese		US	
	1980	1992	1980	1992	1980	1992	1980	1992
Output/worker	–	55	27	56	102	61	34	51
Value-added/worker	–	39	22	32	–	–	29	41
Investment/worker	–	67	46	103	333	209	39	79
Intermediate input/worker	–	68	35	79	175	96	41	57
ATC/worker	–	24	31	23	–	−12	29	27
Average wage ATC	–	–	–	8	–	–	10	13
Average wage OPs	–	25	–	10	–	–	9	16

Source: Author's calculations using ARD.
Notes: Reported numbers are $\exp(\beta) - 1$ from a regression of ln(characteristic) with a full set of industry and ownership dummies included. See Griffith (1999).

characteristics of domestic and foreign-owned establishments, conditional on their industry. These difference are calculated by regressing the log of the characteristic on a set of 2-digit industry dummies and a set of country dummies. The omitted category is domestic-owned establishments so $\exp(\beta) - 1$, where β is the coefficient on a country dummy, gives the proportional difference from domestic-owned establishments. This is what is reported in Table 7 for those coefficients that are significantly different from zero.

Output per worker is higher in all but French-owned establishments in 1980, while value-added per worker is only higher in German and US-owned establishments and French-owned in 1992. Investment and intermediate inputs per worker are higher in all cases, while only German and US-owned employ a higher proportion of administrative, technical and clerical workers (ATC). Average wages do not vary much by ownership, although they are somewhat higher, particularly for operatives in French-owned establishments. These differences are on the whole quite large.

Griffith (1999) examines one industry, the motor vehicle industry. This industry is chosen because it has one of the highest shares of foreign ownership in the United Kingdom, with on average less than half of output coming from domestic-owned establishments. US-owned establishments account for the largest proportion of foreign-owned output. Table 8 shows the proportion of output from establishments in the ARD selected data that is accounted for by foreign-owned establishments in 1980, 1985, 1990 and 1995.

The motor vehicles industry is one which has seen an increase in foreign-ownership, going from around 40% in 1980 to nearer 70% in 1995. The motor vehicle and parts industry is made up of three 3-digit industries – motor vehicles and engines industry (SIC 1980 code equals 351) is the largest and has the largest proportion of foreign owned establishments. Motor vehicle parts (353) is also a large industry, while the other 3-digit industry, motor vehicle bodies (352), is fairly small and largely domestic-owned.

The ARD selected data includes 5,314 observations on 1,176 establishments

Table 8

Proportion of Value-added in the Motor Vehicle Industry by Ownership, 1980, 1985, 1990, 1995

	1980	1985	1990	1995
Domestic	0.576	0.574	0.488	0.326
Japanese	0.000	0.000	0.010	0.067
North American	0.409	0.407	0.391	0.359
EU	0.014	0.017	0.100	0.238
Other	0.001	0.001	0.011	0.011

Source: Author's calculations using ARD.

in the motor vehicle industry over the period 1980 to 1992. Of these, 2,092 observations can not be used for econometric estimation of the production function either because they do not contain sufficient information or because there are not at least four contiguous time series observations for the establishment. In a small number of cases value-added is negative, these observations have also been excluded. Requiring four contiguous years of data means that many of the smaller establishments are not included, since establishments with under 100 employees are not a census but are sampled, so it is much less likely that they appear in four contiguous years. This is only really an issue in the motor vehicle parts industry (353), as not many motor vehicle and engine establishments (351) are small. While it also affects motor vehicle bodies (352) this is a very small industry.

Table 9 shows the proportion of total output that was accounted for by both the ARD selected data, and the sample (of those establishments with at least four contiguous observations) used in the analysis of production functions. The ARD selected data accounts for 98% of output in the motor vehicle industry (351), and the sample used below accounts for 92%. This high proportion of output accounted for by the sample reflects the fact that a few very large establishments in this industry account for most of output, while there are only a small number of establishments with fewer than 100 employ-

Table 9

Proportion of Output Covered by ARD Selected Data and Sample

SIC80	Motor vehicles and engines (351)		Motor vehicle bodies (352)		Motor vehicle parts (353)	
Output in 1992 (£m)	14,679		707		3,026	
	ARD selected	sample	ARD selected	sample	ARD selected	sample
% of population	98	92	67	53	85	68

Note: Population totals are reported in PACSTAT from 1986 and before that are available from the ONS. They are calculated by the ONS by grossing up the ARD data. The proportion is the average over the year 1980 to 1992.

ees. In the other two 3-digit industries there are a higher proportion of small establishments and thus both the ARD selected data and the sample represent a smaller proportion of total output. On average a higher proportion of these smaller establishments are domestic-owned so the sample contains a somewhat higher proportion of foreign-owned establishments in the motor vehicle parts industry (353) than in the full population.

Value-added per worker in the motor vehicles and engines industry (351) rose markedly over this period, as shown in Fig. 3.[11] Value-added is used because output can not be aggregated to the industry level since the output of one establishment may be an input for another establishment in the same industry. This figure uses the ARD data aggregated up to the 3-digit industry level. All values are expressed in 1980 pounds sterling. In the motor vehicles and engines industry (351) value-added rose from just over £7,000 per worker in 1980 to almost £20,000 per worker in 1993. Value-added per worker also rose in the other two 3-digit industries, rising by around 75% between 1980 to 1993 in the motor vehicle parts industry (353), and just about doubling in the motor vehicle bodies industry (352). There is a dramatic dip in output per worker over the 1990–1 recession in the motor vehicle and engines industry (351).

Table 10 contains a set of descriptive statistics on sampled establishments in one of the 3-digit industries included in the sample – the motor vehicle and

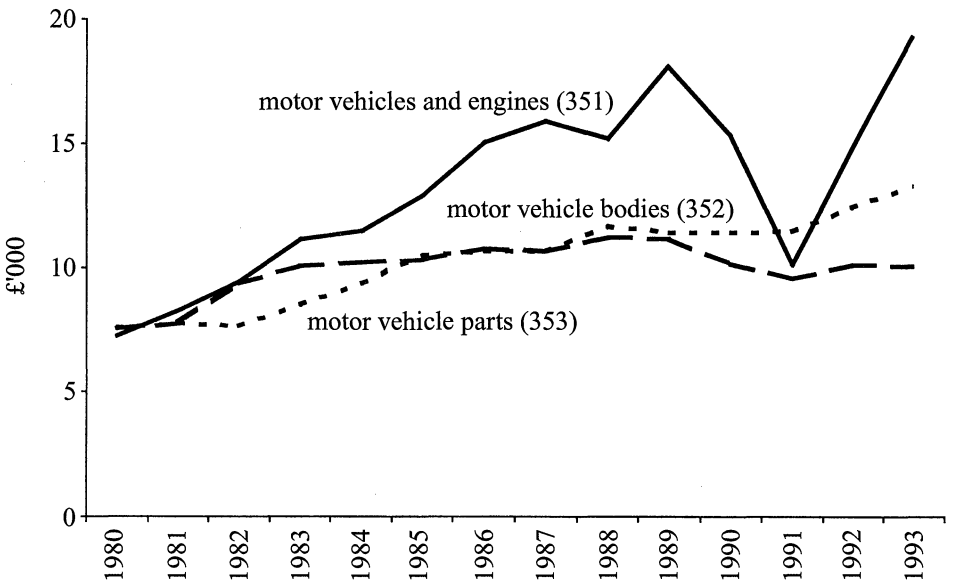

Fig. 3. *Aggregate Value-added per Worker in the Motor Vehicle Industry*

[11] Value-added is deflated by a 4-digit industry output price deflator, see Oulton and O'Mahony (1994) for a discussion of the bias this creates.

Table 10

Descriptive Statistics of the Sample of Establishments in the Motor Vehicle and Engines Industry (351)

	1980			1992		
	Domestic-owned	Foreign-owned	Foreign / Domestic	Domestic-owned	Foreign-owned	Foreign / Domestic
number observations	19	5		11	12	
Output (£'000)	119,600	733,966	6.14	333,982	922,480	2.76
Value-added (£'000)	38,034	180,713	4.75	119,033	162,289	1.36
Investment (£'000)	10,641	45,844	4.31	18,011	40,022	2.22
Employment	6,256	21,763	3.48	3,411	5,720	1.68
Output/employee (£'000)	26	28	1.08	90	136	1.51
Value-added/employee (£'000)	8	6	0.75	27	31	1.15
Investment/employee (£)	710	1,864	2.63	1,279	6,758	5.28
Intermediate inputs/employee (£'000)	17	23	1.35	60,958	103,421	1.69
% employees ATC	0.28	0.25	0.89	0.38	0.33	0.87
% wage bill ATC	0.31	0.32	1.03	0.43	0.41	0.95
Average wage ATC (£)	6,676	8,415	1.26	19,213	23,749	1.24
Average wage Ops (£)	5,567	5,776	1.04	15,532	15,796	1.02

Note: Variable definitions with ARD variables numbers are: gross value-added (q837), net capital expenditure (q844), employment (q845), proportion of wage bill accounted for by administrative, technical and clerical workers (q301/(q301+q304)), average wage of administrative, technical and clerical workers (q301/q202).
Source: Author's calculations using the ARD data.

engine industry (351) – split into domestic and foreign-owned establishments for the first and last years in the sample. The differences between the two groups are pronounced. In 1980 there were 19 domestic-owned and 5 foreign-owned establishments. The foreign-owned establishment were over six times as large on average as the domestic-owned and produced almost five times as much value-added.

Foreign-owned establishments invested and employed around four times as much as domestic-owned. Average output per worker was similar across the two groups in 1980, while value-added per worker was slightly higher in domestic-owned establishments. Foreign-owned establishments invested over two and a half times as much per worker and used around 35% more intermediate goods. Administrative, technical and clerical workers represented a slightly smaller proportion of the wage bill in foreign-owned establishments, though they were paid around 25% better on average. Operative workers were paid at about the same levels on average in foreign and domestic-owned establishment.

By 1992 there were over twice as many foreign-owned establishments as in 1980 and fewer domestic-owned. The difference in size between the two groups was smaller with foreign-owned being less than three times as large as domestic-owned. Value-added was 36% higher (down from nearly five times as

much in 1980) and investment was just over and employment just under twice as much. The fall in the average numbers employed from 1980 to 1992 is dramatic. This is due to both down sizing of existing establishments and the entry of smaller plants. Output per employee is 50% higher and value-added around 15% higher in foreign-owned than in domestic-owned establishments in 1992.

While differences in the level of investment have declined from 1980 to 1992, investment per employee is over five times as high in foreign-owned establishments as in domestic-owned in 1992, more than in 1980. Foreign-owned use around 70% more intermediate inputs in 1992 relative to 35% more in 1980. Foreign-owned establishments employ a slightly lower proportion of administrative, technical and clerical workers but their wages are about 25% higher than in domestic-owned establishments, as they were in 1980, and operative workers are paid about the same in domestic and foreign-owned establishments. The differences between domestic and foreign-owned establishments in the other 3-digit industries in motor vehicle manufacture are discussed in Griffith (1999).

Table 11 reports the percentage difference between foreign and domestic-owned establishments in the same way as Table 7 but for the motor vehicle industry. The biggest differences in output per worker are in Japanese establishments, while the larger number of US-owned have around 25% higher than domestic-owned. These high levels of output per worker correspond to higher levels of intermediate inputs – value-added per worker is not so much higher except in German-owned establishments. Investment per worker is much higher in Japanese-owned establishments and quite a lot higher in German and US-owned ones. This could be an age affect with higher investment levels in earlier years. Only French-owned employ significantly more administrative, technical and clerical workers (not shown). German and US-owned pay their ATC workers more and Japanese, Swedish and US-owned pay their operatives more, while French-owned establishments pay them some what less on average.

Table 11

Percentage Differences Foreign-owned Establishments in the Motor Vehicle Industry (35)

	output per employee	value-added per employee	investment per employee	intermediate inputs per employee	ATC average wage	Ops average wage
French	–	–	–	–	–	−10
German	39	44	190	46	–	12
Japanese	80	−43	272	127	–	–
US	27	18	55	32	15	13

Notes: Sample includes 414 establishments in an unbalanced panel running from 1980–1992. All regressions include time dummies. Numbers in italics are standard errors. Percentage differences are calculated as $\exp(\beta) - 1$.

In order to investigate whether these differences in output and value-added levels between domestic and foreign-owned establishments are fully explained by differences in factor usage Griffith (1999) estimates production functions where productivity shocks are allowed to take a very general form. The more commonly taken approach is to use an index number measure to measuring TFP differences. This has the attractive property that it does not involve specification of the precise form of the production function or estimation of the structural parameters (see, *inter alia*, Caves *et al.* (1982)). Taking an index approach observed factor share can be used to calculate TFP. However, for index numbers to yield unbiased estimates of TFP a number of assumptions are required. These include: constant returns to scale technology, competitive input and output markets, full utilisation of all inputs and instantaneous adjustment of all inputs to their desired demand levels.[12]

Econometric estimation allows the possibility of relaxing these assumptions, although it presents its own challenges. Which of the assumptions can be relaxed in practice depends largely on the richness of the data used for estimation – this is one of the great advantages offered by the ARD data. Practical requirements generally mean imposing a stricter set of assumptions about the functional form of the production technology and the stability of parameters across time. However, a dynamic production function, as estimated below, allows many of these assumptions to be relaxed and provides a useful tool for analysing their empirical importance, though only under the maintained hypothesis that the functional form is correct. The assumptions of perfectly competitive product and factor markets are maintained. Consider an establishment i that produces a single output at time t with a Cobb-Douglas production function of the form

$$Y_{it} = A_{it} K_{it}^{\alpha} L_{it}^{\beta} X_{it}^{\gamma} \tag{1}$$

where Y is output, A is a Hicks-neutral productivity shift parameter, K, capital input, L, labour input, X, intermediate inputs, α, β and γ are the elasticity of output with respect to the relevant factor. The Cobb-Douglas production function (1) can be estimated in log-linear form

$$y_{it} = \alpha k_{it} + \beta l_{it} + \gamma x_{it} + a_{it} \tag{2}$$

where variables in lower case are logs. Since the work of Solow the residual, a_{it}, has been interpreted as TFP and it can be decomposed into the following components,

$$a_{it} = \eta_i + t_t + e_{it} \tag{3}$$

where η_i captures establishment-specific differences in productivity, which are fixed over time, t_t captures common macro (productivity) shocks and e_{it}, captures establishment-specific productivity shocks which is assumed to be idiosyncratic, and thus serially uncorrelated.

[12] See Caves *et al.* (1982), Nadiri and Prucha (1998) and Diewert and Nakumura (1998).

Griffith (1999) is concerned with testing whether one group of establishments (foreign-owned) has a higher unexplained contribution to output (i.e. has higher total factor productivity) than another (domestic-owned). This is done by comparison of the mean of η_i across the two groups – the mean for domestic establishments, $\overline{\eta}_i^d$ is compared with the mean for foreign establishments, $\overline{\eta}_i^f$. If $\overline{\eta}_i^d < \overline{\eta}_i^f$ this suggests that foreign establishments that have chosen to locate in the UK market have, on average, a permanently higher level of TFP than UK establishments.[13] This approach assumes that any measurement error is the same across the two groups.

One worry is that the establishment-specific productivity, e_{it}, may not be idiosyncratic, but may persist over time.[14] This can be captured by allowing this component of the error term to be serially correlated,

$$a_{it} = \eta_i + t_t + e_{it} \tag{4}$$

$$e_{it} = \rho e_{it-1} + u_{it} \tag{5}$$

where u_{it} is an idiosyncratic error term.

Lagging (2) by one period and multiplying through by ρ gives

$$\rho y_{it-1} = \rho\alpha k_{it-1} + \rho\beta l_{it-1} + \rho\gamma x_{it-1} + \rho a_{it-1}. \tag{6}$$

Subtracting (6) from (2) yields a dynamic form of the production function with a well behaved error term

$$y_{it} = \lambda_1 y_{it-1} + \lambda_2 k_{it} + \lambda_3 k_{it-1} + \lambda_4 l_{it} + \lambda_5 l_{it-1} + \lambda_6 x_{it} + \lambda_7 x_{it-1} + (1-\rho)\eta_i + (1-\rho)\, t_t + u_{it} \tag{7}$$

where

$$\lambda_1 = \rho,\ \lambda_2 = \alpha,\ \lambda_3 = -\rho\alpha,\ \lambda_4 = \beta,\ \lambda_5 = -\rho\beta,\ \lambda_6 = +\gamma,\ \lambda_7 = -\rho\gamma \tag{8}$$

and the common factor restrictions can be imposed or tested.

4.1. *Data for Estimating Production Functions*

Several data problems have to be overcome in using the ARD data to estimate production functions of the form given by (2) and (7). The main difficulties arise in the measurement of prices and of capital stock. These are briefly discussed here, but see also the work by Harris and Drinkwater (1998) and Oulton and O'Mahony (1994) on measuring capital stock.

The ARD data do not contain any information on the prices firms charge on output or pay for inputs. This is problematic for applications such as this one.

[13] Care must be taken, however, in interpreting these differences in productivity levels. They do not necessarily imply a causal relationship between being foreign-owned and being more productive. Only the best foreign establishments will choose to locate in the United Kingdom, so only the top of the distribution is observed. However, domestic firms will include a longer tail of poorly performing firms that are just setting up or just going out of business. It would be useful to compare the distribution of the two groups.

[14] This could reflect an omitted variable, for example knowledge capital, or the fact that establishments do not instantaneously adjust.

What is observed is the value of output, i.e. price times quantity. An output price index at the 4-digit industry level is available for output and some inputs. Because this is an average of the price over all establishments in the industry this potentially introduces measurement error in the variables and could lead to biased estimates of the coefficients of interest.[15] These problems with output apply to the prices used for inputs as well.

The ARD data contains information on investment (both cost of acquisition and proceeds from disposal, though not scrapping). There are no data on capital stocks or depreciation rates. Estimates of the initial capital stock are obtained using industry level data. Establishment net capital stocks are estimated by using industry level capital stock estimates from Oulton and O'Mahony (1994) and using an allocation rule – in this case the share of each establishment's energy usage in total industry energy usage – to divide the capital stock among establishments. The perpetual inventory method (PIM) is then used at the establishment level for subsequent years (see Appendix for formula).

4.2. *Production Function Estimates*

Estimates of the coefficients from a regression of the form of (7) are shown in Table 12. In column (1) OLS estimates of the coefficients in the static model shown in (2) are presented. A full set of year dummies and dummies for all nationalities of ownership are also included. The coefficients on the country dummies provide an estimate of the conditional difference between the firm-specific component of productivity, η_i, for these foreign-owned establishments and domestic-owned ones (since the omitted category is domestic-owned).[16] The coefficients on US and German-owned are both significant and indicate that US-owned establishments produce around 5% more output than domestic-owned, conditional on inputs and time effects, and that German-owned produce around 7% more. Constant returns to scale (CRS) is rejected and the test statistics indicate that the error term is serially correlated.

One concern about the estimates in column (1) is that unobserved factors at the establishment level may be correlated with right-hand side regressors. This would mean that the OLS coefficients will be biased. The classic solution to this problem is to use the first-difference GMM estimator (see Arellano and Bond (1991, 1998)). These are presented in column (2). This first-difference estimator will be consistent, but will suffer from finite sample bias due to the fact that the levels of the regressors are weak instruments for differences. An alternative is the systems estimator described in Blundell and Bond (1998*a*,*b*) and Arellano and Bover (1995) which uses an additional set of moment conditions where the differences are used as instruments for the levels

[15] Klette and Griliches (1992) show that deflating sales or normalising on industry-year medians can lead to errors-in-variables bias – firm specific productivity advances may lead the firm to lower its price and expand output. Using a common deflator will underestimate output and thus underestimate the scale coefficient in production function estimation.

[16] The proportional difference in output, conditional on all over regressors, is given by $\exp(\beta) - 1$.

Table 12

Dynamic Cobb-Douglas Production Function

Dependent variable: output, y_{it}	(1) OLS	(2) diff	(3) system	(4) OLS	(5) diff	(6) system
instruments			$t-3$ $\Delta t-2$	–	$t-2$	$t-3$, $\Delta t-2$
l_{it}	0.362	0.198	0.505	0.396	0.452	0.393
	(0.015)	(0.070)	(0.056)	(0.027)	(0.070)	(0.082)
l_{it-1}	–	–	–	−0.307	−0.272	−0.249
				(0.026)	(0.066)	(0.074)
k_{it}	0.049	−0.059	0.048	0.061	−0.035	−0.002
	(0.013)	(0.083)	(0.031)	(0.024)	(0.093)	(0.097)
k_{it-1}	–	–	–	−0.045	−0.087	−0.054
				(0.023)	(0.091)	(0.094)
x_{it}	0.601	0.625	0.527	0.547	0.436	0.471
	(0.018)	(0.071)	(0.035)	(0.023)	(0.054)	(0.048)
x_{it-1}	–	–	–	−0.398	−0.079	−0.167
				(0.026)	(0.049)	(0.068)
y_{it-1}	–	–	–	0.749	0.271	0.502
				(0.019)	(0.053)	(0.078)
US	0.048		0.008	0.013	–	0.024
	(0.015)		(0.029)	(0.006)		(0.019)
German	0.071		0.154	0.038	–	0.068
	(0.066)		(0.074)	(0.023)		(0.036)
Sargan (P-value)	–	0.546	0.094	–	0.294	0.092
CRS (P-value)	0.035	0.036	0.001	0.179	0.007	0.394
m1	0.000	0.000	0.000	0.000	0.000	0.000
m2	0.000	0.028	0.010	0.157	0.575	0.923
coefficient estimates imposing common factor restrictions						
α				0.373	0.423	0.376
				(0.018)	(0.061)	(0.072)
β				0.069	0.004	0.084
				(0.013)	(0.071)	(0.044)
γ				0.573	0.432	0.500
				(0.017)	(0.051)	(0.045)
ρ				0.762	0.358	0.587
				(0.017)	(0.038)	(0.058)
Comfac (P-value)				0.367	0.103	0.290

Note: The sample is an unbalanced panel of 414 establishments from 1980–1992 with 3,259 observations; all regressions are estimated in DPD; difference and system estimates are GMM with instrument indicating the dating of instruments used for right-hand side variables; numbers in parenthesis are one-step robust standard errors from DPD; Sargan is the P-value from a test of the validity of the over-identifying restrictions for the GMM estimators; CRS is the P-value from a Wald test for constant returns to scale; m1 and m2 are the P-values from tests for first and second order serial correlation (see Arellano and Bond (1991, 1998)); coefficients in the bottom part are one-step parameter estimates obtained using minimum distance estimator and imposing the common factor restrictions given by (8); Comfac is the P-value from a chi-squared test of the restrictions. Canadian, French and other foreign-owned dummies are included in all specifications but never significant.

equations. Estimates of the coefficients using the system estimator are presented in column (3). These will provide consistent estimates of the coefficients even if the firm-specific component of the error term, η_i, is correlated with the other regressors and the regressors are highly persistent, and thus provide weak instruments in a first-differenced setting.

The system estimates in column (3) indicate a larger role for labour and smaller role for intermediate inputs than implied by the OLS or first-difference estimates. The US-owned dummy has fallen into insignificance while the German-owned dummy has increased. CRS is still rejected and the test statistics indicate serial correlation.

The serial correlation tests in columns (1)–(3) suggest that this static model may be mis-specified and that (7) may be a more appropriate model. In columns (4)–(6) estimates of the dynamic Cobb-Douglas production function are presented. In column (4) the OLS estimates indicate a high degree of persistence, with a coefficient on the lagged dependent variable of 0.75. CRS is not rejected and there is no longer an indication of second-order serial correlation.

In the bottom part of the table estimates of the coefficients estimated imposing the common factor restrictions given in (8) are shown. The restrictions are accepted in all three columns as indicated by the P-value in the final row of the table.

The coefficient on US-owned rises and is now significant, indicating that US-owned establishments have about 1% higher output after conditioning on inputs. The German-owned dummy is now insignificant. As discussed above the OLS estimates of the coefficients will be biased upward. In column (5) estimates of the coefficients using the first-difference estimator are presented. Again, these will be consistent but suffer from weak instruments. Column (6) shows estimates obtained using the system estimator. The common factor restrictions are accepted and the test statistics indicate first-order serial correlations, which is what we expect with this estimator. More worrying perhaps is the Sargan statistic, this does not reject the instruments at the 5% level but does at the 10% level. The US-owned dummy is insignificant in column (6) while German-owned establishments appear to produce around 7% more output, conditional on inputs, than domestic-owned establishments.

One drawback of using econometric methods to estimate TFP is that in order to obtain consistent estimates of the parameters data have to be pooled – in this case across 3-digit industries. Ideally TFP would be estimated by running separate regressions for each 3-digit industry. However, due to the small sample size that would be available this is not possible. The consistency of these panel data estimators rely on large N asymptotics. A partial attempt is made to overcome this problem by allowing the differences between TFP levels to vary within 3-digit industries.

Estimates of TFP (the residual) are obtained from each establishment using the parameter estimates in columns (3) and (6) with the ownership and time dummies omitted. This residual is then regressed on the time and ownership

dummies for each 3-digit industry separately. The coefficients in Table 13 are estimates of the difference in the level of TFP between foreign and domestic-owned establishments within each 3-digit industry – $[\exp(\beta_c) - 1]$ gives the proportional difference.

Using the estimates of TFP from the static specification (the first two columns), German-owned establishments in the motor vehicle and engines industry (351) have around 12% and other foreign-owned have around 18% higher TFP than domestic-owned establishments. In the motor vehicle parts industry (353), US and German-owned have 2% and 7% higher TFP respectively.

The estimates of TFP obtained using the dynamic specification (last two columns), indicate that only US-owned establishments have higher TFP levels than domestic-owned establishments in the motor vehicle and engines industry (351), and this difference is fairly small, at around 6%, compared to the differences in output or value-added per worker reported in Table 11. In the motor vehicle parts industry (353) the differences have also gone down relative to the static model – US-owned still have significantly higher TFP levels than domestic-owned establishments but by only 9% and 1% respectively This compares to differences in output per worker of over 50% and around 25% (see Griffith (1999)).

5. Conclusion

The ARD data represents a valuable resource to empirical economists in the UK. It opens up the possibility of investigating a large number of issues. The split between operative and non-operative workers means that it is possible to examine the factors that are driving increases in wage inequality in the United Kingdom. The information that is available in the disaggregate data on computer usage makes it possible to investigate the interaction between technical change, employment and other establishment characteristics. Information on ownership makes it possible to look at the impact that foreign ownership, takeovers and start-ups (to name but a few) of establishments have had on UK industrial performance. These represent only a small number of the possible research projects.

Table 13

Differences in Mean of Residual (TFP) by 3-digit Industry

	residual from column (3)		residual from column (6)	
	Motor vehicles and engines (351)	Motor vehicles parts (353)	Motor vehicles and engines (351)	Motor vehicles parts (353)
US	0.037	0.023	0.058	0.014
	(0.024)	(0.011)	(0.016)	(0.007)
German	0.115	0.074	0.055	0.023
	(0.034)	(0.033)	(0.036)	(0.024)
Other foreign	0.163	−0.028	0.022	−0.002
	(0.053)	(0.035)	(0.034)	(0.026)

The level of disaggregation and the panel nature of the data (the fact that we observe the same individuals over time) are two of its most attractive features. They mean that these and other economic issues can be addressed using the latest econometric techniques. The advantages of micro panel data are numerous and have been discussed in many other places, but a few are mentioned here. In the analysis of company behaviour in the United Kingdom we have generally been limited to at best firm level datasets, and more commonly to investigating the activities of firms using macro (country or industry) level data. First, many of the questions we want to address are about the behaviour of micro-economic agents (i.e. firms or plants) and thus understanding how the impact differs across these agents is in itself interesting and is not possible with macro data. Secondly, micro panel data make it possible to control for unobservable characteristics which are specific to the individual and may be correlated with the other regressors. These have been shown to be important in many econometric studies.[17] Thirdly, the theory upon which most of these empirical studies draw is based on the profit maximising behaviour of firms. Explicitly aggregating these models will not necessarily yield a model of the same form as implied by the disaggregated version. Using aggregate data to estimate models describing firm behaviour will also introduce aggregation bias simply for the reason that $\sum_{i=1}^{N} \ln x_i \neq \ln \sum_{i=1}^{N} x_i$.[18] A final problem arises if a dynamic model is being estimated with aggregate data in that the composition of firms in the industry or country at time t and $t-1$ will not be the same. This means that changes over time reflect both changes in composition and changes in behaviour and that using lagged values as regressors or instruments becomes invalid.[19]

The ARD data should open up many new avenues of research to empirical economists who are interested in describing and gaining a better understanding the behaviour of firms. The article has described some of it key advantages and pointed out some of the potential problems that researchers using the data might face and has described some recent work using the data.

References

Aghion, P. and Howitt, P. (1998), *Endogenous Growth Theory*, Cambridge MA: MIT Press.

Arellano, M. and Bond, S. R. (1991), 'Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations', *Review of Economic Studies*, vol. 58, pp. 277–97.

Arellano, M. and Bond, S. R. (1998), 'Dynamic panel data estimation using DPD98 for GAUSS', mimeo, Institute for Fiscal Studies.

Arellano, M. and Bover, O. (1995), 'Another look a the instrumental-variable estimation of error-components models', *Journal of Econometrics*, vol. 68, pp. 29–52.

Attanasio, O. and Weber, G. (1991), 'Consumption growth, the interest rate and aggregation' *Review of Economic Studies*, vol. 60, pp. 631–649.

[17] See, *inter alia*, Attanasio and Weber (1991), Stoker (1998) and Blundell and Stoker (1998).

[18] See, *inter alia*, Attanasio and Weber (1991).

[19] See Pischke (1995).

Auerbach, A. J. and Hassett, K. (1993), 'Taxation and foreign direct investment in the United States: a reconsideration of the evidence', in (A. Giovannini, R. G. Hubbard and J. Slemrod eds.) *Studies in International Taxation*, Chicago: University of Chicago Press, pp. 119–47.

Bean, C. and Crafts, N. (1995), 'British economic growth since 1945: relative economic decline .. and renaissance?' CEPR Discussion Paper No. 1092.

Bean, C. and Symons (1989), 'Ten years of Mrs T.' *NBER Macroeconomic Annual*, vol 4, pp. 13–61.

Blundell, R. and Bond, S. R. (1998*a*), 'Initial conditions and moment restrictions in dynamic panel data models', *Journal of Econometrics*, vol. 87(1), pp. 115–44.

Blundell, R. and Bond, S. R. (1998*b*), 'GMM estimation with persistent panel data: an application to production functions', mimeo, Institute for Fiscal Studies.

Blundell, R. and Stoker, T. (1998), 'Models of aggregate economic relationships that account for heterogeneity', forthcoming in (R. Blundell, J. Heckman and E. Leamer, eds.) *Handbook of Econometrics*, Amsterdam: North-Holland.

Cameron, G., Proudman, J. and Redding, S. (1998), 'Openness and its association with productivity growth in UK manufacturing industry' in (J. Proudman and S. Redding, eds.) *Openness and Growth*, London: Bank of England.

Caves, D., Christensen, L. and Diewert, W. E. (1982), 'Multilateral comparisons of output, input, and productivity using superlative index numbers', ECONOMIC JOURNAL, vol. 92, pp. 73–86.

Diewert, I. and Nakamura, A. (1998), 'A survey of empirical methods of productivity measurement and analysis', forthcoming in (R. Blundell, J. Heckman and E. Leamer, eds.) *Handbook of Econometrics*, Amsterdam: North-Holland.

Disney, R., Haskel, J. and Heden, Y. (1999), 'Entry, exit and survival in UK Manufacturing', Queen Mary and Westfield College, draft paper.

Dougherty, C. and Jorgenson, D. (1997), 'There is no silver bullet: investment and growth in the G7', *National Institute Economic Review*, pp. 57–74 (CSO, 1996).

Gerschenkron, A. (1962), *Economic Backwardness in Historical Perspective*, Cambridge: Belknap Press.

Griffith, R. (1999), 'Productivity and foreign ownership in the UK car industry', Institute for Fiscal Studies Working paper 99/11.

Grossman, G. and Helpman, E. (1991), *Innovation and Growth in the Global Economy*, Cambridge MA: MIT Press.

Grubert, H. and Mutti, J. (1991), 'Financial flows versus capital spending: alternative measures of US-Canadian investment and trade in the analysis of taxes,' in (P. Hooper and J. D. Richardson, eds.) *International Economic Transactions, Issues in Measurement and Empirical Research*, Chicago: University of Chicago Press, pp. 293–317.

Haskel, J. and Heden, Y., (1999), 'Computers and the demand for skilled labour: industry and establishment panel evidence for the UK', ECONOMIC JOURNAL, vol. 109, no. 454, pp. 68–79.

Harris, R. and Drinkwater, S. (1998), 'UK plant and machinery capital stocks and plant closures', University of Portsmouth mimeo.

Hildreth, A. K. G. and Pudney, S. E. (1998), 'Econometric issues in the analysis of linked cross-section employer-worker surveys' (presented at the International Symposium on Linked Employer-Employee Data, Washington May 21 1998), Center for Labor Economics, UC Berkeley Working Paper No. 10.

Hildreth, A. K. G. and Pudney, S. E. (1999), 'The hiring practices of firms: estimates from linked employer-worker survey data', mimeo.

Klette, T. and Griliches, Z. (1996), 'The inconsistency of common scale estimators when output prices are unobserved and endogenous', *Journal of Applied Econometrics*, vol. 11, pp. 343–61.

Krugman, P. R. (1991*a*), 'Increasing returns and economic geography', *Journal of Political Economy*, vol. 99, pp. 483–99.

Krugman, P. R. (1991*b*), *Geography and Trade*, Cambridge MA: MIT Press.

Krugman, P. R. (1994), *Rethinking International Trade*, Cambridge MA: MIT Press.

Layard, R. and Nickell, S. (1989), 'The Thatcher miracle?' *American Economic Review (Papers and Proceedings)*, Vol. 79, 215–9.

Mayes, D. G. (1996), *Sources of Productivity Growth*, Cambridge: Cambridge University Press.

McGuckin, R. (1995), 'Establishment microdata for economic research and policy analysis: looking beyond the aggregates', *Journal of Business and Economic Statistics*, vol. 13, pp. 121–6.

Nadiri, M. I. and Prucha, I. (1998), 'Dynamic factor demand models and productivity analysis', NBER mimeo.

Nelson, R. and Phelps, S. (1966), 'Investment in humans, technological diffusion and economic growth', *American Economic Review*, vol. 56, pp. 69–75.

Nickell, S. J. (1995), *The Performance of Companies*, Oxford: Blackwell.

Nickell, S. J. (1996), 'Competition and corporate performance', *Journal of Political Economy*, vol. 104, pp. 724–46.

O'Mahony, M. (1998), 'Britain's relative productivity performance, 1950–1996: a sectoral analysis', NIESR mimeo.
Oulton, N. and O'Mahony, M (1994), *Productivity and Growth: a study of British industry 1954–1986*, NIESR: London.
Oulton, N. (1997), 'The ABI respondents database: a new resource for industrial economics research', *Economic Trends* No. 528 November.
Oulton, N. (1998*a*), 'A tale of two cycles: closure, downsizing and productivity growth in UK manufacturing, 1973–1989', National Institute of Economic and Social Research Discussion paper no. 140.
Oulton, N. (1998*b*), 'Investment, capital and foreign ownership in UK manufacturing', National Institute of Economic and Social Research Discussion paper no. 141.
Perry, J. (1995), 'The inter-departmental business register' *Economics Trends* No. 505 November.
Smith, A. (1994), 'Strategic trade policy in the European car market' in (P. Krugman and A. Smith, eds) *Empirical Studies of Strategic Trade Policy*, Chicago: Chicago University Press.
Stoker, T. (1993), 'Empirical approaches to the problem of aggregation over individuals', *Journal of Economic Literature*, vol. 31, pp. 1837–74.
Venables, A. (1994), 'Trade policy under imperfect competition: a numerical assessment' in (P. Krugman and A. Smith, eds) *Empirical Studies of Strategic Trade Policy*, Chicago: Chicago University Press.

Appendix: Main ARD Variables and Price Data

There are something like 500 variables available in the ARD dataset. A selection of the main ones of interest are listed here.

Variable number	Description
Output	
q837	gross value added at factor costs
q842	net output
q841	gross output = value of sales *plus* the increase in the value of stocks of work in progress and of goods on hand for sale
Stocks	
q401, q402	materials, stores and fuel, beginning year and end year respectively
q403, q404	work in progress, beginning year and end year respectively
q413, q414	goods on hand for sale, beginning year and end year respectively
Investment	
q501	cost of new building work
q502	cost of land and buildings purchased
q503	proceeds from land and existing buildings disposed of
q504	cost of new and second hand vehicles purchased
q505	proceeds from vehicles disposed of
q511	computer equipment purchased (1986 and 1988 only)
q517	plant, machinery, office equipment and other capital equipment purchased
q518	proceeds from equipment disposed of
q655	amounts payable for hire of plant and machinery
q656	rent of industrial and commercial buildings
q836	other net capex
q844	total net capex

Labour input	
q201	working proprietors
q202	average number of administrative, technical and clerical (ATC) employees
q205	average number of operative (Op) employees
q207	computer employees (1986 and 1988 only)
q845	total employment
q301	wages and salaries ATCs
q304	wages and salaries Ops
q315	employers national insurance contributions
Intermediate input	
q702	cost of materials and fuel used (these are broken down into different types of fuels and by cost and quantity from 1980–86)
q734	cost of materials and fuel purchased
q733	cost of goods purchased for resale without processing
q838	all non-industrial services received

In addition there are a number of questions that have only been asked in some years. These include information about computer usage, insurance premiums, bank charges, transport costs, pollution abatement costs, excise duties, whether R&D is conducted (but not how much) on site, detail about fuel usage plus much more.

output price index for 191 four digit industries in 1990 prices from the ONS directly, published in *Annual Abstract of Statistics*
price index for plant and machinery in 27 production industries in 1980 prices from Price Index Numbers for Current Cost Accounting, various years
single price index for buildings and works in 1980 prices from Price Index Numbers for Current Cost Accounting, various years
single price index for road motor vehicles constructed in 1980 prices from two series from Price Index Numbers for Current Cost Accounting, various years. The first series ran from 1974–1983 (1980 = 100) and the second from 1984–... (1985 = 100) but there was no common year to convert it. The price index for private vehicles published in CSO Retail Prices 1914–1990, Tables 70 and 71 are used to merge the two series.
input (intermediate) price index for 200 four digit industries in 1990 prices from the ONS directly, published in Annual Abstract of Statistics

Estimates of the value of the capital stock are obtained using observed investment data on each type of capital for each establishment in the first observed period by $K_{i1} = I_{i1} + (1-\delta) w_i K_{j0} (p^K_{i1}/p^K_{i0})$, where I is investment, w_i is that establishment's share of industry energy usage, K_j is the industry capital stock, p^K is the price index and δ is the geometric depreciation rate. A price index at the 2/3-digit industry level is used to deflate the capital stock. In all other periods it is given by $K_{it} = I_{it} + (1-\delta) K_{it-1} (p^K_{it}/p^K_{it-1})$.