UK Manufacturing Productivity Performance in an International Perspective

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Abstract

The purpose of this paper is to revisit the productivity gap in manufacturing between the UK and other industrialized countries over the period 1970 to 1998. To this end, new estimates of growth performance and levels of productivity are provided for the aggregate manufacturing sector and for a set of eight manufacturing industries. The stress is placed upon the sensitivity of the size and direction of the productivity differential to measurement issues and restrictive assumptions. The results indicate that the bias in traditional TFP estimates does not impact greatly on the size of the British productivity gap at the aggregate manufacturing level but does so at a more disaggregated level. Adjusting for measurement bias, the results show that the productivity gap remains significant and the productivity of UK manufacturing still trails behind that achieved in the US, France and Germany, regardless of the sector.

Keywords: Total Factor Productivity; International Comparison; Panel Data; Competitiveness; Capacity Utilisation.

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"Productivity is a fundamental yardstick of economic performance…we are not as productive as our major partners and the extent of our under-performance is very substantial…tackling it must be a central priority"

HM Treasury (1998: p. 28)

1 INTRODUCTION

Recent studies of international productivity comparisons[1] draw attention to the significance of the UK productivity gap in manufacturing relative to other industrialized countries. Particularly, latest evidence from O'Mahony and de Boer (2002) indicates that the UK differential in terms of TFP in manufacturing in 1999 is of the order of 10% and 21% compared with France and Germany respectively, and 43% with respect to the US. As documented by Maddison (1991), Broadberry (1997) and Crafts (2002), among others, this productivity gap is not a recent phenomenon; it has been a persistent feature of British industry, opening up with the US at the beginning of the 20th century, and with Europe during the 1970s.

Following Harrigan's (1999: p. 268) argument, one possibility for the existence and reported size of the productivity gap is the fact that *"this is the result of a mismatch between the theory of productivity comparisons and the technological and measurement process which generate the data.*" In this regard, measurement errors and/or restrictive assumptions underlying traditional methods of productivity measurement may cause biases that can alter the size and direction of the measured productivity gap differential.

While previous findings on international productivity differentials have largely been in terms of labour productivity measures, comparisons based on total factor productivity (TFP) are less frequent[2]. Additionally, most of earlier studies have been restricted to aggregate productivity

[1] See for instance O'Mahony (1999), HM Treasury (2000), O'Mahony and de Boer (2002) and Malley *et al.* (2003).

[2] Exceptions to this are provided by O'Mahony (1999), O'Mahony and de Boer (2002) and Malley *et al.* (2003), who all study Britain's relative productivity performance. Their studies are discussed in the next section.

analysis based on value added as a measure of real output (van Ark 1993; O'Mahony 1999), instead of gross output. As emphasized in the works of Basu and Fernald (1995; 1997), the use of value added may constitute a potential source of bias when certain conditions are not met. One of the primary interests in this paper is to analyse the sensitiveness of the magnitude of the UK's productivity gap in manufacturing to different measures of productivity. To this end, the paper reviews some previous attempts along these lines and provides comparative estimates of relative productivity in terms of both alternative productivity and output concepts.

The second aim of this paper is to provide new estimates of growth performance and levels of productivity at sectoral level and compare them with earlier findings. The present research aims to provide a detailed evaluation of productivity performance for the major branches of UK manufacturing relative to other industrialized countries. The reason for this is that the aggregate analysis of productivity performance may hide significant differences in trends across sectors (see Bernard and Jones 1996).

Additionally, this study pays particular attention to the impact of different measurement issues on the analysis of international productivity comparisons. The problem with traditional growth accounting estimates of TFP is that they may not be an accurate measure of the true concept of TFP. The reason is that these estimates ignore the role of market power, scale economies and adjustments in capacity utilisation. Thus, this study aims to determine whether and to what extent adjusting traditional TFP estimates for measurement bias has an impact on the size and direction of the productivity gap.

To these ends, a panel regression is conducted in which imperfect competition; returns to scale and adjustments for capacity utilisation are allowed. The resulting parametric estimates of TFP growth are then compared to those derived from the traditional accounting framework. The new estimates of sectoral TFP are important because not only do they cover an important range of countries and industries, but also they use recent data and try to improve, if not overcome, some of the data and index number problems of previous work. However, it has to be emphasized that the coverage and depth of analysis in this paper is necessarily constrained by the availability, accuracy and international comparability of economic statistics.

The rest of the paper is organized as follows. The next section reviews some of the studies that consider Britain's productivity position in manufacturing in an international perspective. Section 3 briefly describes the data and industry characteristics. Section 4 outlines the basic concepts and traditional methods of measurement used to quantify comparative productivity differentials. This section also analyses the sensitivity of the productivity gap in manufacturing to measurement issues. Section 5 presents sectoral measures of TFP. Section 6 sets out the econometric approach used to implement the adjustments in traditional measures of TFP to allow for imperfect competition, scale economies and adjustments for capacity utilisation. Additionally, this section reports the result of this estimation. Section 7 discusses the implication of these results. Finally, section 8 draws conclusions and discusses the relevance of the results.

2 PREVIOUS STUDIES ON RELATIVE PRODUCTIVITY PERFORMANCE IN UK MANUFACTURING

In recent years there has been renewed interest in international comparisons of factor productivity. The literature on this topic is considerable and diverse in terms of approaches followed, breadth of coverage, levels of detail and questions addressed. Table 1 gives an overview of studies that consider Britain's relative productivity position in manufacturing in an international perspective[3]. Despite the diversity in approaches, these studies coincide in recognising the laggard position of British manufacturing performance relative to other industrialized countries. The earliest comparative studies were mainly based on the UK industry compared to the US[4]. However, the productivity gap between the UK and other European countries that had emerged during the post-war period started receiving increasing attention during the 1980s in studies by the NIESR, among others[5].

[3] See Kravis (1976) and Islam (1995) for other surveys of international comparisons of productivity.
[4] See Broadberry and Crafts (1990) and Broadberry (1994) for a detailed analysis of the various Anglo-American cross-country comparisons.
[5] For comparisons between the UK and Germany see Smith *et al.* (1982), O'Mahony and Wagner (1996) and Broadberry (1997), among others. For comparisons between France and UK see van Ark(1990).

Table 1
Empirical Studies on British Manufacturing Relative Productivity Performance

Author	Benchmark Year(s)	Country Coverage (1)	Industry Coverage	Productivity Concept (2)	Output Concept (3)
Industry of Origin Approach					
Rostas (1948)	1935-39	UK/US	31 industries	LP	GO
Maddison (1952)	1935	UK/US CD/US	34 products	LP	GO
Smith et al. (1982)	1967/68	US/UK GY/UK	87 industries 69 industries	LP	VA
van Ark (1990)	1984	NT/UK FR/UK	16 industries 14 industries	LP LP	VA VA
O'Mahony (1992)	1987	GY/UK	14 industries	LP	VA
van Ark (1992)	1987	UK/US	16 industries Manufacturing	LP TFP	VA VA
O'Mahony & Wagner (1996)	1979-89	UK/GY	30 industries	TFP	VA
Pilat (1996)	1987	AU, FR, GY, IT, JP, NT, SW, UK, US.	36 industries	LP	VA
van-Ark (1996)	1970-1994	FR, GY, JP, UK, US	6 Industries	LP	VA
Broadberry (1997)	1950-1990	US, UK, GY	70 Industries	LP TFP	VA VA
O'Mahony (1999)	1950-95	FR, GY, JP, UK, US	40 Industries	LP TFP	VA VA
O'Mahony & de Boer (2002)	1950-99	FR, GY, UK, US.	47 Industries	LP TFP	VA VA
Expenditure Approach					
Prais (1981)	1950-80	US, UK, GY	Manufacturing	LP	VA
Roy (1982)	1973, 1980	US, UK, JP, IT, GY, FR, BG, NT	11 Industries	LP	VA
Roy (1987)	1980	44 countries	7 Industries	LP	VA
Hooper & Larin (1989)	1960-89	10 countries	Manufacturing	LP	VA
Hooper (1996)	1975-90	US, UK, JP, IT, GY, FR, CD	7 Industries	LP	VA
Harrigan (1999)	1980-89	US, UK, JP, IT, GY, FI, NW, CD	8 Industries	TFP	VA
Malley et al. (2003)	1971-95	FR, GY, IT, JP, UK, US.	13 industries	TFP	GO

Notes: (1) Country Coverage: AU: Australia, BG: Belgium, CD: Canada, FI: Finland, FR: France, GY: Germany, IT: Italy, JP: Japan, NT: Netherlands, NW: Norway, SW: Sweden, UK: United Kingdom, US: United States.
(2) Productivity Concepts: LP: Labour Productivity; TFP: Total Factor Productivity.
(3) Output Concepts: GO: Gross Output; VA: Value Added.
Sources: Author

The earliest comparisons of Britain's productivity during the 1940's and 1950's, including those of Rostas[6] (1948) and Maddison (1952), were frequently made by comparing physical quantities of output. As the number of product varieties in manufacturing increased these comparisons based on physical quantities became less feasible. This led to a shift in methodology from physical quantity comparisons to converting output to a common unit using currency conversion factors. Since then, two different approaches have been used to compute currency conversion factors specific to manufacturing output. One approach, "the industry-of-origin approach", is based on computing unit value ratios (UVRs) using data on output and prices at the industry level. In this line, Smith *et al.* (1982) compared British, German and American output and productivity by constructing UVRs using census data on net output and prices for a large number of individual industries. Later studies largely replicated and refined this method.

The second approach to calculating currency conversion factors is "the expenditure approach". This approach uses data on the comparative levels of prices of disaggregated final expenditures. For several reasons[7] it is considered less desirable for sectoral international productivity comparisons than the former approach. Some scholars, for instance Malley *et al.* (2003), have used the aggregate expenditure purchasing parities (PPPs) for total GDP as proxies for manufacturing output price ratios. This is considered an inferior method, as it does not take account of differences in price levels across industries (see Pilat and Prasada Rao 1996, van Ark 1996 and Harrigan 1999). Others have attempted to refine these proxies by computing weighted averages of disaggregated expenditure PPPs specific to manufactured categories. For instance, Prais (1981) uses disaggregated PPPs to compare manufacturing output in Germany, UK and the US in the 1970s. Roy (1982) and Roy (1987) did much the same for a wider set of countries in 1975 and 1989. Hooper and Larin (1989) improve this methodology by "peeling off" indirect taxes and trade and transportation margins from the expenditure PPPs for the ten major industrialised countries. All these adjustments represent an

[6] Rostas (1948) also included a comparison with Germany and, though based on much smaller samples with some other countries including the Netherlands. For an up-date of the Germany versus UK comparison of Rostas, see Broadberry and Fremdling (1990).
[7] See van Ark (1996) and O'Mahony (1996) for an elaborate discussion of the relative merits of different deflators.

improvement over the use of unadjusted expenditure PPPs. However, they also make the expenditure PPPs increasingly sensitive to the procedure used and the quality of data.

As can be observed from Table 1, most of these studies base their findings on measures of labour productivity (e.g. Maddison 1952 and Pilat 1996, among others). These partial productivity measures can be misleading indicators of technological differences. This is because they may be positively influenced by the availability of other factors of production[8] (see Hulten 2000). Less extensive, however, is the empirical literature dealing with comparisons based on TFP, which is considered a preferable measure of technological differences – provided that the measures control for market power, scale and cyclical effects. Studies that consider TFP[9] call attention to the fact that the impact of generally lower capital intensity in British industry is to considerably reduce the UK's productivity differential with respect to other industrialised countries when measured by TFP.

Another critical issue in the literature is the output concept used for sectoral productivity comparisons. While real gross output is the most theoretically appealing concept for output[10] in productivity analysis at the industry level, value added is, however, the concept used in the great majority of empirical productivity studies[11]. The studies of Rostas (1948), Maddison (1952) and, more recently, the studies by Craft and Mills[12] (2001) and Malley *et al.* (2003) are some of the few examples that use gross output for studying Britain's relative productivity performance in an international context[13].

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[8] The major problem with the use of partial productivity measures is that they also incorporate the effects of factor substitution. As Harris and Trainor (1997: p. 485) point out "*the factor-price ratio between capital and labour services have been falling in UK manufacturing for a good deal of the last quarter century, and thus much of the gain in labour productivity has been achieved through 'capital deepening' rather than 'capital-widening'.*"

[9] O'Mahony and Wagner (1996), O'Mahony (1999), Harrigan (1999) and Malley*et al.* (2003)

[10] The use of gross output has, among others; analytical advantages in that intermediate inputs can be treated symmetrically with inputs of capital and labour services in measuring productivity.

[11] See, for instance, van Ark (1990, 1992 and 1996).

[12] The study by Crafts and Mills (2001) considers growth rates instead of levels through estimating a cost function.

[13] Other studies that use gross output for international comparisons are Jorgenson, Kuroda and Nishimizu (1987), Jorgenson and Kuroda (1990), and Cameron (2000). These studies refer to productivity comparisons between US and Japan.

Finally, growth accounting exercises are traditionally used to measure international differences in productivity. As mentioned previously, the assumptions underlying the accounting approach can potentially bias the magnitude of the productivity differential if they are not correct. Few researchers, however, "correct" the standard productivity measures to account at least for the presence of imperfect competition, returns to scale and/ or adjustments in factor utilisation. The exceptions to this are the studies by Harrigan (1999), Crafts and Mills (2001) and Malley *et al.* (2003), which make use of econometric techniques to estimate productivity differentials. Overall these studies conclude that these biases are important and vary substantially over time, but tend not to impact heavily on the estimate of the British productivity gap.

The main difference between the present study and that of Harrigan (1999) is that here gross output instead of value added is used to obtain adjusted TFP measures. This research differs from the study of Crafts and Mills (2001) in several aspects. First, the main focus here is on eight manufacturing industries, while Crafts and Mills base their results on the aggregate manufacturing sector. Second, they compare productivity growth rates for Germany and UK based on the dual approach. This study, conversely, provides estimates of growth performance and levels of productivity for the G7 countries based on the primal approach to productivity measurement.

The main differences between the present research and the contemporaneous study by Malley *et al.* (2003) are the following. First, the data sources for gross output and intermediate inputs are different. Malley and co-authors obtain their data from the national input-output model databases provided by the Inforum Group at the University of Maryland[14] whereas this study uses OECD STAN data[15]. Second, the proxy for capacity utilisation is also different. Malley's *et al.* employ data on raw materials and energy inputs to proxy the capacity utilisation parameter while this study uses deviation from the hours trend. Third, the sample period in Malley's *et al.* study is curtailed for some of the countries in the analysis. For instance, in the case of UK the

[14] See the technical note by Wilson and Mead (1998), which is available from http://www.gla.ac.uk/economics/TFP. In this technical note the main caveats of the database are discussed. In particular, the main problems come from the fact that Input-Output Tables are not available for every year and country. Therefore, extrapolation methods have to be employed to obtain estimates of the missing series.

[15] The OECD STAN database is mainly based on national accounts data of individual OECD country members. The use of national accounts has the advantage that its components are harmonised across countries on the basis of the International System of National Accounts.

period for which data is available is 1970-1987. This paper, on the other hand, extends the period of analysis until 1998.

3 DATA AND CHARACTERISATION OF UK SECTORS RELATIVE TO THE G7-AVERAGE

This section discusses briefly some features of the data and characteristics of the British manufacturing sectors relative to their principal competitors.

3.1 Data

In order to compute the various measures of productivity the present study uses data on eight two-digit manufacturing industries and on the manufacturing sector as an aggregate of the G7 economies over the period 1970-1998. The countries are: Canada, France, Germany, Italy, Japan, the UK, and the US. Due to international comparability issues, the main data set used to construct these series is the OECD STAN-2002 database[16]. This was updated for missing series from other OECD databases (e.g. ISDB, STAN-1998) and O'Mahony and de Boer (2002). Data, however, was not always complete for every country-industry. Particularly, data for Germany is available only up until 1996 and it refers to the former Western Germany. Data limitations in the case of Japan for the capital stock did not allow one to obtain a TFP series for the wood and basic metal industries.

In this study productivity measures are provided both in terms of levels and growth rates. Particularly, international comparisons of productivity levels require three main components, namely comparable information on output, comparable information on factor inputs and currency conversion factors in order to translate output and factor inputs expressed in national currencies into a common currency. The latter is not required when growth rates of productivity are computed. Appendix A provides a more detail analysis about the data and data sources.

[16] See Appendix A for a detailed analysis of the data and data sources.

3.2 Characteristics of British Manufacturing Sectors Relative to the G7-Average

In Table 2 some features of the data for the UK manufacturing industries relative to the G7 average are highlighted. In particular, the information in Table 2 contains the relative difference on average growth rates for output and input factors between the UK industries and the average of the G7 economies during 1970 to 1998.

Table 2
Differences in Average Annual Growth Rates - UK vs. G7-Average (1970-1998)ǂ

Industry	*Symbol*	*1*	*2*	*3*	*4*	*5*
		$\Delta \ln\left(\frac{Q^{UK}}{Q^{G7}}\right)$	$\Delta \ln\left(\frac{K^{UK}}{K^{G7}}\right)$	$\Delta \ln\left(\frac{L^{UK}}{L^{G7}}\right)$	$\Delta \ln\left(\frac{M^{UK}}{M^{G7}}\right)$	1-3
Food, Beverages & Tobacco	FBT	-1.97	-1.67	-1.28	-2.67	-0.69
Textile & Leather	TL	-1.75	-2.49	-0.92	-2.01	-0.83
Wood & Wood Products	WWP	-2.34	-3.23	0.24	-2.78	-2.58
Paper & Paper Products	PPP	-0.70	-1.55	-1.07	-0.77	0.37
Chemicals, man-made fibres, rubber & plastic products	CH	0.05	-1.59	-1.10	0.22	1.15
Other Non-Metallic Mineral Products	NMM	-1.27	1.32	-1.93	-1.13	0.66
Manufacture of Basic Metals & Fabricated Metal Products	BFM	-2.29	-2.52	-2.47	-2.50	0.18
Machinery, Optical Equipment & Transport Equipment	MOT	-1.29	-2.40	-2.03	-0.89	0.75
Average		-1.45	-1.77	-1.32	-1.57	-0.13
Std. Dev.		0.77	1.29	0.78	1.02	

Sources: Data are from STAN database and O'Mahony and de Boer (2002). See Data Appendix A for further detail.
Notes: ǂ Yearly average in percentage (%) terms.
Q represents gross output, K is the physical capital stock, L is labour measured as hours per man, and M refers to intermediate inputs.

Over the period considered, real output (measured in terms of real gross output) in the British industries grew at lower rates than the output of the G7 average, except in the chemical industry. Additionally, lower rates than British competitors were also found with respect to the labour input. However, significant differences can be observed in growth dynamics between industry groups. The last column of Table 2 shows relative differences in gross output based labour productivity as the difference between column 1 and column 3. The UK achieved higher labour productivity growth rates than the G7 average in the paper, chemical, minerals, basic metals and machinery industries. On the other hand, capital stock was the variable that had relatively lower rates in comparison with the G7 average.

4 SENSITIVITY OF THE UK PRODUCTIVITY GAP IN MANUFACTURING TO MEASUREMENT ISSUES

Different productivity concepts are often used without sufficient clarity about the specific concept that is being employed and its correct interpretation. Broadly, productivity concepts can be classified as partial factor productivity (relating a measure of real output to a single measure of real input) or multifactor productivity (relating a measure of output to a bundle of inputs). As can be observed from above, international comparisons have been habitually made in terms of labour productivity, which may be a misleading indicator of technological differences as it may be positively influenced by other factors of production, as intermediate inputs or capital stock (see Hulten 2000).

Another distinction of particular relevance at the industry level is between productivity concepts that relate gross output to one or several inputs and those which use the value added concept to capture movements of real output. Empirically, the choice of concepts matters. As pointed out by Dollar and Wolff (1993) "*the value added concept creates a problem for productivity studies since intermediate inputs are transferred from a "source" of output to an explanation of output growth*". Contrary to value added, gross output allows a symmetrical treatment of intermediate inputs and primary inputs (labour and capital). Despite the theoretical recognition of gross output as the relevant output concept for productivity analysis at industry level, value added is still the concept used in the great majority of international productivity comparisons (Dollar and Wolff 1993; van Ark and Pilat 1993), exceptions being the works of Jorgenson (1995) and his co-authors.

The aim of this section is to analyse the sensitiveness of the measure of the productivity gap in British manufacturing to different concepts of productivity. To this end, the section provides estimates of relative labour and total factor productivity for manufacturing based on both value added and gross output, respectively. These estimates are calculated from the data described above on output, factor inputs and currency conversion factors and use the traditional growth accounting framework.

First, the relative labour productivity index is defined according to equation (1) and (2) depending on the output concept used, value added[17] (V_t) or gross output (Q_t), respectively.

$$(1) \qquad LP^{V}_{t_{AB}} = \left(\frac{V_t^{A(\$)}}{L_t^A} \right) \left(\frac{L_t^B}{V_t^{B(\$)}} \right)$$

$$(2) \qquad LP^{Q}_{t_{AB}} = \left(\frac{Q_t^{A(\$)}}{L_t^A} \right) \left(\frac{L_t^B}{Q_t^{B(\$)}} \right)$$

On the other hand, following much of the literature on productivity comparisons, the relative TFP index presented is that derived by Caves *et al.* (1982), which compares, for any two countries and for a particular industry, how much output the industry of each country can produce given a weighted measure of input factors. An advantage of the multilateral TFP index used is that is superlative (i.e. it is exact[18] for the flexible translog functional form) and it is transitive, so that the choice of the base country is unimportant. The TFP index requires the assumption of constant returns to scale in production and perfect competition through this section. The index is presented, respectively, in terms of value added, equation (3), and gross output, equation (4).

$$(3) \qquad TFP^{V}_{t_{AB}} = \frac{V_t^A}{V_t^B} \left(\frac{\bar{L}}{L_t^A} \right)^{\tilde{\sigma}_A} \left(\frac{\bar{K}}{K_t^A} \right)^{1-\tilde{\sigma}_A} \left(\frac{L_t^B}{\bar{L}} \right)^{\tilde{\sigma}_B} \left(\frac{K_t^B}{\bar{K}} \right)^{1-\tilde{\sigma}_B}$$

[17] Two main approaches can be distinguished to convert value added in national currencies into a common currency. These are single deflation and double deflation. In the single deflation procedure, the currency conversion factor based on relative prices of gross output is used to convert value added. In the double deflation approach outputs and intermediate inputs are converted separately.

[18] An index number is said to be exact for a particular functional form ifit equals the Fisher ideal index for that functional form, i.e. it is equal to the geometric mean of the Paasche and Laspeyres index. An index is said to be superlative if it is exact for a flexible functional form such as the translog(Diewert 1976).

(4) $$TFP^{Q}_{t_{AB}} = \frac{Q_t^A}{Q_t^B}\left(\frac{\overline{L}}{L_t^A}\right)^{\sigma_A}\left(\frac{\overline{K}}{K_t^A}\right)^{1-\sigma_A-\theta_A}\left(\frac{\overline{M}}{M_t^A}\right)^{\theta_A}\left(\frac{L_t^B}{\overline{L}}\right)^{\sigma_B}\left(\frac{K_t^B}{\overline{K}}\right)^{1-\sigma_B-\theta_B}\left(\frac{M_t^B}{\overline{M}}\right)^{\theta_B}$$

where a bar denotes the geometric mean over all the observations in the sample. The variable $\sigma_c = (s_c + \overline{s})/2$ is the average of the labour share in country *c* (s_c) and the geometric mean labour share ($\overline{s}$). Additionally, the variable $\theta_c = (m_c + \overline{m})/2$ is the average of the intermediate input share in country *c* (m_c) and the geometric mean of the intermediate input share ($\overline{m}$)

Table 3
Productivity Estimates for Alternative Output Concepts
Total Manufacturing, 1995

Country	LP(VA)	r	LP(GO)	r	TFP(VA)	r	TFP(GO)	r
US	100	1	100	1	100	1	100	1
JP	84.0	4	82.0	5	65.4	5	85.9	5
GY	87.3	3	89.7	3	83.2	2	93.6	2
FR	95.3	2	96.6	2	82.8	3	93.4	3
IT	72.3	5	61.1	7	52.8	7	74.5	7
UK	64.1	7	63.5	6	67.8	4	87.0	4
CD	65.0	6	83.1	4	61.9	6	84.5	6
Std Dev.	14.31		15.14		16.05		8.21	

Note: r refers to the rank position of each country relative to the total

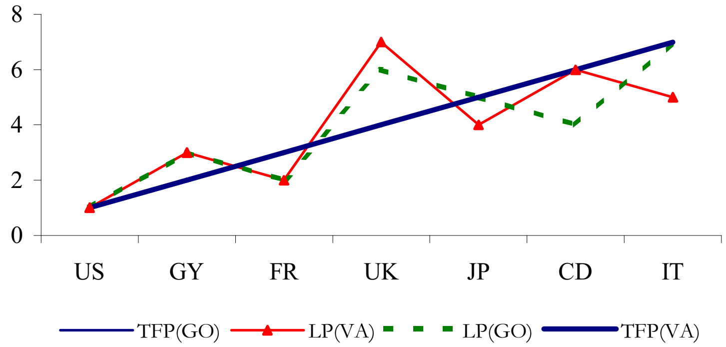
Notwithstanding the number of factors affecting productivity measurement it is, nonetheless, of importance to assess the sensitivity of the results obtained through adopting different productivity concepts. Table 3 reports relative productivity estimates in 1995 for manufacturing in terms of labour and total factor productivity respectively for alternative output concepts. The country of comparison is the US, which is set equal to 100. Additionally, ordinal information contained in the indices is summarized in the form of ranks. Independently of the productivity concept used, the United States clearly stands out as the productivity leader in total manufacturing in 1995[19]. The UK's manufacturing relative position, on the other hand, changes considerably depending on the productivity concept used. While UK is ranked the least productive in terms of LP(VA), with a productivity gap of 35% with respect to the US, its relative productivity position is improved in terms of TFP. As already

[19] To the extent that the countries' business cycles are not synchronized, relative TFP may change due to changes in relative capacity utilisation.

pointed out by other studies (O'Mahony 1999), the relatively low levels of labour productivity in UK manufacturing are partially caused by less capital-intensive production.

Not only the relative position of some of these countries varies with the productivity concept used, but the size of the productivity gap changes considerably too. In the case of the UK manufacturing sector, for instance, the productivity differential with respect to the leader by 1995 is estimated of the order of 32% in terms of TFP(VA) while is reduced to only 13% in terms of TFP(GO). Overall, one can observe that TFP(GO) reports smaller productivity differentials than the rest of the productivity estimates presented. Nevertheless, despite the apparent closeness in gross output based productivity levels, one must consider that the TFP growth rates based on gross output will be lower than those based on value added[20]. In other words, the speed by which the gap with respect to the leader is reducing or broadening will be lower in terms of gross output based productivity measures. Additionally, gross output based TFP tends to show a less marked variation across countries than the other productivity estimates.

Figure 1
Comparisons of Manufacturing Productivity Concepts
Data relative to 1995



On the other hand, Figure 1 considers the question of how alternative productivity concepts affect the ranking of the G7 economies according to their performance in manufacturing. In

[20] Specifically, the rate of change of value added based TFP equals the rate of change of gross output based TFP, multiplied by the inverse of the nominal share of value added in gross output.

the horizontal axis of Figure 1, countries have been arrayed in order of their TFP(GO) levels. Thus, while the line corresponding to TFP(GO) is continuously increasing by definition, changes in the sign of the slope for other productivity estimate represent a change in the ranking of countries. Some countries, and this is the case for the UK, sharply change their position from one data set to the other. While TFP(GO) and TFP(VA) overlap in Figure 1, it is worth mentioning that in terms of magnitudes the distance to the leader is reduced, on average, by half when gross output[21] is used.

One way of formalizing the closeness of these various rankings presented in Table 3 is to compute rank correlation. The results in Table 4 suggest that the ranking provided by the commonly used LP(VA) is only significantly (rank) correlated with the ranking provided by LP(GO) at the 5% level of significance. Additionally, LP(GO), a measure of labour productivity rarely used, appears to be significantly correlated with the rankings provided by the other different measures at 5% significance level. Not surprising the null hypothesis of independence of the two rankings provided by TFP(VA) and TFP(GO) is rejected.

Table 4
Spearman's Rank Correlation Coefficients

	LP(VA)	**LP(GO)**	**TFP(VA)**
LP(GO)	.8214* [0.023]		
TFP(VA)	0.7143 [0.071]	.8214* [0.023]	
TFP(GO)	0.7143 [0.071]	.8214* [0.023]	1.00** [0 .000]

Notes: The Table reports Spearman rank correlation coefficients
* Significant at 5% level.
** Significant at 1% level.

[21] Note that, in particular, for the year 1995 currency conversion factors for gross output, intermediate inputs and value added are assumed to be the same, and equal to the UVR used for output. The lack of reliable information on international price data on intermediate goods makes the double deflation approach not practicable here.

5 THE UK'S RELATIVE PRODUCTIVITY PERFORMANCE IN MANUFACTURING INDUSTRIES: A GROWTH ACCOUNTING APPROACH

Aggregate patterns of manufacturing convergence and relative decline may be represented by similar movements at a more disaggregated level or may hide diverging trends. This section considers the empirical evidence on UK's productivity performance at sectoral level relative to some of its major and most influential competitors. The growth accounting framework is used throughout this section as a method of describing and benchmarking productivity performance based on gross output, both in terms of levels and in terms of growth rates.

5.1. Sectoral TFP Levels

This section aims to examine the patterns that emerge from the sectoral gross output based TFP level data. Moreover it seeks to identify those sectors which in relation to productivity performance in other countries have represented the engines of the British industry over the past three decades. To this end Table 5 shows how the level of TFP in terms of gross output has evolved for several manufacturing industries in a comparative context. The figures relate to the level of TFP on three intermediate dates (i.e. 1975, 1985 and 1995).

Although the US stands out as the clear leader in productivity in total manufacturing for the period considered; it does not lead in some of the manufacturing subsectors, rather Germany and France do. In fact, by 1985, Germany and France had even higher productivity levels than the US in the manufacture of textiles (TL), non-metallic mineral products (NMM) and basic metals (BFM); and Germany was also ahead in food (FBT), chemicals (CH) and machinery (MOT). However, the trend by which these countries were catching up with the US stagnated or even began to diverge in the 1990's. Overall, it can be observed that most of the countries were closer to the US in 1985 than in 1995, the exception being the UK, which continued converging to US values, at least until 1995, and closed the gap with Germany and France in many industries. Particularly, by 1995, the productivity gap in the British chemical, mineral and paper industries with respect to the best country performer was of order of 8-10% (in terms of gross output based TFP measures).

Table 5
Total Factor Productivity Levels, Relative to US level (US=100)

Country	Year	FBT	TL	WWP	PPP	CH	NMM	BFM	MOT	MAN [1]
		Industry								
CD	**1995**	84	93	92	83	81	86	84	86	85
	1985	87	96	89	86	86	96	90	86	89
	1975	90	98	85	81	87	97	88	79	88
FR	**1995**	84	96	95	105	94	105	98	85	93
	1985	88	103	96	99	94	114	103	86	97
	1975	94	109	107	92	92	110	93	78	94
GY	**1995**	96	97	88	82	102	97	109	96	94
	1985	101	103	81	74	105	101	111	107	99
	1975	101	111	88	69	100	95	107	97	96
IT	**1995**	77	73	69	79	75	70	75	73	74
	1985	79	73	60	71	95	73	76	74	78
	1975	80	79	56	54	101	66	63	69	76
JP	**1995**	74	77	n/a	82	87	n/a	89	95	86
	1985	86	90	n/a	80	99	n/a	93	95	90
	1975	97	100	n/a	78	104	n/a	86	79	86
UK	**1995**	85	89	80	95	92	96	87	87	87
	1985	84	94	71	79	91	99	88	80	86
	1975	83	98	80	76	86	96	77	77	82

Note: See Data Appendix A
(1) MAN denotes Total Manufacturing

From Table 5 one can conclude that over the period 1970 to 1998, British industries were, on average, ranked amongst the laggards in terms of TFP levels in the context of the G7 economies, with an average differential over 15%[22]. However, their relative position improved over time. Particularly, by 1995, the best British industry performers in relative terms were the food and paper industries, which were ranked in third position within the G7 economies, while the worst performers were the textile, basic metals and wood industries, which were ranked in fifth position.

[22] Italian sectors were, on average, the least productive in relative terms over the period considered.

5.2 Sectoral TFP Growth Rates

This section turns now to describe the patterns of TFP growth rates using standard methods of growth accounting. The advantage of computing growth rates of TFP is that it does not require the time series data for different countries to be converted to a common currency. Table 6 shows the average annual growth rates of TFP for the manufacturing industries for the individual countries over the sample period 1970-1990 and 1990-1998, respectively. The first observation is that productivity growth rates do not exceed 2% per annum, thus the speed by which these industries tend to converge (or diverge) towards the productivity leader (in case a pattern of catching-up exists) is relatively very low.

Table 6
Annual Average TFP(GO) Growth Rates of Manufacturing Industries

Industry	FBT	TL	WWP	PPP	CH	NMM	BFM	MOT	Average	Std. Dev.	MAN
Country	*Growth rates of TFP(GO), 1970-90 (in % terms)*								(1)	(1)	
CD	0.12	1.15	0.56	0.01	0.55	0.61	0.16	0.89	0.51	0.40	0.51
FR	-0.13	0.82	1.28	0.45	0.90	1.05	0.75	1.05	0.77	0.44	0.67
GY	0.22	0.85	0.32	0.71	0.94	0.95	0.94	0.77	0.71	0.29	0.77
IT	0.23	0.87	1.45	1.41	-0.71	1.88	0.81	0.28	0.78	0.83	0.58
JP	-0.84	0.41	n/a	-0.50	0.02	n/a	0.18	1.25	0.08	0.73	0.44
UK	0.62	1.03	-0.11	0.99	1.16	0.74	1.08	1.28	0.85	0.44	1.04
US	0.20	1.20	0.67	0.17	0.64	0.63	0.21	0.56	0.54	0.35	0.61
Average	0.06	0.91	0.70	0.46	0.50	0.98	0.59	0.87			0.66
Std. Dev.	0.45	0.27	0.59	0.64	0.65	0.48	0.39	0.36			0.20
Country	*Growth rates of TFP(GO), 1990-98 (in % terms)*										
CD	0.07	-0.14	-0.53	-0.45	0.94	1.07	0.75	0.91	0.33	0.66	0.62
FR	-0.05	0.39	0.22	-0.05	0.70	-0.02	0.21	1.28	0.34	0.46	0.66
GY(2)	-0.94	-0.89	-1.40	-1.15	1.36	-1.26	-0.26	0.13	-0.55	0.93	0.34
IT	-0.23	0.49	1.06	-0.02	0.58	-0.19	0.73	-0.12	0.29	0.49	0.33
JP	-0.76	-1.32	n/a	-0.83	-0.21	n/a	-0.31	0.22	-0.54	0.54	0.06
UK	0.21	0.07	-0.13	0.02	0.96	0.32	0.37	0.81	0.33	0.38	0.56
US	-0.26	0.62	-1.05	-0.64	0.31	0.81	0.87	1.76	0.30	0.91	0.91
Average	-0.28	-0.11	-0.31	-0.45	0.66	0.12	0.34	0.71			0.50
Std. Dev.	0.43	0.74	0.89	0.46	0.51	0.83	0.48	0.68			0.28

Notes: (1) Average & standard deviation excludes total manufacturing
(2) Germany refers to Western Germany, and growth rates are calculated for the period 1990-96

Second, significant differences in growth dynamics can be observed between industry groups. Overall, the industries that, on average, grew at lower rates over both periods were the food and paper industries. On the other hand, the machinery industry (an ICT producing industry) was amongst the industries with higher productivity growth rates, particularly during the last decade. With respect to differences in growth dynamics across countries, the results show that UK manufacturing industries performed better than the average of the G7 countries over the two first decades, except in the case of the wood industry. Japan, on the other hand, performed poorly, except for the machinery industry, which was the driving force behind productivity growth in the Japanese manufacturing sector.

The second panel of Table 6 shows a significant decline in productivity growth rates over the last decade (1990-1998), experienced by most of the industries considered. Despite this slowdown, TFP in the British manufacturing industries continued growing at rates above the G7-average. The figures reveal that the markedly greater slowdown in other countries, particularly in Germany and Japan, rather than an acceleration in UK productivity growth rates, explains the relative better performance in British industry in recent years. It is worth mentioning that this last period brings two opposite country experiences. On the one hand, the decline of Japan, and on the other, the resurgence of the US. Total manufacturing productivity growth rates accelerated significantly in the US during the last decade, boosted principally by the machinery (MOT) industry.

6 ECONOMETRIC ESTIMATION OF TFP GROWTH DIFFERENCES

The results presented in the previous section were based on standard neoclassical methods of growth accounting. Although the growth accounting methodology serves as the framework for TFP computation, there is always the concern that the actual conditions of an economy may be different from the neoclassical assumptions. In fact, different studies (see for instance Lynde and Richmond 1993, Cameron 2003 and Malley *et al.* 2003) showed that the conditions of the UK manufacturing industries differ from those postulated by the growth accounting approach. In particular, evidence was found of the importance of the role of market power

(Harris and Trainor 1997; Small 1997) and adjustments in capacity utilisation (Cameron 2003). As pointed out by Crafts and Mills (2001: p.1), "*in standard growth accounting comparisons these problems are either assumed away or, for the purpose of benchmarking, taken to impart equal bias in each case*." Thus, in order to correct for the potential bias this section describes a methodology for calculating productivity growth rate differences by econometric estimation of country-industry gross output production functions. In developing the analytical framework this section follows the methodology initially advocated by Hall (1988) and extended by Harrigan (1999), among others.

6.1 The Model

Using a homogeneous production function one can represent actual output for a particular industry (*i*) in country (*c*) in year (*t*) in the following way:

$$(5)\qquad Q_{ict} = A_{ict} F(L^s, K^s, M)_{ict}$$

where Q_t denotes gross output[23], A_t represents the industry's level of technology in a particular country and, L^s_t, K^s_t, M_t stands for labour and capital services and intermediate inputs, respectively. The function F will be assumed to be homogeneous of degree $(1+\lambda)$ in total inputs. Thus, $\lambda=0$ will correspond to constant returns to scale.

Following Basu and Kimball (1997), one can express input services as follows: $K^s_t=Z_tK_t$, and $L^s_t=N_tH_tE_t=L_tE_t$. In this way, capital services can be represented as the function of the capital stock, K_t, and its degree of utilisation, Z_t. Additionally, labour services can be decomposed in terms of number of employees, N_t, the number of hours worked, H_t, and the effort of each worker, E_t.

Logarithmically differentiating equation (5) with respect to time and rearranging one obtains the following expression:

[23] For easy of exposition country and industry subscripts are reported only when strictly necessary

$$(6) \quad \Delta\ln Q_{ict} = \Delta\ln A_{ict} + \frac{\partial F_{ict}}{\partial L_{ict}}\frac{L_{ict}}{F_{ict}}\Delta\ln L_{ict} + \frac{\partial F_{ict}}{\partial K_{ict}}\frac{K_{ict}}{F_{ict}}\Delta\ln K_{ict} + \frac{\partial F_{ict}}{\partial M_{ict}}\frac{M_{ict}}{F_{ict}}\Delta\ln M_{ict} + \delta_{ict}\Delta\ln CU_{ict}$$

where $CU_t = G(Z_t, E_t)$, represents the level of capacity utilisation, which is defined as a function of the intensity with which input factors are used in the production process. This variable is not observed by the econometrician.

A challenge in estimating expression (6) is to relate the unobservable $\Delta lnCU_t$ to observable variables. Notice that if this effect is present and it is not considered, estimated technological growth would be biased by the cyclical utilisation of inputs. Data on deviation from the hours trend for each national industry is used to construct the cyclical utilisation index.

Additionally, market imperfection in the output market is accommodated. The analysis proceeds assuming that producers charge a price, P_t, which is a mark up, μ_t, over marginal cost. Nevertheless, they act as price-takers in input markets when choosing their factor inputs so as to maximise profit (or minimise cost). In this regard, producers take the price of all J inputs, P_t^J, as given by competitive markets.

The first-order conditions for cost minimisation imply that the value of a factor's marginal product is set equal to a mark-up over the factor's input price. That is:

$$(7) \qquad \frac{\partial F_{ict}}{\partial J_{ict}}\frac{J_{ict}}{F_{ict}} = \left(\frac{P_{ict}}{MC_{ict}}\right)\frac{P_{ict}^J J_{ict}}{P_{ict} Q_{ict}} = \mu_{ict} s_{ict}^J$$

where: P_t and P_t^J are the output and input prices respectively; MC_t is marginal cost, $\mu_t = P_t/MC_t$ is the mark up ratio and s_{it}^J are the input revenue shares. Equation (7) means that the ratio of the input payment to output valued at marginal cost measures the elasticity of output with respect to this input. In other words, the revenue shares, s_t, are an exact measure of the elasticity when marginal price and cost are equal ($\mu_t = 1$) but underestimates it when the marginal cost falls short of price.

Combining equation (6) and (7) and rearranging after applying Euler's theorem[24], one obtains an equation similar to Hall's (1988) econometric model, although allowing for variations in capacity utilisation[25].

$$(8)\quad \Delta\ln(Q/K)_{ict} = \beta_{ic} + \mu_{ic}[s^L_{ict}\Delta\ln(L/K)_{ict} + s^M_{ict}\Delta\ln(M/K)_{ict}] + \lambda_{ic}\Delta\ln(K)_{ict} + \delta_{ic}\Delta\ln CU_{ict} + \upsilon_{ict}$$

The resulting equation (8) permits one to simultaneously estimate price-cost margins (μ) alongside returns to scale (1+λ). The parameter λ is a convenient measure of the extent to which the industry production function differs from constant returns to scale.

To simplify notation, let $\Delta\ln FC_{ict} = [s^L_{ict}\Delta\ln(L/K)_{ict} + s^M_{ict}\Delta\ln(M/K)_{ict}]$ then equation (8) becomes[26]:

$$(9)\qquad \Delta\ln(Q/K)_{ict} = \Delta\ln A_{ict} + \mu_{ic}\Delta\ln FC_{ict} + \lambda_{ic}\Delta\ln K_{ict} + \delta_{ic}\Delta\ln CU_{ict}$$

As mentioned above, productivity differences between industries and across countries tend to be highly persistent over time. In equation (9) the term ΔlnA_{ict} represents the national industry's productivity growth rate, which will be represented by an error component structure in the following way:

$$(10)\qquad \Delta\ln A_{ict} = \beta_{ic} + \nu_{ict}$$

where the term β_{ic}, represents the average growth rate of productivity for a particular industry in a particular location. On the other hand, the term ν_{ict} is an idiosyncratic disturbance to industry *i* in nation *c* at time *t*, assumed to be an independent identically distributed normal random variable.

[24] Note that since the output elasticities of factors J sum up to the scale elasticity (Euler's Theorem) one can compute the capital elasticity as the following difference: $\frac{\partial F}{\partial K}\frac{K}{F} = 1 + \lambda - \mu s^L - \mu s^M$. This relation is very useful as it avoids the problematic computation of the shadow value of capital.

[25] The mark up, the capacity utilisation and scale coefficients are considered as average parameters.

[26] For empirical purpose, discrete growth rates replace continuous ones and the index of input growth (FC) is a Törnqvist one, where the weights are the arithmetic average of the shares in year (t) and (t-1) respectively.

Finally, inserting equation (10) into equation (9) one obtains the equation to be estimated:

$$(11) \qquad \Delta \ln(Q/K)_{ict} = \beta_{ic} + \mu_{ic}\Delta \ln FC_{ict} + \lambda_{ic}\Delta \ln(K)_{ict} + \delta_i \Delta \ln CU_{ict} + \nu_{ict}$$

6.2 Econometric Issues

Before turning to the results, there are a number of issues to discuss relating to equation (11). First, it is in principle sensible to assume that there may be important differences between industries in each country. However, it is assumed that the production structure of the same industry is very likely to be similar in a set of industrialized countries. Therefore, parameters estimated are assumed to be the same across industries in different countries[27] except for the estimated TFP growth rates, which, in principle, are allowed to vary across sectors and countries.

Second, this model is based on the assumptions of stationarity of all the variables included in the regression. Failing such an assumption one might be dealing with spurious regressions. Unit root tests are performed on the individual series to ensure all variables entering equation (11) are stationary. Among the various tests proposed in the literature, the Im, Pesaran and Shin (1997), IPS, panel unit root test is suitable here. The IPS *t*-bar test is based on an average of the individual country industry Dickey Fuller (ADF) tests while allowing for heterogeneous coefficients under the alternative hypothesis and different serial correlation patterns across groups. Under the null hypothesis, all groups exhibit a unit root while under the alternative this is not true for some.

Table B in Appendix B presents the results of the panel unit root tests allowing for an intercept. Applying by industry the *t*-bar test to the variables in first differences, test statistics are obtained above the critical value to reject the hypothesis of the presence of a unit root. These tests are based on an ADF regression of 1 lag and a DF regression. Therefore, the rejection of the null hypothesis implies that the data series in growth rates are stationary and

[27] The mark-up, the capacity utilisation and the scale coefficients are assumed to be constant across countries but allowed to vary across industries. This is achieved using slope dummy variables for each industry.

consequently, traditional estimation methods can be used to estimate the relationship between them.

Equation (11) can be estimated in various ways depending on how one considers the error term and addresses potential correlation between the right hand side variables and the composite error term due to simultaneity and/or omitted variable problems. The appropriate solution to the potential correlation problem is to use an instrumental variable estimator. The difficulty, however, is the lack of appropriate instruments in this kind of regressions (as shown in other studies, see Griliches and Mairesse 1998). In fact, Basu and Fernald (1997) find that using OLS does not greatly affect the result. The estimated parameters of (11) are thus non-instrumented[28].

Finally, an issue in estimating equation (11) is the possibility of serial correlation and heteroskedasticity in the residuals. A preliminary regression of equation (11) by OLS (results not reported) suggests the non-existence of serial correlation in the residuals. The Baltagi autocorrelation LM test for panel data predicts a $\chi^2(1)$ statistic for the null of no serial correlation of 0.124 with a probability value of 0.724, and the Durbin-Watson statistic for panel data is 1.90. However, pre-testing the null of a constant variance rejects the assumption of homoskedasticity[29]. Assuming homoskedasticity disturbances when heteroskedasticity is present will still result in consistent estimates of the regression coefficients, but these estimates will not be efficient. In particular, the modified Wald test for groupwise heteroskedasticity (H_o: $\sigma^2_{ic} = \sigma^2, \forall\, ic$) predicts a $\chi^2(54)$ statistic of 1597.99 with a probability value of 0.000. On the basis of this test the analysis proceeds by estimating the regression allowing for heteroskedasticity in the residuals.

In the cases of heteroskedastic panels one has two possibilities to proceed: (a) making assumptions about the precise form of heteroskedasticity and estimating the model again with GLS; or (b) using a covariance matrix estimator that is robust against heteroskedasticity of unknown form. The results presented in this paper are based on the first approach.

[28] They should be interpreted with caution, as they may not be consistent estimates of the structural parameters due to the simultaneity problem.

[29] The Breuch and Pagan LM test for cross-sectional correlation cannot reject the null of spatial independence of the residuals. The $\chi^2(1431)$ statistic reports a value of 1461.61 with probability value of 0.281.

Nevertheless, point estimates under both approaches were very similar, although standard errors were slightly higher under the second approach, but in no case changing the significance of the coefficients. In particular, the Kmenta/CHTA correction for panel heteroskedasticity is used, i.e. Panel Weighted Least Squares (PWLS). This estimator is a form of GLS although it applies the finite sample normalisation adjustment to the estimated variances. The analysis starts by estimating equation (11) via OLS and generating residuals, which are then used to estimate the error variances. The estimated variances are then used to weight every observation in a particular unit "*ic*", and OLS is run again on the weighted data[30].

6.3 Empirical Results

Table 7 reports estimates of three variants of equation (11). The estimator in each case is PWLS as discussed above. Model 1 is the unrestricted equation, while Model 2 imposes constant returns to scale. Model 3 imposes restriction across countries on the TFP growth term at the industry level and, finally, Model 4 is the constant returns restricted version of Model 3.

The unrestricted model allows for two sources of industry productivity growth differences: differences in the scale of production within industry and industry-country differences in productivity growth rates. The imposition of constant returns to scale ($\lambda = 0$) in Model 2 means that any differences in productivity growth will be attributed to industry-country specific growth rates. In fact, the test of the null hypothesis of $\lambda_i = 0$ for all industries cannot be rejected at the 5% level of significance on the basis of an F-test, F(8, 1410)=1.96. On the other hand, the assumption of equal TFP growth rates for industry *i* across countries (H_0: $\beta_{ic} = \beta_i$) cannot be rejected (Model 1 to Model 3, and Model 2 to Model 4). In other words, the results suggest that differences in productivity growth rates within an industry across the G7 economies are not statistically significant.

30 This is roughly analogous to "robust" standard error in a panel context.

Table 7
Estimates of Equation (11)

	Model 1		Model 2		Model 3		Model 4	
	Coeff.	**Std. Err.**	**Coeff.**	**Std. Err.**	**Coeff.**	**Std. Err.**	**Coeff.**	**Std.**
Mark-up								
FBT	1.015***	(0.030)	1.035***	(0.030)	0.998***	(0.028)	1.032***	(0.028)
TL	1.136***	(0.023)	1.136***	(0.023)	1.141***	(0.022)	1.141***	(0.022)
WWP	1.081***	(0.019)	1.091***	(0.018)	1.082***	(0.018)	1.086***	(0.016)
PPP	1.118***	(0.028)	1.131***	(0.022)	1.113***	(0.027)	1.135***	(0.021)
CH	1.052***	(0.019)	1.057***	(0.019)	1.052***	(0.019)	1.060***	(0.019)
NMM	1.210***	(0.040)	1.209***	(0.040)	1.189***	(0.039)	1.186***	(0.038)
BFM	1.081***	(0.024)	1.088***	(0.023)	1.078***	(0.024)	1.089***	(0.023)
MOT	1.166***	(0.021)	1.173***	(0.021)	1.160***	(0.021)	1.166***	(0.021)
Returns to scale								
FBT	-0.132**	(0.054)			-0.167***	(0.038)		
TL	0.006	(0.048)			-0.010	(0.036)		
WWP	-0.030	(0.024)			-0.008	(0.021)		
PPP	-0.029	(0.036)			-0.042	(0.034)		
CH	-0.094*	(0.055)			-0.110**	(0.050)		
NMM	-0.002	(0.048)			0.015	(0.046)		
BFM	-0.062	(0.050)			-0.067	(0.041)		
MOT	-0.073*	(0.043)			-0.063	(0.038)		
Capacity Utilisation								
FBT	-0.819	(0.519)	-0.683	(0.525)	-0.824	(0.514)	-0.639	(0.527)
TL	-1.750***	(0.429)	-1.751***	(0.424)	-1.785***	(0.422)	-1.771***	(0.422)
WWP	-0.431	(0.653)	-0.476	(0.648)	-0.410	(0.645)	-0.449	(0.642)
PPP	1.571**	(0.689)	1.501**	(0.677)	1.598**	(0.687)	1.463**	(0.676)
CH	2.010***	(0.734)	2.195***	(0.739)	2.051***	(0.736)	2.259***	(0.744)
NMM	-0.557	(0.925)	-0.518	(0.914)	-0.231	(0.907)	-0.215	(0.906)
BFM	1.172**	(0.543)	1.248**	(0.543)	1.188**	(0.540)	1.256**	(0.544)
MOT	-0.033	(0.578)	0.080	(0.569)	0.075	(0.577)	0.181	(0.576)
Industry Productivity Growth Rates in % (averages)	(1)		(1)					
FBT	0.361**	(0.002)	0.019	(0.001)	0.509***	(0.001)	0.160**	(0.001)
TL	0.826***	(0.001)	0.830***	(0.001)	0.899***	(0.001)	0.897***	(0.001)
WWP	0.546***	(0.002)	0.462***	(0.001)	0.423***	(0.001)	0.406***	(0.001)
PPP	0.575***	(0.002)	0.490***	(0.001)	0.521***	(0.002)	0.402***	(0.001)
CH	0.805***	(0.002)	0.569***	(0.001)	1.005***	(0.002)	0.751***	(0.001)
NMM	1.042***	(0.002)	1.039***	(0.002)	0.957***	(0.002)	0.976***	(0.001)
BFM	0.772***	(0.001)	0.671***	(0.001)	0.755***	(0.001)	0.668***	(0.001)
MOT	1.244***	(0.002)	0.975***	(0.001)	1.240***	(0.002)	1.016***	(0.001)
Adj R^2	0.947		0.947		0.947		0.946	
N. Obs	1488		1488		1488		1488	
RMSE	0.013		0.013		0.013		0.013	
LL	4356.4		4347.2		4330.3		4311.1	
H_o: β_{ic} =	7.06	[0.000]	8.48	[0.000]	4.15	[0.000](2)	11.31	[0.000](2)

Notes: Standard errors are in parenthesis and probabilities in brackets. Number of observations is 28 time periods (except for Germany), by 8 industries (except for Japan), by 7 countries.
(1) Averages within industries across countries from point estimates. (2) H_o: $\beta_i = 0$.
* significant at 10% level, ** at 5% level and *** at 1% level.

As can be verified in Table 7, the coefficient estimates confirm the presence of positive and statistically significant mark-ups, except for the FBT industries, where the 95% confidence interval of the estimate of μ includes 1 in any of the models analysed. Industries with higher mark-ups are the non-metallic mineral industry followed by the machinery industry. In prior studies, estimates for mark-ups obtained within the primal framework vary in size, but all of them point toward the existence of market power (Hall 1988, 1990). The crucial factor when estimating mark-ups appears to be the definition of output.[31] Regardless of the output concept used in prior studies, mark-up estimates presented in this research are in general both more homogeneous across industries and lower, mostly ranging between 1.1 and being well below 1.3 for every industry.

Mark-ups and returns to scale are economically related such $\mu(TR/TC)=(1+\lambda)$[32]. However, in this case the results suggest deviation from constant returns to scale is individually non significant for all the considered industries, except for the FBT industry which appears to show significant decreasing returns to scale, although its mark-up is not significantly different from 1. As far as economies of scale is concerned, the finding of constant returns is nothing new (Burnside 1996; Burnside *et al.* 1995; Haskel *et al.* 1995). Results obtained within the primal approach are mixed. Some estimates imply high increasing returns to scale (Hall 1990), while others find only moderate economies of scale (Bartelsman *et al.* 1994), constant (Burnside 1996; Burnside *et al.* 1995) or even decreasing returns (Basu and Fernald 1997).

The capacity utilisation term, on the other hand, appears significant for 4 of the industries considered. Correcting measures of input for cyclical changes in capacity utilisation has a significant impact on estimates of the mark-ups and returns to scale. When capacity utilisation is included in the regression the significance and sizes of the mark-up diminishes. The same applies to the estimates of the returns to scale.

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[31] Basu and Fernald (1997) show that the use of value added data estimated mark-ups upwards. In fact, estimates obtained with gross output data are generally lower than those obtained with value added data.
[32] TR and TC stand for total revenues and total costs respectively.

7 DISCUSSION

The interest in this section is multiple. Based on the results derived in previous sections, the first objective is to examine the direction and size of the bias in the productivity residual by using the traditional growth accounting approach. The second goal is to study whether adjusting for bias materially affects international comparisons of TFP over time. Finally, the results reported here are compared with those from other recent studies.

7.1 Bias in Traditional TFP Estimates

Table 8 presents the implied average gross output based TFP rates using both the parametric and non-parametric techniques for different industry groups and countries over the period 1970-1998. Particularly, the parametric estimates are those based on the results reported in the last column of Table 7, corresponding to the estimation of Model 4. On the other hand, the non-parametric estimates are those based on the accounting approach outlined in section 5.

Are traditional growth accounting measures of TFP growth seriously biased? The results presented in Table 8 suggest that the growth accounting TFP rates estimates, which are not corrected for biases resulting from imperfect competition and adjustments in capacity utilisation are a poor guide to the "adjusted" TFP. The latter are obtained when those biases have been removed and they may be thought of as a better measure of the contribution of innovation to productivity growth. Overall, for the period 1970 to 1998, the sign of the bias is positive, in the sense that growth accounting estimates underestimate true average TFP growth rates, the only exception being for the wood industry. The size of the bias changes across industries and countries. For the case of UK the average estimated bias is equal to 0.17. The major differences between both approaches are found for Japan and Germany. Additionally, the industry for which the results differ most is the textile industry.

Although the magnitudes of the results presented in the first two panels of Table 8 are rather different, similar patterns across industries over the sample period emerge. In particular, the industry with lowest productivity growth rates is the food industry, while the machinery industry is the one experiencing fastest growth rates under both approaches.

Table 8
Parametric vs. Non-Parametric Gross Output-Based TFP Growth Estimates
1970-1998 (in % terms)

	FBT	TL	WWP	PPP	CH	NMM	BFM	MOT	Average	Std. Dev.	MAN
	Growth rates of TFP(GO) - Growth Accounting								**(1)**	**(1)**	
CD	0.11	0.78	0.25	-0.12	0.66	0.74	0.33	0.90	0.46	0.37	0.54
FR	-0.11	0.70	0.98	0.31	0.84	0.75	0.60	1.12	0.65	0.39	0.67
GY	-0.05	0.45	-0.08	0.28	1.03	0.44	0.67	0.63	0.42	0.37	0.67
IT	0.10	0.76	1.34	1.00	-0.34	1.29	0.79	0.17	0.64	0.60	0.51
JP	-0.82	-0.09	n/a	-0.60	-0.05	n/a	0.04	0.95	-0.09	0.61	0.33
UK	0.50	0.76	-0.12	0.72	1.10	0.62	0.87	1.15	0.70	0.40	0.90
US	0.07	1.04	0.18	-0.06	0.55	0.68	0.40	0.90	0.47	0.40	0.70
Average	-0.03	0.63	0.43	0.22	0.54	0.75	0.53	0.83	0.50	0.56	0.62
UK-Avg.	0.53	0.13	-0.54	0.50	0.56	-0.13	0.35	0.32	0.20		0.28
Std. Dev.	0.40	0.36	0.60	0.54	0.55	0.29	0.29	0.34			
	Growth rates of TFP(GO) - Parametric results										
CD	0.26	0.95	0.26	0.02	0.85	0.53	0.39	0.91	0.52	0.35	0.58
FR	0.09	1.20	0.77	0.14	1.06	1.00	0.69	1.39	0.79	0.47	0.79
GY(2)	0.18	0.89	0.25	0.57	1.08	0.90	0.97	0.94	0.72	0.34	0.78
IT	0.26	0.84	1.14	1.25	-0.08	1.50	0.82	0.27	0.75	0.55	0.55
JP	-0.58	0.40	n/a	0.07	0.28	n/a	0.42	1.30	0.32	0.61	0.67
UK	0.72	0.87	-0.10	0.79	1.29	1.23	0.97	1.19	0.87	0.44	1.00
US	0.18	1.13	0.11	-0.03	0.78	0.69	0.41	1.10	0.55	0.45	0.76
Average	0.16	0.90	0.41	0.40	0.75	0.98	0.67	1.02	0.66	0.72	0.73
UK-Avg.	0.56	-0.03	-0.50	0.39	0.54	0.25	0.31	0.18	0.21		0.27
Std. Dev.	0.38	0.26	0.46	0.48	0.49	0.35	0.26	0.37			
	Bias: Parametric –Growth Accounting										
CD	0.16	0.16	0.01	0.14	0.19	-0.21	0.06	0.02	0.06		0.03
FR	0.20	0.50	-0.20	-0.16	0.22	0.25	0.09	0.28	0.15		0.12
GY(2)	0.23	0.44	0.33	0.29	0.04	0.47	0.31	0.31	0.30		0.11
IT	0.16	0.08	-0.20	0.25	0.26	0.21	0.03	0.10	0.11		0.05
JP	0.24	0.48	n/a	0.67	0.33	n/a	0.38	0.35	0.41		0.34
UK	0.21	0.11	0.02	0.07	0.18	0.61	0.10	0.05	0.17		0.10
US	0.11	0.10	-0.07	0.03	0.24	0.01	0.01	0.20	0.08		0.07
Average	0.19	0.27	-0.02	0.18	0.21	0.22	0.14	0.19			

Source: Results from Table 6 and Table 7.
Note: (1) Average & standard deviation excludes total manufacturing
(2) Germany refers to Western Germany, and growth rates are calculated for the period 199096

Does adjusting for bias affect comparisons between British and the G7 average TFP growth rates? The results presented in Table 8 suggest that with respect to the performance of the British industries, both approaches conclude that overall UK manufacturing industries experienced higher rates than the G7 average, with very few exceptions. Major differences between both approaches are found for the mineral industry, followed by the textile and machinery industry (industries with high estimated mark-ups).

Does adjusting for bias affect the size and direction of the British productivity gap with respect to the TFP performance of the G7 countries? To answer this question Table 9 presents the estimated bias of the UK relative productivity gap. The bias is obtained as the difference between the gross output based TFP levels in 1995 obtained from adjusting for imperfect competition and capacity utilisation and the TFP levels from the accounting approach outlined in section 5.

Table 9
Bias of UK Relative TFP Gap

	US	JP	GY	FR	IT	CD	Average
MAN	-1.5	5.7	0.2	1.6	7.2	-0.4	2.1
FBT	-1.6	1.2	-1.4	0.7	1.5	-1.2	-0.1
TL	-6.5	2.6	-9.4	-0.1	6.5	-9.5	-2.8
WWP	-1.5	n/a	-1.8	2.3	7.1	-1.9	0.8
PPP	0.0	10.3	8.5	-2.6	7.6	8.3	5.3
CH	0.1	5.4	-0.9	-0.1	5.9	1.6	2.0
NMM	4.4	n/a	10.1	8.6	17.5	9.5	10.0
BFM	1.0	9.6	-3.0	2.9	8.3	1.6	3.4
MOT	-1.3	2.5	-11.7	4.4	8.7	-2.5	0.0
Average	-0.7	5.3	-1.2	2.0	7.9	0.7	

Note: The bias is calculated as the difference between the TFP level in 1995 obtained from the results presented in Table 7 and the TFP level from the growth accounting approach in Table 5.

For Total Manufacturing (MAN), the estimated bias is negative for the US and Canada and positive otherwise. A negative bias means that relative TFP levels estimates from the growth accounting approach are larger than the "adjusted TFP" levels. At sectoral level, the sign of the bias is positive and its size of the order of 5% in both directions. Larger biases are found for the mineral, paper and the textile industries. Across countries major differences are estimated with respect to Italy (with an average bias of 8%), Germany, and Japan (with an average bias of 5%).

Overall, these estimates imply that it is important to be concerned about biases in traditional estimates of TFP, particularly at the sectoral level. Although for total manufacturing the average bias of the productivity gap is estimated of the order of 2.5%, there are some industries for which this bias is even above 10%.

7.2. Comparison with Previous Studies

As mentioned in the introduction to this paper, there has been much recent interest in comparing the UK's performance in terms of productivity levels with that of other industrialized economies. This is reflected in the studies by O'Mahony (1999), O'Mahony and de Boer (2002) and Malley *et al.* (2003). The first two studies are based on growth accounting and use value added as a measure of output. The latter uses gross output and adjust for the presence of imperfect competition and capacity utilisation. But how do these other estimates of relative UK TFP for manufacturing compare with those reported here? Table 10 compares relative TFP levels derived from previous sections with those reported by others. All data refer to 1995, with the exception of the data reported by Malley *et al.* (2003), which refers to 1994. For ease of comparison, the indices of Table 10 have been rebased so the UK's TFP level is set equal to 100.

Although our approach is closest to the Malley *et al.* (2003) study our results differ to some degree. Major differences with Malley's results refer to the estimated gap with respect to the US. In fact, their result is called into question. Focusing on the differential with the US: Malley's productivity gap of 36% implies that, at average gross output based TFP growth rates of 1% and 0.78% for UK and the US respectively, it will take 128 years for the UK to catch-up with the US levels in manufacturing. On the other hand, the reported O'Mahony's gap of 42%

implies that at value added based TFP growth rates[33] of 1.85% and 1.21% for UK and US respectively, it will take just 55 years to converge to the US levels. Therefore, the differences between both studies are quite considerable, although the reported gap looks similar. The results reported here are more in line with the estimates by O'Mahony (1999), in the sense that they imply a 51-year span to attain the US levels in manufacturing (given constant rates of growth).

Table 10
UK Manufacturing Productivity Gap: Comparisons with Previous Studies

Studies	TFP Measure	US	JP	GY	FR	IT	UK	CD
Author	Adjusted GO-TFP	113	104	108	109	93	100	97
Author	Solow(GO)	115	99	108	107	86	100	97
Author	Solow(VA)	147	96	123	122	78	100	91
Malley et al. (2003)	Adjusted GO-TFP	136		112	113		100	
O'Mahony(1999)	Solow(VA)	142	116	108	103		100	
O'Mahony(2002)	Solow(VA)	143		121	110		100	

Notes: Malley *et al.* (2003) data refers to 1994

The preferred estimates here (those adjusted for market power and variations in capacity utilisation) confirm the finding of these previous studies that UK manufacturing faces a significant productivity lag in terms of TFP. Additionally, in agreement with other studies, the analysis concludes that adjusting for biases does not impact heavily on the British productivity gap for the manufacturing sector in aggregate. In particular, the results obtained in the present study suggest that the gap in terms of gross output based TFP with respect to the US is of the order of 13%, with respect to Germany and France of 8-9%, and of 4% with respect to Japan.

8 CONCLUSIONS

The purpose of this paper was to revisit the well-documented productivity gap in manufacturing between the UK and its most direct and influential competitors. To this end, new estimates of growth performance and levels of productivity were provided for the

[33] These growth rates are the ones reported in O'Mahony (1999) for value added based TFP for the period 1973-1996.

aggregate manufacturing sector and for a set of eight manufacturing industries over the period 1970-1998. Particularly, the stress of the present study was placed upon the sensitivity of the size and direction of the productivity differential to measurement issues and restrictive assumptions.

First of all, the results showed that the British productivity gap in total manufacturing is particularly sensitive to different productivity concepts. Not only the relative position of the UK manufacturing sector with respect to the performance of other countries varies with the productivity concept used, but also the size of the reported productivity differential changes considerably too.

Growth accounting productivity estimates were presented together with parametric estimates. The problem with growth accounting estimates is that they may not be an accurate measure of the true TFP since they ignore the role of market power, scale economies and adjustments in capacity utilisation. In fact, the econometric results presented in this paper suggest that some of the assumptions underlying the growth accounting approach are not sustainable. Particularly, the results confirm the presence of positive and statistically significant mark-ups for all industries considered, except for the food industry, and the significance of the capacity utilisation term. However, the assumption of constant returns to scale could not be rejected.

Taking into account these results, "adjusted" TFP estimates were presented, which are obtained when those biases have been removed and which might be thought of as more accurate measures of the underlying technological differential. These estimates permitted the study of the bias and its impact on the UK's productivity differential. The results presented in this paper showed that the magnitude and direction of the bias varies across industries as well as across countries. Nevertheless, the sign of the bias was on average positive, in the sense that traditional growth accounting productivity estimates are significantly downward biased for the period 1970-1998.

Overall, these results suggested that is important to be concerned about biases in traditional estimates of TFP but, mainly, at sectoral level. Although for total manufacturing the average bias of the size of the productivity gap was found of the order of 2.5%, there are some industries for which this bias was even greater to 10%. This implies that adjusting for biases does not impact greatly on the size of the British productivity gap at the aggregate manufacturing level but it does at a more disaggregated level.

Despite the concern about biases, the results showed that, although there are British success stories (such as chemicals, minerals and paper and printing industries), the productivity gap still remains significant. Moreover, although the productivity gap has been reduced over time (at least until 1995), the productivity of the UK still trails behind that in the US, France and Germany and to a lesser extent Japan, almost regardless of the sector.

Finally, what emerges as a conclusion is that productivity growth estimates are highly sensitive. However, despite the sensitivity of productivity measures, one must be cautious about the use of the standard accounting approach to benchmark productivity performance and study differences in productivity across countries. Such criticism must be taken seriously in the interpretation and use of productivity measures as representations of the theoretical concept of TFP.

Appendix A. Data Description and Sources

The main data are obtained from the OECD Structural Analysis (STAN) database. This database, which is largely based on national accounts of individuals OECD member states, provides a comprehensive tool for analysing industrial performance across countries using the ISIC Rev. 3 Industry classification. The use of national accounts for the purpose of international comparisons has the advantage that its components are harmonised across countries on the basis of the International System of National Accounts.

International comparisons of productivity levels require three main components, namely comparable information on output, comparable information on factor inputs and currency conversion factors in order to translate output and factor inputs expressed in national currencies into a common currency.

Currency Conversion Factors: One of the most serious limitations in attempting to estimate relative productivity levels is the lack of adequate data on internationally comparable prices. The individual country data sets contain price indexes for inputs and outputs which are normalized in some particular year. As an example consider the price of output. For the countries considered, the data set records the price of output in each country as 1 in 1995. However, it would be incorrect to assume that the relative output price across countries is 1 in 1995. Therefore, one needs to know the relative industry output prices across countries for at least one year. The lack of this information implies that output will be measured in different units. A similar argument holds for each input.

This study uses the UVR for 1987 employed by Pilat (1996) and extrapolated to 1995, except for Italy, which is not included in this study. Following van Ark (1996) these UVRs are extrapolated[34] for each industry (*i*) with the industry specific national price indexes obtained from the OECD[35], as represented in equation (A.1):

[34] van Ark and Pilat (1993) used the same methodology to extrapolate their 1987 UVRs for Germany and Japan to 1990.

[35] The reliability of this extrapolation procedure is affected by the differences in data and methodology used to construct the UVRs and the national price indices respectively.

(A.1) $$UVR_{it}^{AB} = UVR_{i0}^{AB} \frac{P_{it}^{A} / P_{i0}^{A}}{P_{it}^{B} / P_{i0}^{B}}$$

with superscripts refer to country A and B, and "*i*" refers to the industry.

The extrapolated UVR for year 1995 are then used to convert the real output for year 1995 expressed in its own currency to a common currency (US$).

(A.2) $$Q_{i95}^{A(\$)} = \frac{Q_{i95}^{A(A)}}{UVR_{i95}^{AB}}$$

In the case of Italy, output was converted to US$ using the specific output price ratios (based on the expenditure PPPs adjusted for net taxes and subsidies and, for import and export prices) provided by Hooper (1996). These are additionally extrapolated to 1995 using the above procedure.

Real Output: Through the paper, two output concepts are used for comparison purposes. These are gross output and value added.

a) *Gross Output*[36]*:* The nominal gross output data by sector was obtained from the STAN database. The industry-specific producer price indices, obtained from the Historical Indicators ISIC (OECD), were used to deflate nominal gross output. Finally, data in real terms (in 1995 prices) was converted into dollar terms using the updated Pilat (1996) UVR for individual industries.

b) *Value Added:* Real value added data by sector was obtained from the STAN database. The data series in real terms were converted into dollar terms using the updated Pilat (1996) UVR for individual industries. In principle, different conversion factors should be used for gross output and intermediate inputs (double deflation approach) to obtain

[36] Gross output is the preferred measure for productivity analysis at lower levels of aggregation, but the problem of double counting remains at higher levels. It seems that at the level of analysis proposed in this study, the benefits of using gross output are bigger than the potential disadvantages (see also OECD 2001).

a measure of real value added in a common currency[37]. However, the lack of reliable information on international price data on intermediate goods makes this option not practicable.

Intermediate Inputs: Nominal intermediate inputs were obtained as the difference between nominal gross output and nominal value added. As there is no official price deflator for intermediate inputs at sectoral level, real intermediates inputs in national currencies are obtained using the Divisia definition of real value added, in other words, using the implicit deflator used by the OECD database to construct the real value added. In this sense:

(A.3) $$\Delta \ln V_t = \frac{1}{1-s_M}\left[\Delta \ln Q_t - s_M \Delta \ln M_t\right]$$

Expression (A.5) is the Divisia definition of value added discussed by Sims (1969) (that is, in growth rates in continuous time)[38].

Finally, to obtain intermediate inputs into a common currency, due to the problems highlighted above on international prices on intermediate good, specific conversion factors for gross output are applied to real intermediate inputs.

Labour: The labour input refers to the number of annual hours worked in manufacturing calculated on the basis of employment (from industry employment figures in the STAN dataset) and the annual average of hours worked (STAN and O'Mahony and de Boer 2002, for missing series) at the sectoral level. In the case of Italy, annual average hours worked for total manufacturing are applied at the sectoral level.

Capital Stock: International comparisons of levels of TFP require that an industry conversion factor is also needed to translate capital into a common currency. In principle, these can be

[37] There is also some doubt as to the validity of international price data on intermediate goods outside the agriculture sector and relatively "heroic" assumptions such as the application of the "law of one price" to such products have to be made (Roy 1987).
[38] In practice it may not be possible to construct a chained Divisia index. Instead, the use of a discrete Törqvist index (the geometric mean of the two estimates) is a good first approximation to the desired figure

derived from official PPPs for investment by converting investment series to a common currency and then calculating capital stock in a common currency.

In this study, capital stock data for UK, US, France and Germany come from O'Mahony and de Boer (2002). This data was originally in constant 1996 US$, and was rebased to 1995 using investment specific PPPs from the OECD. Capital stock data for Italy, Japan and Canada come from the OECD (STAN database) and are converted to a common currency on the basis of PPPs for investment derived from the OECD.

Appendix B. Panel Unit Root Test

Table B
Panel Unit Root Test for Variables in First Differences
(Intercept Included)

	t-bar			
Variables	**$\Delta ln(Q/K)$**	**$\Delta ln(FC)$**	**$\Delta ln(K)$**	**$\Delta ln(CU)$**
No-lags				
FBT	-4.524	-4.484	-2.328	-4.388
TL	-4.240	-4.348	-2.870	-4.647
WWP	-4.178	-4.199	-2.700	-4.991
PPP	-4.102	-4.141	-3.537	-4.318
CH	-5.068	-5.003	-2.188	-4.513
NMM	-3.996	-3.905	-2.316	-4.810
BFM	-4.135	-4.138	-2.827	-5.349
MOT	-3.995	-3.909	-2.375	-4.486
1-lag				
FBT	-4.361	-4.297	-2.246	-4.505
TL	-4.245	-4.386	-3.023	-4.512
WWP	-4.026	-4.101	-2.763	-4.512
PPP	-3.776	-3.854	-3.371	-4.195
CH	-5.101	-5.113	-2.187	-4.427
NMM	-4.021	-4.082	-2.476	-4.410
BFM	-3.960	-3.872	-2.789	-5.155
MOT	-3.995	-3.909	-2.375	-4.486
Critical Values of t-bar (Im et al. 1997)				
	cv10	**cv5**	**cv1**	
	-1.950	-2.080	-2.320	

Source: See Appendix Data A.

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