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UNITED KINGDOM

Selected Issues

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Approved by European I Department

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United Kingdom: Basic Data

Demographic and other data:

Area	94,247 square miles (244,100 sq. km.)
Population (mid-1999)	59.5 million
Infant mortality (per 1,000 live births)	6.1
Doctors per 1,000 inhabitants	0.5
GDP per capita (1999)	SDR 17,814

Composition of GDP in 1999, at current prices	In billions of Pounds	Distribution in Percent
Private consumption	585.5	65.7
Public consumption	165.0	18.5
Total investment (including stockbuilding)	155.9	17.5
Total domestic demand	906.4	101.7
Exports of goods and services	231.0	25.9
Imports of goods and services	245.9	27.6
GDP at market prices (average estimate)	891.0	100

Selected economic data	1998	1999	2000	
Output and unemployment:	(Annual percentage change)			
Real GDP (at market prices, average estimate)	2.6	2.3	3.0	
Manufacturing production	0.5	0.0	0.7	1/
Average unemployment (Labor force survey, in percent)	6.3	6.0	5.3	1/
Earnings and prices:				
Average earnings in manufacturing	4.5	4.0	4.5	1/
Retail price index, excluding mortgage interest	2.6	2.3	2.1	
Money and interest rates:				
M0 (end of period)	5.6	12.1	4.8	
M4 (end of period)	8.4	4.1	8.0	
3-month Interbank rate	7.3	5.4	5.9	2/
10-year government bond yield	4.3	5.4	4.9	2/
	(In billions of pounds sterling)			
Fiscal accounts (In percent of GDP): 4/				
General government balance	0.7	1.7	3.6	4/
Public sector balance	0.6	1.7	3.5	4/
Public sector net debt	40.6	37.6	33.1	4/
Balance of payments:				
Current account balance	-0.1	-9.9	-9.9	5/
(In percent of GDP)	0.0	-1.1	-1.4	5/
Trade balance (goods)	-20.5	-26.2	-25.3	6/
Exports	164.1	166.2	171.2	6/
Imports	184.6	192.4	196.5	6/
Direct investment (net)	-33.5	-73.0	-82.4	5/
Portfolio investment (net)	-18.8	110.2	74.4	5/
Gross reserves,official basis	22.4	25.9	33.0	2/

Source: Office for National Statistics; and staff estimates.

1/ September - November 2000.

2/ December 2000.

3/ Fiscal year beginning April 1.

4/ Includes 2.4 percentage points of GDP in 2000/01 corresponding to the auction proceeds of spectrum licenses.

5/ January - September 2000.

6/ January - November 2000.

I. What's So Special About This Cyclical Expansion in the United Kingdom? A New Perspective from Labor Market Data*

A. Introduction

1. **During the latter half of the 1990s, the U. K. economy has been characterized by strong employment growth**, low unemployment and high employment rates, and, despite the apparently advanced stage of the business cycle, relatively moderate growth in real wages. In an attempt to shed light on these developments, this paper explores recent labor market developments using micro data from the New Earnings Survey (NES).

2. **Micro data (at the level of individual workers) have the potential to reveal patterns in the evolutions of employment and wages that could be masked in aggregate data**. In addition, such data can be used to study composition effects that could make aggregate data misleading in certain respects. For instance, cyclical changes in the skill composition of employment could result in measures of average wages and average labor productivity being severely biased as measures of the returns to a given unit of labor input or the output per unit of labor input, respectively.[1] Similar biases could result from changes in the sectoral and regional compositions of output.

3. **In addition, such micro data could also shed light on differences in wage and employment developments across occupational groups, industries and regions**. Using disaggregated data could be important for understanding asymmetries in labor market outcomes across these different dimensions and their potential macroeconomic implications.

4. **The results reported in this paper paint a sanguine picture of labor market developments in the United Kingdom.** Employment growth has been as strong for workers in high-skill (and high-wage) occupations as it has among lower-skill occupations, indicating that employment growth has been broad-based. This also implies that skill-composition biases in aggregate measures of average wages have not been significant. There is some evidence, however, that sectoral composition effects could be more important and could imply a slight downward bias in aggregate measures of average real wage growth. Overall, the analysis of composition effects does not reveal much evidence of underlying wage pressures that could be latent in the aggregate data. In addition, measures of average weekly hours and overtime hours, which tend to be leading indicators of the business cycle, show few hints of potential

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* This chapter was prepared by Eswar Prasad (Research Department).

[1] See Prasad (1996) for a review of the empirical literature and a discussion of the implications of this type of aggregation bias for matching moments from theoretical models to moments of actual data. Using U. K. data, Blundell, Reed and Stoker (1999) argue that composition effects arising from endogenous labor force participation decisions create an additional source of bias.

inflationary risks arising from labor market tightness. The implications of these results are discussed in the concluding section of the paper.

5. **A striking phenomenon of the U.K. labor market over the last two decades, as in many other industrial countries, is the increasing influence of women in terms of labor force participation and employment.** This paper also examines the quantitative importance of this phenomenon and its implications for the evolution of wage and earnings inequality and other aspects of labor market performance.

6. **Another feature of the U.K. economy in the mid-1990s is that, despite sustained and historically high levels of investment in physical capital, labor productivity growth has remained muted** (and so has TFP growth), even by the U.K.'s own historical standards. In the final section, this paper ventures an explanation that attempts to reconcile these and other stylized facts in both the microeconomic and macroeconomic dimensions. The explanation relies on the favorable effects resulting from the interactions of the labor market reforms of the last two decades and the stable and supportive macroeconomic policy environment that has characterized the period since the mid-1990s. If true, this explanation suggests a more benign outlook for labor productivity growth in the near future.

B. The Dataset

7. **The New Earnings Survey (NES) is an annual survey that covers roughly one percent of all employed persons in the United Kingdom.** It is conducted by the U.K. Office of National Statistics (ONS) in April of each year. The sampling frame is derived from the National Insurance records and, through their income tax records, information on employed persons from that sample are then obtained from their employers. Although worker characteristics other than gender and age are not available in the survey, it does contain a great deal of reliable information about earnings and hours as well as various occupational characteristics.

8. **The NES has a panel element but, given problems with sample attrition over time and given the purposes of this study, the data are treated here as a set of repeated cross-sections.** Since panel attrition could be systematically correlated with certain worker characteristics, this cross-sectional approach is also helpful for maintaining the representativeness of the sample, which is important for the analysis in this paper.

9. **Note that, by construction, the NES does not contain any information on non–employed persons,** so it can not be used to examine changes in labor force participation or other aspects of labor supply. In addition, since employers are traced through workers' income tax records, the NES undersamples individuals whose earnings fall below the income tax

threshold. Nevertheless, the NES remains the most reliable source of information on earnings and occupational characteristics that are relevant for the analysis conducted here.[2]

10. **The analysis in this paper is based on NES data for the period 1975-99.** Nominal variables such as hourly wages and weekly earnings are deflated by the RPI.[3] The NES also provides very detailed information on industry and region of occupation and occupational classification. Various categories have been aggregated in each of these dimensions in order to present the data more concisely and also to ensure consistency over time in the classifications (which are not constant over the entire sample).

11. **The ONS also conducts the Labor Force Survey (LFS), a quarterly survey of actual and potential labor force participants.** This survey provides more detailed information on education levels and other attributes of individual workers. The LFS also contains information on earnings, hours and occupational characteristics, but these data are subject to recall bias and are considered much less reliable than the corresponding data in the NES. However, the ONS grosses up LFS survey data to match the U.K. population in many respects, thereby providing a more accurate picture of trends in labor force participation, unemployment and employment. Hence, although LFS micro data are not used in this paper, time series data from that survey (available through the ONS website) are used in some of the analysis below.

C. Basic Facts

12. **To begin with, an overview of the main features of the labor market that can be gleaned from this dataset. Figure 1 shows the evolution of two measures of the returns to labor—the (real) hourly wage and (real) weekly earnings.** The hourly wage measure is a more appropriate measure of labor input but weekly earnings subsume information about variations in weekly hours as well. The top panels, which show means and medians for the full sample, suggest an increase in wage inequality led by the upper half of the distribution as the mean has grown more over the entire sample than the median, using either measure of labor compensation. The lower panels plot annual growth in wages and earnings. An interesting feature is that both wage and earnings growth have remained moderate during the recent cyclical recovery and, despite an increase in 1999, have remained well below the higher levels seen in the mid-1980s and, occasionally, in the 1970s and early 1980s. Figure 2, constructed using LFS data, confirms that wage growth has actually declined in 2000 and that this is true of all of the main sectors of the economy.

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[2] See Dickens (2000) for more details on the NES dataset and for a comparison of this dataset with Labour Force Survey data on low-wage workers.

[3] The use of the RPI-X or the private consumption deflator made little difference to the results reported in this paper.

Wage Inequality

13. **Many authors have pointed to the labor market reforms of the 1980s and early 1990s as being likely to have had a salutary but delayed effect on labor market performance.** One measure of labor market "flexibility" is the ability of the wage structure to respond to changes in the relative demands for workers of different skill levels and to industry- and region-specific shocks. Under certain conditions, the evolution of wage inequality can provide some hints about this aspect of flexibility in the labor market.

14. **Wage inequality has risen quite substantially in the U.K. over the last 25 years.**[4] Figure 3 (top left panel) shows that the 90/10 percentile differential for the hourly wage has increased quite sharply from 1975 to 1999. The 75/25 percentile differential shows a more modest increase, suggesting that much of the increase in overall wage inequality has come from the top and bottom parts of the distribution rather the middle. The two lower panels indicate that within-group inequality among major occupational groups has trended upward in a manner very similar to the overall increase in inequality.

15. **The top right panel of Figure 3 shows that between-group inequality has also followed a similar pattern across broad occupational groups.**[5] In addition, the regional and inter-industry dispersion of wages have increased modestly. These results are similar to those for the United States, where both within- and between-group inequality have risen sharply in the last three decades.

16. **Figure 4 provides a different perspective by plotting the change in log wages at different points of the aggregate wage distribution**. The top left panel shows that wage growth was significantly higher at the top percentiles of the distribution than at the lower percentiles. An interesting point to note, however, is that cumulative wage growth from 1975-99 was only about 50 percent lower for the bottom percentiles compared to the top percentiles of the distribution. This is in sharp contrast to the experience of the United States, where the differences are more stark. In fact, in the United States, real wage growth at the lower percentiles of the distribution has actually been negative for most of the last two decades (see Juhn, Murphy and Pierce, 1993). The other panels of this figure break down the total log wage

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[4] Note that, since the dataset used in this paper ends in 1999, this analysis may not fully capture the effects of the National Minimum Wage (which was introduced in April 1999) on wage inequality. There is some evidence that, in 2000, hourly wage rates of workers in the bottom decile of the bottom decile of the wage distribution rose significantly faster than those of workers in the top decile.

[5] The downward level shift after 1991 in between-group inequality across occupational groups is the artifact of a change in occupational coding that occurred in that year. It has not yet been possible to consistently match the pre- and post-1991 occupational codes. This does not affect any of the results shown below that are restricted to the post-1990 period.

changes into changes over each of the three decades covered by the dataset. The dispersion of wages appears to have risen most sharply in the 1980s; the increase in the 1990s is significant but more moderate.

17. **Figures 5 and 6, which show similar plots separately for men and women show that wage inequality has risen more for men than it has for women.** The pattern of the sharpest increases in wage dispersion occurring in the 1980s is, however, true for both groups. The top panel of Table 1 presents (3-year averages off) percentile differentials of log wages for the full economy, as well as for men and women separately.[6] One interesting aspect is that the increase in overall wage inequality is much lower than the increase among men or women. For instance, the change in the 90/10 differential from 1976 to 1998 is 0.39 for men, 0.30 for women, but only 0.28 overall. Changes in the corresponding 75-25 differentials are 0.24 (men), 0.20 (women) and 0.18 (all). This set of results has some interesting implications that are discussed in more detail in the next sub-section.

18. **One important question when analyzing changes in wage inequality is whether the changes are attributable to within- or between-group changes in inequality.** A formal approach to get at this is to run annual regressions of individual wages on observable group attributes, thereby controlling for between-group variation, and to interpret inequality of the wage residuals as capturing within-group inequality.[7] Percentile differentials of (log) hourly wage residuals are shown in the lower panel of Table 1. Within-group inequality clearly accounts for most of overall wage inequality. Interestingly, however, it appears that the changes in within-group inequality are markedly lower for women than for men. In other words, changes in the dispersion of occupational characteristics and/or sectoral preferences of employed women appear to account for much of the change in wage inequality among women. An analysis of this finding is left for future research.

19. **Given the exalted status of the U.S. labor market as the standard that all other labor markets are measured by, the similarity** (although not quite in degree) of the increases in wage inequality in the United States and the United Kingdom suggests that the United Kingdom has a rather "flexible" labor market. By itself, however, the increase in wage inequality or wage dispersion merits no such approbation. What matters is the joint outcome in terms of both quantities (employment) and prices (wages).[8]

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[6] To abstract from year-to-year variation, the percentile differentials reported in this table are 3-year averages, centered on the years shown.

[7] This approach was popularized by Juhn, Murphy and Pierce (1993). Using this technique, these authors show that, in the U.S., both within- and between-group inequality rose sharply among men during the 1980s.

[8] See Prasad (2000) for more discussion of this point and for an interesting contrast provided by the German experience.

20. **On this metric, the U.K. labor market does in fact come out well since the increase in wage inequality has coincided with a strong employment performance,** with employment ratios increasing for all skill levels and independent of observed skill attributes. Thus, there is reason to believe that the non–inflationary growth experienced in recent years might be the fruit of the labor market reforms undertaken in earlier years. This issue is discussed at greater length in the concluding section.

Women and the Labor Market

21. **One feature noted above is that women appear to have had a significant influence on the overall wage distribution. Indeed, as in many other industrial countries,** the share of U.K. women in total employment and in the labor force has increased markedly since the 1970s. Figure 7, based on LFS data, shows that employment and participation rates for women have continued to increase during the 1990s. The contributions of these changes to overall labor market developments, including changes in wage inequality, could have important policy implications. This sub-section presents some preliminary, yet fascinating, evidence on this subject.

22. **To visually examine changes in the wage distributions for men and women and their joint effects on the overall wage distribution,** this chapter now turns to an examination of kernel density estimates (which are essentially smoothed histograms) of these distributions. Figure 8 shows, for selected years, kernel density estimates of the overall wage distribution and also those for men and women separately, with the latter distributions weighted by the respective shares of men and women in the total sample for each year.[9] The striking conclusion from this set of plots is that the wage distributions for men and women have converged markedly over time, thereby partly diminishing the effects of rising within-group inequality on overall wage inequality. The relative importance of women in determining the shape of the overall distribution has clearly risen sharply over the last two decades.[10] Figure 9, which shows

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[9] This weighting procedure is similar to that employed by Fortin and Lemieux (2000). The kernel density estimates for log hourly wages were computed using an Epanechnikov kernel with bandwidth set to 0.05. These density estimates were also computed using optimal bandwidths computed separately for each year—these bandwidths were typically in the range of 0.04-0.06. Using optimal bandwidths had little effect on the shape of the distributions. The use of a fixed bandwidth is solely to maintain consistency when comparing distributions across different years.

[10] Fortin and Lemieux (2000) document a similar phenomenon in the U.S. They argue that this reconciles two findings. One is that male wage inequality has increased sharply in the U.S. in the 1980s and, although at a slower rate, also in the 1990s, with both within- and between-group inequality among men contributing to this increase (see, e.g., Juhn, Murphy and Pierce, 1993). The second result, documented by Lee (1999), is that the overall wage distribution in

(continued)

a similar set of plots but restricted to full-time workers shows a similar phenomenon of convergence of wage distributions for men and women. The increase in the relative importance of women as a proportion of full-time employment is smaller than in the case of total employment, but is nevertheless quantitatively very important.

23. **In short, as this evidence suggests, more careful analysis of the determinants of** participation decisions and occupational choices of women could be very important for understanding and interpreting aggregate labor market developments.

Developments in Weekly and Overtime Hours And Implications for Inequality

24. **An important barometer of labor market tightness is the behavior of average weekly hours.** Since employers find it easier to adjust labor input at the intensive margin (hours) rather than the extensive margin (employment) in the short run, hours tend to lead or be coincident with the business cycle in most industrial countries. Again, rather remarkably, both total hours and overtime hours have, if anything, declined moderately since 1995 (Figure 10). Although there is a secular decline in the total hours variable, the absence of an increase in this measure during a period of relatively strong output and employment growth is striking. Detrended measures of total and overtime hours, shown in the lower panels of Figure 10, confirm the typically procyclical behavior of these variables, with the current expansion providing a striking contrast. Figure 11, which shows hours broken down by gender and, in the lower panels, limited further to full-time workers, is consistent with this picture. One minor exception is that weekly hours for full-time women did rise marginally in the mid-1990s and stayed flat since then.

25. **A possible explanation for the atypical nature of labor input adjustment in the second half of the 1990s is that it reflects a permanent rather than temporary shock to productivity.** If employers interpreted it as such, they would tend to increase employment rather than hours as they tried to adjust factor inputs to their optimal levels.[11] But is this consistent with the low rate of productivity growth observed in the latter half of the 1990s? This issue is taken up in greater detail in the concluding section of the paper.

26. **It is also useful to examine if changes in patterns of hours worked have influenced the evolution of labor earnings inequality.** Systematic differences in weekly hours worked

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the U.S., including both men and women, was in fact quite stable in the 1980s and 1990s once the effects of the decline in the real value of the minimum wage are excluded.

[11] Arguably, even in the case of a permanent shock, hours would be adjusted before, or in tandem with, employment. However, the discussion later in the paper notes that capital accumulation is a relatively slow process. Hence, there would be little incentive, given the gradual increase in the requirement of labor inputs in concert with slow changes in the scale of production, to adjust labor at the intensive margin.

by workers at different points of the wage distribution could either exacerbate or dampen the dispersion of weekly earnings relative to hourly wages. For instance, it is possible that high-wage workers tend to work (and get paid for) more hours per week than low-wage workers. This would imply that wage inequality is a downward-biased measure of earnings inequality.[12]

27. **The annual cross-sectional variance of weekly earnings** can be decomposed as follows (all variables in logarithms):

Var (Earnings) = Var (Hourly Wages) + Var (Weekly Hours) + 2 Cov (Wages, Hours)

Figure 12 shows this decomposition for each year over the period 1975-99. For full-time workers (lower left panel), the variances of weekly earnings and hourly wages move very closely together, with the variance of hours worked and the covariance component being very small and roughly off-setting each other. The same pattern holds for the samples of men and women who are employed full time. Interestingly, when all women are taken together, the variance of weekly hours is much larger. This can be seen in the top right panel of the figure. For this group, the covariance component is positive and rises slightly over the full sample. Thus, the increase in earnings inequality among all women is slightly greater than the increase in wage inequality. However, the basic time profile of changes in inequality for this group, and for all workers taken together (top left panel), is essentially the same, irrespective of whether the wage or earnings measure is used.

D. A Disaggregated Perspective

28. **The analysis in the previous section is suggestive of a reasonably well-functioning labor market.** But, before assessing the economy's potential for further non-inflationary employment growth, it is important to examine disaggregated data on different dimensions to look for demons that might be lurking behind the veil of the aggregate data. In particular, there is the possibility that aggregate measures of wage growth could be misleading if there were major compositional changes in the structure of employment. For instance, it is typically the case that employment of unskilled workers tends to be more procyclical than that of skilled workers. In other words, at the margin, relatively more unskilled workers are hired during expansions while more of them are laid off in recessions.[13] This could result in a smaller apparent growth in average wages (because unskilled workers tend to have lower wages),

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[12] In addition, the dispersion of annual earnings could differ from that of monthly earnings. However, the NES does not have information on annual earnings (or on the number of months of employment per year).

[13] A variety of human capital and implicit contracting theories have been developed to explain this stylized fact. Keane and Prasad (1993) review this literature and provide some empirical evidence for the United State on the cyclical variability of employment, hours and wages for workers of different skill types.

which would be smaller than wage growth of each group independently or the growth rate of a composition-corrected measure of average wages.

29. **Similar effects could result from shifts in the composition of employment from high-wage to low-wage sectors.** One must, of course, be careful in interpreting the general equilibrium effects of such shifts but, even as a simple accounting matter, these shifts could have interesting implications for policy. A simple descriptive approach is to examine the evolution of employment shares and wage levels for groups classified on the basis of different occupational characteristics.

30. **Figure 13 plots the shares in employment and aggregate hours (employment*weekly hours) of four broad occupational groups over the period 1991-99.** The share of managers, professional and technical workers in both employment and aggregate hours has increased significantly during the 1990s. The employment share of unskilled non-manual workers, primarily reflecting the increase in low-level service sector employment, also rose moderately over this period. The employment shares of both skilled and unskilled manual workers have fallen since 1991, reflecting changes in the structure of production in the economy and the secular decline in manufacturing sector employment. The shares of total hours reveal a pattern similar to that of employment for each group.

31. **Interestingly, the group of managers, professional and technical workers also had the largest wage** and earnings increases over this period, reflecting the increase in the relative demand for high-skill workers with technical skills. Further, given that this group had significant increases in both employment and real wages in the 1990s, employment growth during the current expansion has evidently not been built solely on low-level service sector jobs.

32. **Figure 14 shows that, overall, the share of the broadly-defined service sector in total employment increased from 1991 to 1999,** while those of other sectors declined or stayed flat.[14] Although the average hourly wage in the services sector is not that different from that of other private sector industries, weekly earnings are significantly lower in services than in other sectors, possibly reflecting the existence of more part-time employment in this sector. This suggests that the reallocation of labor from other sectors to services could impart a downward bias at least to average measures of earnings growth. The next section of the paper explores this issue in greater detail.

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[14] This 4-group classification is based on 1-digit industry codes as follows: Manufacturing (metal manufacturing; textiles, leather, clothing; other manufacturing); Construction, utilities and transportation (construction; gas, electricity and water; transport and communications); Services (retail and wholesale trade; financial and professional services; other services). Excluded from this classification are agriculture, forestry and fishing; mining and quarrying; and food, drink and tobacco. Together, these 3 industries account for only about 6 percent of total employment during the 1990s.

33. **Figure 15 plots regional shares of employment and total hours for the period 1991-99 using a broad classification of regions into 4 groups.**[15] These shares have stayed relatively stable during the recent expansion, indicating that the expansion has had relatively symmetric effects on employment growth across these broadly-defined regions. Wage and earnings growth in these regions have also followed a roughly similar pattern in recent years although, in terms of wage and earnings *levels*, workers in London, the South East and the South West appear to do a great deal better. This presumably reflects the fact that higher-wage industries are located in those regions.

E. Composition Effects

34. **This section presents a more formal analysis of composition effects on measured wage growth.** For the analysis of composition effects during the current expansion, 1992 is chosen as the base year since that is widely regarded as the most recent cyclical trough. A brief description of the methodology (which is fairly standard in the literature) follows.

35. Let s denote the employment share of a skill group and let W be the average hourly wage for a skill group, with i being the index for skill group and t denoting the year. The aggregate average wage at time t, $\overline{W}_t$ is then given by

$$\sum_i s_{it} W_{it}$$

36. **As an accounting matter, one can ask how much of the change in the average wage over time is due to changes in group-specific wages** and how much is attributable to changes in the employment shares of different groups.[16] In other words, one can isolate the effects of changes in employment shares by calculating a measure of the average wage that strips out these effects. This is done by constructing a new average wage measure holding fixed the skill-group weights at their levels in the base period:

$$\sum_i s_{io} W_{it}$$

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[15] This 4-group classification is based on regional codes as follows: North (North East, North West, Merseyside); Midlands, Eastern (East Midlands, West Midlands, Eastern); London, South (London, South East, South West); and Wales and Scotland.

[16] As emphasized earlier, the exercise conducted here is purely an accounting one and sets aside some general equilibrium considerations. Changes in the observed levels of employment and wages for different skill groups are the result of shifts in relative demands and supplies for different types of labor. The sort of conditional exercise conducted here ignores behavioral responses of workers and firms to these shifts.

37. **This measure provides a composition-adjusted measure of changes in the average wage.** A similar measure can be constructed on the basis of any group characteristic, including industry and region.

38. **This framework is now used to look at composition effects of changes in the relative employment shares** of different skill groups, based on occupational classifications. One additional factor that needs to be taken into consideration is that changes in employment may not accurately reflect changes in labor input since weekly hours worked could systematically vary across different groups. To account for this, total hours worked were calculated for each group and these were used to create measures of relative shares of total labor input.

39. **Figure 16A (top left panel) shows the mean hourly wage and a composition-adjusted measure of the mean wage.** The adjusted measure is constructed by holding fixed the employment shares of different occupational groups at their 1992 levels. Interestingly, the composition-adjusted mean wage (indexed to 100 in 1992) is at a lower level in 1999 than the unadjusted mean wage. In other words, consistent with the results of the previous section, it appears that there has been a shift in labor inputs towards high-wage occupations during this recovery. This suggests that, if anything, wage pressures are more muted than suggested by the aggregate data. The top right panel of this figure, which plots growth rates of the raw averages and composition-adjusted measures, tells a similar story and indicates that the evolution of both measures has been similar since the mid-1990s.

40. **The next two panels of Figure 16A look at industry composition effects. Consistent with the descriptive analysis** in the previous section, it appears that there has been a relative increase in the labor input (and employment) shares of low-wage industries. Consequently, the mean wage, which doesn't control for these changes, is a downward-biased measure of the composition-adjusted mean wage. The economic magnitude of this bias is, however, quite small and, as shown by the growth rates of the two measures, not crucial for understanding wage growth in the mid-1990s.

41. **The last two panels of this figure show the effects of changes in the regional composition of labor inputs.** As in the case of the industry results, the downward bias in the unadjusted mean wage relative to the composition-adjusted mean wage is quite small.

42. **Figure 16B repeats the analysis for weekly earnings. For this part of the analysis, the adjustment** is for relative employment (rather than labor input) shares. The differences compared to the results for the hourly wage are small. The only significant difference is the larger downward bias in unadjusted mean earnings when compared with a measure that adjusts for changes in the inter-industry composition of employment (middle panel).

43. **Extending the decomposition analysis, the total change in mean wages (or earnings) can be split into components** attributable to within-group mean wage changes and to changes in the employment or labor input shares of different groups. Using the notation described above, one can write this arithmetical decomposition as follows:

$$\Delta\overline{W} = \sum_i \Delta s_i \cdot W_{i0} + \sum_i \Delta W_i \cdot s_{i0}$$

44. **The results of this decomposition, for the total change in mean hourly wages and mean earnings from 1992 to 1999**, are shown in Table 2. It is clear that a substantial fraction of the change in mean wages is attributable to changes in within-group mean wages, irrespective of whether these groups are defined on the basis of occupational classification, industry or region. Similar results are obtained with the weekly earnings measure. This confirms the graphical analysis showing that composition effects have had little effect on measurements of mean changes in labor compensation during this expansion.

F. Discussion

45. **The stylized facts presented in this paper do not provide any indication of imminent or latent wage pressures in the U.K. economy.** Quantity measures of labor demand such as average and overtime hours show little evidence of constraints on labor input growth. Nor do measures of wage growth, even those that account for changes in the skill or industry composition of employment, show much evidence of labor market tightness. In short, it is difficult to detect evidence of clouds gathering on the horizon.

46. **And yet, the ointment is not without its proverbial fly.** One troubling feature of the current expansion is that, after strong growth in the first half of the 1990s, labor productivity has since risen at anemic rates. In fact, if one considers labor input measures adjusted for compositional changes in skill levels of employed workers, labor productivity growth during the latter half of the 1990s was, if anything, marginally lower than suggested by unadjusted measures. And this despite the remarkable and sustained surge in business fixed investment since the mid-1990s.

47. **One way of reconciling at least some of these facts is to argue that the surge in investment can be explained by the decline in the relative price of capital.** Indeed, this relative price decline is particularly striking in the context of information and communication technology (ICT) related capital goods.[17] Given capital-skill complementarity, this would imply an increase in the demand for skilled labor. The labor supply response resulting from labor market reforms over the last two decades would, however, have held down the wage growth, both in absolute and relative terms, that would otherwise have resulted from this shift in labor demand. This interpretation of the data suggests a shift in relative factor proportions in the aggregate production function but with few obvious implications for productivity growth in the future.

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[17] See the paper "The 'New Economy' in the United Kingdom" in this volume.

48. **An alternative story that could account for the stylized facts described in this paper is that employers are responding to a permanent country-specific shock.**[18] Consequently, their desired levels of capital and other inputs, including labor, would have increased. Given capital-skill complementarity, employment levels for skilled workers would be expected to continue rising at a relatively faster rate. This would also be consistent with the high rates of business fixed investment observed recently, particularly since the mid-1990s. The permanent productivity shock interpretation would also explain the employment growth in the mid-1990s that has coincided with little change in average hours or overtime work. In response to such a shock, employers would have an incentive to adjust labor inputs at the extensive margin (employment) rather than at the intensive margin (hours).

49. **During the transition to a new steady state with a larger scale of production, however, labor productivity growth rates** could be temporarily lower if there were significant costs to adjusting the scale of production.[19] Indeed, further support for this notion comes from the marked change in production structures implied by the fact that the recent surge in investment has been largely concentrated in ICT goods. In addition to traditional time-to-build considerations, time-to-learn factors could also be important as workers and firms adapt to the new technologies. A production structure that formalizes the notion of adjustment costs and also builds in capital-skill complementarity (necessary to explain the increase in the relative wage and relative employment share of skilled workers) is presented in the appendix.

50. **But, as noted above, increases in employment rates across all categories of workers without commensurate wage growth suggests** that other forces are at work. In particular, the labor market reforms introduced in the 1980s, by reducing the bargaining powers of unions and by eliciting strong labor supply responses by increasing the incentives for acquiring and maintaining employment, may have played an important role. These labor market reforms were reinforced by additional policy measures during the 1990s. There is a fairly extensive literature arguing that major reforms affect the functioning of labor markets only with a significant lag. Furthermore, a more recent literature has argued that a favorable macroeconomic environment is required for the full effects of the labor market reforms to blossom forth. [20] Thus, the persistence of non–inflationary growth in the United Kingdom may be the result of a fortuitous interaction of earlier labor market reforms and favorable

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[18] The mechanism discussed here requires a country-specific productivity shock in an open economy, which the United Kingdom clearly is.

[19] Cotis and Rignols (1998) make a similar point in the context of France, although the circumstances there, and the mechanism suggested by these authors, are rather different.

[20] On the former, see, e.g., the papers in the Barrell (1994) volume and references therein. Olivier Blanchard is one of the principal proponents of the latter argument. Blanchard and Wolfers (2000), for instance, argue for that interactions of institutions and shocks are important for explaining cross-country differences in labor market performance.

macroeconomic shocks. In fact, the effects of such an interaction, which results from a set of circumstances particular to the United Kingdom, might in fact constitute the country-specific "shock" that this story relies on.

51. **Is there evidence that the labor market reforms instituted over the last two decades could have had a delayed effect of the sort posited here?** The volume edited by Ray Barrell (1994) provides an interesting set of perspectives in this context. For instance, in their contribution, Blanchflower and Freeman conclude that " ...the Thatcher reforms succeeded in reducing union power and increasing the incentive to work—and may have increased the responsiveness of wages and employment at the micro level." But "...there is no strong evidence that the British labor market experienced a deep microeconomic change." They mention the possibility that more time might be required for the reforms to have their full effects and note skeptically "Just wait until the mid-1990s, and we will all be praising the labor market reforms for setting the precondition for the British economic miracle." Minford and Riley observe that "...micro problems have been substantially diminished by the supply-side reforms of the 1980s..." and conclude more optimistically that "...we see promising scope for bringing unemployment down sharply without risks of re-igniting inflation."

52. **In short, the favorable macroeconomic performance of the U.K. economy in the mid to late 1990s might in fact have served** as the catalyst for the effects of the labor market reforms to blossom forth. Under at least one interpretation of the U.K. data suggested here, significant gains in labor productivity are likely in the next few years. Indeed, the pickup in labor productivity growth in 1999-2000 is consistent with this interpretation. Whether this increase in labor productivity growth will be sustained and validate this story remains to be seen. It should also be noted that a pickup relative to the second half of the 1990s would still imply a fairly moderate rate of labor productivity (and TFP) growth, perhaps only to the trend level witnessed after the productivity slowdown in the 1970s. This would still leave productivity growth rates (and levels) in the United Kingdom well below those of most other industrial countries.

53. **Thus, for a more sustained and durable increase in productivity, more fundamental reforms to the education and training system** to improve both the general and technical skills of the workforce are required. In addition, although the labor market reforms of the last two decades have created a well-functioning labor market, residual concerns like the declining participation rates for men (especially low-skilled men) need to be addressed.

A PRODUCTION FUNCTION WITH CAPITAL-SKILL COMPLEMENTARITY

54. This appendix describes a production structure that allows for capital-skill complementarity and formalizes the notions discussed in the concluding section of the paper on the relationship between the rate of capital accumulation and measured labor productivity growth.[21]

55. Krusell et al. (2000) propose the following production function with four inputs—capital structures, capital equipment, skilled labor and unskilled labor.[22] The production function is Cobb-Douglas over capital structures (K_s) and a constant elasticity of substitution (CES) aggregate of the three remaining inputs. The specification they find to be consistent with U.S. data is as follows:

$$F(T_t, K_{st}, K_{et}, U_t, S_t) \quad T_t K_{st}^{D} \quad PU_t^{V} \quad \left(1 \quad P\right)\left(OK_{et}^{U} \quad (1 \quad O) S_t^{U}\right)^{\frac{V}{U}}\Big|^{\frac{1-\alpha}{\sigma}} \qquad (A1)$$

56. The parameters σ and ρ determine the elasticities of substitution among capital equipment (K_e), skilled labor (S) and unskilled labor (U). This production function is also flexible enough to incorporate changes in relative efficiency of different skill categories. Inputs of skilled and unskilled labor may be considered as the products of aggregate hours (h_i) and an efficiency index (ψ_i), where *i* is an index for skill type. Exogenous factor neutral productivity is represented by θ_t.

57. There are a couple of reasons for splitting capital into two types. First, the phenomenon of capital deepening in many industrial economies in recent years is largely attributable to equipment investment (including computers) rather than investment in structures. Second, it is not obvious that skilled and unskilled labor would have different degrees of substitutability with structures, while differences in substitutability with capital equipment are more plausible.

58. Note that this production function specification implies that the elasticity of substitution between equipment and unskilled labor is the same as that between skilled and unskilled labor.

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[21] For direct evidence on capital-skill complementarity, see, e.g., Griliches (1969) and Goldin and Katz (1998). Keane and Prasad (1996) provide more references and a discussion of substitutability/complementarity in an extended production function that includes physical capital, energy, and skilled and unskilled labor.

[22] These authors use this framework to examine the effects of relative demand shifts (for different types of skill) and capital-skill complementarity on the equilibrium skill premium. In an analysis of the West German labor market, Prasad (2000) adapts this model to study the potential employment effects of rigidities that prevent adjustment in the skill premium in response to different shocks.

This restriction follows from the symmetry property of the CES aggregation and is consistent with empirical estimates of these elasticities. The elasticity of substitution between capital equipment and unskilled labor is $1/(1-\sigma)$ and that between capital and skilled labor is $1/(1-\rho)$. Hence, setting $\sigma > \rho$ implies capital-skill complementarity.

59. The notion of adjustment costs could be most relevant for equipment investment in the second half of the 1990s. In particular, the surge in investment in information and communication technologies (ICT) during this period has been enormous and unprecedented. Indeed, as shown in another paper in this volume[23], this increase could be even larger, in real terms, at correctly measured prices. In addition to standard time-to-build considerations, the adjustment costs at such high levels of investment could be rationalized on a number of grounds. As firms change the nature of their production processes and their mix of different vintages of capital, there could be significant lags in optimizing production processes. In addition, the use of new high-tech capital could imply higher depreciation and obsolescence rates for older vintages of equipment. Further, there could be a substantial lag in training even relatively-skilled workers in the use of new capital goods.

60. In terms of modeling, these adjustment costs could easily be added to the production function as a quadratic of the change in the stock of equipment investment. This would yield a modified version of equation (A1):

$$F(\theta_t, K_{st}, K_{et}, U_t, S_t) = \theta_t K_{st}^{\alpha} \left[\mu U_t^{\sigma} + \left(1-\mu\right) \left(\lambda K_{et}^{\rho} + (1-\lambda) S_t^{\rho}\right)^{\frac{\sigma}{\rho}} \right]^{\frac{1-\alpha}{\sigma}} - \frac{d}{2}\left(K_{et} - K_{et-1}\right)^2 \qquad \text{(A2)}$$

61. This modification would not add any state variables to the model; hence, calibrating and simulating such a model would impose no additional computational constraints. Intuitively, it is clear that periods with high levels of equipment investment would then have lower levels of output and labor productivity, compared to a steady state with a higher level of equipment capital. In other words, the transition path to a new steady state with higher productivity (both in terms of labor productivity and TFP) might in fact be one with lower measured productivity growth.

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[23] See the paper "The 'New Economy' in the United Kingdom" in this volume.

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Table 1. Wage Inequality in the United Kingdom

		90-10 differential			75-25 differential		
		All	Men	Women	All	Men	Women
HOURLY WAGE	1976	0.95	0.88	0.81	0.47	0.43	0.40
	1980	0.99	0.94	0.8	0.50	0.47	0.41
	1990	1.15	1.16	1.03	0.6	0.59	0.54
	1998	1.23	1.27	1.11	0.65	0.67	0.60
HOURLY WAGE RESIDUALS	1976	0.75	0.74	0.75	0.37	0.36	0.4
	1980	0.75	0.77	0.72	0.38	0.38	0.38
	1990	0.88	0.89	0.84	0.45	0.46	0.43
	1998	0.95	0.99	0.84	0.48	0.51	0.42

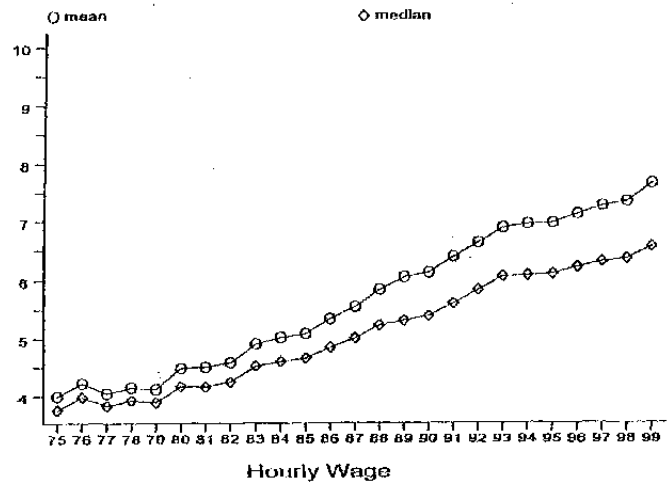
Notes: Differentials of log hourly wages; 3-year averages centered on years shown. Wage residuals are from regressions of wages on sectoral and occupational dummies (and gender dummy, where appropriate). Maximal standard error for differentials shown above is 0.01.

Table 2. Decomposition of Real Wage Growth

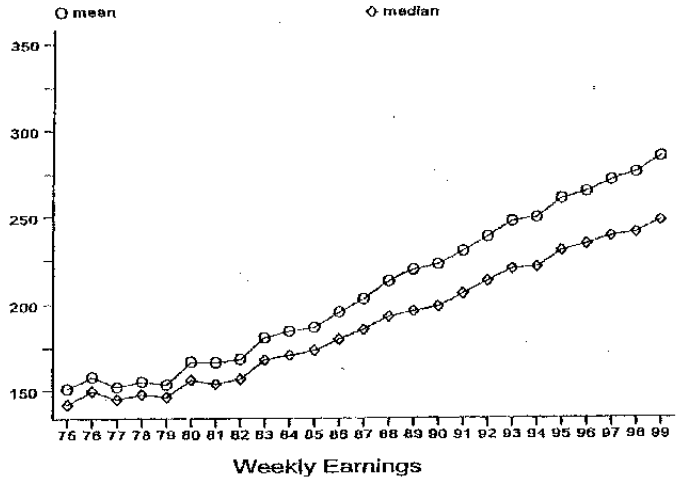
Group Definitions		Total increase 1992-99	Within-group component	Between-group component
Occupation:	Hourly wage	10.4	7.4	3.0
	Weekly earnings	9.0	6.9	2.1
Industry:	Hourly wage	10.4	10.2	0.3
	Weekly earnings	9.2	10.5	-1.2
Region:	Hourly wage	10.4	10.3	0.1
	Weekly earnings	8.9	8.8	0.1

Notes: The first column shows the total percentage change in the mean real wage from 1992 to 1999. The second column shows the change in the mean real wage resulting from the change in within-group mean real wages, holding fixed the employment (or labor input) shares of each group at its 1992 levels.

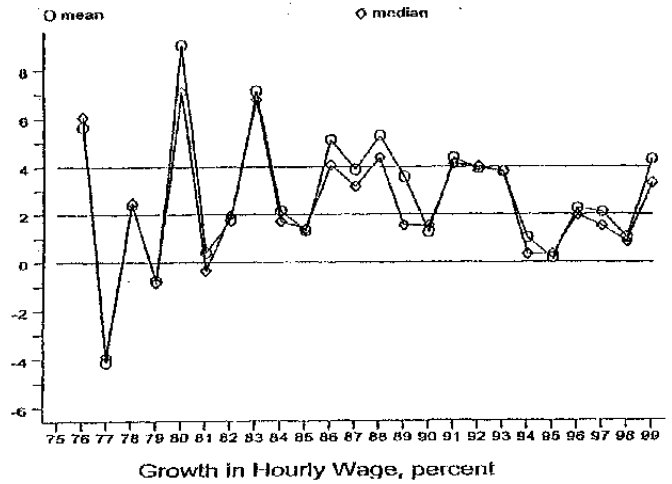
Figure 1. United Kingdom: Evolution of Wages and Earnings



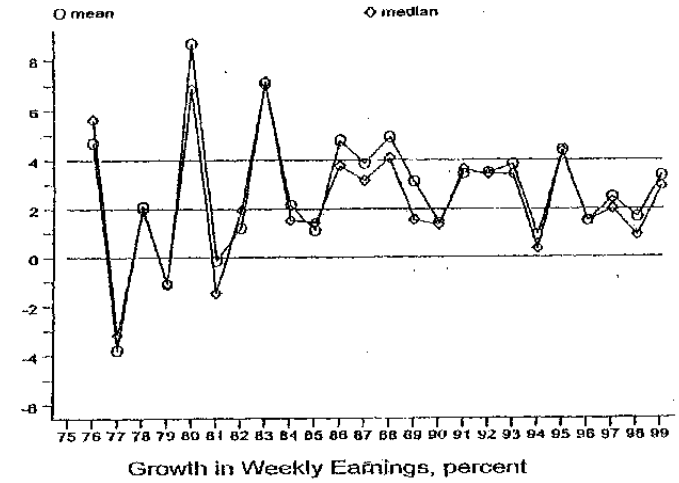
Hourly Wage



Weekly Earnings

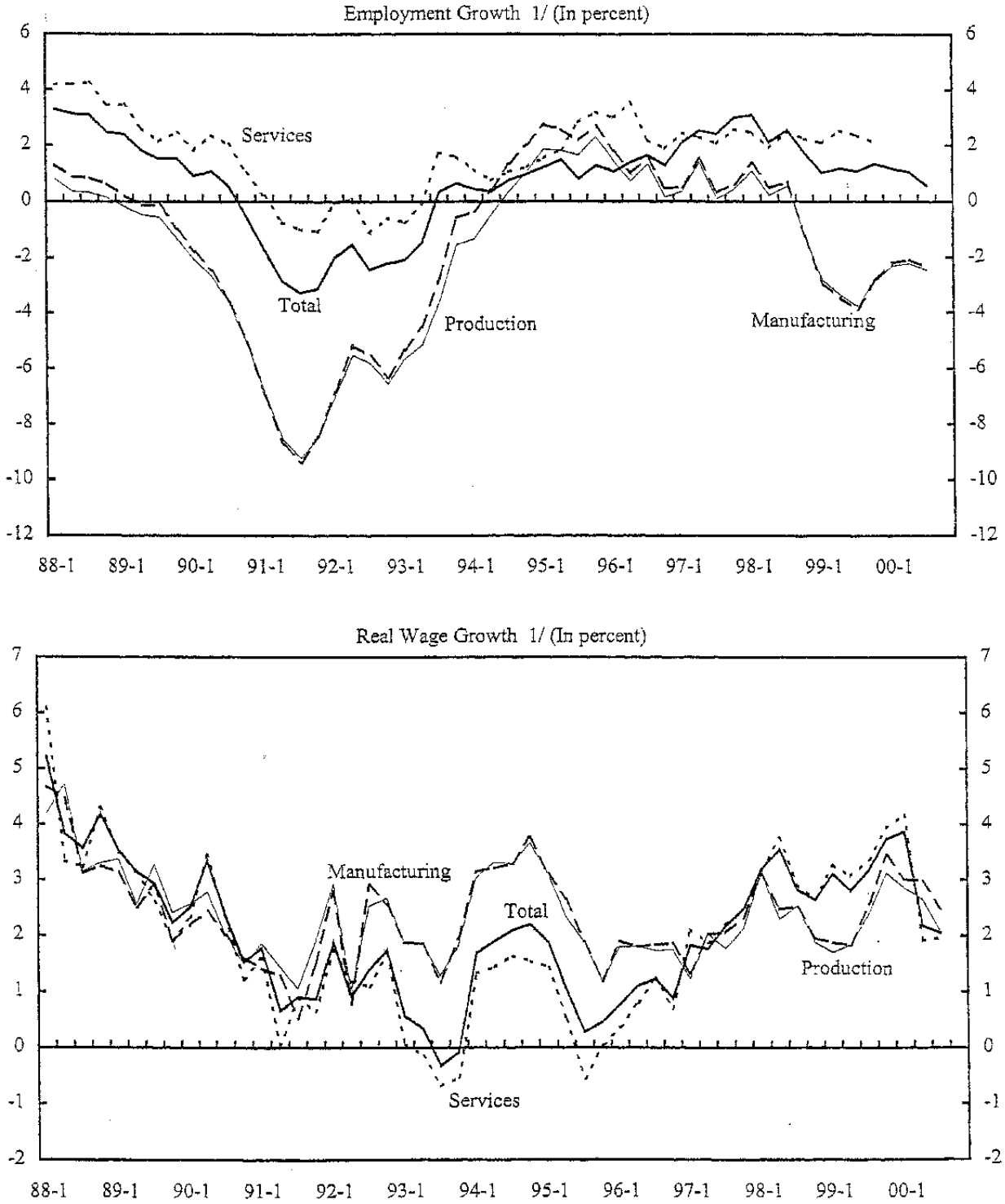


Growth in Hourly Wage, percent



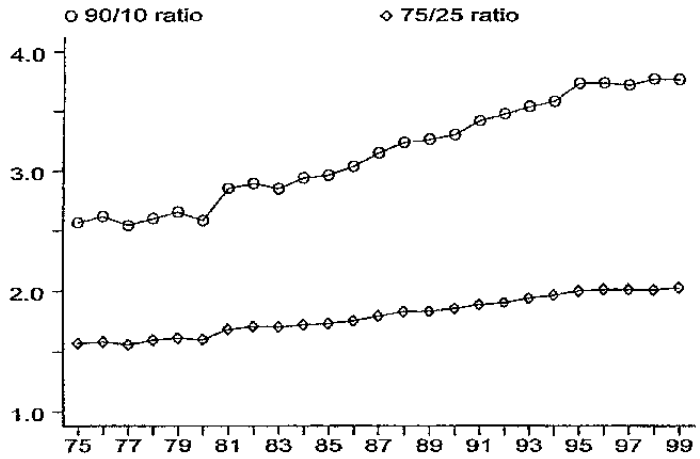
Growth in Weekly Earnings, percent

Figure 2. Employment and Real Wage Growth

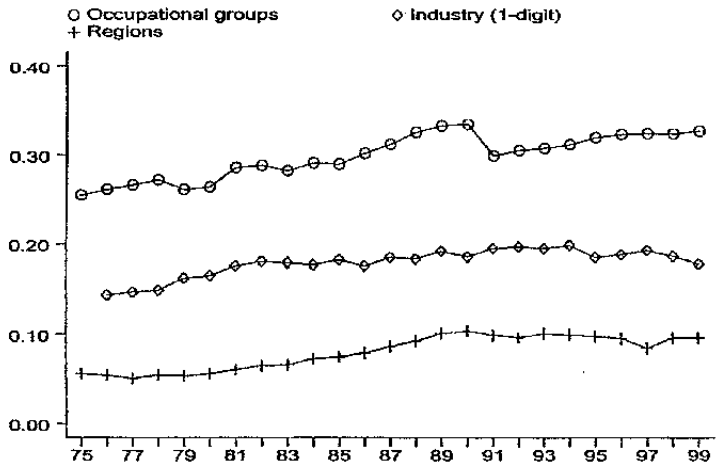


Source: United Kingdom National Statistical Office, Labor Force Survey.
1/ Four-quarter percent changes, seasonally adjusted.

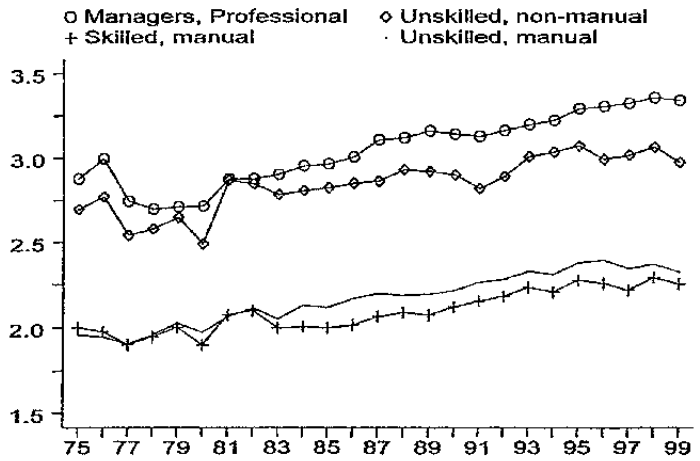
Figure 3. United Kingdom: Percentile Differentials for Hourly Wages



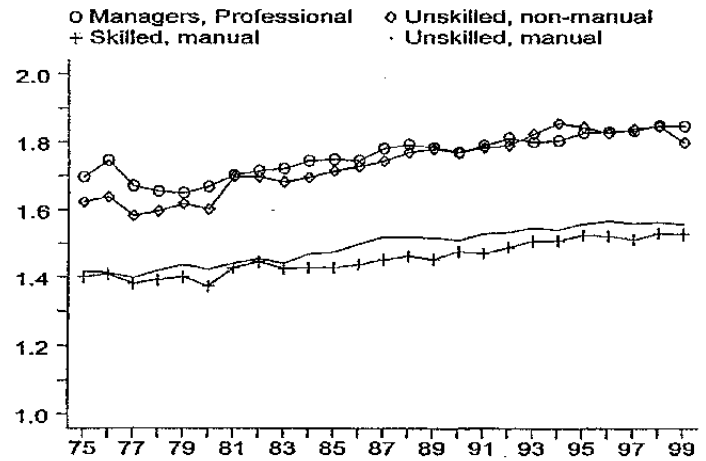
Percentile Differentials



Between-Group Inequality

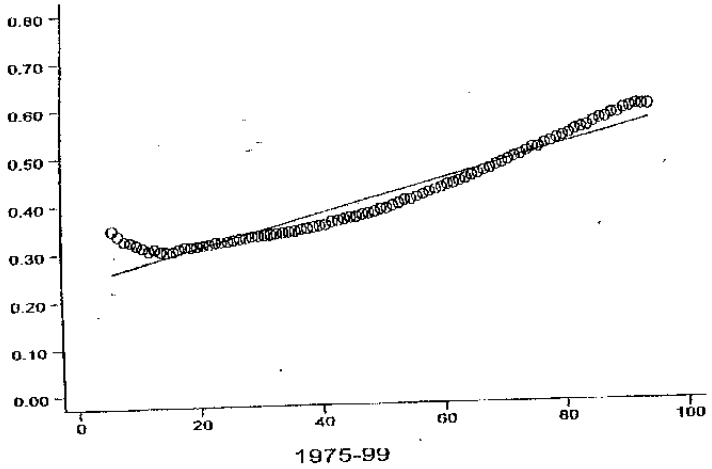


90/10 Differential by Occupational Group

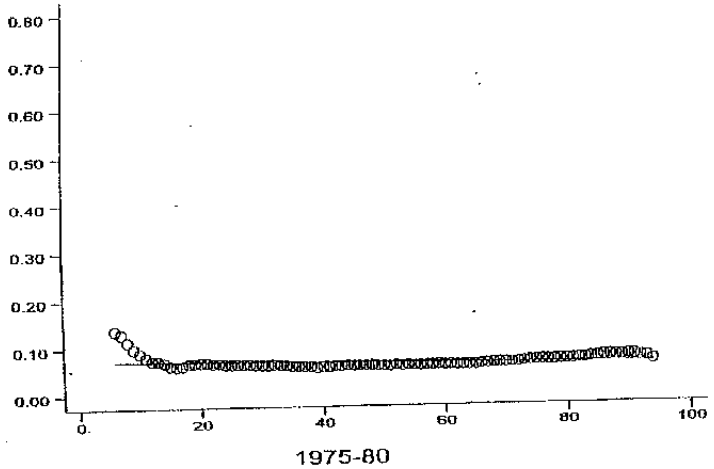


75/25 Differential by Occupational Group

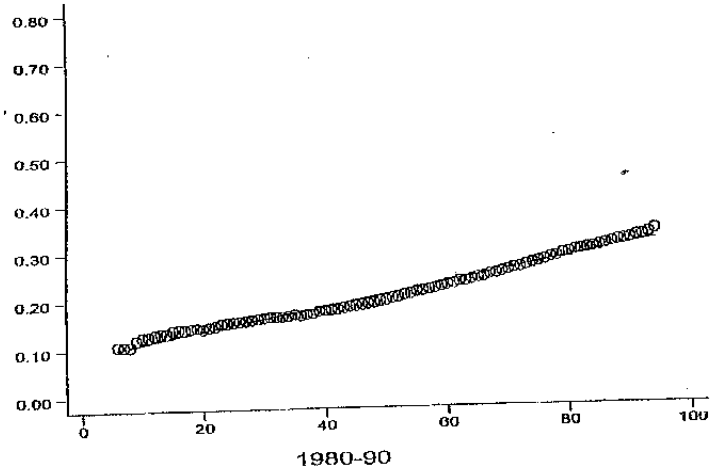
Figure 4. United Kingdom: Wages Growth Across Percentiles, All



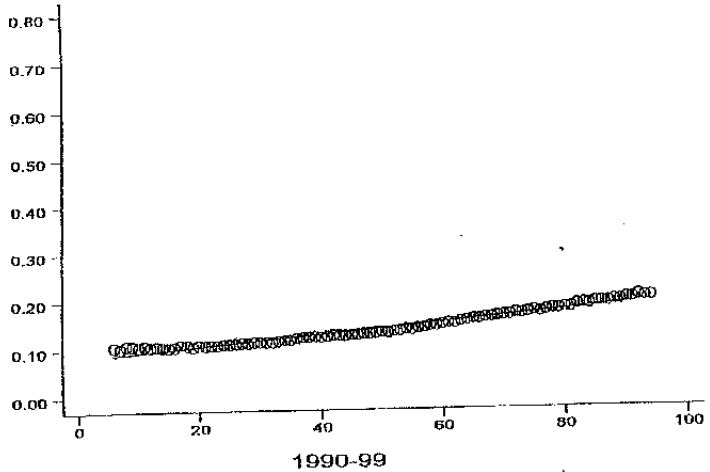
1975-99



1975-80

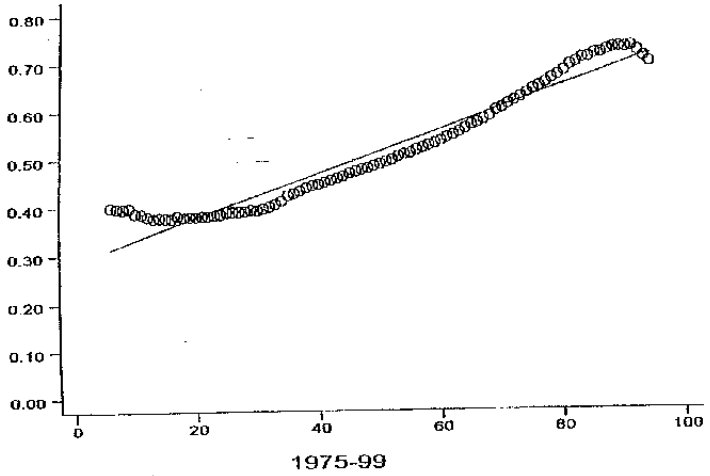


1980-90

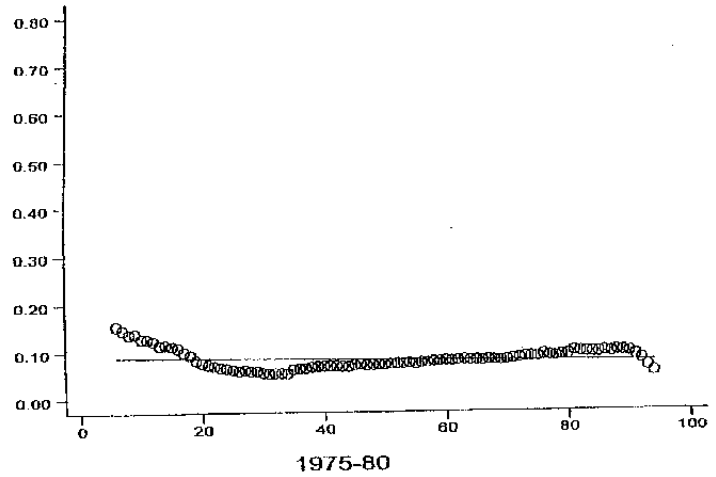


1990-99

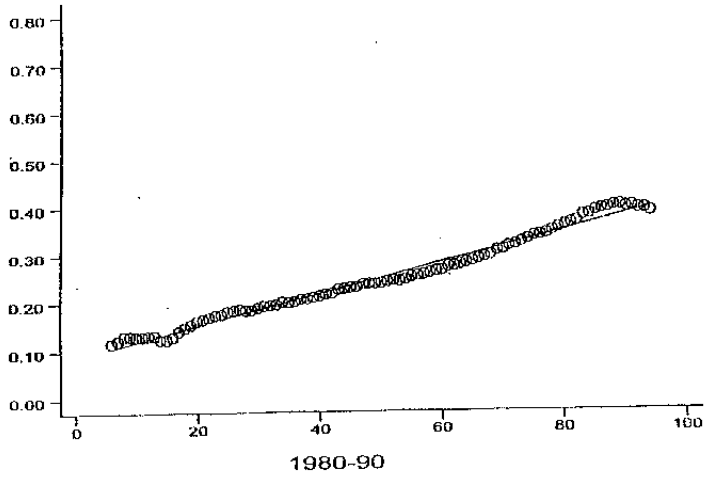
Figure 5. United Kingdom: Wage Growth Across Percentiles, Women



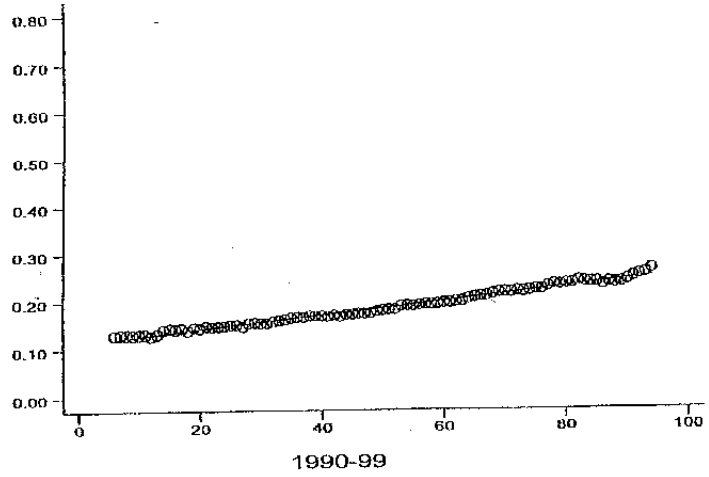
1975-99



1975-80

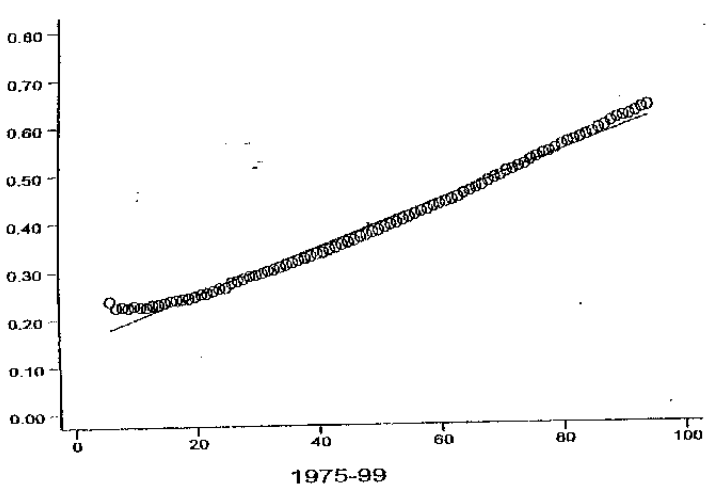


1980-90

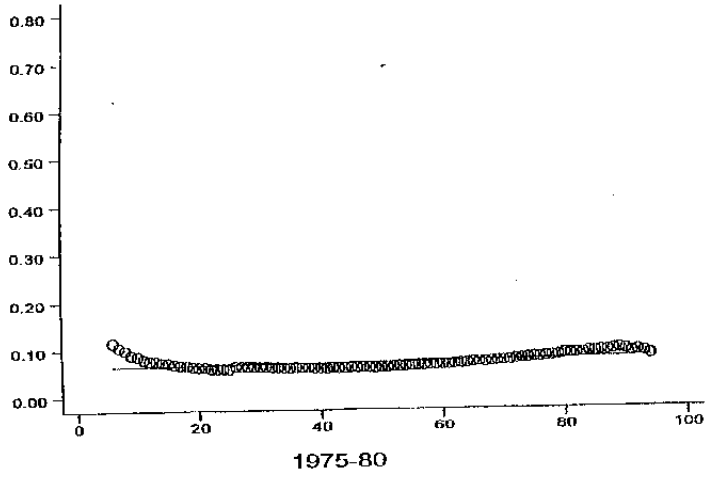


1990-99

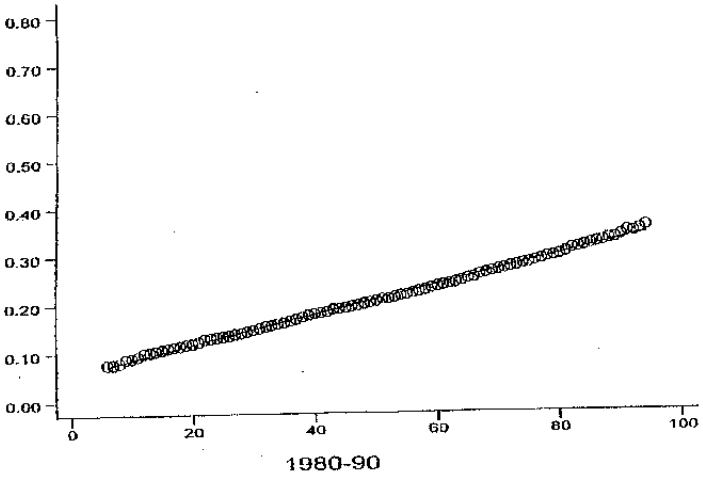
Figure 6. United Kingdom: Wage Growth Across Percentiles, Men



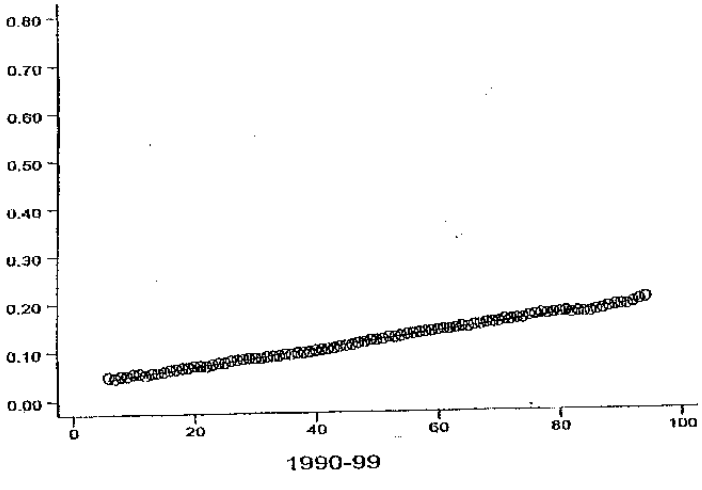
1975-99



1975-80

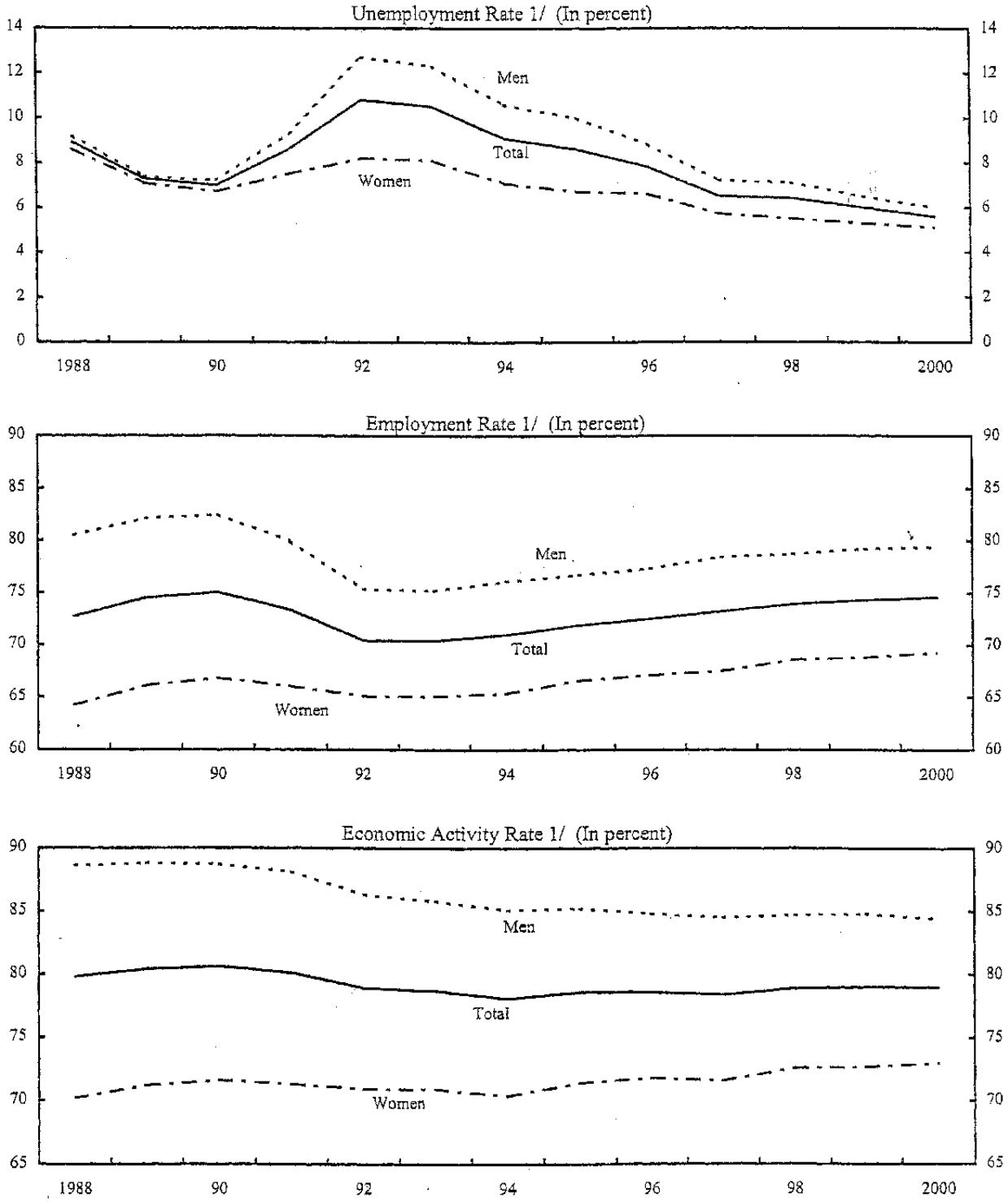


1980-90



1990-99

Figure 7. Labor Force Status by Gender



Source: United Kingdom National Statistical Office, Labor Force Survey.
1/ Ratios are for men aged 16-64 and women aged 16-59.

Figure 8. United Kingdom: Kernel Density Estimates, All

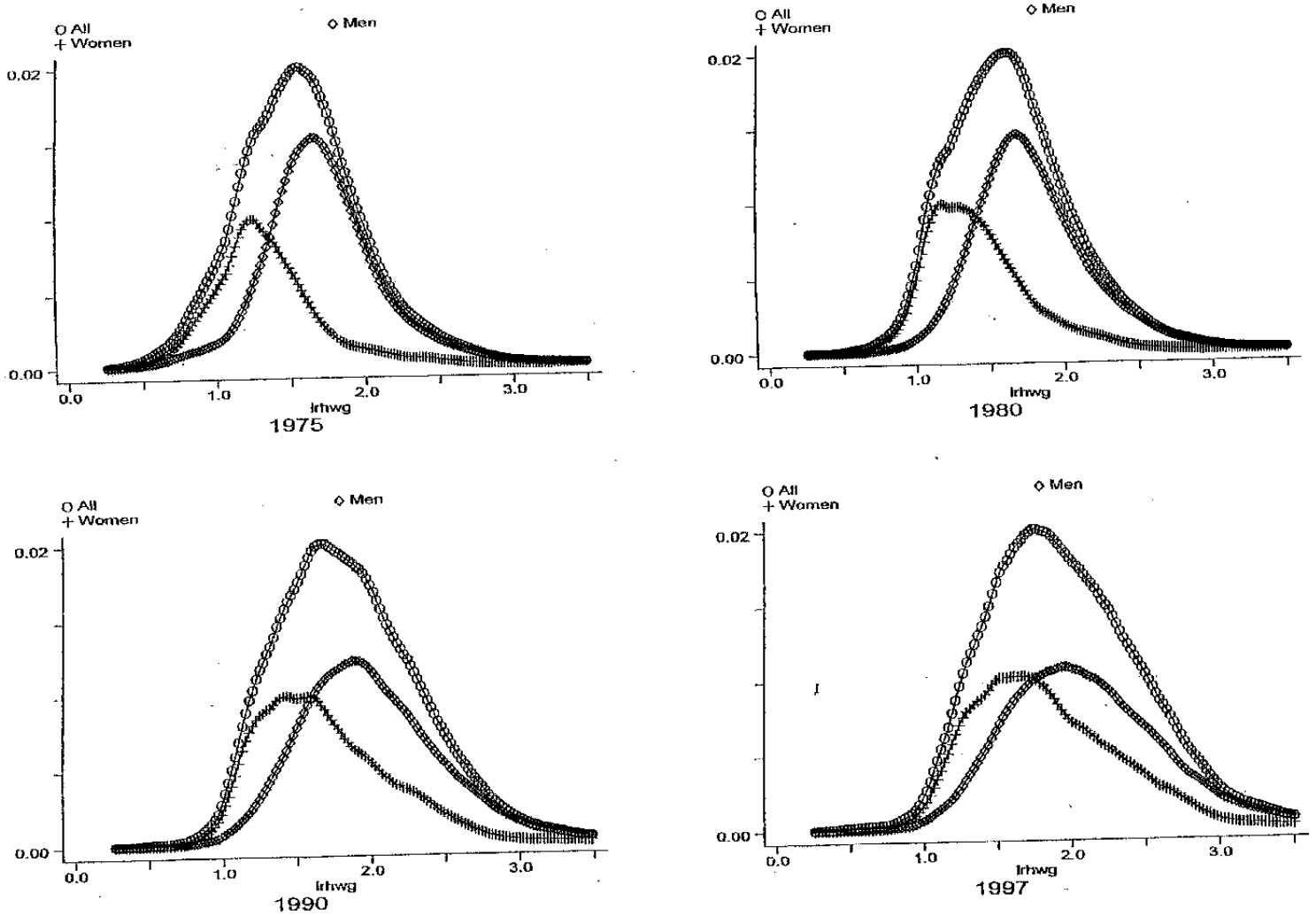


Figure 9. United Kingdom: Kernel Density Estimates, Full-Time Workers

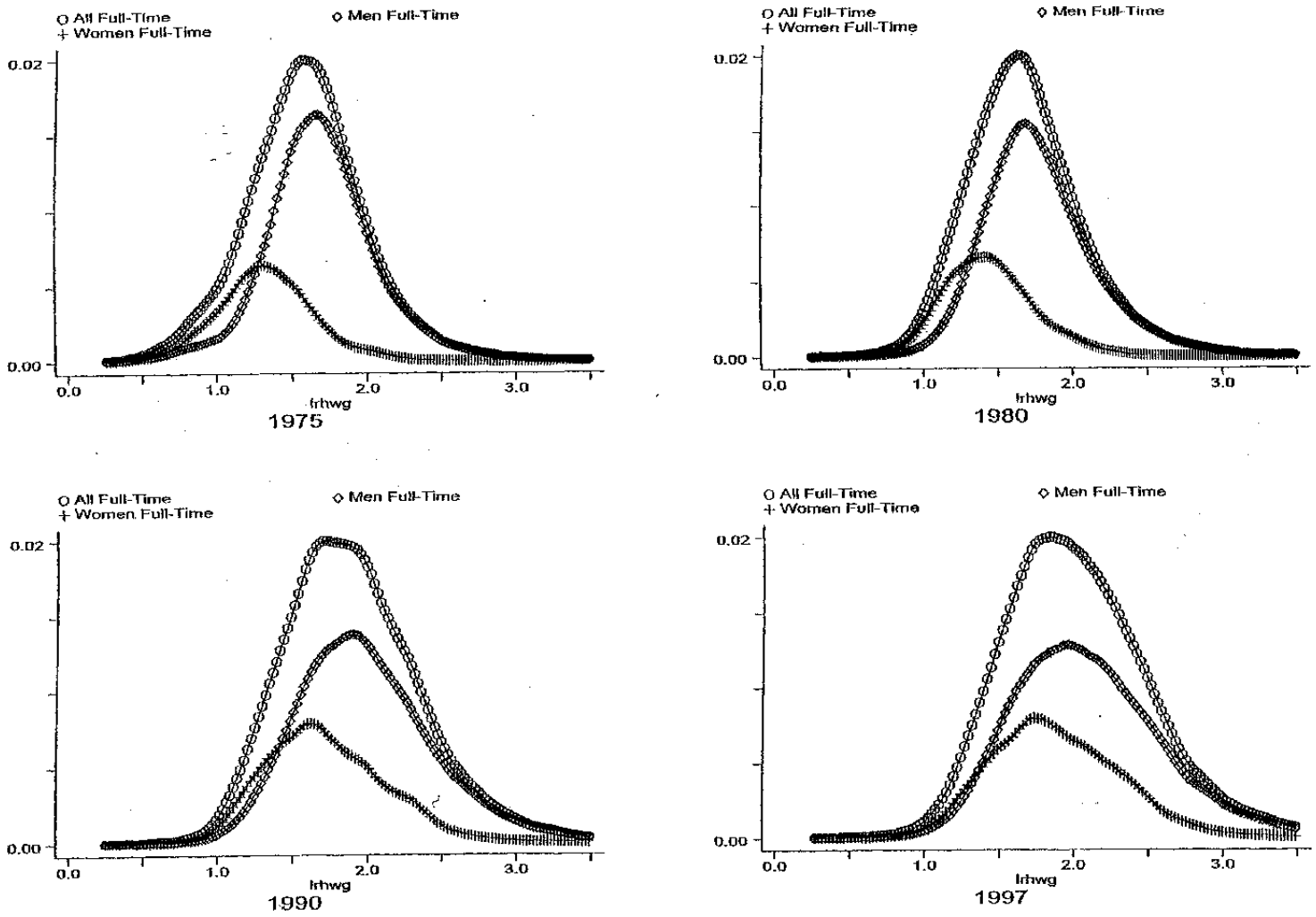
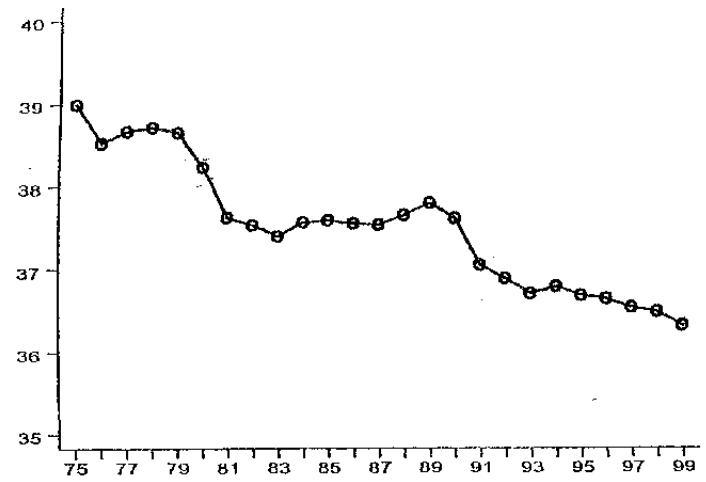
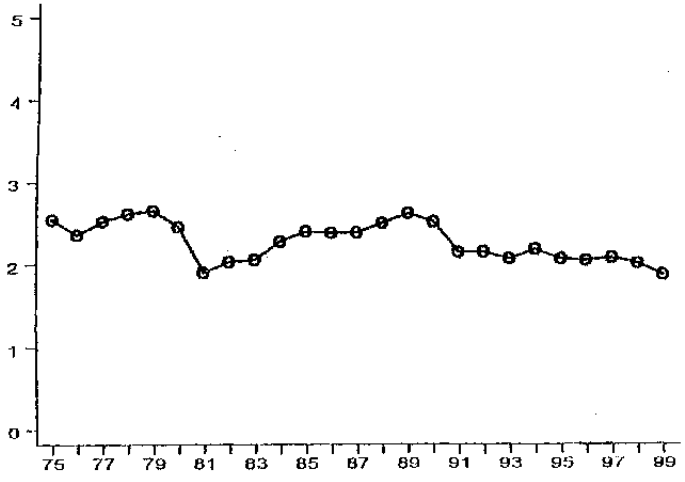


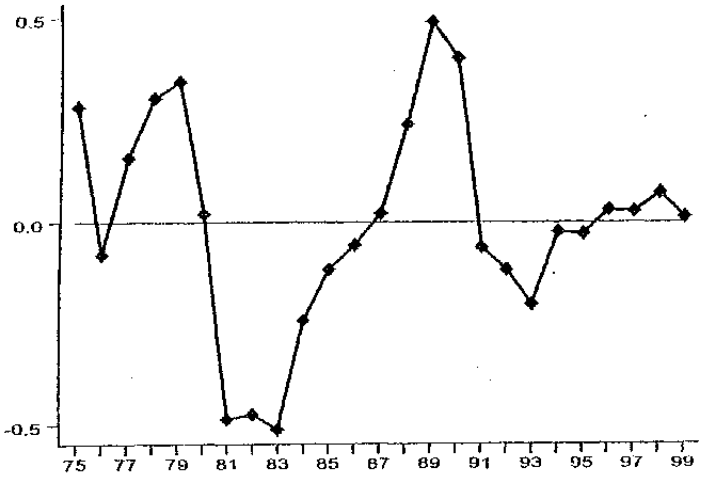
Figure 10. United Kingdom: Average Weekly Hours—Total and Overtime



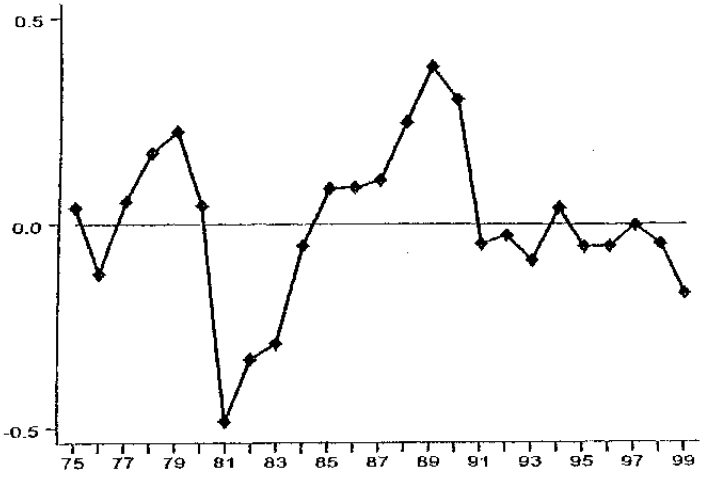
Average Total Hours



Average Overtime Hours

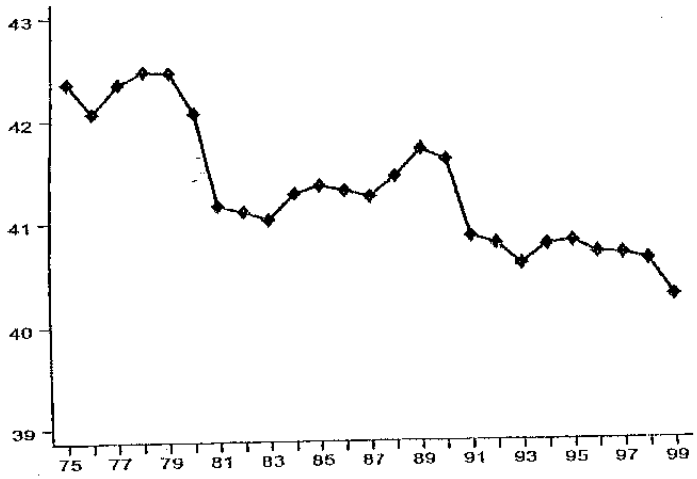


Detrended Average Total Hours

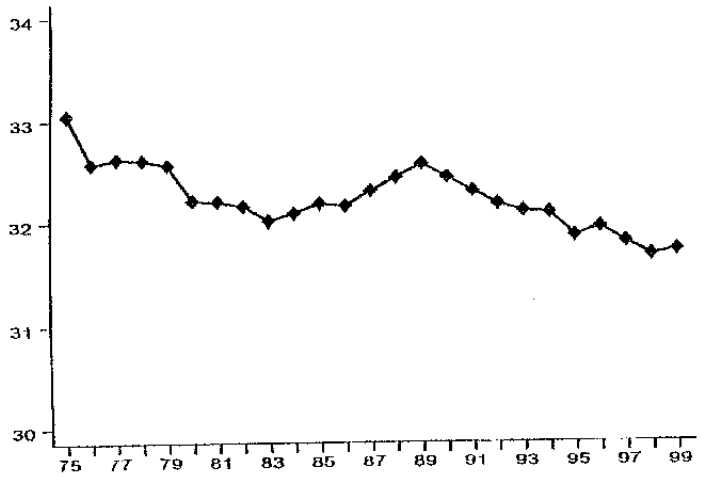


Detrended Average Overtime Hours

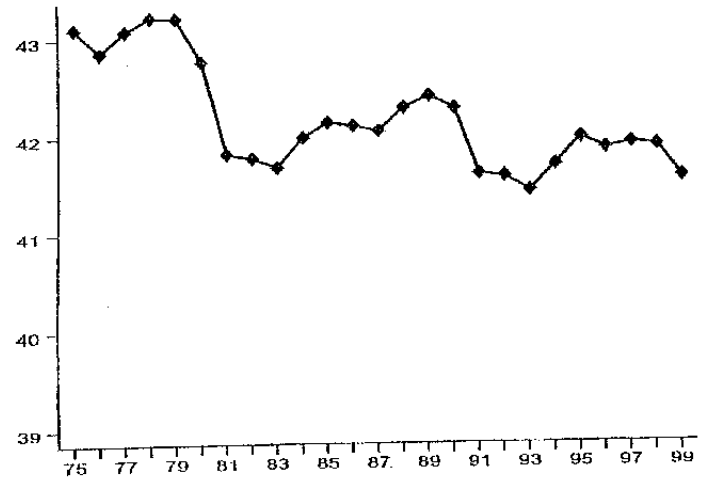
Figure 11. United Kingdom: Average Weekly Hours by Gender



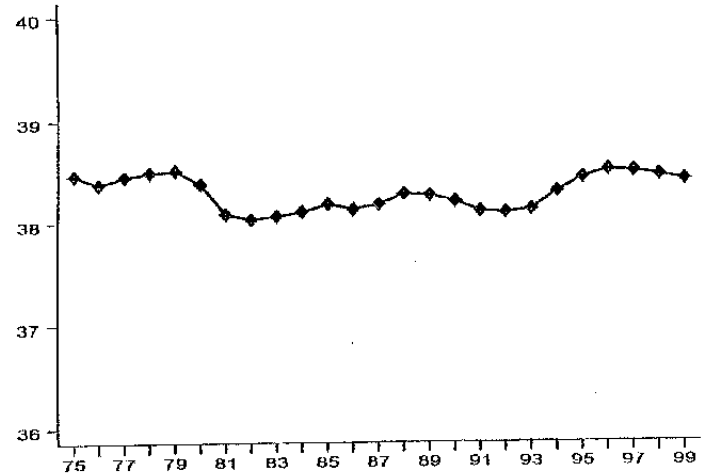
Average Total Hours: Men



Average Total Hours: Women



Average Total Hours: Men, Full-Time



Average Total Hours: Women, Full-Time

Figure 12. United Kingdom: Variance Decomposition for Earnings

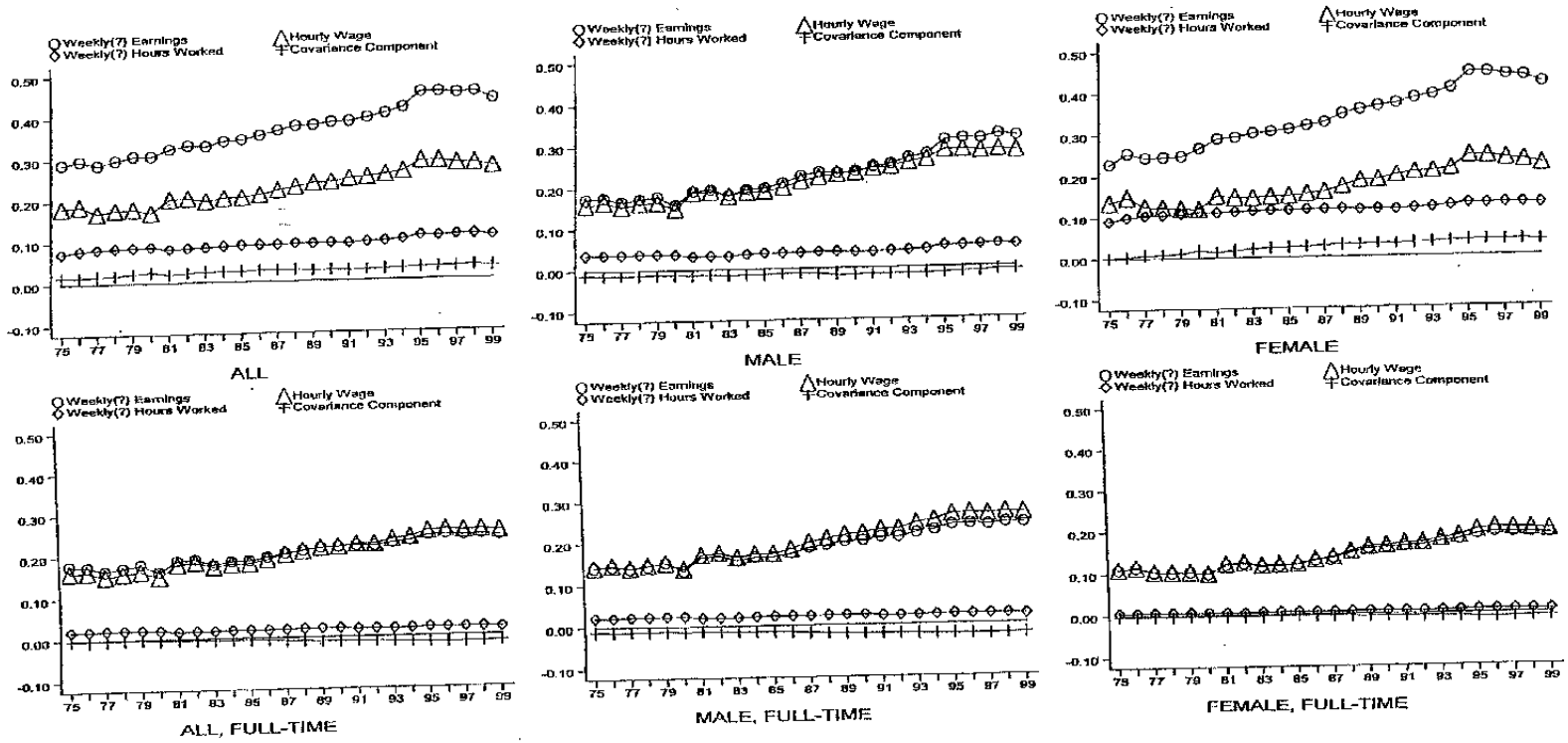
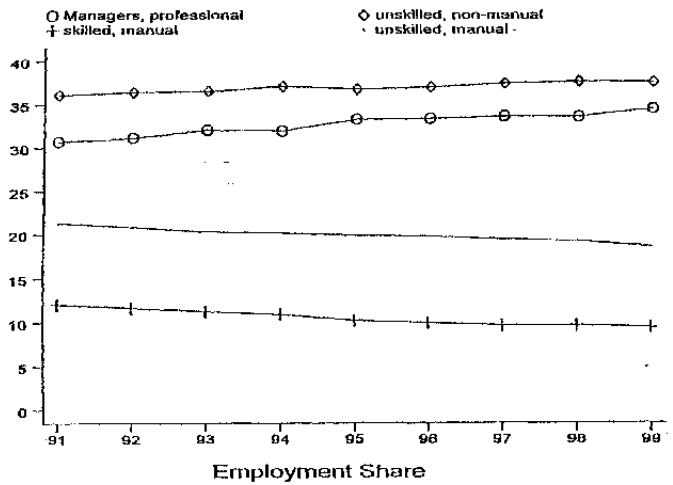
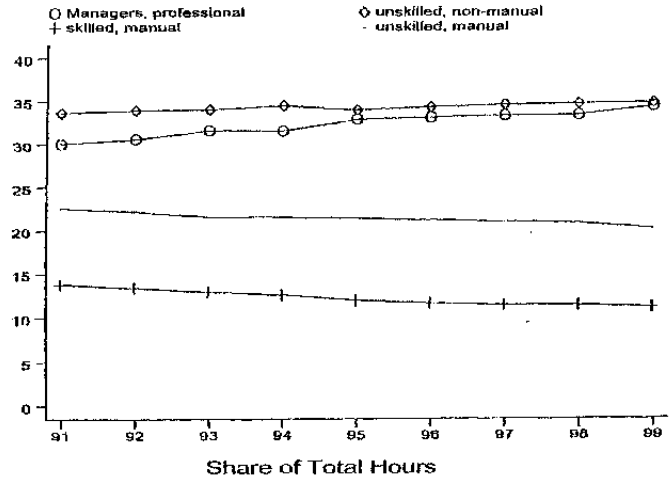
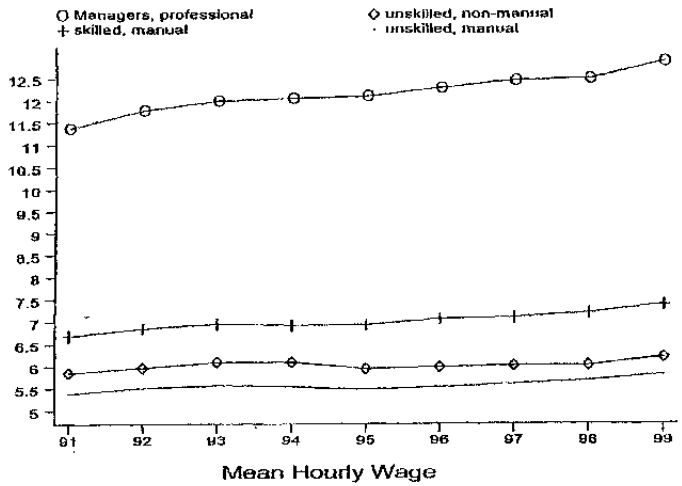


Figure 13. United Kingdom: Employment and Earnings by Occupation Group







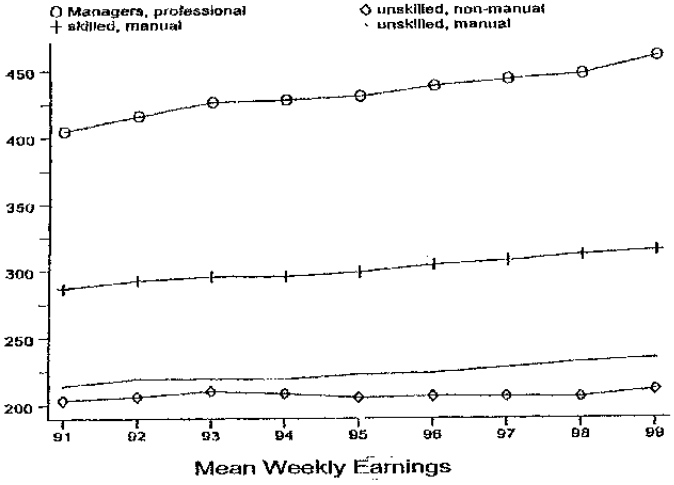
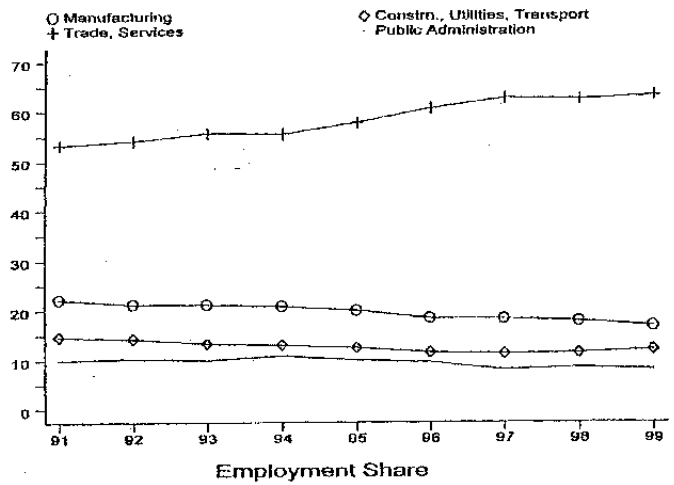
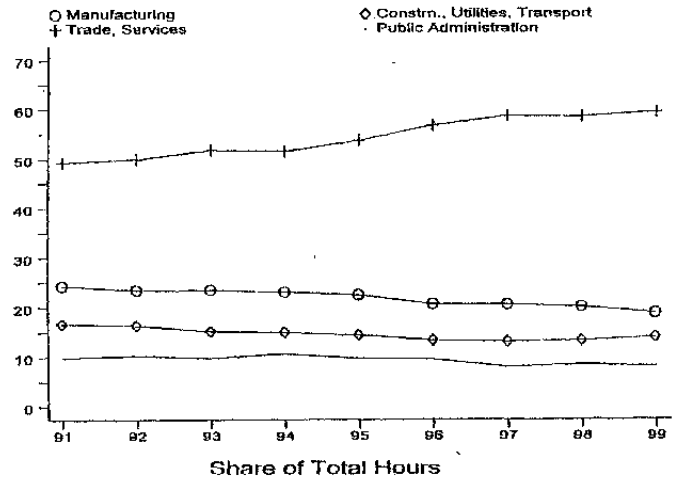
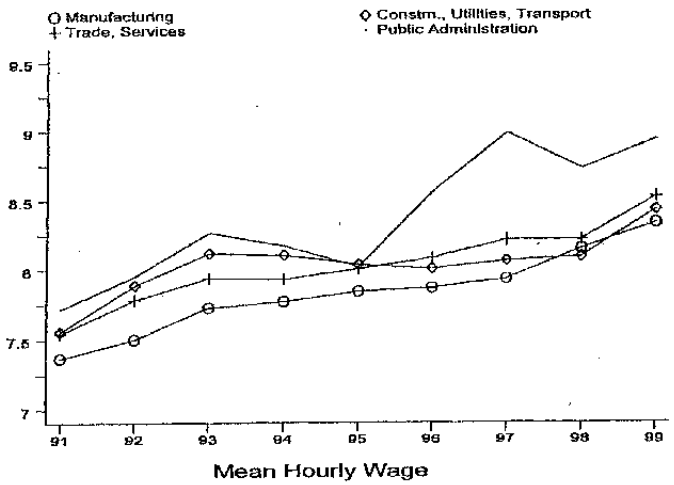


Figure 14. United Kingdom: Employment and Earnings by Industry Group







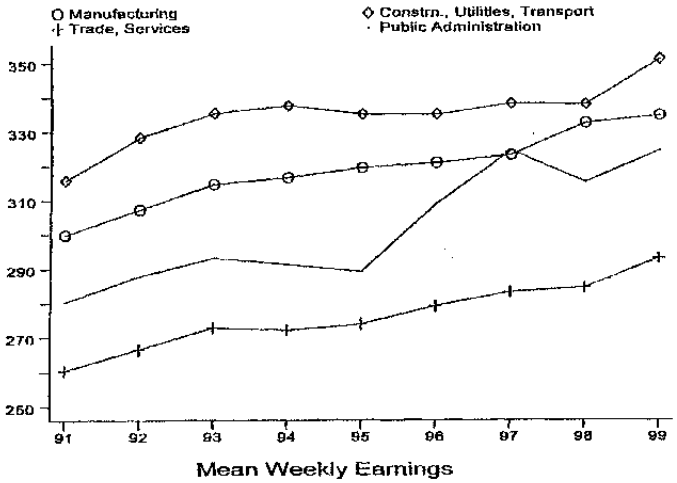
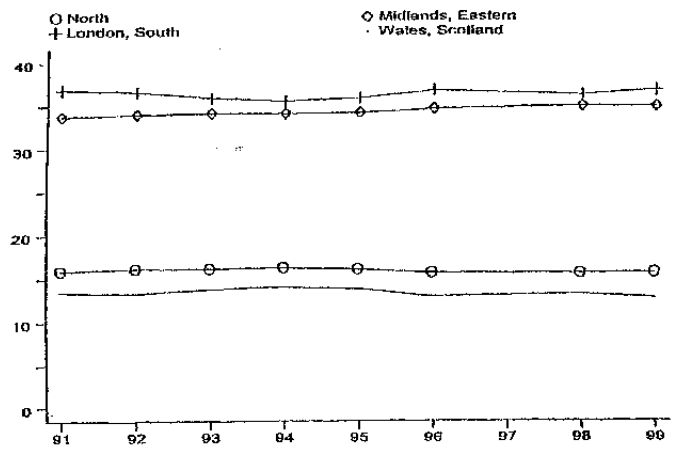
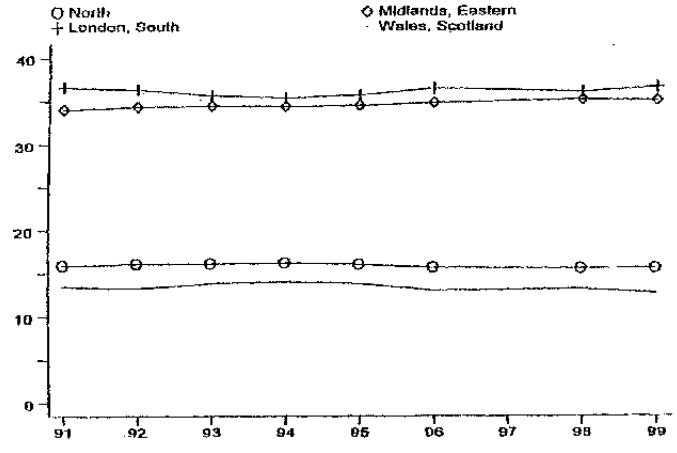
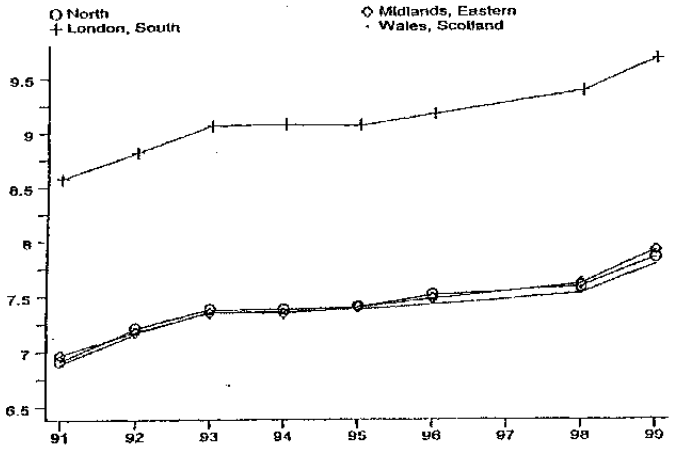


Figure 15. United Kingdom: Employment and Earnings by Region







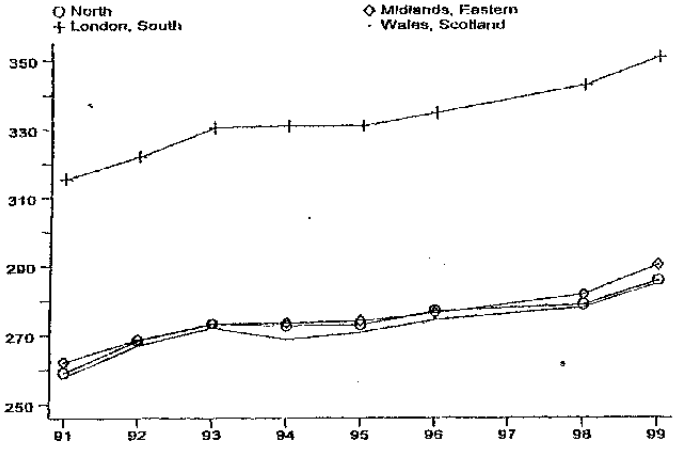


Figure 16A. United Kingdom: Composition Effects: Wages

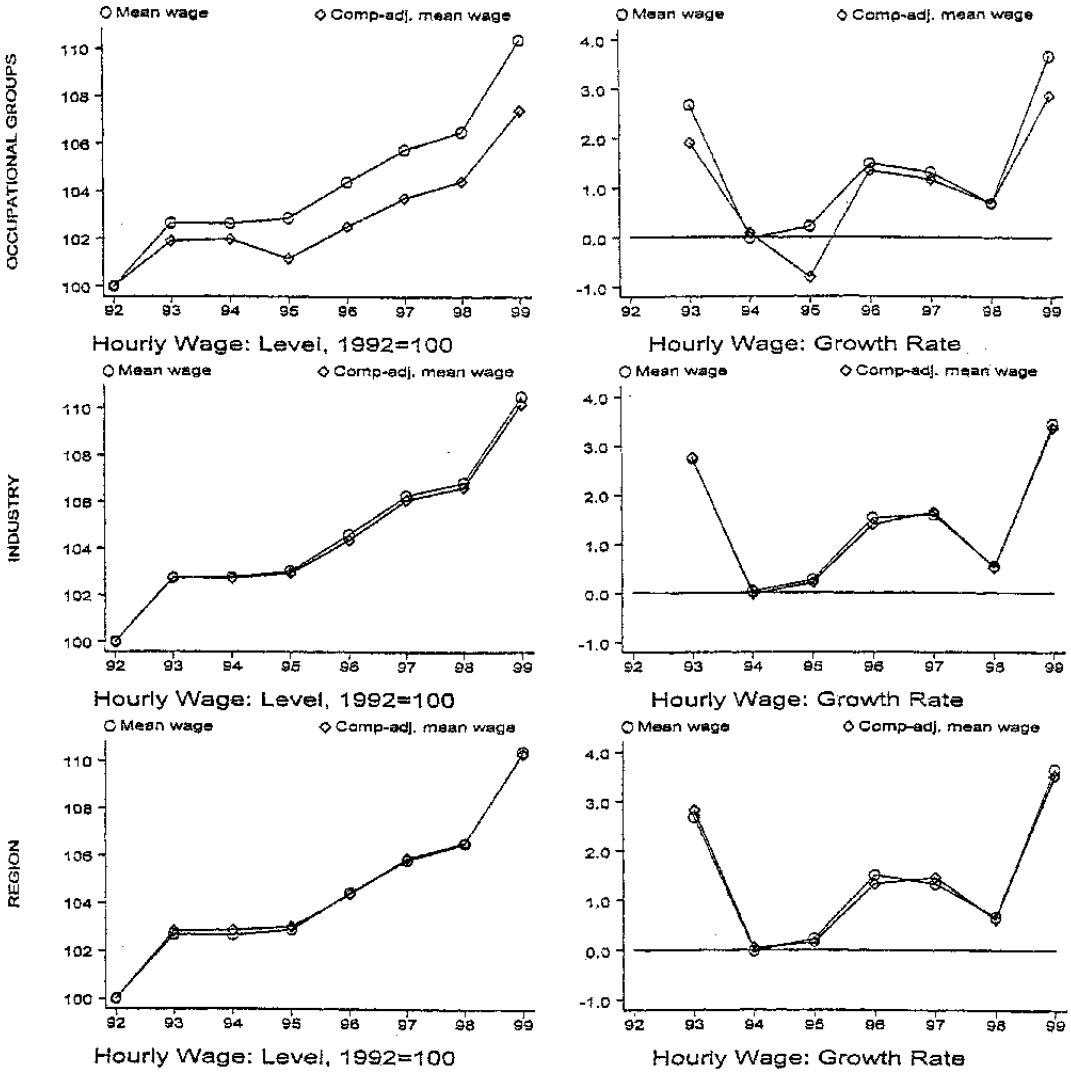
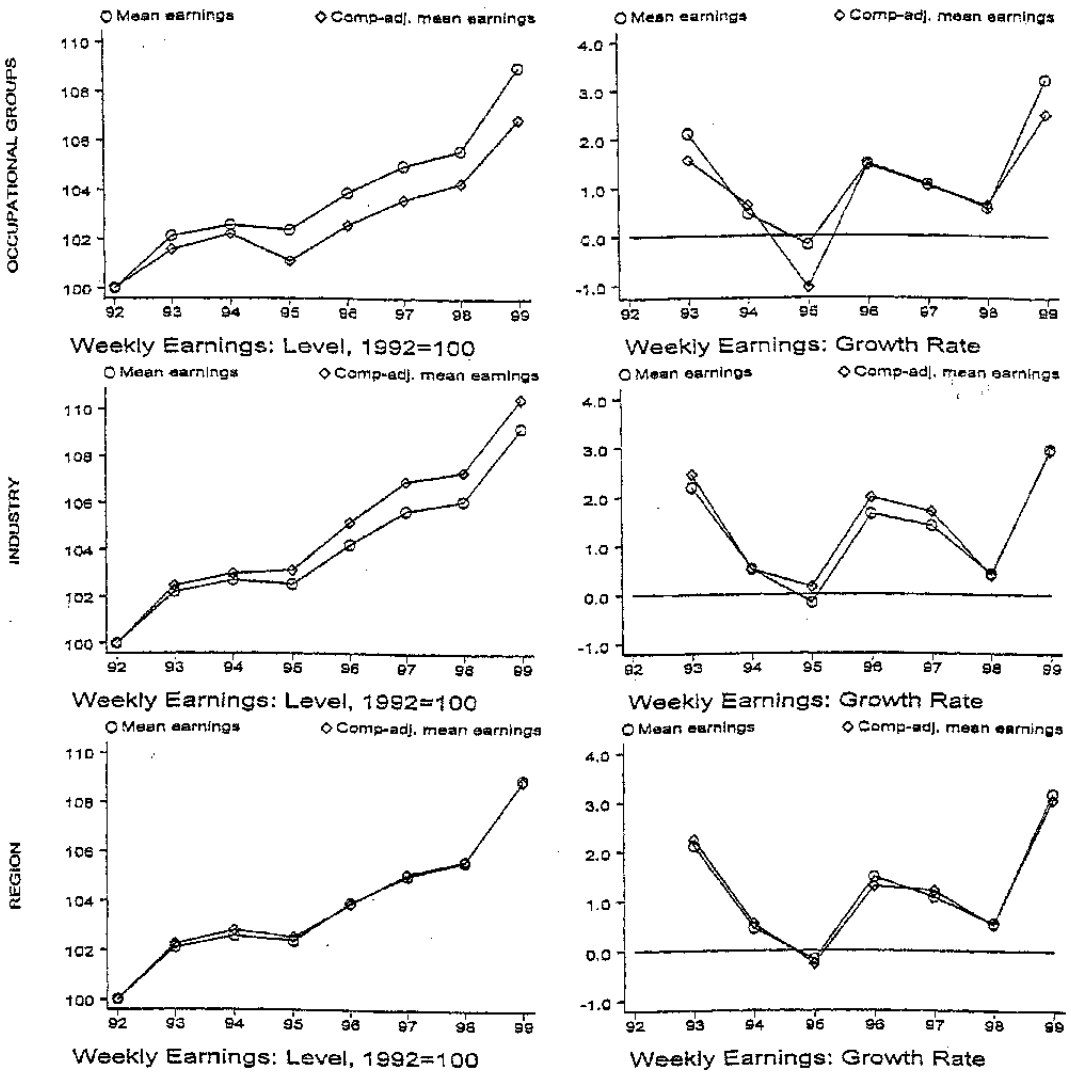


Figure 16B. United Kingdom: Composition Effects Earnings



II. THE "NEW ECONOMY" IN THE UNITED KINGDOM[1]

A. Introduction

1. **Of the three elements most frequently identified with the "new economy"—sustained output growth, subdued inflation, and an acceleration of labor productivity—only the third is conspicuously absent in the United Kingdom.** Labor productivity growth has fallen in the latter part of the 1990s compared to the first half. This fact is puzzling when one observes that investment in Information and Communications Technologies (ICT) is relatively high (almost on par with the United States) when measured comparably.[2]

2. **This paper examines this conundrum by looking closely at the contributions of ICT investment to output and labor productivity growth in the United Kingdom.** Several studies have attributed the absence of evidence of the new economy outside the United States to mismeasured ICT capital and associated output, and particularly, to deflators that fail to account for quality improvements in ICT goods. To be able to distinguish the impact of different deflators, both U.S. and U.K. price deflators for ICT investment and output are used to decompose labor productivity growth into the contributions from capital deepening (that proportion of labor productivity growth related to the growth of the capital stock available to each worker) and total factor productivity (that proportion measured as a residual component and not attributable to the capital or labor inputs, usually associated with better techniques or organizational aspects of production).[3] Each of these two components, in turn, is disaggregated into elements representing the ICT sector (computers and office equipment, software, and telecommunications) and the rest of the economy. Though the data are not completely comparable, the analysis broadly suggests that the cause of the relatively low productivity growth in the United Kingdom does not lie with insufficient use or production of ICT goods, as these elements of productivity growth are similar to those of the United States, but with sub par total factor productivity growth in the rest of the economy.

3. **It should be acknowledged at the onset of this examination that the use of U.S. deflators, while becoming the standard for deflating nominal ICT investment and output, is controversial**. The use of the U.S. deflators for the United Kingdom is not necessarily the "correct" method—as it depends on a number of assumptions—but

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[1] Prepared by Laura E. Kodres. The author is grateful to the U.K. Office of National Statistics, particularly Prabhat Vaze, as well as Garry Young, Daniel Sichel, Ben Broadbent, Nicholas Oulton, and participants at a round-table discussion in the HM Treasury for their provision of data, results, valuable insights, and comments. These individuals are absolved from all remaining errors in this paper.

[2] Another characteristic of the "new economy" is reduced volatility of output and inflation. This attribute has been evident in the United Kingdom as well.

[3] A variable measuring possible improvements in labor quality is not available and thus any productivity gains related to labor quality will be subsumed in total factor productivity.

simply one that shows the difference in the magnitude of the results when a more dramatic decline in prices is assumed. The adoption of U.S.-type deflators will depend upon the costs and benefits of maintaining the different methodology and its appropriateness in the U.K. context.

4. **Though new research is now providing more insight into the role of ICT in the U.K. economy, most commentators had subscribed to the following explanations for the lack of evidence of the "new economy" in the United Kingdom.**

- Much of the higher productivity in the United States has been generated by the actual production of computers and semiconductors. The computer production industry in the United Kingdom amounts to only half the size that it is in the United States and thus the United Kingdom cannot expect to have the type of acceleration in labor productivity that the United States has experienced.

- The recent dramatic fall in the unemployment rate in the United Kingdom is thought to be, in large part, due to a fall in the unemployment rate of unskilled workers. Adding unskilled workers to the labor pool (relative to skilled ones) could lower labor productivity for a time.

- Possible data mismeasurement may have introduced a downward bias in labor productivity. Output could be "mismeasured" if deflators for ICT output do not adequately account for quality improvements and thus underestimate price declines. And the output of the service sector, where adoption of ICT has been very heavy (e.g., the financial services industry), is also thought to be under recorded because the output of this sector is difficult to define and measure. For these two reasons, recorded labor productivity may not pick up the "new economy" effects that are present.

5. **Yet, even allowing for measurement problems, there is some circumstantial evidence that productivity in the ICT sector is on the upswing and thus these answers are not fully satisfying.** First, while the production of computers may be a relatively small part of the economy compared to the United States, the total ICT sector in the United Kingdom, including the production of telecommunications equipment and software, is not inconsequential. In terms of final output, the broad categories representing computers and office equipment, telecommunications, and software produced some 4¼ percent of nominal GDP. Second, analysis from the New Earnings Survey shows that labor composition effects cannot account for the subdued productivity growth—the employment share of high-skill workers actually increased during this expansion rather than the reverse as is typical in business cycle expansions.[4] Third, although data problems are present in the measurement of productivity, there is evidence of a pickup in productivity in some of the manufacturing industries most closely related to ICT production (optical equipment, engineering) and, as well, in business services,

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[4] See accompanying *United Kingdom—Selected Issues* paper "What's So Special About This Cyclical Expansion in the U.K.? A New Perspective from Labor Markets" for more details.

another heavy user of ICT equipment. Though the potential mismeasurement of output in the services industry also exists in the United States and thus cannot by itself account for the cross country difference in productivity, the fact that the financial sector (one of the most heavy users of ICT) represents a larger share of United Kingdom GDP than the United States suggests that the two countries may be less disparate than the numbers would imply.

6. **Precise estimates of the contribution of ICT to output growth and labor productivity are elusive, but the results provided below are an attempt to gain a more formal understanding.** The paper uses the work of Oliner and Sichel (2000) as the basis for the analysis and applies their techniques, with some adaptation, to the U.K. data. To examine whether mismeasurement of quality improvements of ICT goods plays a large role in the analysis, U.S. deflators, which show larger quality improvements than the U.K. deflators, are used. The basic results of the analysis are as follows.

- Using U.S. output and investment deflators as proxies for the decline in the prices of ICT goods rather than the U.K. deflators, adds nearly a percentage point to average output growth between 1997 and 1999. When chain-weighting is additionally employed (as done in the United States) to permit the changes in the quantities of goods that would normally accompany the large price declines in ICT goods, **output growth in the United Kingdom increases by about ½ percent between 1997 and 1999** rather than a full percentage point.

- **In terms of labor productivity, the contribution of ICT to capital deepening amounts to about one-quarter of the labor productivity growth in the 1997-1999 period.** That is, output per worker has increased by increasing the amount of ICT capital per worker. Moreover the contribution of ICT to capital deepening has increased three-fold compared to the early 1990s. **Total factor productivity (TFP), the remaining component of labor productivity, falls in the latter 1990s.** TFP is where the network benefits and spillovers of ICT are thought to reside. As yet, then, such benefits are not evident in the United Kingdom.

- When an analogous decomposition of TFP is conducted for the United Kingdom as done for the United States by Oliner and Sichel, **the growth of TFP for the computer and office equipment industry is more or less the same as the computer hardware industry in the United States.** One of the most striking results of Oliner and Sichel's paper is the high TFP growth evident within the semiconductor industry. However, since there is no data isolating semiconductor output in the U.K. official statistics, it is difficult to disentangle the possible contributions of this industry to U.K. TFP growth. In this study, any TFP gains for semiconductor production would reside in the residual "other" TFP growth category. Though because the semiconductor industry is thought to be much smaller than in the United States and most semiconductors are imported, any effect is likely to be limited.

7. **Given these results it is hard to know what lies ahead for the United Kingdom since even as of the mid-1990s the United States had yet to show any**

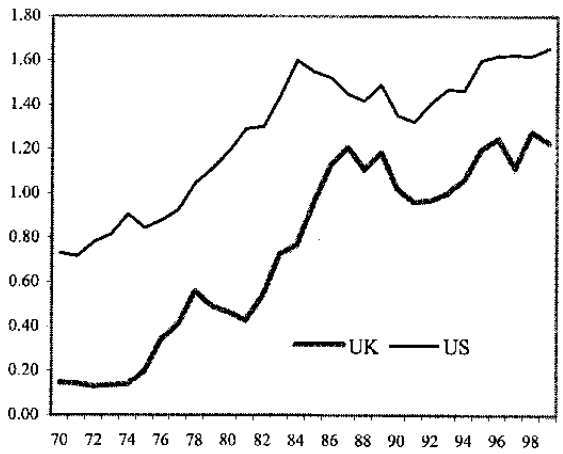
dramatic improvement in labor productivity: there was no evidence of a pickup in capital deepening nor TFP at the time. But, given the current economic environment one could expect that bottlenecks for higher-skilled labor (and thus higher wage bills) may imply that firms will attempt to substitute capital (possibly ICT capital) adding to capital deepening and productivity growth. This is where most of the productivity growth has come from to date. Further in the future, better use of ICT through better organized work processes and network externalities are likely to increase TFP particularly given its low level currently. Given that the share of ICT in output and investment is likely to rise, even with no change in the productivity of the ICT sector, measured productivity at the economy-wide level is likely to increase.

8. The paper will be presented as follows. The next section provides the motivation for the puzzle—if the United Kingdom has been investing in ICT at similar rates of growth as the United States why hasn't it seen the acceleration in labor productivity? The following part of the paper presents the methodology and results from a formal examination of the U.K. data. Various data measurement issues are discussed though the technical details of the composition of various series are relegated to an annex. Additional, circumstantial evidence of the "new economy" in the United Kingdom is then presented briefly.

B. The Puzzle

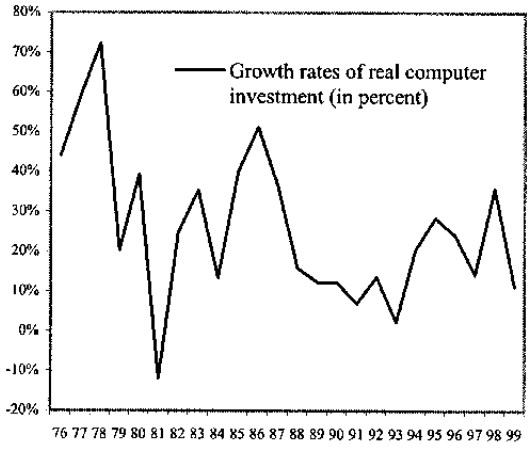
9. **Investment in ICT has been strong in the United Kingdom for an extended period of time.** As a share of nominal GDP, investment in computers and office equipment has been above one percent since 1986, with the exception of a marginal dip during a couple of recession years in the early nineties (Figure 1). ICT investment in the United States has been higher, but not appreciably so. The proportion of total nominal investment in other machinery and equipment devoted to computers and office equipment averaged 18 percent during the period from 1991 to 1999. The growth rate of real investment in computers has also been relatively high, averaging 17 percent in the 1990s and 26 percent in the 1980s (Figure 2).

Figure 1. U.K. and U.S. Nominal Investment in Computers as Share of GDP (In percent)



Sources: U.S. Survey of Current Business;and U.K. Blue Book.

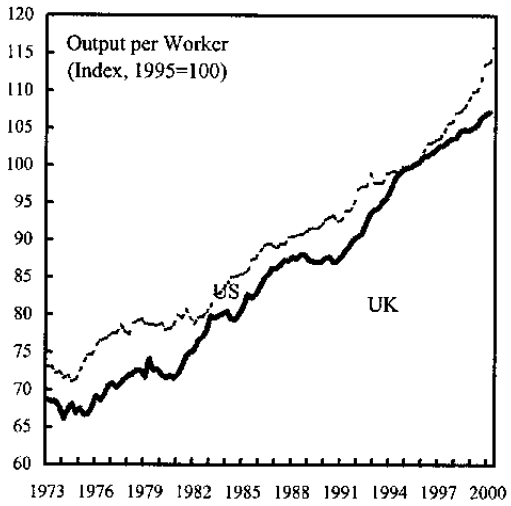
Figure 2. U.K.: Real Computer Investment



Sources: U.K. Input-Output Supply and Use Balances Tables; U.S. Bureau of Economic Analysis; and International Finance Statistics.

10. **Though investment in computers has been relatively high, labor productivity has not shown a commensurate increase.** After averaging 2.6 percent from 1990q1 to 1995q1, labor productivity (output per job) fell to 1.5 percent in the latter part of the 1990s. While U.K. productivity growth was higher than that in the United States in the earlier period, it has fallen significant below the United States since 1994 (Figure 3).[5]

Figure 3. U.K. and U.S.: Labor Productivity



Sources: Output per filled job, whole economy, U.K. Office of National Statistics; and U.S. business sector output per hours of all persons, Bureau of Labor Statistics.

C. Formal Results for the "New Economy" in the United Kingdom

The Data

11. **To examine the contribution of ICT capital to growth of real output and labor productivity, a series representing the ICT capital stock in real terms is required.** For the United Kingdom, as an initial benchmark, the following four broad industrial categories are used from national statistics to obtain investment data: "office machinery" (referred to below as computers and office equipment) is used as a proxy for computers; "computing services" is used as a proxy for software; and two categories "transmitters for TV, radio, and phone" and "receivers for TV and radio" are considered proxies for telecommunications. These data, though overestimates of a strictly defined ICT sector, will provide an "optimistic" estimate of the contributions.[6]

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[5] In the United Kingdom, labor productivity is traditionally measured as output per worker whereas in the United States the measure is output per hour worked of all persons.

[6] Though the series includes anything from staplers to Pentium 4 computers, most of the growth in the series is thought to reflect the growth of computers and peripherals.

12. **The net capital stock for each of the three components of the ICT capital stock is individually constructed from investment in these three categories of equipment.** The underlying investment data come from the Input-Output Tables and estimates for other parameters come from Oliner and Sichel (2000) (see Annex I for details). The basic approach is the "perpetual inventory method" (PIM) and is used by the United Kingdom and the United States in the construction of their net capital stocks. In its most basic form, it takes gross investment, subtracts depreciation over the period to arrive at net investment, and adds this to the existing capital stock at the beginning of a period. Notably, a constant depreciation rate of 30 percent per annum on a nominal basis was assumed as a first approximation for computers and office equipment and software and a constant depreciation rate of 11 percent per annum was assumed for the telecommunications category to construct the capital stocks.[7]

13. **The assumption used for investment price deflators for the nominal capital stocks is an important one as the declines in prices for ICT have been large in the last several years.** The rapid price declines imply high real capital stock levels and higher growth rates of ICT capital than for the remaining "other" capital stock. Because U.S. price deflators are thought by some to be representative of the price declines in ICT, they are used in the first set of results. The deflators used in the United Kingdom are then employed to observe the sensitivity to the results in section E below.

14. **The differences between the U.S. deflators and the U.K. ones arise primarily through different methodologies to control for quality improvement—although note that other limitations, for instance, due to small survey samples may be present.** In the United States hedonic methods for computers are used and in the United Kingdom option costing and manufacturer costing, both of which adjust a price quote for a new computer to be comparable to an older model, are used. In the hedonic method, various features of the computer are assigned an indicator—e.g., RAM size, hard disk size, and the presence of a CD drive. A regression is run with the price of the whole computer as the independent variable and the indicator variables as dependent variables. Then fitted values of the regression using the estimated sensitivities to the indicators are used to adjust price quotes so that quality changes are accommodated. In the manufacturer costing method used in the United Kingdom, manufacturers are asked to estimate the cost of any change in the product specification. Because costs are usually overestimated—due to economies of scale in production, for example—half of the manufacturers' costs are taken as the value of the quality change. This is then used to adjust the producer price indices. The option costing methodology bases prices on various options costs and the prices of particular technical specifications as advertised in computer magazines and then applies the 50 percent rule.

15. **Even though the exact categories differ the closest matching U.S. deflator is used for adjusting nominal values in the United Kingdom.** Because the "office

[7] These rates were also used by Jorgenson and Stiroh (2000). A measurement of the "productive" capital stock is the preferred concept, but as such a measure is unavailable, the PIM is used as an approximation. See Annex I for further discussion of the notions of productive capital stock versus wealth stocks.

machinery" category includes more than just computers, a weighted average of U.S. price indices that cover various parts of the office machinery category are used. Software deflators in the United Kingdom are not adjusted for quality. The U.S. software deflators use a combination of hedonics and a matching model to incorporate quality changes. For telecommunications equipment, both the United States and the United Kingdom use quality adjustment. In the United States, the hedonic techniques are only used for some the components of this industry (e.g., electronic switches) but not for others (e.g., fiber-optic cables) and thus the deflator does not decline as fast as for computers and is thought to underestimated quality changes. The telecommuncations deflator in the United Kingdom is quality-adjusted as described above. The U.S. deflators are adjusted for the dollar/pound exchange rate before being applied to the U.K. data. Implicit in this adjustment is that ICT goods compete in a global market and that the U.K. prices quoted in pounds reflect the price declines represented by U.S. dollar deflators. The above-described deflators are used to obtain the real capital stocks for the three ICT capital stocks. The remaining net capital stock uses the implicit deflator obtained from the total real and nominal net capital stocks. The real "other" net capital stock is the total nominal net capital stock less the nominal capital stocks for the three ICT categories divided by the implicit deflator for the entire capital stock.

16. **The output series is adjusted to account for the different deflators associated with ICT equipment as well.** In this case, output deflators (as opposed to investment deflators) from the United States are used—again matching the industrial categories as closely as possible for the deflators. The nominal output of the three ICT categories is obtained from the Input-Output Table 3 (net of intermediate input that goes back into these categories). The nominal ICT output categories are deflated by the associated U.S. output deflators to obtain the real ICT output. Then the same procedure as for the capital stock is used to reconstruct a "U.S. ICT price adjusted" measure of U.K. GDP assuring some comparability between the net capital stock and output measures.

17. **The income shares, also necessary for the exercise performed below, are calculated using national income statistics from the Office of National Statistics (ONS).** First, the labor share is taken as the proportion of income earned by labor in the economy each year. This is subtracted from one to obtain the share attributable to capital. To obtain the individual shares for the various ICT categories, the relative nominal proportions of ICT capital in the total nominal capital stock are calculated, year by year. These are weights multiplied by the total share attributable to capital to obtain the income shares of ICT and "other" capital.[8]

[8] Oliner and Sichel (2000) provide a more precise method for calculating income shares that include the depreciation rate, the capital loss, the real rate of return on capital, and a tax factor. Further work will need to be done to reproduce these weights for the United Kingdom with data provided by the ONS and others.

Contributions of ICT to Real GDP Growth

18. **The first set of exercises utilize a framework first proposed by Robert Solow (1957) to attribute the growth of output to various inputs.** Starting with a Cobb-Douglas, constant returns-to-scale production function, one can derive the following:

$$y = \alpha_C k_C + \alpha_S k_S + \alpha_T k_T + \alpha_O k_O + \alpha_L l + a, \quad (1)$$

where y and l are the growth rates (expressed in log differences) in output and labor (workforce filled jobs), the growth of the three capital stocks, k_C, k_S, k_T, represent those associated with computers, software, and telecommunications equipment. The contributions from the growth of the remaining capital stock is denoted, k_O. The final term, a, is TFP and is calculated as a residual. This formulation differs slightly from that used by Oliner and Sichel (2000) as they include a labor "quality" factor which is unavailable for the United Kingdom. Because this factor is absent, improvements in labor quality are captured by TFP. The α terms represent income shares. Under neoclassical assumptions, these shares equal the output elasticities for each input and they sum to one.[9] Thus, the methodology uses a simple disaggregation: the contribution of computers, for instance, is the share of national income which is attributable to the net real stock of computers multiplied by the growth rate in that stock of computers.

19. **For the United Kingdom, using data from 1987 through 1999 and U.S. deflators to adjust real output and capital stocks, the contribution from ICT grows from negligible in the 1987-1990 period to 0.6 percent of GDP growth per annum by the 1997-1999 period (Table 1).**[10] Examining only the component proxying for computers, the contribution to GDP growth calculated here was about 0.5 percent in the final three years. The dominance of this ICT component within the total ICT contribution is probably a result of the larger price declines in this sector relative to the price declines in software and telecommunications equipment. Examining the same ICT category, Kneller and Young (2000) find similar results, computers contribute 0.5 percent to real GDP growth, although they cover slightly different set of years (1996 and 1997). The contribution is probably overstated because semiconductors are not included in the four industry subcategories used to construct the ICT capital stock. Because semiconductors are used as inputs for computers and most of the semiconductors are imported, their inclusion would probably subtract from the overall ICT contribution.

20. **The revaluation of ICT output using U.S. deflators raises real GDP growth by a full percentage point in the final three years of the sample, though considerably less in the earlier years.** Using similar techniques to examine the effect of hedonic price indices on business sector real GDP growth, Goldman Sachs finds they raise U.K.

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[9] Such assumptions include perfect competition (implying prices are equal to their marginal costs), constant returns-to-scale technology, and that the economy is on the production possibility frontier (implying businesses are at or near their optimal long-run levels of labor and capital inputs).

[10] The breakdown into the 1991 to 1996 and 1997 to 1999 periods is undertaken to accord with the time periods represented by negative and positive output gap periods.

business sector real GDP by slightly more than ½ percent. The discrepancy with these results could be due to their focus on business sector GDP rather than the broader GDP measure used here, but it appears that much of the difference disappears when output growth is recalculated using chain-weighting. In the early 1990s, the use of U.S. deflators makes little difference in either study.

Table 1. Contributions to Growth of Output in the United States and the United Kingdom, 1987-1999

	IMF U.K 1987-1990	Oliner&Sichel U.S. 1987-1990	IMF U.K. 1991-1996	Oliner&Sichel U.S 1991-1996	IMF U.K. 1997-1999	Oliner&Sichel U.S. 1997-1999
Growth rate of output: adjusted with U.S. deflators 1/	3.17	3.18	1.92	3.00	3.73	4.94
Contribution from:						
ICT	0.09	0.53	0.21	0.62	0.59	1.16
Computers & Office Equip. 2/	0.09	0.24	0.16	0.28	0.49	0.65
Software	n.a.	0.20	0.03	0.26	0.05	0.37
Communications Equip.	n.a.	0.10	0.03	0.08	0.05	0.14
Memo:						
Income shares:						
Computers & Office Equip. 2/	0.26	1.53	0.75	1.45	1.89	1.78
Software	n.a.	1.45	0.09	2.11	0.23	2.66
Communications Equip.	n.a.	1.78	0.09	1.92	0.22	1.88
Growth rate of inputs:						
Computers & Office Equip. 2/	35.28	15.74	20.24	18.85	26.56	37.31
Software	n.a.	14.28	36.64	12.81	22.49	14.12
Communications Equip.	n.a.	5.84	34.69	4.31	21.56	7.69
Growth rate of output (unadjusted for U.S. deflators)	3.03		1.74		2.73	

Sources: Oliner and Sichel (2000); and staff estimates.
1/ All numbers are average annual log difference for years shown multiplied by 100.
2/ Oliner and Sichel's category is termed "hardware."

21. **One of the reasons for the large increase in real GDP is that the two sets of deflators (for the United States and the United Kingdom) show a slightly widening discrepancy in the latter half of the 1990s though income shares also play a role.** One should keep in mind, however, that when using price deflators that show large declines, as in the case of ICT goods, it is reasonable to expect quantities to adjust. The technique of chain-linking used in the United States and France allows these changes to occur, but

the use of base-weighted (Laspeyres) indices in the United Kingdom does not.[11] This implies that the fixed value weights of ICT output assigned in 1995 (the base year) will understate the (true) relative weight of the ICT sector for the United Kingdom as time progresses, leading to an overestimate of the residually calculated real quantities. The reason this is the problem of "substitution bias": categories with declining relative prices are associated with faster growth in quantities. In a Laspeyres index, the (price times quantity) weights are not permitted to adjust so all the impact of lower prices is seen as "real" quantity increases. Thus, the estimates in Table 1 of real GDP growth are biased up and the more so since prices fell dramatically in the latter years.

22. **Table 2 presents the same analysis but with chain-linked real GDP and, as expected, real GDP growth falls relative to the non-chain-linked results.**[12] In the last subperiod (the one with the largest potential impact) the growth rate drops from 3.73 percent per year to 3.22 percent per annum. Alternatively viewed, the growth rate of real output increases by about ½ percent using U.S. deflators *and* chain-weighting. As does the real GDP growth rates, the contribution of the ICT capital to output growth similarly declines slightly from 0.59 to 0.44 percent in the 1997-1999 and slightly less in the earlier periods. The pattern across the sample period remains the same: increasing ICT contributions to output growth.[13]

Contributions to Labor Productivity Growth

23. **One can also examine the contribution of ICT to labor productivity.** Using equation (1), one can subtract the log of the labor input from both sides and arrive at the following equation:

$$y - l = [\alpha_C(k_C - l) + \alpha_S(k_S - l) + \alpha_T(k_T - l) + \alpha_O(k_O - l)] + a, \qquad (2)$$

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[11] See Chapter III, "The New Economy in France: Developments and Prospects," in France: Selected Issues, Staff Country Report No. 00/148 for a similar exercise to that executed here using French hedonic deflators.

[12] The real ICT capital stock was also chain-weighted using a method called a "Tornqvist" index approximation, which is close to the ideal "Fisher formula" used in the United States. In this approximation, the growth rate of the index is a weighted average of nominal shares in the current and previous periods. This growth rate is then used to construct levels by assuming a base year (here assumed to be 1995). Inventories are ignored in the construction of this chain-weighted capital stock. For a discussion of the issues regarding chain-weighted in the United States and possible pitfalls in the area of ICT investment and output see Whalen (2000b). For a review of these concepts by the Office of National Statistics, see Lynch (1996).

[13] The higher contribution of the telecommunications sector in Table 2 is partly due to a change in the assumptions for depreciation. Table 1 assumed that all three categories of ICT used a depreciation rate of 30 percent and a capital loss of 34 percent per annum. In Table 2 the capital loss component was eliminated and the depreciation rate for telecommunications capital was assumed to be 11 percent.

Table 2. Contributions to Growth of Output in the United States and the United Kingdom, 1987-1999
Chain-weighted U.K. Output using U.S. Deflators for ICT Adjustments

	IMF U.K 1987-1990	Oliner&Sichel U.S. 1987-1990	IMF U.K. 1991-1996	Oliner&Sichel U.S 1991-1996	IMF U.K. 1997-1999	Oliner&Sichel U.S. 1997-1999
Growth rate of output: adjusted with U.S. deflators 1/	3.11	3.18	1.91	3.00	3.22	4.94
Contribution from:						
ICT	0.07	0.53	0.18	0.62	0.44	1.16
Computers & Office Equip. 2/	0.07	0.24	0.09	0.28	0.28	0.65
Software	n.a.	0.20	0.03	0.26	0.05	0.37
Communications Equip.	n.a.	0.10	0.06	0.08	0.11	0.14
Memo:						
Income shares:						
Computers & Office Equip. 2/	0.30	1.53	0.57	1.45	1.26	1.78
Software	n.a.	1.45	0.18	2.11	0.32	2.66
Communications Equip.	n.a.	1.78	0.26	1.92	0.58	1.88
Growth rate of inputs:						
Computers & Office Equip. 2/	26.01	15.74	14.72	18.85	22.75	37.31
Software	n.a.	14.28	16.64	12.81	15.70	14.12
Communications Equip.	n.a.	5.84	23.05	4.31	19.07	7.69
Growth rate of output (unadjusted for U.S. deflators)	3.03		1.74		2.73	

Source: Oliner and Sichel (2000); and staff estimates.
1/ All numbers are average annual log difference for years shown multiplied by 100.
2/ Oliner and Sichel's category is termed "hardware."

This formulation divides labor productivity growth, $(y - l)$, into capital deepening, the bracketed term, and total factor productivity (TFP), a. By examining the growth in the ICT capital stocks relative to the total numbers of employees in the economy, the amount of capital deepening attributable to each type of capital can be calculated. And, by adding them, the contribution of ICT capital to capital deepening can be examined. Recall that the final term, a, is calculated as a residual after the contributions of three types of ICT capital and "other" capital are subtracted. The contribution of changes in the ICT capital/labor ratio, $[\alpha_C(k_C - l) + \alpha_S(k_S - l) + \alpha_T(k_T - l)]$ an be interpreted as the contribution of changes in the *use* of ICT equipment by the economy at large.

24. **Table 3 shows a less dramatic decrease in labor productivity growth than previously reported using U.K. deflators in the 1997-1999 period.** Note that once real GDP is adjusted for real ICT output using U.S. deflators, the drop in the labor productivity growth rate cited in earlier papers and official statistics is not as dramatic—

this is simply a reflection of the increased growth rate for real GDP, which is most striking in the latter 1990s, noted above. For comparison purposes, the "unadjusted" productivity growth rates are given as a memo item in Table 3.

Table 3. Contributions to Labor Productivity for the United States and the United Kingdom, 1987-1999

	IMF 1987-1990 U.K	Oliner&Sichel 1987-1990 U.S.	IMF 1991-1996 U.K.	Oliner&Sichel 1991-1995 U.S	IMF 1997-1999 U.K.	Oliner&Sichel 1997-1999 U.S.
Growth rate of labor productivity: 1/	0.75	0.90	2.67	1.71	2.33	2.45
Contribution from: 2/						
Capital Deepening	0.10	0.28	0.87	0.55	1.19	0.96
ICT	0.08	0.44	0.22	0.55	0.56	1.01
Computers & Office Equip. 3/	0.08	0.20	0.16	0.26	0.47	0.61
Software	n.a.	0.17	0.03	0.23	0.05	0.30
Communications Equip.	n.a.	0.06	0.03	0.06	0.04	0.10
Other capital	0.02	-0.16	0.66	0.00	0.63	-0.05
Labor quality	n.a.	0.34	n.a.	0.41	n.a.	0.27
Total Factor Productivity	0.65	0.29	1.80	0.74	1.14	1.23
Memo Item:						
Growth rate of labor productivity (unadjusted for U.S. deflators)	0.61		2.50		1.33	

Sources: Oliner and Sichel (2000); and staff estimates.

1/ Average annual log difference for years shown multiplied by 100. GDP revalued with U.S. deflators for ICT sector.

2/ Percentage points per year.

3/ For Oliner & Sichel, this category includes hardware and semiconductors.

25. **Capital deepening attributable to the use of ICT capital amounts to over one-half of the total capital deepening in the 1997-1999 period, 0.56 percent of the total 1.19 percent.** This component also increases relative to the earlier periods from a mere 0.08 percent to 0.56 percent in the final period. Comparing the first half of the 90's with the second, Goldman Sachs reports that the ICT contribution to capital deepening increases from 0.37 to 0.84, slightly higher contributions than the numbers reported here.

26. **Within the ICT sector, capital deepening through the use of computers and office equipment is most prominent, accounting for most of the capital deepening regardless of which period is examined.** It is somewhat surprising that the telecommunications capital stock contributes so little given the public perception regarding the amount of investment in this area. Two factors are responsible. First, although throughout most of the 1990s the growth of the real telecom capital stock (and the underlying investment growth) has been as robust as for computers and office equipment, the much faster relative declines in computer prices in the last three years has

meant faster relative real growth in the computer sector—the real telecom capital stock, while growing, has fallen somewhat behind the real growth of the computer sector. Telecom prices (U.S. deflators) have declined by about 1 percent per year since 1991 and have not seen the dramatic fall in recent years along the lines of computer and office equipment prices (telecom prices declined 1.5 percent per year since 1997 compared to 14.8 percent for computers and office equipment.) Second, the total size of the telecom capital stock is smaller than for computers and thus its income share is also commensurately smaller.

27. **Despite a full percentage point increase in TFP relative to unadjusted output figures in the 1997-99 period, TFP still drops compared to the early 1990s—falling from 1.8 percent per year to 1.1 percent.** This decline contrasts with the U.S. results in which TFP increased by about ½ percent in the latter period. The results from Goldman Sachs for the United Kingdom also suggest that TFP has also fallen to just over 1 percent per annum in the 1996-99 period. Overall, the labor productivity growth rate declines in the latter period can be viewed as declines in TFP and capital deepening associated with "other" capital which do not match the significant gains made in capital deepening from investment in ICT.

28. **The contributions of ICT to labor productivity are also calculated with the chain-weighted output and capital stocks with the results showing similar, but slightly muted, effects (Table 4).** The lower GDP growth rates calculated when chain weighted is employed are associated with a lower TFP contribution compared to Table 3—from 1.14 percent to 0.73 percent per annum in the 1997-1999 period. As well, the contributions of ICT capital per worker to productivity are also slightly lower, dropping from 1.19 percent to 1.09 percent per annum in the latter period. Proportionately, however, around one-quarter of the labor productivity growth can be attributed to ICT capital deepening using either of the two GDP growth calculations.

The ICT Production Component of TFP

29. **Another way to the examine the effect of ICT on labor productivity and growth is to examine the productivity of the ICT sector itself.** The above examination of labor productivity and the associated capital deepening component results in an examination of the "use" of computers: the effects of the "production" of ICT is addressed in this section. In principle, one could examine labor productivity, and thus TFP, of the ICT sector directly by applying the same technique used above on a sectoral basis, using capital and labor within the ICT sector. However, employment statistics are not provided for the same industry breakdowns as for investment and output at this level of specificity in the U.K. statistics and thus this approach is foreclosed. Another approach, used by Oliner and Sichel, who build on the work of Hulten (1987), Triplett (1996), and Whelan (2000a), attempts to solve for TFP in the ICT sector using the so-called "dual" method. Their approach is modified somewhat to better fit the U.K.'s ICT sector.

Table 4. Contributions to Labor Productivity for the United States and the United Kingdom, 1987-1999
Chain-weighted U.K. Output using U.S. Deflators for ICT Adjustments

	IMF 1987-1990 U.K	Oliner&Sichel 1987-1990 U.S.	IMF 1991-1996 U.K.	Oliner&Sichel 1991-1995 U.S	IMF 1997-1999 U.K.	Oliner&Sichel 1997-1999 U.S.
Growth rate of labor productivity: 1/	0.70	0.90	2.67	1.71	1.82	2.45
Contribution from: 2/						
Capital Deepening	0.06	0.28	0.84	0.55	1.09	0.96
ICT	0.07	0.44	0.19	0.55	0.41	1.01
Computers & Office Equip. 3/	0.07	0.20	0.10	0.26	0.27	0.61
Software	n.a.	0.17	0.03	0.23	0.05	0.30
Communications Equip.	n.a.	0.06	0.06	0.06	0.10	0.10
Other capital	-0.01	-0.16	0.66	0.00	0.67	-0.05
Labor quality	n.a.	0.34	n.a.	0.41	n.a.	0.27
Total Factor Productivity	0.64	0.29	1.82	0.74	0.73	1.23
Memorandum item:						
Growth rate of labor productivity (unadjusted for U.S. deflators)	0.61		2.50		1.33	

Sources: Oliner and Sichel (2000); and staff estimates.
1/ Average annual log difference for years shown multiplied by 100. GDP revalued with U.S. deflators for ICT sector.
2/ Percentage points per year.
3/ For Oliner & Sichel, this category includes hardware and semiconductors.

30. **The model of the U.K. economy for the TFP analysis is assumed to have two industrial sectors: an ICT sector and all other sectors.**[14] Each sector has its own production function. The ICT sector produces final output, but also intermediate inputs to the rest of the sectors. Additionally, the ICT sector utilizes some of its own output as intermediate inputs, perhaps in other firms in the industry. The growth of TFP can be represented by:

$$TFP = \mu_C \, TFP^{ICT} + \mu_O TFP^{O}, \qquad (3)$$

where aggregate TFP growth equals the weighted sum of the TFP growth in each of the two sectors. The weights are the share of gross output in the ICT sector as a share of total output (in current pound prices). Gross output includes final output, but also intermediate inputs to the rest of the sectors. The intermediate inputs of ICT goods to the ICT sector are subtracted as they are already included as final output of the ICT sector. The "dual

[14] The exercise performed here is also reproduced for the computer and office equipment sector alone. Oliner and Sichel (2000) use three sectors, including a semiconductor sector.

method" used to estimate sectoral TFP relies on the prices of outputs and inputs, rather than their quantities. Very loosely, the basic intuition is that if output prices are falling in a sector, but input prices are relatively stable, then (assuming firms are able to cover costs), the falling output prices are evidence of TFP gains. Said another way, more output is able to be produced with the given inputs, i.e. TFP gains, and these gains allow price declines without firms failing. The derivation of the method and a further discussion of the data are presented in Annex II. Using the annual TFP residuals from the above exercise and the constructed parameters as described, TFP for the ICT sector and the rest of the economy is calculated.

31. **Although the growth rate of economy-wide TFP falls in the latter 1990s, an increasing contribution comes from production in the ICT sector (Table 5).** Most of this contribution comes from a dramatic rise in the growth rate of TFP in this sector rather than the size of the sector. In the earlier period, 1993-1996, TFP^{ICT} is 3.9 percent per annum, higher, but not dramatically higher, than the 2.1 percent of the rest of the economy. By the 1997-1998 period, TFP^{ICT} is 14.7 percent per annum while that of the rest of the economy drops to 0.2 percent per annum. The result depends on the relative difference in the logged difference in the output deflator for ITC goods versus the same variable associated with rest of the economy. Given that output prices in the ICT sector are falling and other prices are rising the gap is non-negligible. The final two years of the sample saw ICT prices fall by 8 and 10 percent, respectively, while the rest of the economy witnessed price increases. Overall, then, it is the large price declines in the ICT sector that are reflected in the large increases in TFP in this sector.

32. **The TFP growth for the entire ICT sector recorded in the 1997-1998 period is only slightly below that recorded for the computer hardware sector in the United States as computed by Oliner and Sichel (2000)—14.7 percent versus 16.7 percent.** The numbers are not directly comparable, however, as Oliner and Sichel's computer sector does not include the software and telecom sectors included here. To make the comparison closer, the exercise is repeated using only the office equipment and computers sector. In this case, real GDP in the United Kingdom is readjusted by only the price deflator for this single sector using the procedure outlined earlier. Thus, the total economy TFP estimates change as well as the growth rates and output shares. In this case (Table 6), the contribution to total economy-wide TFP is lower than in the ICT case, as expected, but is very close to that of the United States. Moreover, the share of this sector's gross output in GDP is slightly larger in the United Kingdom, also as expected, since it includes a slightly larger definition of the computer sector. Table 6 also shows that TFP in the U.K. office equipment and computer sector is growing at 22.1 percent on average over the 1997-1998 period, while for the United States, the growth rate is about 16.7 over the same period. Probably not too much should be made of this discrepancy since over the entire sample 1993-1998 TFP in the respective U.K. and U.S. computer sectors were 15.3 percent and 15.2 percent—basically the same. The TFP growth in the remaining sectors of the economy are relatively low in both countries, particularly in the latter period.[15]

[15] Updated numbers for the United States for the year 2000 show a marked pickup in TFP in the rest of the economy and a slowdown in TFP of the computer sector.

Table 5. Sectoral Contributions to Growth in United States and United Kingdom TFP

	IMF U.K. 1993-1996	Oliner&Sichel U.S 1993-1996	IMF U.K. 1997-1998	Oliner & Sichel U.S. 1997-1998
Growth rate of total economy TFP:	2.23	0.86	1.49	1.18
Contribution from:				
ICT sector 1/	0.32	0.21	1.35	0.28
Other total economy	1.91	0.44	0.13	0.46
Memo:				
Output shares:				
ICT sector 2/	8.03	2.12	9.13	2.56
Other total economy	91.97	98.78	90.87	98.63
Growth rate of TFP				
ICT sector 2/	3.85	14.38	14.74	16.71
Other total economy	2.08	0.44	0.15	0.46

Sources: Oliner and Sichel (2000); and staff estimates.
1/ ICT sector is analagous to "computers" from Oliner and Sichel.
2/ For Oliner & Sichel, ITC sums shares of computers and semiconductors. Since semiconductors treated as an input, shares do not sum to 100. Computer shares were 1.63 and semiconductor shares were 0.94 in 1997-98.

33. **The TFP growth rates for the U.K. ICT sector (or computer sector) may be biased because they do not include the semiconductor industry and the degree and direction of the bias is not easily assigned.** The semiconductor industry is in a different national accounts industrial category (electronic components) that has not been included in the ICT sector. If the U.K. semiconductor industry were to be as productive as the U.S. semiconductor industry and much of the input to the computer sector came from the U.K. semiconductor industry then the huge price declines for semiconductors would add to TFP there and increase the TFP of the entire ICT sector. However, most of the semiconductors used in U.K computer production are imported and thus final domestic ICT output may be lower with their inclusion, which will be reflected in lower economy-wide TFP growth. The split in TFP between the ICT sector and the rest of economy will depend on the output shares, which may be lower for the ICT sector under these circumstances, the input shares, which will be greater, and the relative price changes between the ICT sector, the rest of the economy and the economy as a whole. Without further analysis regarding the size of these offsetting effects the size and direction of the bias to TFP in the ICT sector is uncertain.

Table 6. Sectoral Contributions to Growth in United States and United Kingdom TFP

	IMF U.K. 1993-1996	Oliner&Sichel U.S 1993-1996	IMF U.K. 1997-1998	Oliner & Sichel U.S. 1997-1998
Growth rate of total economy TFP:	2.19	0.86	1.04	1.18
Contribution from:				
Computers and Office Equip. 1/	0.35	0.21	0.66	0.28
Other total economy	1.84	0.44	0.37	0.46
Memo:				
Output shares:				
Computers and Office Equip.	2.87	2.12	3.00	2.56
Other total economy	97.13	98.78	97.00	98.63
Growth rate of TFP				
Computers and Office Equip. 2/	11.89	14.38	22.12	16.71
Other total economy	1.90	0.44	0.38	0.46

Sources: Oliner and Sichel (2000); and staff estimates.
1/ For Oliner & Sichel, ITC sums shares of computers and semiconductors. Since semiconductors treated as an input, shares do not sum to 100. Computer shares were 1.63 and semiconductor shares were 0.94 in 1997-98.
2/ For Oliner & Sichel, semiconductor TFP growth was 22.3 percent in earlier period, 45.0 percent in latter.

34. **The output shares presented in Table 5, however, represent total gross output shares and do not account for the fact that much of the ICT sector's output is used as intermediate inputs to other sectors.** When shares are calculated to exclude intermediate inputs, they are not nearly as large (Table 7). Excluding these intermediate inputs, the share of total final output is less than half as large. Table 7 also utilizes the chain-weighted method for GDP to calculate the residual TFP (though this has no effect on the output shares in equation (4) above), showing that the contribution of TFP in the ICT sector to total TFP drops to slightly less than half—still a surprising showing considering the now smaller relative size of the sector. Moreover, while the TFP growth in the ICT sector is somewhat smaller than recorded in Table 5—12.2 percent per annum versus 14.7 percent—it is still quite high.

Table 7. Sectoral Contributions to Growth in United States and United Kingdom TFP
Chain-Aggregated U.K. Output using U.S. Deflators for ICT Adjustments

	IMF	Oliner&Sichel	IMF	Oliner & Sichel

	U.K. 1993-1996	U.S 1993-1996	U.K. 1997-1998	U.S. 1997-1998
Growth rate of total economy TFP:	2.26	0.86	1.15	1.18
Contribution from:				
ICT sector 1/	0.35	0.21	0.53	0.28
Other total economy	1.92	0.44	0.61	0.46
Memo:				
Output shares:				
ICT sector 2/	3.71	2.12	4.38	2.56
Other total economy	96.29	98.78	95.62	98.63
Growth rate of TFP				
ICT sector 2/	8.57	14.38	12.21	16.71
Other total economy	1.98	0.44	0.64	0.46

Source: Oliner and Sichel (2000); and staff estimates.
1/ ICT sector is analagous to "computers" from Oliner and Sichel
2/ For Oliner & Sichel, ITC sums shares of computers and semiconductors. Since semiconductors treated as an input, shares do not sum to 100. Computer shares were 1.63 and semiconductor shares were 0.94 in 1997-98.

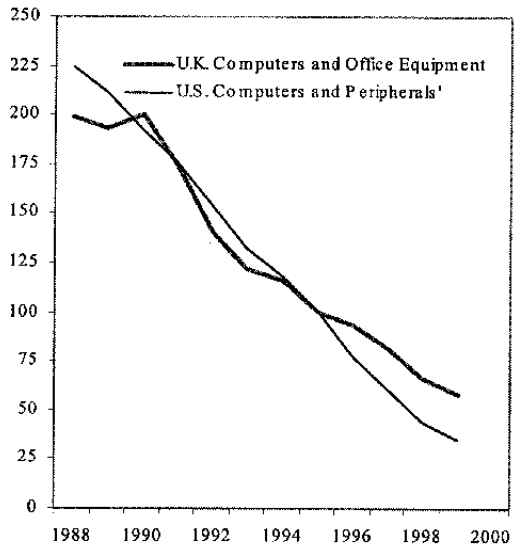
35. **Thus, an breakdown in the economy-wide TFP for the United Kingdom shows that the ICT sector is contributing to productivity and output by its high level of TFP growth.** It is producing more output per unit of labor and capital inputs as demonstrated by falling prices in the output of this sector relative to its input prices. In fact, over the 1993 to 1998 period, the productivity of the United Kingdom's computers and office equipment sector was on par with that of the United States.

D. Data Problems and Measurement Issues

36. **As mentioned above, the U.K. national accounts data quality-adjusts its producer prices indices using two methods: option costing and manufacturer costing.** These methods are considered by some to be inferior to the use of hedonic methods in situations in which the quality of the product is changing rapidly, as in the ICT sector. However, the costs and benefits of using hedonic methods need to be considered carefully: the upfront and maintenance costs of hedonic models are larger and the statistical office needs to assure itself that all the indicators of quality are "valued" by consumers assuring that these elements are priced and, as these elements of quality change, they are included in the model. There are also other limitations that may be present in the U.S. and U.K. indices, for example due to sampling error.

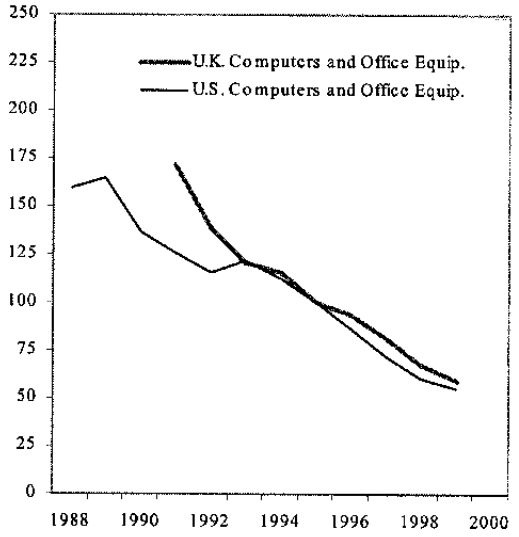
37. **Without taking a stand on the relative desirability of hedonic methods, there is, nonetheless, a difference between U.S. and U.K. deflators for computers, (strictly defined) with the United States' deflators showing sharper declines (Figure 4).** Even the weighted average of U.S. output deflators representing a somewhat broader office equipment category shows a difference with the U.K. output deflator applied to the office equipment and computer sector (Figure 5).

Figure 4. U.S. and U.K. Computer Deflators (1995=100)



Sources: U.K. Office of National Statistics; and U.S. Bureau of Economic Analysis.

Figure 5. U.S. and U.K. Computers and Office Equipment Deflator (1995=100)



Sources: U.K. Office of National Statistics; U.S. Bureau of Economic Analysis; and staff calculations for comparable U.S. index.

38. **It is useful to emphasize that the case for using U.S. deflators to examine other countries' ICT sectors relies on several assumptions.** First, price declines—and the quality improvements they represent—are assumed to be the same in the United States and in the other country. This is more likely if computers are a freely tradable good and international competition encourages computers produced in different countries to have similar features. If all U.K. computers were to be imported then the quality improvements imbedded in U.S. price deflators would be the same in the United Kingdom as in the United States. Further, it would seem appropriate to adjust the (annual) U.S. deflator for the average exchange rate (pound/dollar) during each year. This is done in the above analysis. However, the U.K. also exports computers and many computers are purchased domestically. One must assume, then, that markets are competitive so that, imported computers cost the same as domestically produced ones, after accounting for the exchange rate. This assumption may be reasonable for the

computer industry, but it appears less likely that software and telecommunications markets are as competitive.[16]

39. **Aside from different price index methodologies, the United Kingdom does not yet use the chain-weighted methodology for national accounts, though it is expected to do so by 2003.** Thus, as mentioned above, estimates of growth are biased to the extent that the 1995 weights have changed. A positive bias in the level of real GDP is likely to result given that the volume weights are likely to be too small when prices are falling in areas like the computers, software, and telecom. The continually falling prices imply that the real GDP growth rates are upwardly biased, even without considering the effects of deflators. Though an attempt was made in this paper to discern the effect of chain-weighting, a final answer regarding the degree of the bias would require the chain-weighting exercise to be applied to all components of GDP.

40. **The estimates of the real net capital stocks in the three ICT sectors depend on the assumed depreciation—a difficult parameter to nail down.** Measuring real net capital stocks is tricky even when price deflators are "correct" since the depreciation of computers, software, and high-tech equipment is not due to normal wear and tear, but is in terms of obsolescence, which is changing through time. For simplicity, little attempt is made in the above calculations to distinguish between the depreciation across the three categories, nor is there any attempt to vary these parameters across time.[17] The parameters chosen were the ones used by Oliner and Sichel for 1997 for personal computers and by Jorgenson and Stiroh for software and telecommunications.[18]

41. **A general problem that becomes obvious when this sort of study is undertaken is that the industrial classifications and the collection of data on investment is not precise enough to isolate output of the ICT sector nor investment in ICT goods.** The United Kingdom is not the only country for which such data limitations exist. The results of this study, thus need to be viewed tentatively, as "back of the envelope" calculations. Moreover, the nature of the calculations does not allow one to assign statistical errors or to determine the statistical significance of the "estimates"—making comparisons with other countries, e.g. the United States, difficult to assess.

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[16] The U.S. Justice Department's case against Microsoft alleged that it was a dominant firm in the software market and inhibited competition, driving up prices. Even though deregulation of the telecommunications market has taken place there have been various complaints about the level of competition both in the United States and the United Kingdom.

[17] A lower depreciation rate, 11 percent, underlies the capital stock for the telecom sector in the calculations for Tables 2, 4, and 7.

[18] Oliner and Sichel, however, differentiate between the various ICT sectors and allow the depreciation rates to change through time, for the most part following the assumptions used by the Bureau of Labor Statistics. Further work will be needed to remedy some of these shortcomings.

E. "Robustness" Tests

42. **To investigate the effect that using U.S. deflators have on the analysis, the first two exercises above are repeated using U.K. deflators for computers and office equipment and software.** The U.S. deflator for telecom investment continued to be used because there is no U.K. deflator that is appropriate to apply to the aggregation of the two U.K. telecom sectors used. The software deflator provided by the ONS represents an implicit deflator constructed with "new" estimates of actual software investment, rather than the category "computer services" as used above. The new estimates of nominal and real software investment are used in conjunction with the U.K. deflator. These investment numbers are substantially smaller than the ones used in the study so far and, since there is no corresponding data from which to construct final output, intermediate demand, and net exports, a recalculation of the decomposition of TFP is not done.

43. **Not surprisingly, the growth rate of real GDP using the U.K. deflators slows relative to the situation in which the U.S. deflators are used—from 3.73 percent annual growth in the 1997-1999 period to 2.91 percent growth (Table 8).** The contributions from ICT capital similarly drop. The ICT capital stock contributes 0.40 percent to the overall output growth rather than the 0.59 percent with the U.S. deflators. The contribution made by computers and office equipment falls from 0.49 percent to 0.34 percent and software falls from 0.05 to 0.01. The miniscule contribution of software investment reflects the now smaller stock of software capital (and its much smaller growth rate) as calculated by the ONS relative to the use of the broad category "computer services." Since there was no adjustment to the telecom sectors' deflator, the contribution remains the same at 0.05 percent per annum. The changes for the earlier periods are less dramatic since the difference in the U.S. and the U.K. deflators is smaller in these periods. However, despite the smaller contributions compared to the U.S. case, the ICT sectors' contribution to output growth is growing over time. For instance, capital deepening associated with computers and office equipment triples between the 1991-96 period and 1997-99.

44. **Again, not unexpectedly, using the U.K. deflators results in lower labor productivity growth rates across the sample period, with a larger deceleration in the 1997-99 period, than when using U.S. deflators (Table 9).** Economy-wide productivity growth drops from 2.59 percent per year to 1.51 percent per year, on average, when comparing the first and second part of the 1990s. However, even with the U.K. deflators, and the decline in labor productivity generally, capital deepening associated with ICT *increases* in the last three years of the decade—from 0.84 percent per annum to 1.10 percent. The obverse of this feature is the steep deceleration in TFP growth—from a respectable 1.75 percent per annum in 1991-96 to 0.41 in the 1997-99 period. It is the very low TFP growth that has worried policy-makers in the United Kingdom. Although use of the U.S. deflators makes TFP look better, the phenomenon does not disappear and is more strikingly demonstrated when examined against the U.S. numbers which show an increase of around ½ percent between the two periods.

Table 8. Contributions to Growth of Output in the United States and the United Kingdom, 1987-1999
Using U.K. Deflators for Computers and Software

	IMF U.K 1987-1990	Oliner&Sichel U.S. 1987-1990	IMF U.K. 1991-1996	Oliner&Sichel U.S 1991-1996	IMF U.K. 1997-1999	Oliner&Sichel U.S. 1997-1999
Growth rate of output: 1/	3.03	3.18	1.83	3.00	2.91	4.94
Contribution from:						
ICT	0.01	0.53	0.15	0.62	0.40	1.16
Computers & Office Equip. 2/	n.a.	0.24	0.11	0.28	0.34	0.65
Software	0.01	0.20	0.02	0.26	0.01	0.37
Communications Equip.	n.a.	0.10	0.03	0.08	0.05	0.14
Memo:						
Income shares:						
Computers & Office Equip.	n.a.	1.53	0.52	1.45	1.30	1.78
Software	0.06	1.45	0.10	2.11	0.15	2.66
Communications Equip.	n.a.	1.78	0.09	1.92	0.24	1.88
Growth rate of inputs:						
Computers & Office Equip.	n.a.	15.74	20.27	18.85	26.30	37.31
Software	14.52	14.28	14.20	12.81	8.51	14.12
Communications Equip.	n.a.	5.84	34.69	4.31	21.56	7.69

Source: Oliner and Sichel (2000); and staff estimates.
1/ All numbers are average annual log difference for years shown multiplied by 100.
2/ Oliner and Sichel's category is termed "hardware."

Table 9. Contributions to Labor Productivity in real GDP for the United States and the United Kingdom, 1987-1999
Using U.K. Deflators for Computers and Software

	IMF 1987-1990	Oliner&Sichel 1987-1990	IMF 1991-1996	Oliner&Sichel 1991-1996	IMF 1997-1999	Oliner&Sichel 1997-1999
	U.K	U.S.	U.K.	U.S	U.K.	U.S.
Growth rate of labor productivity: 1/	0.61	0.90	2.59	1.71	1.51	2.45
Contribution from: 2/						
Capital Deepening	0.03	0.28	0.84	0.55	1.10	0.96
ICT	0.01	0.44	0.16	0.55	0.38	1.01
Computers & Office Equip. 3/	n.a.	0.20	0.11	0.26	0.32	0.61
Software	0.01	0.17	0.02	0.23	0.01	0.30
Communications Equip.	n.a.	0.06	0.03	0.06	0.05	0.10
Other capital	0.02	-0.16	0.69	0.00	0.72	-0.05
Labor quality	n.a.	0.34	n.a.	0.41	n.a.	0.27
Total Factor Productivity	0.59	0.29	1.75	0.74	0.41	1.23

Source: Oliner and Sichel (2000); and staff estimates.
1/ Average annual log difference for years shown multiplied by 100.
2/ Percentage points per year.
3/ For Oliner & Sichel, this category includes hardware and semiconductors.

F. Other Evidence Regarding the Prospects for "New Economy" Productivity Gains

45. **The above analysis suggests that the ICT sector has contributed to output and labor productivity growth, but does not explain why the other components of labor productivity have fallen or whether they are likely to pick up in the future.** Other evidence for the future of the U.K. "New Economy" focus on whether the lackluster growth in TFP in the rest of the economy is likely to reverse and whether the capital deepening attributable to ICT will continue at its present pace.

46. **The overall productivity trends shown above hide some sectoral changes that can potentially shed light on future productivity performance.** Until mid-1999, productivity growth had been below its long-run trend in the manufacturing sector as a whole while the service sector, specifically business services and finance, enjoyed higher productivity growth (Figure 6). Despite the relatively low productivity growth for the manufacturing sector, recent increases have been noted in some areas: (1) electrical and optical equipment and (2) chemical and man-made fibers (Figure 7). The manufacturing sector only represents 22 percent of gross value added, but the fall in productivity growth has been quite pronounced. The service industries represent 66 percent of GDP of which

the business services and finance industry represents 21 percent of gross value added.[19] Thus, some of the sectoral productivity growth, since it is occurring in sectors that incorporate elements of the ICT sector and other high-tech sectors, such as biotechnology, is suggestive that the most recent set of productivity gains may be related to the new economy.

FIgure 6. United Kingdom: Labor Productivity Growth of Selected Industries

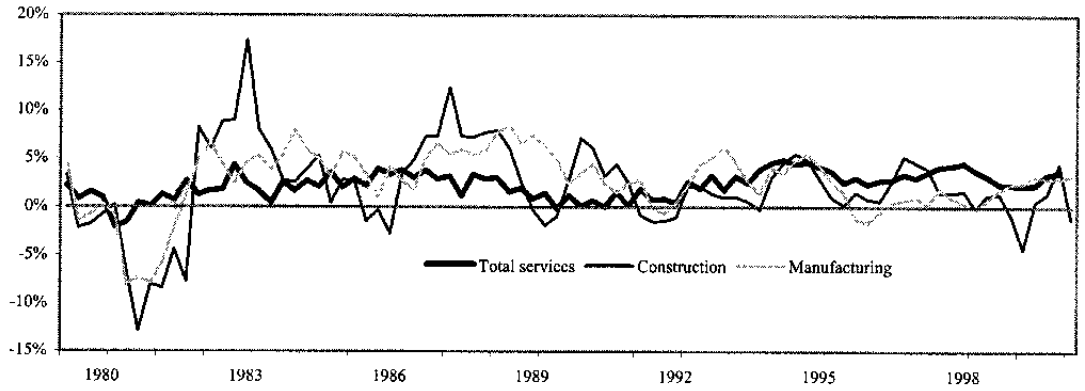
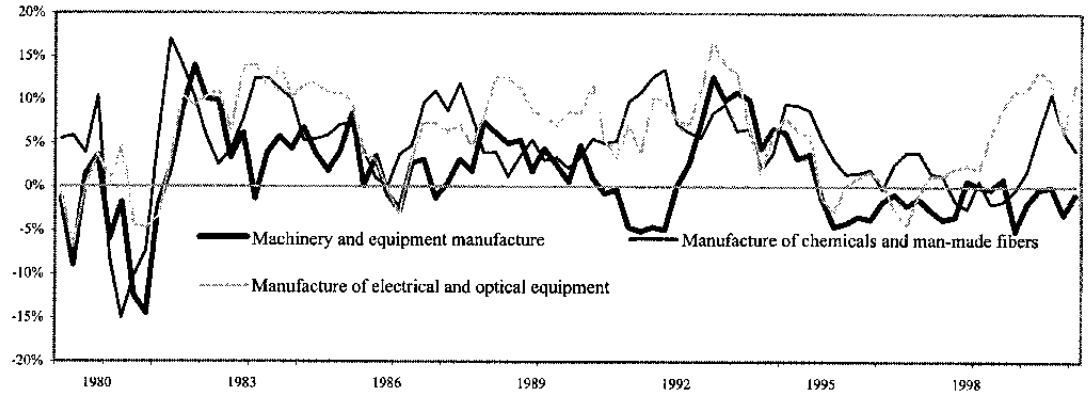


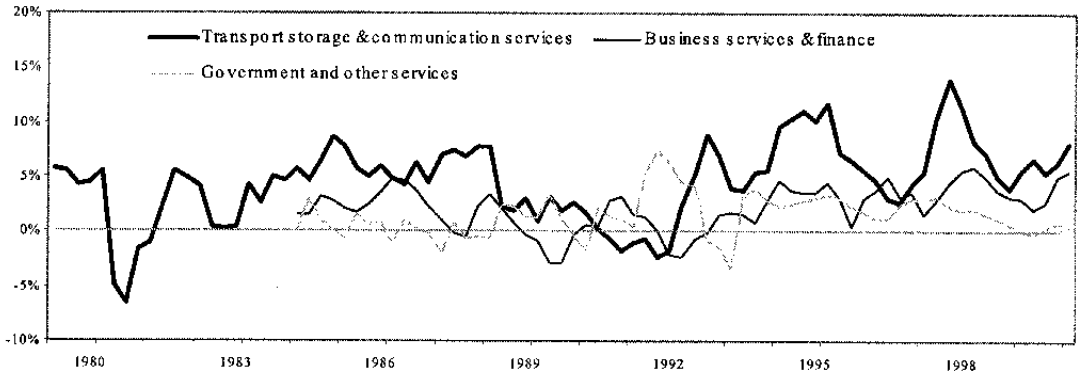
Figure 7. United Kingdom: Labor Productivity Growth in Selected Industries: Manufacturing



[19] In the United States, the output of the financial, insurance, and real estate (FIRE) sector represented 19.4 percent of GDP in 1997.

47. **There is a positive correspondence between the sectors that are heavy users of ICT equipment and those in which there is a pickup in productivity growth.** Such sectors in the United States are financial markets, banking, education, insurance, discrete manufacturing, utilities, and communications and media. While there is not a one-to-one match between these industries and data with which to compute labor productivity growth in the United Kingdom, a glance at some of the broad service industries find some productivity improvement in some of these industries (Figure 8).

Figure 8. United Kingdom: Labor Productivity Growth in Selected Industries: Services



48. **Divining the future of productivity growth in the ICT production sector is more difficult but the sector's superior TFP performance is unlikely to degrade rapidly.** For the narrow computer-producing sector, the above analysis suggests that TFP growth has been equivalent to that in the U.S. during the 1993-1998 period. The newest findings from the United States, however, suggest that TFP growth in this sector is declining though the share of output from this sector continues to increase.[20] A similar phenomenon could be expected in the United Kingdom implying a somewhat lower contribution of ICT production to productivity growth. The ITC sector more generally appears to have lower TFP growth than the narrow computer sector, but still quite healthy rates of growth. No additional information is available from the United States, but it appears that the price *declines* that underlie this estimate have been fairly stable in the last few years and might be expected to continue.

49. **Labor productivity in the rest of the economy is likely to rise over the next few years, though probably due to more technical reasons than to improvements in TFP.** Although the fall in economy-wide labor productivity in the latter 1990s cannot be pinned on an influx of low skilled workers during the cyclical upswing, the low unemployment rate and the several consecutive years of very robust employment growth suggests that available labor resources will not be as plentiful in the future. Assuming the expected slowdown in overall investment is not substantial, the non-ICT sectors of the

[20] The productivity growth in the U.S. semiconductor industry is holding steady at around 50 percent per year according to updated work by Oliner and Sichel.

economy should experience increases in capital deepening. Regarding capital deepening arising from ICT investment, the investment growth rate in ICT may fall off somewhat from its very high levels in recent years. However, as long as ICT capital stock growth exceeds employment growth, capital deepening is still likely to increase from this source as well. Moreover, as the share of ICT investment and output increase in the economy, measures of the contribution to output and labor productivity growth will continue to increase.

50. **Recovery of the low TFP growth in the non-ICT sector is likely to be a longer-term project.** In part because current wisdom regarding TFP growth improvement relies mainly on the upgrading of the structural underpinnings of the economic environment—innovation, research and development, competition, and entrepreneurship—and the enhancement of the education and skill levels of the workforce, which are difficult to effect in the short-run. In particular, the low past investment in physical and human capital cannot be remedied by a surge in investment in ICT capital. The ability to integrate this type of capital in the production processes takes the time and energy of qualified workers and an environment that is conducive to doing so. Previous studies of technology diffusion in the United Kingdom, though, show that the United Kingdom quickly absorbs new ideas, technologies and work practices from abroad.[21] In the areas of the economy unrelated to the New Economy, the low overall level of basic skills of the workforce and the previous low investment levels will need to be improved before TFP growth is likely to pick up—again it is likely to take significant time for improvements to be evident. The government is committed to the task of improving productivity through a multi-pronged approach, as demonstrated by its recent attention to the topic in its Pre-Budget Report and the accompanying paper outlining its strategy.[22]

G. Conclusions

51. **The results of this study suggest that the contribution of the ICT sector in the United Kingdom to output and labor productivity growth has been non-negligible and not very different from the experience of the United States.** Much of the positive impact of the New Economy on labor productivity arises through ICT-related capital deepening—about ¼ of productivity growth can be attributed to the increase in the ICT capital to labor ratio. Labor productivity growth slows in the latter 1990s, unlike the United States, and this presents a "puzzle" given that the rate of investment in ICT goods in the United Kingdom has been on par with that in the United States. This slowing, however, appears to be mostly owing to a slowdown in the TFP growth in the non-ITC sector. The growth of TFP in the production of computers, in particular, is virtually the same as in the United States.

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[21] See, for example, Hubert and Pain (2000).

[22] Chapter 3 of the Pre-Budget Report from the HM Treasury, November 2000 and "Productivity in the U.K.: the Evidence and the Government's Approach", HM Treasury, November 2000.

52. **The conclusions of the above formal analysis should be viewed as the most optimist case for estimates of the contribution of ICT to output and labor productivity growth, but by the same token, they also highlight a relatively dismal picture of labor productivity outside the ICT sector.** The use of U.S. deflators for the ICT sector substantially raises the real net capital stock and real output. Further, the industrial categories used for the ICT sector are quite broadly defined. The category "computers and office equipment" covers not only computers but more generic office equipment and "computing services" entails more than software. Some sensitivity analysis is attempted, but more is necessary before the results could be deemed definitive. Nevertheless, a conclusion that seems warranted is that the productivity doldrums in the United Kingdom are not related to the ICT sector and that, indeed, much of the recent productivity growth can be ascribed to this sector, either through the use of ICT capital or through the production of ICT goods.

ANNEX I

The Data

53. This annex provides details about the data used in the study. It discusses some of the issues arising from the differences between the desired data and that available. The notation is standard: upper-case letters denote levels of a variable and lower-case letters denote its logged difference.

A. Data for Growth Contributions and Labor Productivity Analysis

Real output for the economy (Y)

54. The data for the U.K. real output come from the National Accounts. The output data are gross value added at basic prices, seasonally adjusted. Oliner and Sichel use non-farm business less housing as their concept for output. In the United Kingdom, it is not possible to exclude the agricultural sector, so the output concepts are slightly different.

Capital Stocks (K_C, K_S, K_T, K_O)

55. For the growth accounting exercises above, the appropriate concept of the capital stock is the "productive" capital stock rather than a "wealth" capital stock. Productive stocks measure the income-producing capacity of the current stock of capital during a given period. Wealth stocks are the current market value of the assets in use. Since the exercise is meant to capture the contributions of ICT capital to growth in output and labor productivity, the "productive" capital stock is the desired one—the interest is in how much the ICT capital stock can produce not what it is currently worth. Unfortunately, productive capital stocks are not available yet in the United Kingdom, though there are now ongoing efforts to produce them.

56. To construct the various components of the capital stock, a nominal total capital stock is built up from gross fixed capital formation (investment), capital consumption (depreciation), changes in inventories, and acquisitions less disposals of valuables for the total economy. The nominal stock is constructed under the assumption that the nominal and real stocks were equal in 1995, the base year. Separately, the nominal capital stock for each of the ICT products are built up by using Table 6 of the U.K. Input-Output Annual Supply-Use ("Input-Output") Tables in which the gross fixed capital formation is provided by industry product. Thus, investment in computers and office equipment is summed across all industries to provide a total investment figure. In this case the stock of capital was assumed to be zero in the year before the first figures were available. The industry classifications used are Office Equipment (69) for computers and office equipment; Transmitters for TV, Radio, and Phone (74) added to Receivers for TV and Radio (75) for telecommunications; and Computer Services (107) for software. The investment data begins in 1970 for computers and office equipment and for software. The investment price deflators (discussed below) begin in 1980 for computers and office equipment and 1989 for both software and telecommunications. Official investment data are available through 1998. Investment in computers and office equipment for 1999 is

estimated as the average proportion of office machinery investment in total investment over 1996-1998. For software and telecommunication, the ratio of these components to the office machinery category are maintained at their 1998 level. The capital stock for dwellings is also constructed from investment and depreciation and then subtracted from the total economy nominal capital stock.

57. To obtain the real capital stocks, for each ICT sector, a corresponding deflator from the U.S. investment deflators are used. To obtain the real capital stock for the remaining capital stock, first the sum of the nominal ICT capital stocks is subtracted from the entire economy nominal capital stock. Then, the deflator obtained by dividing the original nominal capital stock series by the real series (both excluding dwellings) is applied to the "other" nominal capital stock. Ideally, one would have preferred a deflator appropriate to the types of capital left in the "other" category, but this would require all the "other" nominal capital stock components and their deflators. It is unlikely this approximation affects the results much, as the ICT capital stocks are relatively small proportions for most of the years.

ICT Investment Deflators

58. The deflators used for obtaining the ICT capital stocks come from the U.S. National Income and Product Accounts (NIPAs). Since the U.K. computers and office equipment category is broader than the "computers and peripherals" category used in the United States the price deflators for three U.S. categories were averaged using weights equal to the nominal share of private fixed investment to the total private fixed investment in these categories. Implicitly this assumes that the U.K. investments are made in the same proportion across these categories as in the United States. The U.S. categories used are "Computers and Peripheral Equipment," "Office and Accounting Equipment," and "Photocopying and Related Equipment." The deflators for software and telecommunications were used without alteration from the U.S. categories "Software" and "Communications Equipment."

59. For the analysis using the U.K. deflators, the deflator for computers and the more general computers and office equipment categories were provided by the ONS and represent the producer price indices used to value real GDP. The deflator for software investment was also provided by ONS and is not publicly available. No specific price indices currently exist for computer software and the general investment-based price indices are used to derive real price estimates.

Labor (*L*)

60. The labor variable is the U.K. workforce jobs, seasonally adjusted, from Labor Market Trends (produced by the ONS). Workforce jobs are calculated by summing employee jobs, self-employment jobs from the Labor Force Survey, HM Forces, and government-supported trainees. Workforce jobs is the concept of the labor force used in domestic measures of productivity. In the United States, by contrast, the labor hours is used in official productivity measures. Oliner and Sichel used the growth rate in hours of

all persons in the non-farm business sector from the BLS Productivity and Cost release. Although hours worked is collected and published in the United Kingdom, these data are thought to be imprecisely measured and most researchers have opted for the workforce jobs variable in previous productivity studies.

B. Data for TFP Disaggregation Analysis

ICT Output Deflators (p_C, p_S, p_T, p_O)

61. The ICT output deflators used in the study come from the database on "shipments of manufacturing industries" produced by the Bureau of Economic Analysis. The data are publicly available at www.bea.doc.gov/bea/dn2/gpo.htm. This database includes chain-type price indices for industries using 2-, 3-, and 4-digit SIC codes. The deflators for the same categories as mentioned above are obtained for the purposes of deflating the U.K. ICT output. The deflator applicable to the remaining output of the economy, p_O, is the implicit GDP deflator for the United Kingdom obtained by dividing nominal value added at basic prices by real value added at basic prices.

62. As stated in section C, the U.S. ICT output deflators are used to revalue the output of the U.K. ICT sector for the purposes of adjusting real U.K. GDP to be consistent with the adjustments made to the capital stock. Thus, nominal final output of the ICT sectors are deflated by the U.S. output deflators to obtain real ICT output. Nominal GDP in the non-ICT sector is obtained from subtracting the nominal ICT output from total nominal GDP. This remaining GDP is then deflated by the implicit GDP deflator described above.

ANNEX II

The "Dual Method" to Disaggregate TFP Growth

63. This Annex describes the "dual method" approach used to disaggregate TFP growth into a component associated with the ICT industry and a component associated with the remaining industries. It outlines the formal model and briefly provides the underlying intuition.

64. As noted in the text, the growth of TFP can be represented as a weighted average of TFP in the two sectors under consideration: ICT and the rest of the economy:

$$TFP = \mu_C \, TFP^{ICT} + \mu_O TFP^{O}, \qquad \text{(a1)}$$

65. The approach of the so-called "dual method" used to estimate sectoral TFP relies on the *prices* of output and input, rather than their quantities. The intuition for this approach is as follows: if output prices in a sector are dropping and input prices are relatively constant, then the TFP growth in this sector must have been more rapid than other sectors. If it were not, the lower output prices (with stable input prices) would have driven this sector out of business. Thus, the lower output prices are viewed as representing the ability to produce more output with the same inputs. For the ICT sector, then, one can derive the following:[23]

$$TFP^{ICT} = TFP^{O} + (p^{ICT} - p^{O}) - \alpha_{ICT}{}^{O}(p^{ICT} - Z), \qquad \text{(a2)}$$

where the p's represent price changes in the ICT sector and "other" sectors and the $\alpha_{ICT}{}^{O}$ represents the share of current pound input costs associated with computer and office equipment inputs to the "other" sector. The numerator of this share represents the pound value of computers and office equipment used as an intermediate input in the "other" industries, excluding the "own" use of such equipment as inputs in the computer and office equipment sector itself. The denominator is the current pound output of the rest of the economy, the "other" sector. Z is the share weighted growth of capital and labor costs of the economy as a whole. That is, Z equals [(RK/PY) r + (WL/PY)w], where R and W are the rental and wage rate respectively, r and w their logged differences, K is the capital stock and P is the price level for the economy as a whole. The final term in the equation represents an adjustment to TFP^{O} based on the notion that TFP^{ICT} should be lower if the "other" industries are also able to benefit from lower (relative) input costs into their businesses. In this analysis, however, this term is small in comparison to the others.

66. In addition to the standard neo-classical assumptions of using Cobb-Douglas, constant returns to scale technology, other assumptions in this formulation are:

- The "other" sector only produces final goods.
- The two sectors employ the same mix of workers and capital goods.

[23] For a more formal derivation of this equation see Appendix B of Oliner and Sichel's Federal Reserve working paper.

- The rental rates and wage rates (and their growth rates) are the same across the sectors.

The two equations above represent a system of two equations and two unknowns (TFP^{ICT} and TFP^{O}) and can thus be solved algebraically.

67. **To calculate the output shares and input cost shares, final domestic output from the three ICT sectors and the associated output price deflators are needed.** The Input-Output Tables 2 and 3 are used for the periods 1992 through 1998.[24] These tables permit the calculation of final output for each of the three ICT sectors as a sum of four categories: final consumers' expenditures, gross capital formation (investment and changes in inventories), and exports less imports.[25] In the tables, government consumption and investment are included in the first two categories. These final outputs are then summed and used to calculate the output shares, μ_{ICT}, and μ_{O}, and the intermediate demands less own-industry (intermediate) demands are summed across the three categories to allow calculation of the α_{ICT}^{O}, the input share ICT going to other industries.[26] The output deflators utilize the U.S. output deflators produced by the BEA that are used to deflate industry output for the U.S. GDP and are the same deflators used to adjust the U.K. output above.[27] Under the assumptions above, the variable Z (the share-weighted growth of capital and labor costs) can be calculated by using the "dual" which says that the growth in the economy's output prices (the GDP deflator in this case) equals the growth in the (share) weighted average of input costs, minus the growth rate of TFP, that is, $p = Z - TFP$, or $Z = p + TFP$. This completes the discussion of the model and the data used for its implementation.

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[24] Consistent data is maintained only for these years as the pre-1992 Input-Output Tables use SIC80 for industrial sector breakdowns.

[25] Distributors trading margins and taxes less subsidies are also added to obtain a similar concept of GDP as used in the rest of the study. Since these sector output levels are used to calculate the share of output in the entire economy (to weight the sectoral TFPs) and the total economy TFP was calculated using this GDP concept, for consistency, these variables are added to obtain final output. Distributors trading margins net to zero across the entire economy.

[26] Table 5 includes intermediate inputs in the calculations of the shares and thus the shares are not representative of final (net) output but represent gross total output of the ICT sector.

[27] Additional information about the data and calculations are in Annex I.

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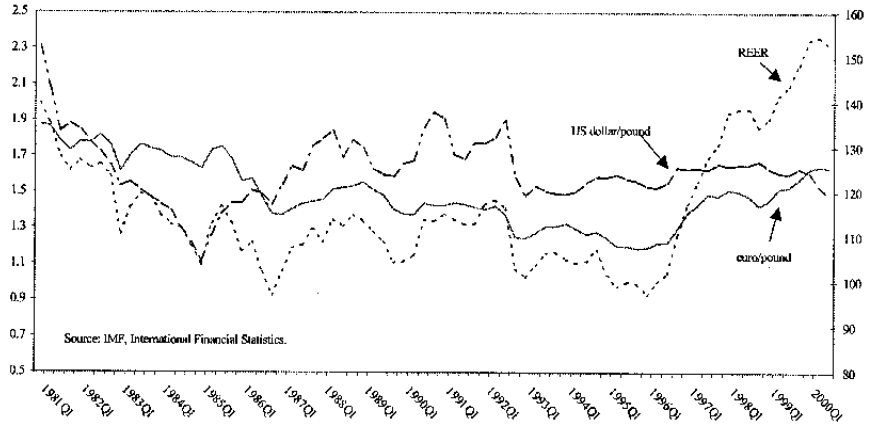
III. The Strong Sterling and the United Kingdom's External Competitiveness[1]

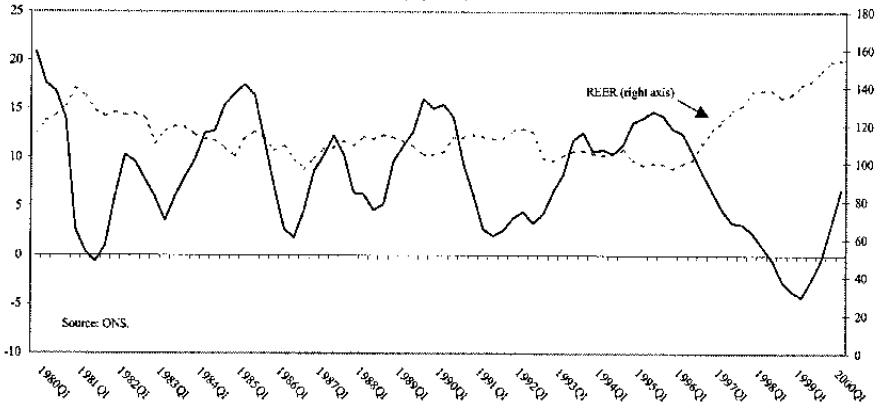
1. **Sterling has appreciated by almost 60 percent in real effective terms from the fourth quarter of 1995 to the fourth quarter of 2000, with two thirds of this appreciation taking place in the first two years (Figure 1).**[2] Considering that the U.K. is a very open economy (total trade accounts for over 50 percent of GDP, more than double when compared to the US and euro area), it stands to reason that such a drastic and fast appreciation must have had a sizable impact on the economy, in particular in the manufacturing sector. This paper tries to form a qualitative assessment of the impact of the appreciation of sterling on U.K. foreign trade, and its effects on competitiveness and the sectoral composition of production.

Figure 1. United Kingdom: Exchange Rates



2. **This appreciation seems to be a significant factor behind the rapid deterioration in the external sector, although fluctuations in external demands particularly stemming from disparities in cyclical positions with respect to the euro area may have also played a role.** The trade deficit has doubled since 1997 and the current account has shifted from a surplus of 0.8 percent of GDP in 1997 to an estimated deficit of 1.3 percent of GDP in 2000, despite the United Kingdom's self-sufficiency in oil

Figure 2. United Kingdom: Non Oil Exports, 12-month Rate of Growth, 4-Quarter Moving Average (in percent)



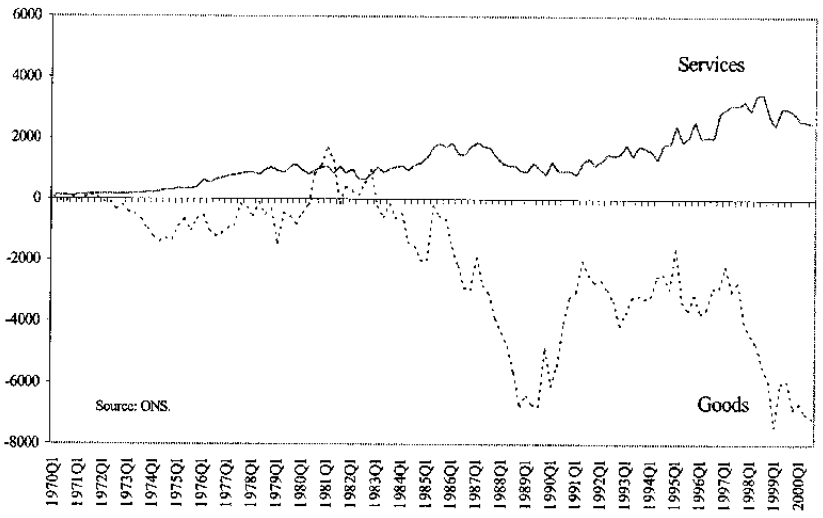
[1] This chapter was prepared by Angel Ubide-Querol.

[2] Real effective exchange rate based on relative manufacturing unit labor costs.

products. Non oil export volumes growth declined sharply after 1996 and did not start to recover until mid-1999 (Figure 2),[3] losing some market share in world as well as euro-area exports (Figure 3). Imports grew strongly during this period, and import penetration (measured as imports as a ratio to GDP) has achieved record levels. As a result, the external sector has made a significantly negative contribution to GDP growth since 1996.

3. **As the relative profitability of tradable goods declined, the trend shift in the structure of output towards services and nontradables become more pronounced in the late 1990s**. Manufacturing output grew by an accumulated 2.2 percent over 1995-1999, while overall GDP grew by over 11 percent and the services sector grew by over 17 percent over the same period—a sharper shift towards services than experienced in France and Germany, for instance[4] (Figure 5). By comparison, during 1985-1990, a period with no sizable misalignment of the exchange rate, accumulated growth in the manufacturing sector was 18 percent, compared to 16 percent for overall GDP and 17 percent for the services sector. This sectoral rebalancing was probably reinforced by the boom in equity markets, given the prominence of financial services in the U.K. economy. Indeed, the trade balance in the service sector improved despite the appreciation of the exchange rate (Figure 6). Some commentators (e.g. Goldman

Figure 6. United Kingdom: Evolution of Trade Balances (in millions of pounds)



[3] This recovery took place despite the still high exchange rate of sterling. CBI survey data shows that, during 1996-97, the exchange rate was the main factor limiting export growth (see Figure 4). Afterwards, and despite the continuation of the appreciation trend of the sterling, the price effect seemed to fade and demand concerns appeared during the emerging market crises. Finally, as developed economies recover after the crisis, it seems as though exports were more responsive to demand than to prices. The evolution of the trade balance with the euro area is an interesting example of this phenomenon: the deficit widens dramatically until mid-1998, but then it recovers along with the expansion of demand in the euro area and approaches surplus by end-2000, despite the still weak euro.

[4] Over 1995-99, GDP grew in France by an accumulated 9.5 percent, manufacturing by 7.5 percent and services by 10 percent. In Germany, GDP grew by an accumulated 7.2 percent, manufacturing by 2 percent and services by 13.5 percent.

Sachs (2000)) have suggested that this boom in equity markets, by increasing the relative price of nontraded goods, explains the appreciation of sterling, similar to a Dutch disease phenomenon. On a related point, to the extent that traded services are more important in the U.K.'s economy than in the economy of its trading partners, the real appreciation measured on the basis of manufacturing unit labor costs (as in Figure 1) is likely to be overstated.

4. **The question that arises is how U.K. firms have reacted to the strong exchange rate[5].** Several aspects are important, including the pricing behavior of firms, the evolution of costs, the impact of the appreciation on investment expectations and the sectoral evolution of exports. These issues are discussed in turn.

5. **U.K. firms appear to have reacted to the strong exchange rate appreciation with a pricing-to-market strategy[6].** This implies that firms lowered export prices in domestic currency and therefore squeezed margins in order to protect market shares. Margins could be squeezed partly because manufacturing exporting firms had accumulated substantial profits after the post-ERM devaluation. Rates of return averaged about 10 percent over 1993-1997 (compared with about 6 percent over 1989-93)[7], which allowed firms to squeeze profits afterwards (Figure 7).[8] Indeed, export prices in sterling declined sharply following the

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[5] The econometric evidence on price elasticities from export equations is mixed. One of the most recent estimates of trade equations for the United Kingdom are those of the Bank of England macroeconomic model. The results show that, in a single equation framework, both the short run and the long run price-elasticities in the export equation are not statistically significant, and basically result in exports depending on both inertia and external demand. Samiei (1994) also finds the short-term price elasticity to be non-significant, and finds evidence of a structural break before and after the ERM period. However, using a more robust panel estimation technique and identifying restrictions on long-run elasticities, Laxton and others (1998) obtain statistically significant coefficients in a panel of G-7 countries, with a parameter estimate of –0.45 for the short run price elasticity.

[6] Export firms could adopt two different strategies: either a policy where firms set prices based on domestic factors in order to preserve profit margins, passing-through exchange rate fluctuations to foreign consumers and sustaining the firm's ability to supply and invest; or a policy of pricing to market, whereby firms take prices in foreign currency as given and offset the effects of exchange rate movements by adjusting local currency export prices, trying to preserve market shares. Samiei (1994) argues that, traditionally, there has been "a tendency for U.K. exporters to use favorable exchange rate movements to improve profit margins rather than to strengthen their competitive position and boost foreign demand."

[7] By comparison, the rate of return for the whole economy was stable at about 11 percent over the period 1989-99.

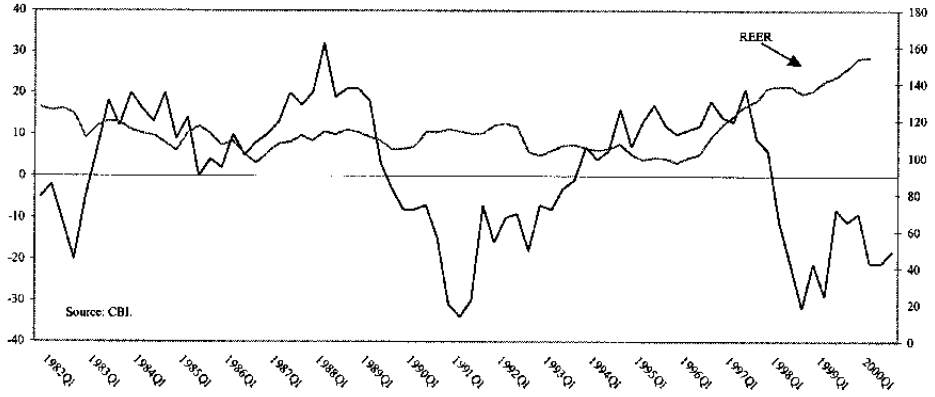
[8] A recent article by the ONS shows that U.K. firms were amongst the most profitable in the world during the mid-90s (see Economic Trends, n565, December 2000).

appreciation of the sterling; this decline took place across all sectors and was more acute for exports to the euro area, because of the weakness of the euro (Figure 8).

6. **An important factor to consider was the behavior of costs.** Unit labor costs in manufacturing grew at a brisk pace since 1995 owing to very low labor productivity growth. This led to stark competitiveness losses that compounded the negative effect of the appreciation of the nominal exchange rate. For instance, normalized unit labor costs in U.K. manufacturing grew by some 18 percent between the fourth quarter of 1995 and the fourth quarter of 2000, while they declined in France and Germany. [9] Firms reacted only in late 1998, when a sudden increase in labor productivity permitted some containment of costs (Figure 9).

7. **An additional response to the real appreciation was the shifting of the supply chain sourcing overseas, seeking lower cost suppliers.** According to the CBI, this has been especially marked in automotive, electronics, and textile sectors (see CBI (2000)). Although optimal from an individual firm's point of view, the side effect of this phenomenon is the threat that it poses to firms further down the supply chain in those sectors, especially in terms of investment plans and long-term profitability. Moreover, this may also inhibit the long-run investment plans of the firms outsourcing the production of intermediate goods, as they may eventually decide to relocate closer to their suppliers

Figure 10. United Kingdom: Investment Expectations (next 12 months)



8. **In this vein, it appears that the evolution of the exchange rate seems to have been in the past an important determinant of investment sentiment.** CBI survey data on investment expectations shows a negative correlation with the evolution of the real exchange rate (the correlation coefficient over the period is about –0.6). 12-month ahead investment expectations in manufacturing declined sharply in 1997, shortly after the appreciation of sterling began, and have not recovered significantly since (Figure 10).

9. **One question remains, however, namely whether the aggregate figures mask reallocation of resources at the sectoral level.** In order to analyze this issue, Figure 11 shows, for various SITC sectors, the cumulative growth differential of exports in each sector

[9] Normalized unit labor costs are calculated by adjusting productivity data for the impact of the business cycle.

with respect to total exports. If there have been no major sectoral shocks, other things equal, the growth differentials across sectors should not be persistent, as the different sectors deal with the appreciated exchange rate with a similar success on average. If, however, exchange rate fluctuations have a differential impact across sectors, growth rates will display divergence over time, although other factors—such as differential demand growth and secular sectoral shifts—could also play a role. In fact, the results show that there are essentially three groups of sectors. First, those that have thrived despite the exchange rate, growing consistently above the average. This group includes electrical machinery, other transport equipment (including aerospace), road vehicles, scientific and photographic, and mechanical machinery. In some sense, new economy, high value added sectors. Second, an intermediate group including miscellaneous finished manufactures, beverages and chemicals, which have gone through ups and downs. Finally, the low value-added sectors, such as crude materials, food, clothing, and material manufactures have fared well below the average. While sectoral shifts in manufacturing exports may also be related to a variety of factors unrelated to the exchange rate, it is likely that the strong real appreciation has hastened some of this restructuring through a differential impact on competitiveness and profitability.

10. **In terms of competitiveness, the crucial issue is whether the strategies adopted by U.K. firms could be sustained in the long run were the exchange rate appreciation to persist.** To the extent that productivity gains—including in tradable services—are made, the negative impact on the economy of real appreciation may be mitigated. Nevertheless, unless productivity improves on a sustained basis and wage differentiation allows for moderate growth or even reduction of manufacturing unit labor costs, further erosion of margins may lead to diminished investment expectations and erode the production base of the tradable sector in the long run.

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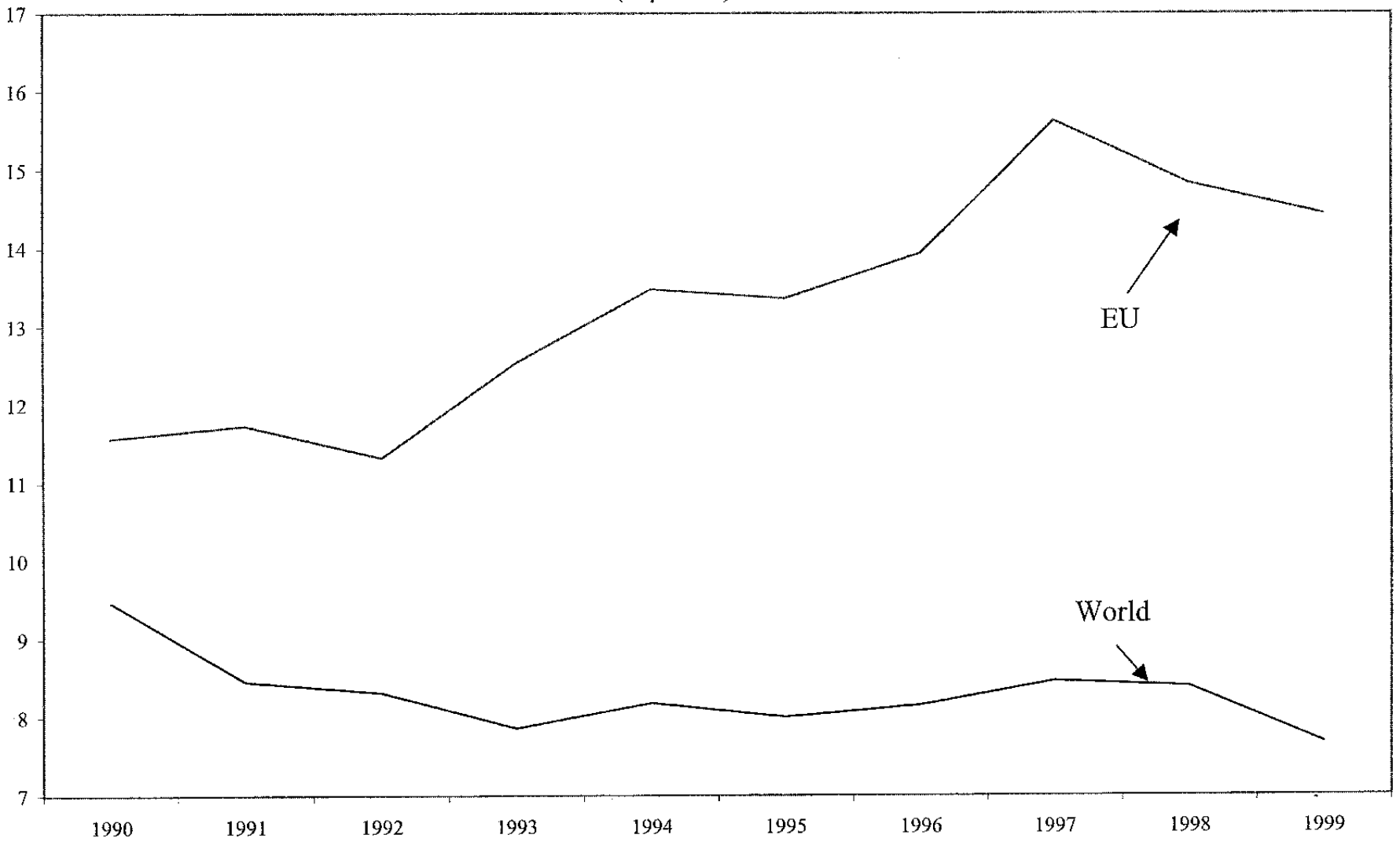
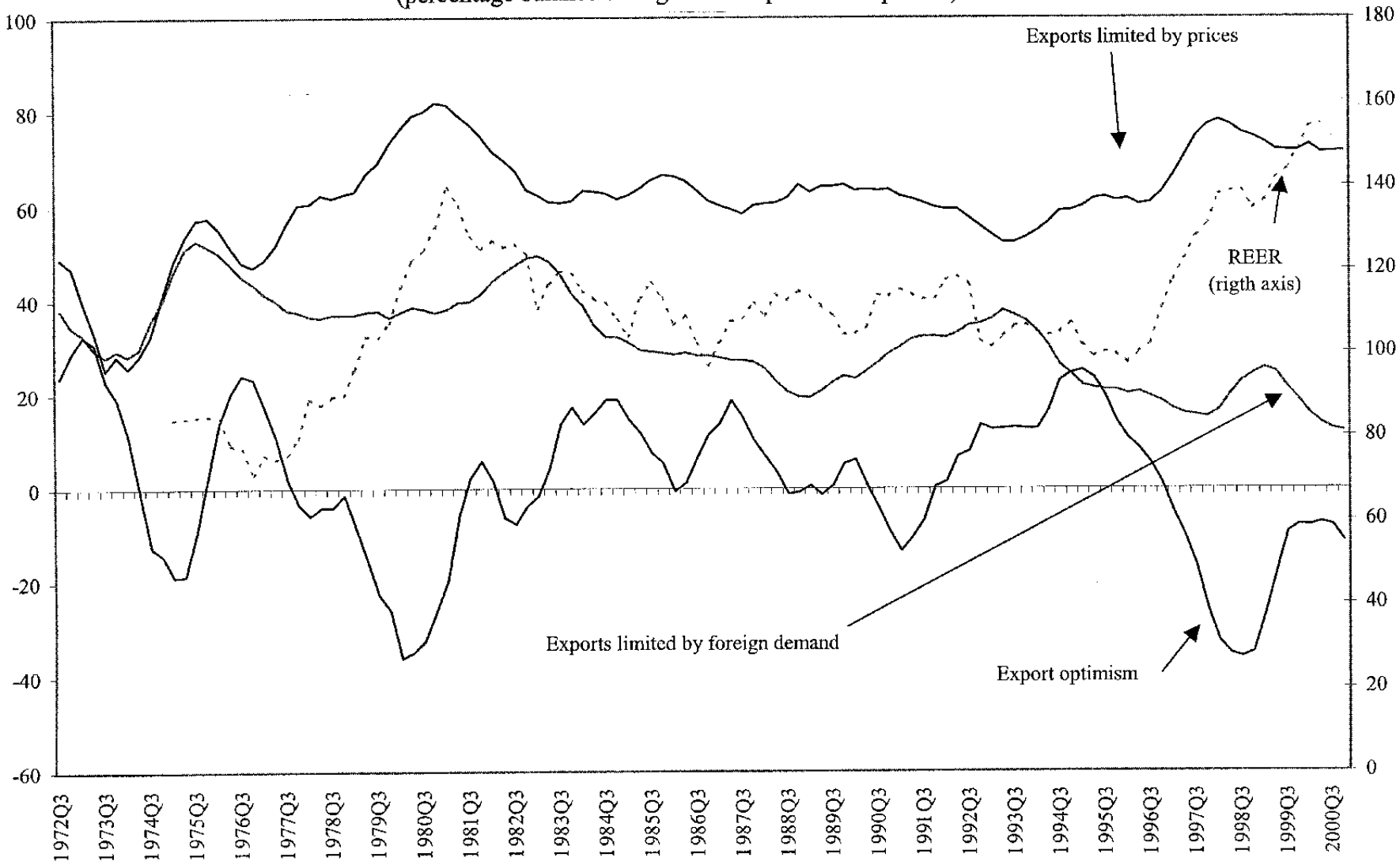
Figure 3. United Kingdom: Market share of Manufacturing Exports
(in percent)



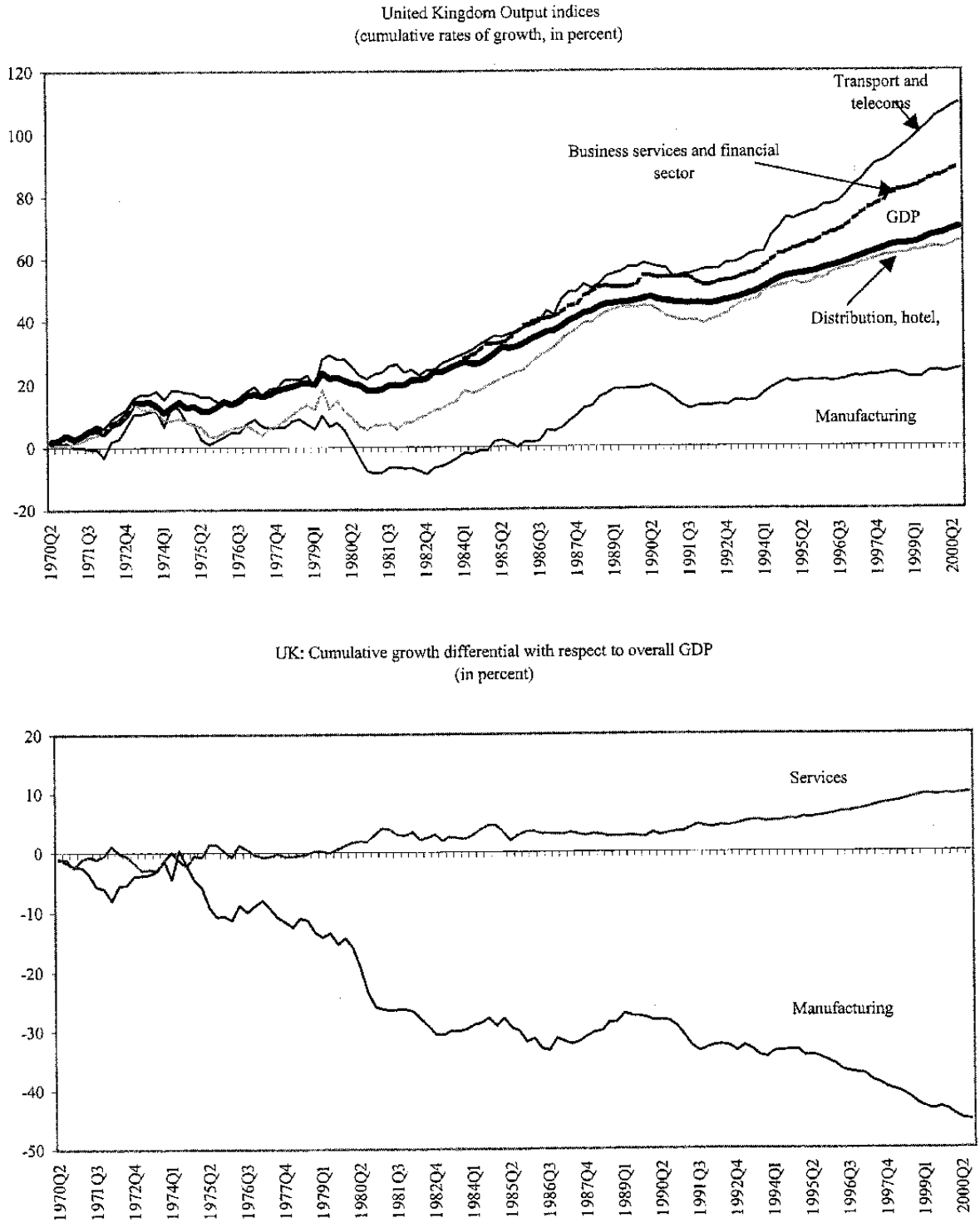
Source: OECD

Figure 4. United Kingdom: Export Market Sentiment
(percentage balance of negative and positive responses)



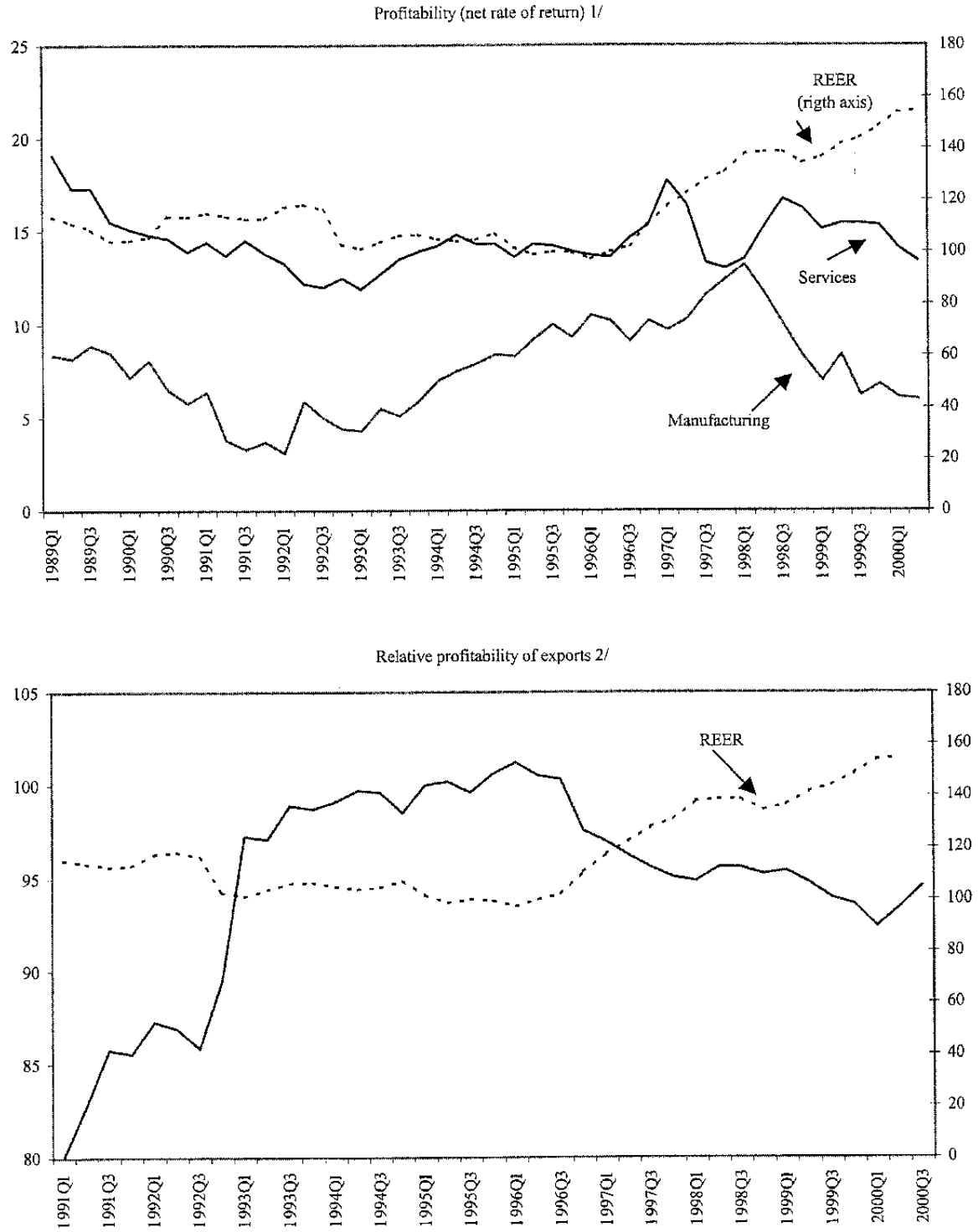
Source: CBI

Figure 5. United Kingdom: Sectoral Analysis of Output



Source: ONS.

Figure 7. United Kingdom: Profitability Indicators

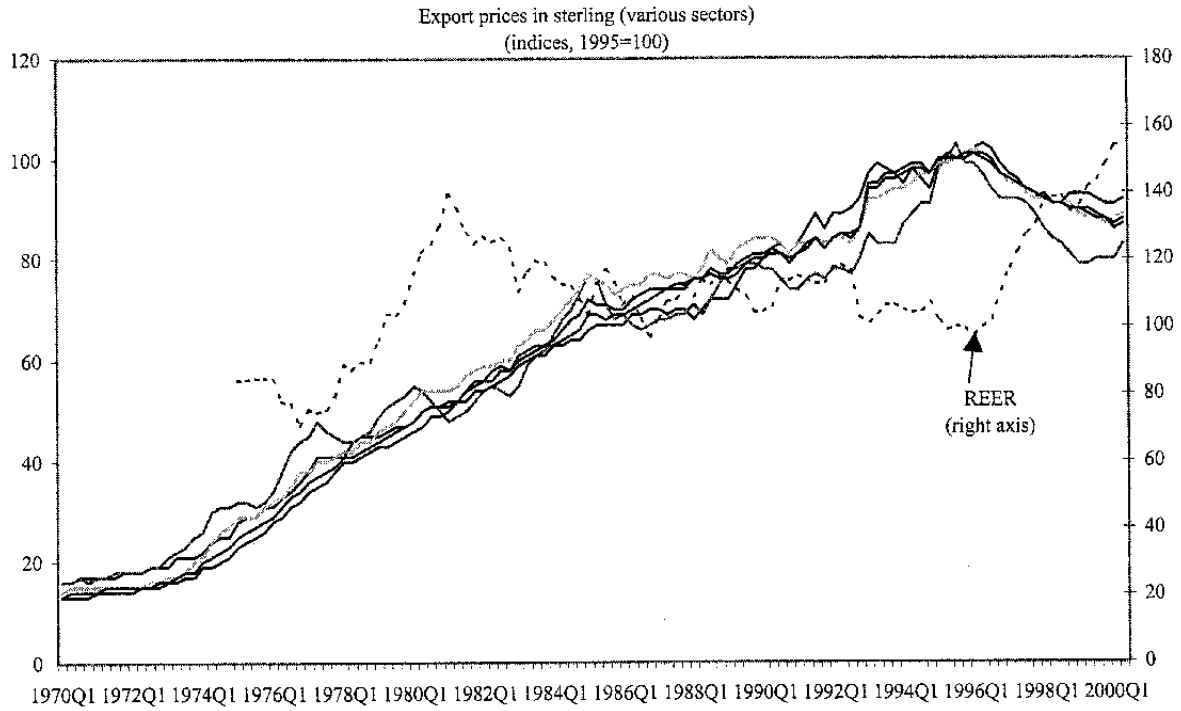


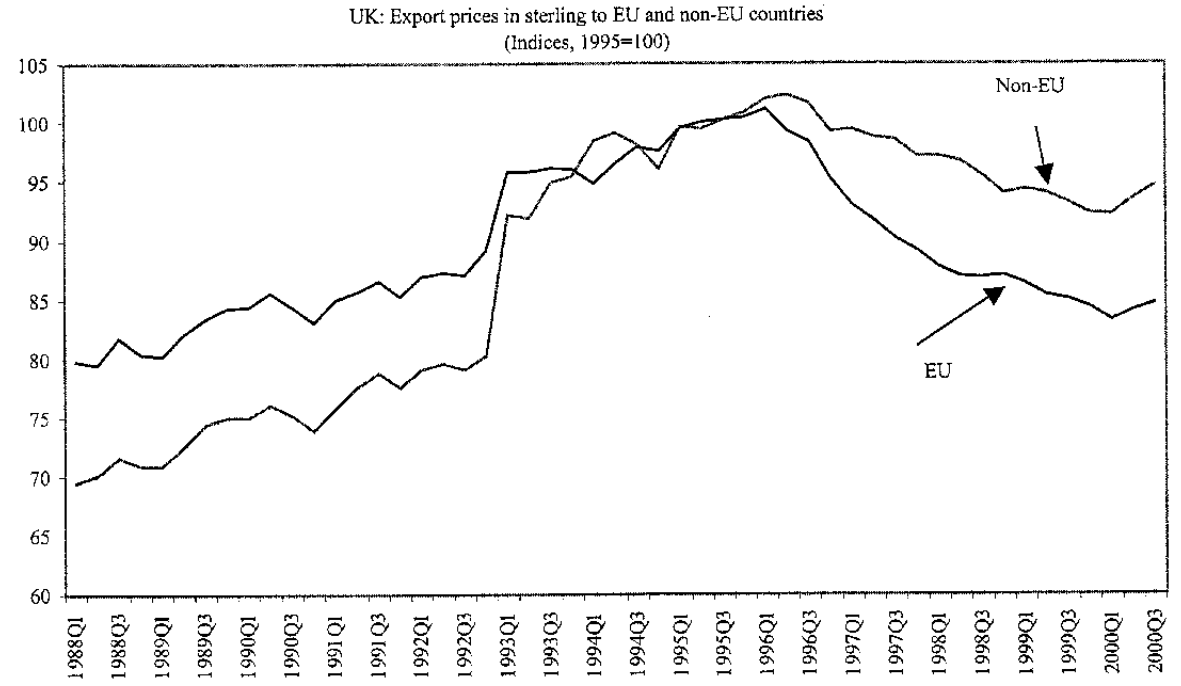
Source: ONS.

1/ Defined as the ratio of operating surpluses compared to capital employed, in percent.

2/ Defined as a the ratio of an index of the unit value of exports of UK manufactures to an export weigthed index of UK producer prices of home sales of manufactures.

Figure 8. United Kingdom: Export Prices





Source: ONS

Figure 9. United Kingdom: ULC in Manufacturing and its Components
(12-month rate of growth, in percent)

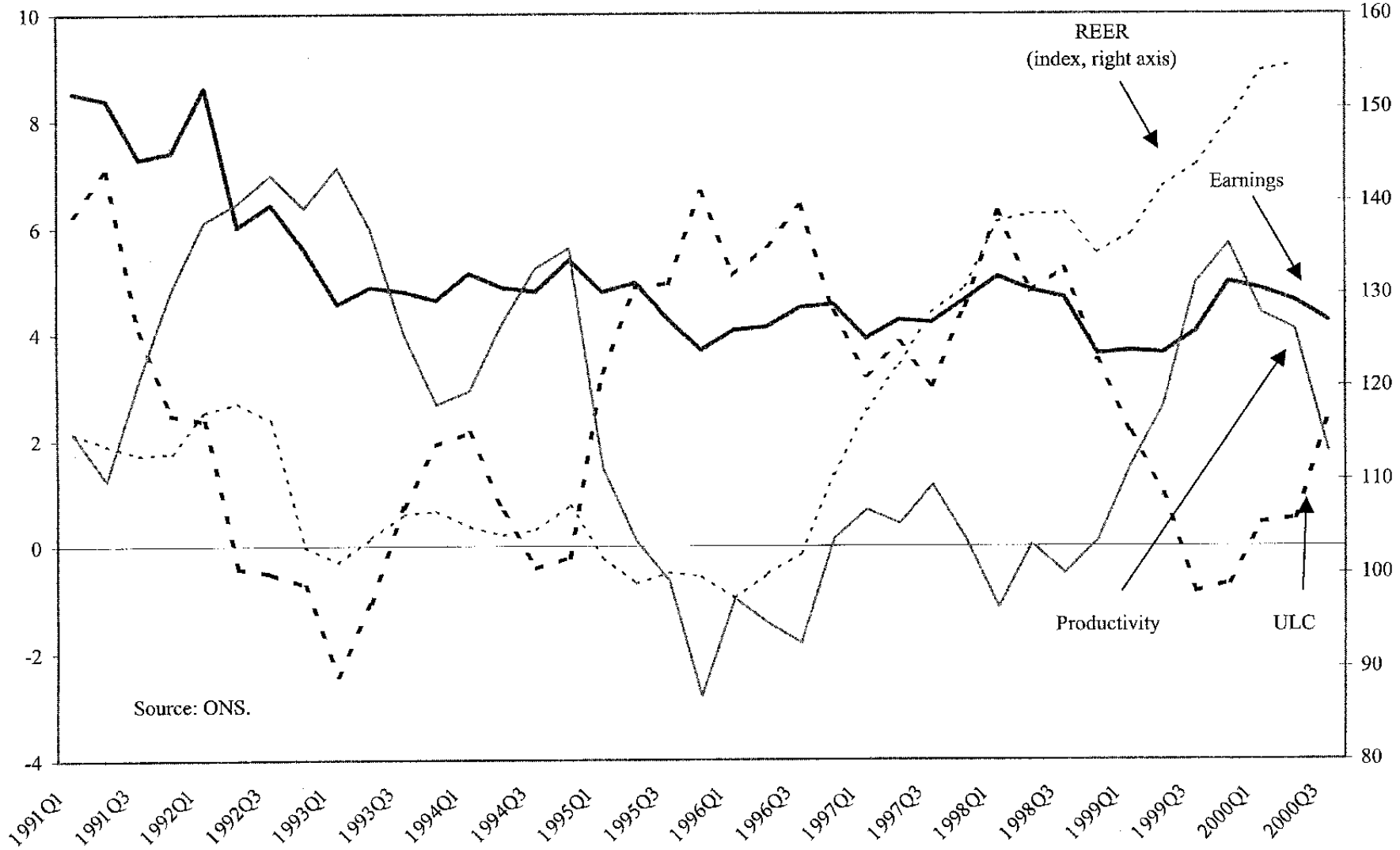
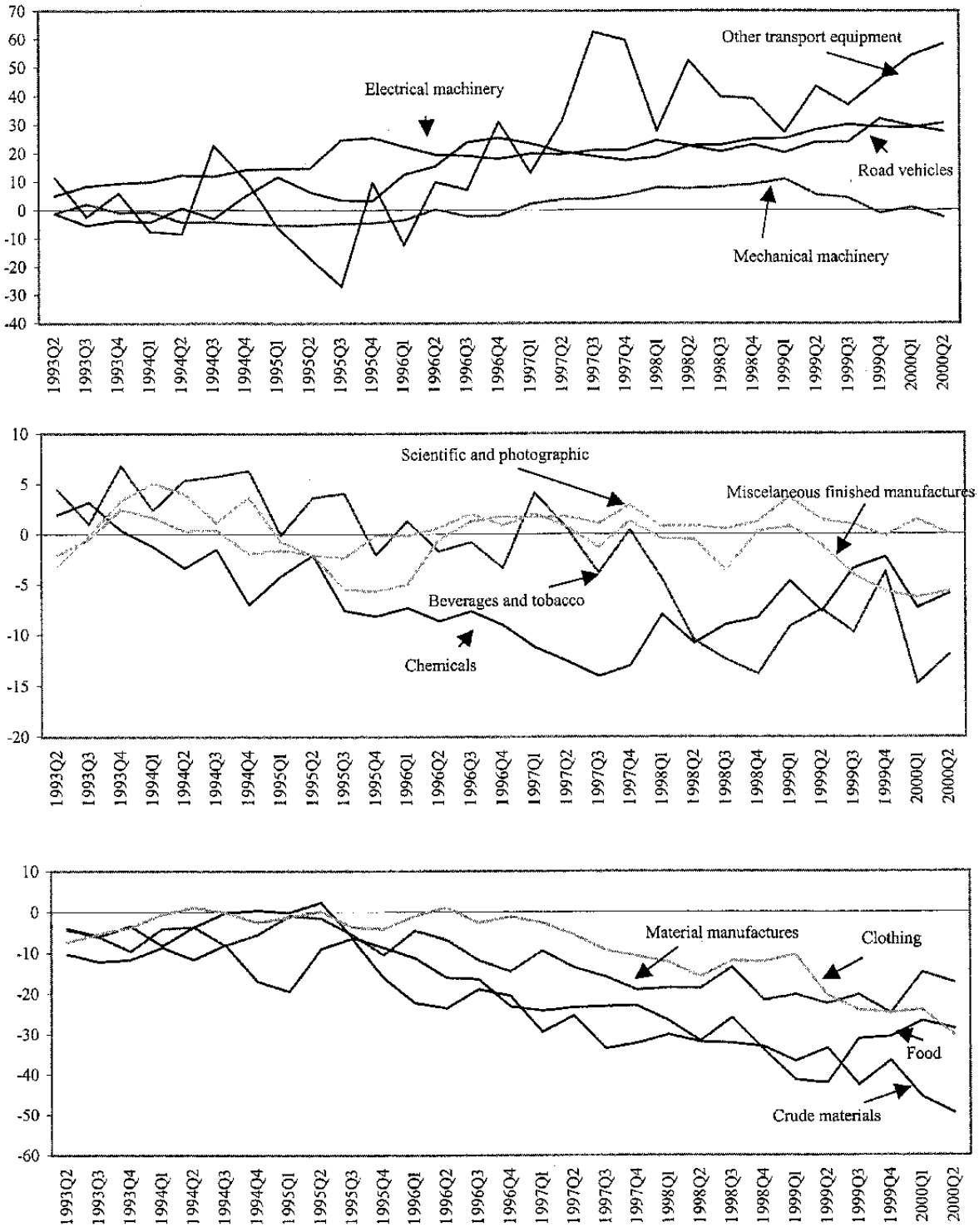


Figure 11. United Kingdom: Export Growth: Cumulative Differential with Respect to Average



Source: ONS; and staff calculations.