Chapter 6

QUALITY ADJUSTMENT OF PRICE INDICES IN INFORMATION AND COMMUNICATION TECHNOLOGY INDUSTRIES: SIMULATION OF EFFECTS ON MEASURED REAL OUTPUT IN FIVE OECD COUNTRIES

by

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Introduction

The problems associated with the construction of price indices for goods whose specification and quality change rapidly have long been recognised by statisticians and economists: if quality improvements are inadequately captured, price indices will tend to overstate inflationary developments and understate quantity changes. Perhaps the best documented example of the effects of quality adjustments on the resulting price and quantity series is the case of computers: in the United States, the introduction of hedonic methods resulted in a deflator for computers and peripheral equipment that declined at an annual average rate of over 12 per cent during the 1980s, significantly faster than the conventional measure of price changes.

Everything else equal, such quality adjustments reduce drastically the measures of producer prices in the computer industry while raising its measure of real gross and net output. The size of the effect of quality adjustments of computer prices on measures of output and productivity of industries that use these computers as investment goods or as intermediate products is, however, less obvious, as is the effect on measured aggregate net output, GDP.

While computers are the best-known example for products with rapid quality change, they are by no means the only example. Quite different products, for example the output of the construction industry, have also undergone quality changes that traditional price indices captured inadequately.[1] Closer to the product nature of computers are other information and communication technology-related products such as telephone systems and services, semiconductors or automatic banking. The current chapter focuses on the effects of quality changes in those industries that are either producers of information and communication technologies (ICT) or heavy users of them.

We identify two major *producer* industries of ICT: the office machinery and computer industry; and the radio, TV and communication equipment industry. The case for considering the effects of quality changes in the computer industry has already been stated; the case for the communication equipment industry arises from the fact that this industry's activities include, among other goods, the production of semiconductors. In terms of the user industries, we take a look at the inter-industry distribution of ICT investment flows (Table 1) to state that the communication services industry and the banking and finance sector are those industries whose output is most clearly marked by the use of ICT capital goods and their services.

Table 1. Investment in information and communication technology

Shares of sectors in total IT and ICT investment,[1] percentages, 1990

	Information technology		Information and communication technology
	Finance, insurance, banking, real estate	Finance, insurance, banking, real estate	Transport and communication services
Canada	18.5	10.5	40.6
France	74.0	49.9	15.9
Germany	44.4	..	..
Japan	47.8	35.1	14.7
United Kingdom	52.2	31.8	22.3
United States	44.0	29.3	22.1

1. Information technology (IT) investment is defined as the flow of capital goods from the office machinery and computer industry to other sectors. Information and communication technology (ICT) investment includes also the capital goods flows from the radio, TV and communication equipment industry.

Source: Motohashi (1996).

With these four ICT-related industries identified, this chapter addresses the following three questions. Supposing that output prices of ICT-related industries are being quality adjusted, how does this affect:

- Measured real value added in ICT-related industries themselves? We note that not only gross output prices may be quality adjusted, prices of intermediate inputs may be as well. What is the net effect on measures of real value added?

- Measured real value added in other industries[2]? Downstream industries of the ICT-related sectors use intermediate ICT inputs. Under quality adjustment, the measured quantities of these intermediate inputs will rise and reduce measured real value added in downstream industries. By how much? Which are the most affected industries?

- Measures of aggregate real value added? Quality adjustment of prices in ICT-related industries will probably raise the measured real value added of these industries but reduce the measured real value added in downstream industries – what is the net effect on GDP? Is it sizeable? What are the issues associated with aggregation of such effects?

These questions have a double focus. First, they all have to do with real value-added – the measure we wish to look at as we are interested in the links between different sectors and between sectoral and aggregate output. Second, real value added provides the link to labour productivity measures: as measures of labour input are independent of any quality adjustments of output prices, any observed effects on measures of real value added directly translate into effects on measures of labour productivity, if the latter is measured in terms of real value added per hour worked or per employed person.

This paper proceeds as follows: the following section provides a non-technical, and empirical description of the approach adopted to provide some answers to the above questions; the third section gives a more formal presentation of the approach and presents results; and the final section presents conclusions.

Quality adjustment: sectoral and aggregate effects

ICT producers and users

For the current purpose of tracing the effects of the quality adjustment of prices in ICT-related industries on measures of sectoral and aggregate real value added, we start with a broad division of industries in three groups.

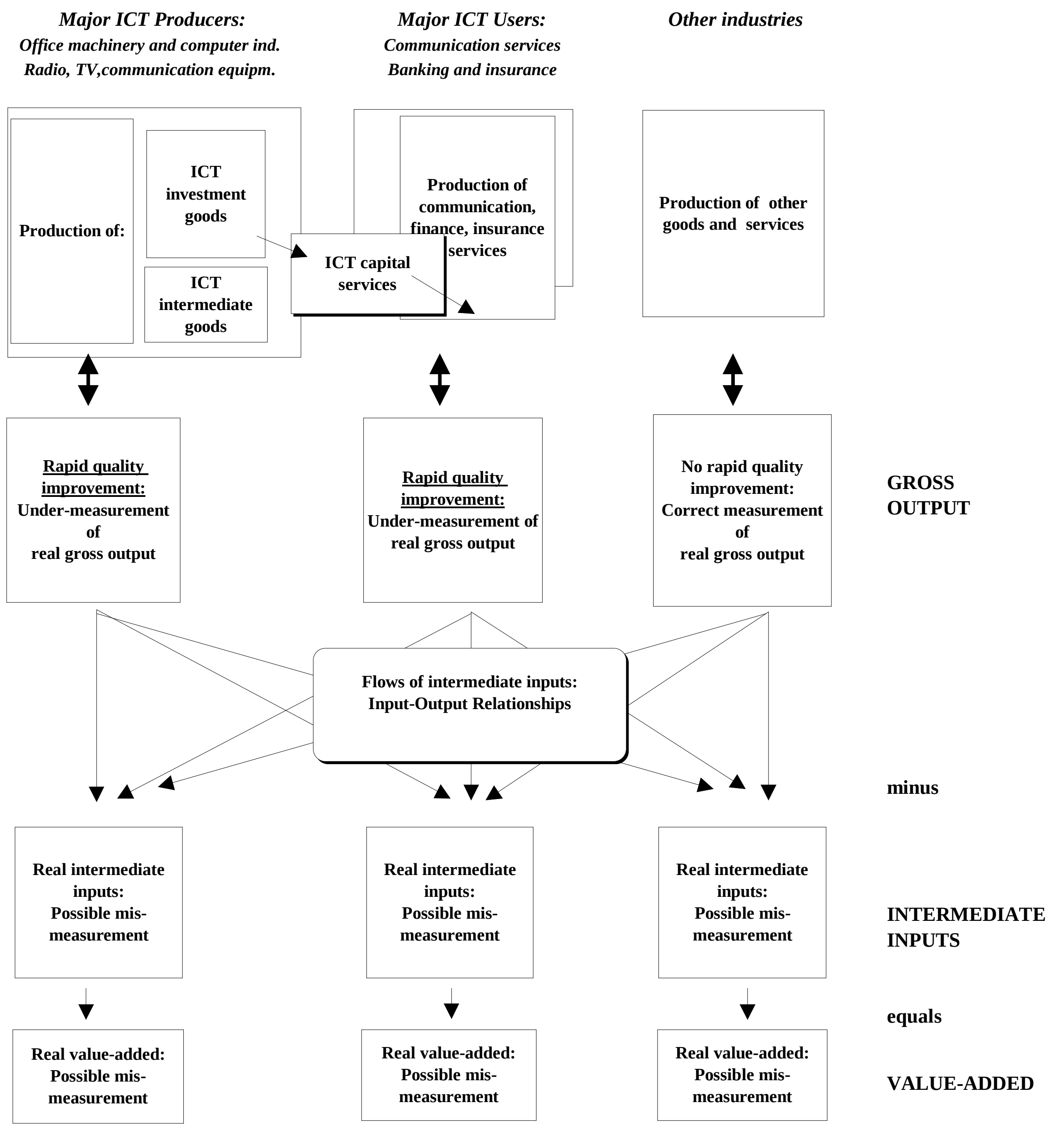
The first group, which we shall call *major ICT producers*, comprises the Office Machinery and Computer Industry (ISIC Rev.2, sector 3825) and the Radio, TV and Communication Equipment Industry (ISIC Rev.2, sector 3832). Practical considerations[3] led us to consider only the activities of these two industries although other relevant ICT products may well remain hidden in other manufacturing or services industries. However, we believe that these two industries capture the larger part of relevant ICT products including computers, computer processors, peripherial equipment, semiconductors, telephones, faxes, etc.

The second group, which we shall call *major ICT users*, comprises the Communication Services Industry (ISIC Rev.2, sector 72) and Banking and Insurance (ISIC Rev.2, sectors 81 and 82). These two industries have in common that the quality and diversity of their output have changed rapidly and that this change is intimately associated with the use of ICT capital goods in the production process. It has been mentioned before that data on inter-industry flows of investment goods show (Table 1) that these two industries have in fact been the biggest acquirers of capital goods from *the major ICT producers*. The third group consists simply of all other industries.

This leads us to observe that there are two distinct occurrences of rapid quality change related to ICT, a point that is best shown with the help of Figure 1: in the upper left corner we show the production of ICT goods. These goods (*e.g.* computer processors or semiconductors) have experienced rapid quality improvements so there is a case of potential under-measurement of real gross output, unless output prices are quality adjusted. Often, the output of these *ICT-producer* industries consists of investment goods (*e.g.* mainframe or desktop computers), widely sold to *major ICT-user* industries where they become part of the capital stock and where improved capital services enter the production process of the *ICT-user* industries. These improved capital inputs (say, the use of computers for telephone or banking services) have also led to rapid quality change in the output of *ICT-user* industries and here is the second case of potential under-measurement of real gross output, unless prices are quality adjusted.[4]

These two basic cases of quality change form the starting point for our analysis. To see how quality adjustments in prices of the four *main ICT producers and users* affect measurement of real value added in other industries, we need to trace the flow of intermediate inputs from the former to the latter. This marks an important distinction: while investment goods are the link between *main ICT producers* and *main ICT users*, flows of intermediate goods need to be traced to find out how real value added measures of other industries could be affected. While computers are the most obvious example for ICT investment goods, semiconductors, disks or CPUs are examples of intermediate goods used by downstream industries such as car manufacturing[5]. This, again, is schematised in Figure 1: flows of intermediate inputs may be mis-measured if they come for *major ICT-producer or -user* industries. Note that there are also mutual flows of intermediate inputs between *major ICT-producer* and *major ICT-user* industries with a potential impact on the measurement of industry real value added.

Figure 1. **Quality adjustment of ICT-prices and their effect on value-added: a stylised presentation**



Assumptions about mis-measurement

Only a small number of countries construct hedonic price indices for the output of the computer industry and even fewer have made adjustments in the construction of price indices for other ICT-related industries. One important reason is that the establishment of hedonic indices is costly; other reasons are of a more conceptual nature, for example, problems in identifying the appropriate unit of output in the banking industry; yet another reason is empirical difficulties in identifying and measuring the characteristics necessary for the establishment of hedonic indices. Given this situation, any assessment of the effects of quality adjustment on measures of real output has to rely on simulations of effects along a reasonable range of parameters. For the four ICT-related industries we chose the following parameter values:

- *Office machinery and computer industry* (ISIC Rev. 2, sector 3825). This is the only sector for which several countries have elaborated hedonic price indices (see Wyckoff, 1995) for an overview). On average, and for the period under consideration (1985-90), quality-adjusted prices of computer processors and peripherial equipment fell at an annual rate of about 12 per cent while unadjusted prices remained roughly constant. Sichel and Oliner (1994) report a annual average rate of change of -8.5 per cent for office, computing and accounting equipment goods in the United States. Office, computing and accounting equipment is an aggregate that, in addition to computers and peripherial equipment, includes typewriters and other non-computer office equipment and appears close to the definition of ISIC sector 3825. To keep things simple, and in line with these orders of magnitude, we set the deviation in the rate of change between adjusted and unadjusted price indices to 10 percentage points.

- *Radio, TV and communication equipment industry* (ISIC Rev.2, sector 3832). This sector is another important producer of information technology, mainly because its products include semiconductors that may have experienced a quality-adjusted price decline not too far from the fall in computer prices. Flamm (1993) presents price indices for dynamic random access memory chips and for erasable programmable read-only memory chips which confirm this point. Flamm's Fisher-type price index oscillates between -35 and +25 per cent during the second half of the 1980s, on average about -8 per cent. However, these products are only part of the entire sector's activities which extend to a number of other products (*e.g.* radio and TV sets) whose quality changed much less radically. At the same time, these items appear to play a minor role in the entire industry: Canadian data (Statistics Canada, 1996) show, for example that in 1994, record player, radio and TV set production generated value added of C$ 0.1 billion (1986 Canadian dollars) while communications and other electronic equipment accounted for some C$ 2.9 billion (1986 Canadian dollars). To allow, nevertheless, for products other than semiconductors, we assume a deviation of quality-adjusted from unadjusted prices of 5 percentage points per year. The exception to this assumption is Germany for which the available input-output tables do not permit sector 3832 to be separated – this sector is included in its parent industry, sector 383. To be able to include Germany in our simulations, we have to adjust sector 383 instead of 3832. However, to account for other products in sector 383 that have not undergone rapid quality improvements, we adjust its output price only by 2 per cent.

- *Communication services* (ISIC Rev. 2, sector 72). This sector, which includes telecommunications and postal services (but not broadcasting), counts among the most significant users of information technology. While difficult to measure, more anecdotal evidence seems to support a plausible claim that the quality of communication services has increased rapidly but may not have been captured in volume indices of the communication service industry. We assume a 2 percentage point difference between adjusted and unadjusted price indices.

- *Finance and insurance* (ISIC Rev. 2, sectors 81 and 82). The banking sector has been the subject of several analyses concerning the measurement of its output. The choice of the unit of production is fraught with conceptual difficulties and proxies include the size of current deposits, new credits accorded or number of portfolios handled.[6] In other cases, industry output is extrapolated based on labour input, with an assumed or no productivity change.[7] It is quite likely, therefore, that these measures only inadequately capture the number and quality of financial services that developed over the past 15 years, including credit cards, automatic telling machines, increased speed of transactions or the development of inter-bank networks. Sichel (1994) reports estimates by Popkin (1992) on banking services and concludes that conventional measures may under-estimate output growth by 1.3 percentage points a year. For insurance, Popkin presents different estimates. The average that maximises under-measurement is 3.9 percentage points per year. Baily and Gordon (1988), in their discussion of US productivity growth in finance, insurance and real estate sectors, suggest a rough estimate of the understatement of around 2 per cent post-1973. For our purposes, we consider an under-measurement of 1 percentage point per year.

Aggregation and additivity

The impact on measured *aggregate* real output is a weighted average of the mis-measurement in real output in individual industries. Obviously, the size of the aggregate effect depends on the size and evolution of measurement errors in individual industries and on the share of these industries in GDP. Griliches (1994) argues that both measurement errors and the share of "unmeasurable" sectors have increased. The second effect (share of unmeasurable sectors) depends, however, on the degree to which measurement biases in real gross output translate into value added which makes up GDP. While the value-added share of services is high and has been rising, it is also true that a relatively large part of service industry output consists of intermediate input to other industries. Thus, an adjustment of a service industry's output price may have different impact on aggregate real output than the price adjustment of an industry with a relatively small share of deliveries to intermediate demand.

This observation led, for example, Sichel (1994) to consider the share of services in final demand rather than in GDP by industry, which showed that the share of services in final demand was much smaller than the share of service industries in GDP. Sichel concludes that measurement errors due to a sectoral shift toward services are small and could not explain any significant portion of the productivity slowdown.

The same point had been made by Baily and Gordon (1988), who drew a clear distinction between the measurement errors in industry productivity that potentially affect aggregate value added and the measurement errors that only change the composition of real output. The first case arises when industry output is mainly directed at final demand (the example given by Baily and Gordon is real consumer purchases of air transportation); the second case arises when industry output is predominantly directed at intermediate demand. Baily and Gordon cite mis-measurement of output growth in the railroad freight industry as a pure industry phenomenon, since all of railroad freight output is an intermediate good. The input-output approach employed in the present chapter offers a natural way to account for the share of intermediate deliveries in service sector output. It also allows the effects on other industries and GDP to be traced via changes in real intermediate deliveries.

One important methodological point in the evaluation of the effects of quality adjustment on measures of real value added is whether *additivity* of real variables is imposed or not. Additivity implies that *levels* of variables at constant prices form a consistent accounting system, for example that the sum of real value added by industry equals real GDP. Alternatively, a less restrictive method can be chosen that does not impose additivity and only ensures a coherent system of *growth rates* of real variables. Under this alternative formulation, growth rates are combined with nominal weights (for example, the growth rate of real GDP is derived as a weighted average of real industry growth rates with current price value added as weights), while under additivity growth rates are implicitly combined with real weights. The distinction is important when relative prices change rapidly between the periods under consideration (see also Sichel, 1994). Take the example of the computer industry with a fast decline in quality-adjusted prices and a corresponding rapid increase in real output. If the real growth rate of the computer industry is weighted with real shares, these shares will increase as they reflect the rise in real output but not the decline in relative prices. Nominal shares, on the other hand, will capture both the rise in quantity and the fall in prices with an unknown net effect. The real growth rate of the computer industry weighted with nominal shares will, therefore, have less of an impact on aggregate GDP than the same growth rate weighted with real shares. Each method has its justification and interpretation[8] (see below for a more technical discussion) – what matters here is the fact that the choice of the aggregation procedure has a sizeable impact on the overall results of our simulations.

Model and results

Input-output relations and deflation

The model applied for our analysis is a standard, open, static input-output model, with data from the OECD Input-Output Database that was analysed for five OECD countries (Canada, Germany, Japan, the United Kingdom and the United States) for 1985 and 1990 or closest years. Throughout the analysis, we maintain ***Assumption No. 1***: mis-measurement, due to rapid quality change, relates only to the splitting of nominal series into price and volume components, not to the nominal values. Current-price flows of intermediate goods, output and value added are considered correctly measured.

The basic flow relation in the input-output models states that each industry's gross output is the sum of sales of intermediate inputs and final demand deliveries, as expressed in equation [1], where X_i stands for the current-price gross output of industry j, Z_{ij} for the flow of current price intermediate inputs from industry i to industry j, y_i for the current-price final demand for industry i's products, and a_{ij} are current-price input coefficients:

$$X_i = \sum_j a_{ij} X_j + y_i \quad with \;\; a_{ij} = Z_{ij} / X_j \qquad [1]$$

In our treatment of this simple relationship, ***Assumption No. 2*** needs to be pointed out: the nominal flows of imported goods are simply added to the flows of domestically produced goods. Although this is a common procedure in input-output analysis (Miller and Blair, 1985), it implies that price indices of imported goods are assumed to move at the same rate as price indices of domestically produced goods. This is of relevance in the next step where a price index of industry i's gross output, P_i,, is applied to intermediate goods flows and to deliveries to final demand.

The next step is the deflation of each industry's output, independent of its destination. ***Assumption No. 3*** behind this row-wise deflation (see also Figure 2) is that there exists a unique price index for each industry that applies independently of the sector to which this industry delivers. Thus, the price index of deliveries by the computer industry destined for final demand (for example, investment demand) is assumed to be the same as the price index of those deliveries destined for other industries' intermediate demand. Obviously, this could introduce a bias if investment and intermediate goods within the computer industry are of such a different nature that their price indices vary at widely different rates and if the composition of deliveries varies widely across receiving industries and final demand.

Figure 2. Input-output approach

Additivity imposed

		To: industry 1	2	..	..	N	Real final demand C+I+G+X-M	Real gross output
	1	Z_{11}/P_1	Z_{12}/P_1	..	..	Z_{1N}/P_1	Y_1/P_1	X_1/P_1
From:	2	Z_{21}/P_2	Z_{22}/P_2	..	..	Z_{1N}/P_2	Y_2/P_2	X_2/P_2
industry	..	..	..	..	..	..	..	..
	..	..	..	..	..	..	..	..
	N	Z_{N1}/P_N	Z_{N2}/P_N	..	..	Z_{NN}/P_N	Y_N/P_N	X_N/P_N
Real value added		X_1/P_{1}- $\Sigma Z_{i1}/Pi$	X_2/P_{2}- $\Sigma Z_{i2}/Pi$	..	..	X_N/P_{N}- $\Sigma Z_{iN}/Pi$	GDP	
Real gross output		X_1/P_1	X_2/P_2			X_N/P_N		

The sectoral price indices that we apply for row-wise deflation are simple sectoral deflators of gross industry output, derived from constant-price input-output table. They are thus fixed-weight (Paasche-type) deflators, normalised to a common base year – 1985. Thus, ***Assumption No. 4*** states that the nature of these sectoral deflators (fixed-weight) – which enter our model as "unadjusted price indices" does not fundamentally change the subsequent simulation results. Whether this is a severe constraint or not rests on the assessment of the underlying aggregation problem: the more disaggregated input-output industries are, the less of a potential problem there is (in the present case, the OECD input-output tables allow to distinguish between 36 industries). It is difficult to assess the severity of this problem, although the short time-period that we consider (five years) might suggest that during such a relatively constrained time span and within fairly homogenous industries, the bias from fixed-weight indices should not be too important.

Introducing adjusted prices

Next, we introduce two alternative price indices for deflation in the four ICT-related industries: p_i^u, a price index unadjusted for quality changes; and p_i^a, a price index adjusted for quality changes. For all other industries, the two price indices coincide. q_i^u and q_i^a denote the resulting variables for industry i's unadjusted and adjusted gross output at constant prices [2]. The expression in [], which represents a system of equations in real gross output, can be solved for values of q_i^u and q_i^a [9].

$$q_i^u = X_i / p_i^u = \sum_j a_{ij} \frac{p_j^u}{p_i^u} q_j^u + \frac{y_i}{p_i^u} \text{ and } q_i^a = X_i / p_i^a = \sum_j a_{ij} \frac{p_j^a}{p_i^a} q_j^a + \frac{y_i}{p_i^a} \quad [2]$$

On the basis of the two sets of deflators, two sets of industry value added at constant prices are calculated, based on double deflation. There are, however, several ways to go about double deflation.[10] The distinction we draw here is between additivity and non-additivity of the levels of real value added.

Double deflation with additivity imposed. In this case, double deflation consists of deducting the value of intermediate inputs at constant prices from the value of gross output at constant prices. In the input-output model, this amounts to subtracting the sum of all intermediate inputs that industry j purchases, from the same industry's constant-price gross output (see the two vertical arrows in Figure 2). Equation [3] shows the so-obtained adjusted and unadjusted sectoral real value added, $\widetilde{VA}_j^u$ and $\widetilde{VA}_j^a$. The expression for real value added combines real gross output, q_j, with $\sum_i N_{ij}$, the sum of all real intermediate inputs used by industry j. As before, the subscripts a and u help to distinguish between adjusted and unadjusted variables:

$$\widetilde{VA}_j^u = q_j^u - \sum_i N_{ij}^u \;\; with \;\; N_{ij}^u = Z_{ij} / p_i^u \text{ and } \widetilde{VA}_j^a = q_j^a - \sum_i N_{ij}^a \;\; with \;\; N_{ij}^a = Z_{ij} / p_i^a \quad [3]$$

From equation [3], the total effect of quality adjustment on each industry's growth rate of real value added is derived as:

$$\Delta \ln \widetilde{VA}_j^a - \Delta \ln \widetilde{VA}_j^u \quad [4]$$

At the same time, a further transformation of [3] allows to show that additivity implicitly amounts to applying real weights to growth rates of real output and intermediate inputs: differentiation of the expressions in[3] (leaving out the superscripts for simplicity) yields equation [5]. This continuous-time expression can be approximated by a discrete Törnqvist-type expression as shown in [6]:

$$\frac{\dot{\widetilde{VA}}_j}{\widetilde{VA}_j} = \frac{q_j}{\widetilde{VA}_j}\frac{\dot{q}_j}{q_j} - \sum_i \frac{N_{ij}}{\widetilde{VA}_j}\frac{\dot{N}_{ij}}{N_{ij}} \quad [5]$$

$$\Delta \ln \widetilde{VA}_j \cong \left(\tilde{\theta}_j(t) + \tilde{\theta}_j(\tau)\right)½\,\Delta \ln q_j - \sum_i \left(\tilde{\chi}_{ij}(t) + \tilde{\chi}_{ij}(\tau)\right)½\,\Delta \ln N_{ij} \quad [6]$$

with $\tilde{\theta}_j = q_j / \widetilde{VA}_j$, the ratio of real gross output to real value added and $\tilde{\chi}_{ij} = N_{ij} / \widetilde{VA}_j$, the ratios of real intermediate inputs to real value-added. Thus, additivity implies aggregation of growth rates with *real* weights.

Double deflation without additivity. Under this formulation, additivity is not assumed across constant price variables and the derivation of growth rates starts from the current-price relationship (see, for example, Kuroda and Shimpo, 1991; or Sakurai *et al.*, 1996) between gross output, value added and intermediate inputs, where p_j^v is a price index of industry j's value added:

$$p_j^v VA_j = p_j q_j - \sum_i p_i N_{ij} \qquad [7]$$

Differentiation of this expression with respect to time and approximation of the continuous-time formula by a discrete Törnqvist index formulation gives an expression akin to equation [6], with one important difference: the weights $\theta_j = p_j q_j / p_j^v VA_j$ and $\chi_{ij} = p_i N_{ij} / p_j^v VA_j$ are expressed in *current* prices:

$$\Delta \ln VA_j \cong \left(\theta_j(t) + \theta_j(\tau)\right)½\, \Delta \ln q_j - \sum_i \left(\chi_{ij}(t) + \chi_{ij}(\tau)\right)½\, \Delta \ln N_{ij} \qquad [8]$$

With the distinction between adjusted and non-adjusted variables, this formulation leads to the following expression for the overall effects of quality adjustment in ICT-related industries on sectoral growth rates of real value added [9]. This formulation also allows the decomposition of the total effect on measured real value added into a gross-output-related effect (first expression on the right-hand side of the equation) and an intermediate input effect (second expression on the right-hand side of the equation):

$$\begin{aligned} &\Delta \ln VA_j^a - \Delta \ln VA_j^u = \\ &\left(\theta_j(t) + \theta_j(\tau)\right)½\left[\Delta \ln q_j^a - \Delta \ln q_j^u\right] - \\ &\left(\chi_{ij}(t) + \chi_{ij}(\tau)\right)½\left[\Delta \ln N_{ij}^a - \Delta \ln N_{ij}^u\right] \end{aligned} \qquad [9]$$

Sectoral value added: results

The effects of the adjustment of gross output prices on real value added growth in the four ICT-related industries and its decomposition are depicted in Table 2. Several points are worth noting:

- Measured change in real value added rises by more than the assumed deviation of quality adjusted from non-adjusted change in gross output prices (10, 5, 2 and 1 percentage points according to industries). Note that the weights that translate the change in measured gross output, $\tilde{\theta}_j$ and ϑ_j (the ratio between gross output and value added) both exceed unity, thus magnifying the gross output effect on measured real value added. The adjustment effect of real intermediate inputs enters with a negative sign, because quantities of ICT-related inputs had been under-measured. The net effect on measured industry value added is, however, clearly positive.

- A comparison of the measurement effects under additivity assumptions and without them shows a marked difference: throughout, the effects on real value added measures are less pronounced when additivity is imposed. The reason lies in the difference between nominal and real weights that distinguishes the two approaches. Under additivity assumptions, the weights that link the rate of change of real gross output with real value added, $\tilde{\theta}_j$, fall over time, while the nominal weights ϑ_j that characterise the absence of additivity remain roughly constant. Thus, in the first case, changes in real gross output generate less of an effect on measures of real value added than in the second case, where weights hardly change. Although there is a counter effect associated with the weights that link the rate of change of real intermediate inputs with real value-added, ($\tilde{\chi}_j$ falls more rapidly in absolute terms than χ_j), it does not outweigh the first.

Table 2. Effects of quality adjustment of gross output prices on measured real value added
Difference between average annual percentage changes of adjusted and unadjusted measures
Method: additivity imposed, 1985-90 or closest year, ICT-related industries

	Canada	Germany	Japan	United Kingdom	United States
Office machinery and computers					
Real value added: total effect	16.3	16.3	18.4	14.5	14.4
gross output effect	21.9	20.9	17.9	14.7	26.4
intermediate input effect	-5.6	-4.6	0.5	-0.2	-12.0
Radio, TV and comm. equipment					
Real value added: total effect	6.4	3.3	8.5	6.7	7.1
gross output effect	10.0	3.7	11.5	9.0	12.9
intermediate input effect	-3.6	-0.4	-3.0	-2.3	-5.8
Communication services					
Real value added: total effect	2.2	2.2	2.4	2.4	2.2
gross output effect	2.4	2.4	2.5	2.7	2.5
intermediate input effect	-0.2	-0.2	-0.1	-0.3	-0.3
Banking and insurance					
Real value added: total effect	1.3	1.3	1.3	1.6	1.3
gross output effect	1.6	1.4	1.4	1.8	1.8
intermediate input effect	-0.3	-0.1	-0.1	-0.2	-0.5

Table 3. Effects of quality adjustment of gross output prices on measured real value added
Difference between average annual percentage changes of adjusted and unadjusted measures
Method: no additivity imposed, 1985-90 or closest year, ICT-related industries

	Canada	Germany	Japan	United Kingdom	United States
Office machinery and computers					
Real value added: total effect	18.1	22.5	24.0	20.9	20.8
gross output effect	29.7	27.0	31.6	27.7	27.7
intermediate input effect	-11.6	-4.5	-7.6	-6.8	-6.9
Radio, TV and comm. equipment					
Real value added: total effect	7.2	3.4	11.3	8.9	10.4
gross output effect	11.6	4.2	15.8	12.3	14.0
intermediate input effect	-4.4	-0.8	-4.5	-3.4	-3.6
Communication services					
Real value added: total effect	2.3	2.2	2.5	2.4	2.4
gross output effect	2.5	2.5	2.6	2.8	2.6
intermediate input effect	-0.2	-0.3	-0.1	-0.4	-0.2
Banking and insurance					
Real value added: total effect	1.3	1.3	1.3	1.5	1.3
gross output effect	1.6	1.4	1.4	2.2	1.9
intermediate input effect	-0.3	-0.1	-0.1	-0.7	-0.6

For a more intuitive understanding, consider the example of computers and semiconductors. Assume that, initially, no price adjustment is present. Next, output prices of the computer industry are adjusted downward by 10 per cent and those of semiconductors by 5 per cent. What happens to real intermediate inputs in the computer industry? The absolute measure of real semiconductor inputs will rise, given the price adjustment of semiconductors. However, at the same time, real output of the computer industry is also adjusted upwards, and by more than the measure of real semiconductor inputs (in addition, intermediate inputs are weighted with their respective input coefficient which, by definition is always less than unity). As a result, the measure of real intermediate inputs *per unit* of real gross output *falls* (a relatively smaller quantity of combined intermediate inputs is measured per unit of quality-adjusted gross output), and the measure of real value added per unit of real gross output rises. But $\tilde{\theta}_j$ is just the inverse of this relationship, namely real gross output over real value added. Hence, $\tilde{\theta}_j$ declines and reduces the weight on real gross output while nominal weights remain unaffected.

Next, it is interesting to examine the effects on other sectors not included in the list of four ICT-related industries. By construction, price adjustment in ICT-related industries has a negative effect on the measure of real value added in other sectors. Measures of real gross output do not change but measures of real intermediate inputs from ICT-related industries rise, in absolute terms as well as relative to real gross output. The new measure shows that more intermediate inputs are needed in real terms to produce one unit of output; turned around, this implies a fall in real value added per unit of gross output. Table 4 shows the changes in measured real value added of downstream industries of the four ICT sectors. The impact can be significant and is most accentuated in a number of manufacturing industries, in particular shipbuilding, aircraft, electrical and non-electrical machinery and professional goods. On average, and for the industries shown inTable 4, measured growth rates of real value added (and therefore labour productivity) fell by 0.7 percentage points per year.

What determines the size of the impact on measures of downstream industries' value added? First, the more important the purchases of intermediate inputs from ICT industries, the more the quality adjustment of prices of these inputs will be felt in the total measure of real intermediate inputs. A look at the input coefficients of the shipbuilding industry, for example, shows that they are in fact high compared to many other industries. This may be due at least partly to the fact that many ICT products (for example computers or navigation equipment installed on a ship, communication equipment, telephone networks, etc.) are accounted for as an intermediate input to the shipbuilding industry while they would most certainly qualify as investment goods in other industries.

Another point is the role of unadjusted prices: industry j's real intermediate inputs per unit of real output depend on nominal input coefficients and on the relative changes of output and input prices. If prices of intermediate inputs fall (because they are quality adjusted) while (unadjusted) output prices of the shipbuilding industry rise rapidly, this will further worsen the measured ratio between real intermediate inputs and real gross output. The unadjusted price index of the shipbuilding industry has, in fact, risen by more than those of other industries and so contributed to the strong effects on measured real value added in the shipbuilding and ship-repairing sector.

Table 4. Quality adjustment of prices in ICT-related industries: 10 most affected sectors

Difference between annual average growth rates of adjusted and unadjusted real value added

Percentage points

Canada	A*	NA*	Germany	A*	NA*
Shipbuilding & repairing	-3.4	-2.8	Shipbuilding & repairing	-1.7	-1.3
Professional goods	-1.1	-1.0	Aircraft	-0.7	-0.6
Petroleum & coal products	-0.9	-0.3	Non-electrical machinery	-0.6	-0.5
Other manufacturing	-0.4	-0.3	Professional goods	-0.6	-0.5
Motor vehicles	-0.2	-0.4	Motor vehicles	-0.5	-0.4
Other producers	-0.2	-0.2	Restaurants & hotels	-0.3	-0.2
Electrical apparatus, nec	-0.2	-0.2	Mining & quarrying	-0.3	-0.3
Community, social & personal services	-0.2	-0.2	Non-ferrous metals	-0.3	-0.1
Wholesale & retail trade	-0.2	-0.2	Construction	-0.3	-0.2
Real estate & business services	-0.2	-0.2	Wood products & furniture	-0.2	-0.2

Japan	A*	NA*	United States	A*	NA*
Shipbuilding & repairing	-0.8	-0.4	Professional goods	-0.9	-0.7
Professional goods	-0.7	-0.5	Electrical apparatus, nec	-0.8	-0.4
Other manufacturing	-0.6	-0.3	Aircraft	-0.5	-0.6
Electrical apparatus, nec	-0.5	-0.5	Other manufacturing	-0.3	-0.2
Transport & storage	-0.5	-0.2	Non-ferrous metals	-0.3	-0.4
Motor vehicles	-0.4	-0.3	Motor vehicles	-0.2	-0.2
Other transport	-0.4	-0.2	Community, social & personal services	-0.1	-0.1
Mining & quarrying	-0.2	-0.1	Petroleum & coal products	-0.1	-0.1
Non-electrical machinery	-0.2	-0.2	Paper, paper products & printing	-0.1	-0.1
Real estate & business services	-0.2	-0.1	Real estate & business services	-0.1	-0.1

United Kingdom	A*	NA*
Electrical apparatus, nec	-1.6	-0.6
Professional goods	-1.3	-1.0
Aircraft	-1.2	-0.8
Shipbuilding & repairing	-0.9	-0.5
Motor vehicles	-0.8	-0.3
Electricity, gas & water	-0.6	-0.2
Non-electrical machinery	-0.5	-0.3
Other transport	-0.4	-0.3
Real estate & business services	-0.4	-0.2
Industrial chemicals	-0.3	-0.2

A*: Additivity imposed.
NA*: No additivity imposed.

Source: OECD, STI/EAS.

Aggregation: real and nominal shares

Aggregation with additivity. As before, we distinguish between two methods to capture the effects of quality adjustment on aggregate value added, depending on the underlying methodology for aggregation. The first method, which is standard practice in national accounts statistics, imposes additivity and thus simply sums up the levels of sectoral real value added to obtain a measure of aggregate real value added: this permits, for instance, the analysis of structures at constant prices and the comparisons of levels of value added at constant prices in a framework that ensures consistency between subsectors and parent industries. Thus, $\widetilde{VA}$, the level of aggregate value added at constant prices, is defined as $\widetilde{VA} = \sum_j \widetilde{VA}_j$, the sum of value added by industry and the associated growth rate is simply $\Delta \ln \widetilde{VA}$. Similar to our earlier treatment, we distinguish between adjusted and unadjusted variables and capture the effects of quality-adjusted price in ICT industries on aggregate measures of real value added by the expression:

$$\Delta \ln \widetilde{VA}^a - \Delta \ln \widetilde{VA}^u = \Delta \ln\left(\sum_j \widetilde{VA}_j^a\right) - \Delta \ln\left(\sum_j \widetilde{VA}_j^u\right) \qquad [10]$$

As before, the right-hand side of equation [10] can be approximated in discrete time by a Törnqvist-type index:

$$\Delta \ln \widetilde{VA}^a - \Delta \ln \widetilde{VA}^u \cong \sum_j \left(\tilde{s}_j^a(t) + \tilde{s}_j^a(\tau)\right)½\,\Delta \ln \widetilde{VA}_j^a - \sum_j \left(\tilde{s}_j^u(t) + \tilde{s}_j^u(\tau)\right)½\,\Delta \ln \widetilde{VA}_j^u \qquad [11]$$

Again, the point that emerges is that this is an aggregation method with weights $\tilde{s}_j = \widetilde{VA}_j / \widetilde{VA}$ at base-year prices as they reflect each industry's *real share* in aggregate value added.

Aggregation without additivity. The alternative method that does not impose additivity starts again from a basic accounting principle: aggregate value added at current prices equals the sum of sectoral value added at current prices. This is spelled out in [12], where $p^v VA$ denotes current-price aggregate value added, the product of an aggregate price index p^v and aggregate real value added VA; similarly, $p_j^v VA_j$ stands for sectoral current-price value added with a price and a volume component:

$$p^v VA = \sum_j p_j^v VA_j \qquad [12]$$

Differentiation with respect to time yields an expression that decomposes the growth rate of nominal value added into a Divisia price index (first expression on the right-hand side of [13] and a Divisia quantity index of aggregate value added (second expression on the right-hand side of [13]. The quantity index is similar to the quantity index in [10] with one important difference: sectoral rates of real value added are aggregated with *nominal* shares s_j, not real shares $\tilde{s}_j$.

$$\frac{\dot{p}^v}{p^v} + \frac{\dot{VA}}{VA} = \sum_j s_j \frac{\dot{p}_j^v}{p_j^v} + \sum_j s_j \frac{\dot{VA}_j}{VA_j} \quad with \;\; s_j = \frac{p_j^v VA_j}{p^v VA} \qquad [13]$$

The quantity indices in [13] can be rewritten in its discrete approximation as a Törnqvist-type index between two time periods t and τ. We then use this formulation to evaluate $\Delta \ln VA$:

$$\Delta \ln VA = \sum_j \left(s_j(t) + s_j(\tau)\right)\tfrac{1}{2}\Delta \ln VA_j \qquad [14]$$

Finally, adjusted and unadjusted variables are introduced to assess the effects of sectoral price adjustment on GDP. Let $\Delta \ln VA^a$ and $\Delta \ln VA^u$ be the quantity indices of real GDP, based on *nominal* sector shares and adjusted or unadjusted sectoral prices. Then, the difference $\Delta \ln VA^a - \Delta \ln VA^u$ represents the aggregate effect of sectoral price adjustment, using nominal shares for aggregation:

$$\Delta \ln VA^a - \Delta \ln VA^u = \sum_j \left(s_j(t) + s_j(\tau)\right)\tfrac{1}{2}(\Delta \ln VA_j^a - \Delta \ln VA_j^u) \qquad [15]$$

Aggregate value added: results

Effects on aggregate real value added of the quality adjustment of price indices in ICT-related industries are displayed in Figures 3 and 4 according to the underlying aggregation procedure (additivity and non-additivity). The following points emerge from these graphs:

Figure 3. Effects of quality adjustment of prices in ICT-related industries

Aggregation method: real shares (additivity imposed)

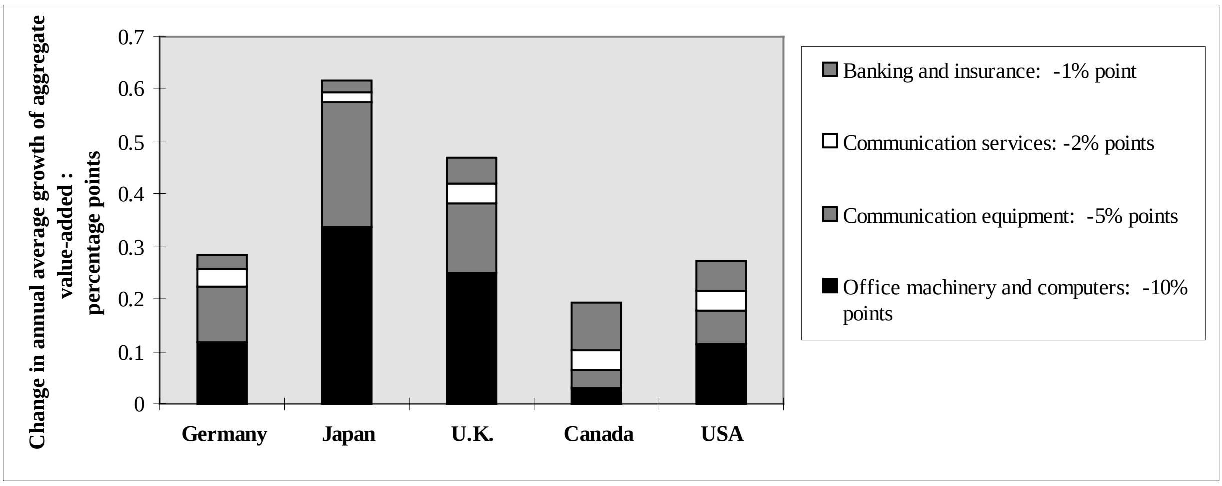
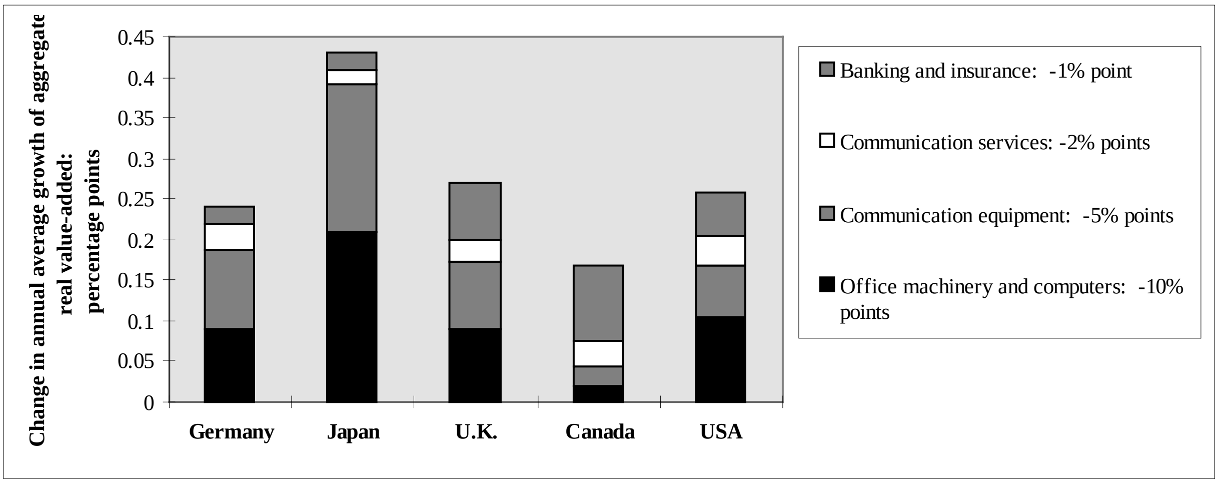


Figure 4. Effects of quality adjustment of prices in ICT-related industries
Aggregation method: nominal shares (no additivity imposed)



First, overall effects are visible, but not overwhelming. According to these results, the real growth rate of aggregate real value added was under-measured by anything between 0.2 percentage points per year in Canada to 0.6 percentage points in Japan. A comparison of these figures with the underlying unadjusted growth rates confirms that the two are roughly in proportion: unadjusted real growth rates were relatively high in Japan and the United Kingdom (over 5 per cent) – the two countries with the largest adjustments; while growth in Canada and the United States was only about 3 per cent – in line with the lower adjustment results. Germany does not quite fit the picture: its (unadjusted) aggregate growth rate of about 4 per cent was clearly higher than that of Canada or the United States, while the order of magnitude of under-measurement is very much in line with these two countries. However, this may be due to an inappropriate adjustment of Germany's communication equipment sector[11].

Second, results in Figure 3 were obtained with the aggregation procedure that assumes additivity between levels of constant-price variables and is therefore based on real shares. Figure 4 shows the same effects but based on the aggregation method that uses nominal shares. As it turns out, the aggregation procedure based on nominal sectoral shares produces a smaller deviation from unadjusted aggregate growth. This is to be expected as:

- Real shares for ICT-related industries increase over time even in the absence of specific quality adjustment of prices. For example, the real (unadjusted) share of Japan's computer industry in GDP rose from 0.77 per cent in 1985 to 0.9 per cent in 1990. Nominal shares of the same industry remain more or less constant; in the Japanese example they even decreased slightly to 0.75 per cent.

- Real shares for ICT-related industries increase even more when prices are adjusted for quality changes. This causes a magnification of the real growth measure of these sectors that in turn raises the measure of aggregate real value added growth. To stay with the example of Japan, the 1990 real share of its computer industry rises from 0.9 per cent to 2.4 per cent when quality-adjusted prices replace conventional price indices, nearly tripling the contribution to measured GDP growth. Nominal shares, on the other hand, are unaffected by quality adjustments of prices and do not magnify the increased real growth measure of ICT-related industries. Thus, a stronger impact should be expected under an aggregation method based on real shares than under one based on nominal shares.[12]

Conclusions

The present chapter examined the effects of an adjustment of sectoral prices for quality changes on sectoral and aggregate measures of real value added. Four principal conclusions arose from this analysis:

- First, the q*uality adjustment of gross output prices in ICT-related industries has a non-negligible impact on measured real value added*, and therefore on measured labour productivity, *both in ICT-related industries and in other sectors of the economy.* The size of the effect on other sectors hinges on the extent to which products of ICT-related industries are used as intermediate inputs in downstream sectors. While there are differences across the countries examined, there is also a common pattern: in each of the countries, manufacturing industries' measures of real value added tended to be more affected than service sectors' measures. Shipbuilding, automobiles, professional goods and aircraft typically appear as those industries for which the downward correction of real value added measures is most pronounced.

- Second, the size of the effects on measures of industry real value added is greatly influenced by the choice of the underlying methodology, specifically by the choice between nominal and real weights to combine the growth rates of variables. As the underlying question – should there be additivity of levels of constant price variables? – remains open, our only conclusion is that *methodology matters* in particular at the industry level.

- Third, the *impact on aggregate value added is visible, but not overwhelming.* On an average annual basis, growth rates of GDP of the five countries under consideration would have to be adjusted upwards by 0.2 to 0.6 percentage points over the period 1985-90 (and rates of inflation downwards, correspondingly). Again, results may change if different weighting procedures are applied to derive aggregate growth rates of real value added from sectoral growth rates.

- Fourth, it needs to be underlined that the quantitative effects derived in this study depend entirely on the *assumptions* about the degree of under-measurement of sectoral real gross output. While it could be argued that the assumed maximum deviations between adjusted and unadjusted price indices are too high, it should be kept in mind that we only evaluated the effects of quality adjustment of prices in ICT-related industries, leaving aside the possibility of under-measurement in other sectors, for example the construction industry, transport services and the retail sector. Also, the period of observation is limited to the second half of the 1980s, not the time of the steepest decrease in prices of some ICT products, for example computers. The inclusion of earlier periods would, most likely, have revealed more pronounced effects at both the sectoral and aggregate levels.

NOTES

1. At the same time it has been shown that there are sectors where hedonic price indices yield results that are hardly distinguishable from those derived under traditional deflators. A case in point are apparel price indices (Liegey, 1994) where effects of hedonic adjustment have been weak and not uni-directional, despite the potentially important role that hedonic-based quality adjustments play in an industry with largely "fashion-driven" goods that are subject to frequent product changes.
2. Wyckoff (1995) addressed the effects of quality adjustment of the office and computing machinery industry prices on productivity measures of that industry and its parent sectors: He showed that "differences in the measurement of the change in output prices of the computer sector have a significant effect on the growth rate of labour productivity for this sector as well as the more aggregate industrial classification in which it is included (non-electrical machinery and fabricated metal products and equipment)". These conclusions are derived from a sensitivity analysis whereby Wyckoff applied the US quality-adjusted price index of the office machinery and computers sector to current-price value added series of the same industry in other OECD countries. He then compared the resulting real value added and labour productivity growth with the changes in labour productivity based on conventional measures of value added.
3. In particular, it could be argued that computer-related service activities such as the creation of software programmes form part of ICT production. However, even if we accepted this notion, the empirical classification we have at our disposal for the current research is too broad to single out this service activity which is hidden in the very broad category of real estate and business services.
4. At this point our analysis meets the discussion about the Solow paradox, that is the apparent contradiction between a growing high quality ICT capital stock and the absence of an economy-wide pick-up of productivity growth. See Oliner and Sichel (1994) for a discussion of the size of the ICT capital stock.
5. In theory, the distinction between investment and intermediate goods cannot be grounded in the nature of the product, rather any product can be investment or intermediate good, – all that counts is whether the good has a service life that exceeds the accounting period, *i.e.* normally one year. A computer, bought and installed in the branch of a bank, for example, is clearly a capital good while the same computer, installed in the navigation cabin of a ship, is an intermediate input to the shipbuilding industry.
6. For a discussion see Petit (1991).
7. For a survey of methods to derive real value added measures in service industries of OECD countries, see OECD (1996).
8. For a presentation of the introduction of current-price chain weights in the calculation of the US GDP at the end of 1995, see, for example, Landefeld and Parker (1995).
9. In matrix form, the system of equations for real gross output by industry is solved as $q = \left[I - \hat{p}^{-1} A \hat{p}\right]^{-1} \hat{p}^{-1} y$ where q is a vector of real gross industry output, $\hat{p}$ is the diagonal matrix of sectoral deflators, A is the matrix of current-price input coefficients and y is the vector of current price final demand.
10. There are alternatives to double-deflation that can be applied in an input-output context. Durand (1994) presents a method that consists of deflating industries' direct and indirect contributions to final demand deliveries (their value added by commodity) by the respective final demand commodity prices. Durand shows that this method features economic and statistical advantages in that it avoids, for example, negative real value added and in that the quality of commodity price measurement tends to be superior to that of producer price measurement by industry. However, Durand's approach requires matrices of intermediate uses by commodities and industries. *The OECD Input-Output Database* is confined to industry-by-industry intermediate flow matrices and precludes therefore the deflation via commodity prices as suggested by Durand.
11. See Section "Assumptions about mis-measurement".
12. A look at the five countries reveals that the impact of changing methodology are particularly pronounced in the United Kingdom. Partly this may be due to the fact that the base year for the UK industry deflators is 1980 (other countries 1985, 1986 and 1982), leading to a particular wide gap between the growth of

industries' real and nominal shares in GDP. At the same time, the base year for the United States is also quite remote (1982) with little differential effects from the two methodologies while Japan, whose base year is 1985, shows a sizeable difference in the results from the two aggregation procedures.

Annex

DATA SOURCES

All data for the present chapter are from *The OECD Input-Output Database* (OECD, 1995) which provides input-output tables in comparable industry structure for 10 OECD countries (Australia, Canada, Denmark, France, Germany, Italy, Japan, Netherlands, the United Kingdom, the United States). The input-output tables are industry-by-industry tables that cover 36 industries as shown in the table below. In the present analysis, producers of government services were excluded, as the treatment of the government sector in input-output tables varies across countries.

Although 1985-90 is the reference period in the present study, this time span had to be adjusted as a function of the availability of countries' input-output tables: Canada: 1986-90, Germany: 1986-90, Japan: 1985-90, United Kingdom: 1984-90, United States: 1985-90. Constant price matrices in the *OECD Input-Output Database* are expressed in prices of different base years: Canada: 1986, Germany: 1985, Japan: 1985, United Kingdom: 1980, United States: 1982. Although the present analysis does not use constant price matrices as such, they provide the source for implicit deflators of gross output by industry, the "unadjusted" prices indices used in the simulation.

OECD Input-Output Database: sector classification

No	ISIC Rev. 2 codes	Description
1	1	Agriculture, forestry and fishery
2	2	Mining and quarrying
3	31	Food, beverage and tobacco
4	32	Textiles, apparel and leather
5	33	Wood products and furniture
6	34	Paper, paper products and printing
7	351+352-3522	Industrial chemicals
8	3522	Drugs and medicines
9	353+354	Petroleum and coal products
10	355+356	Rubber and plastic products
11	36	Non-metallic mineral products
12	371	Iron and steel
13	372	Non-ferrous metals
14	381	Metal products
15	382-3825	Non-electrical machinery
16	3825	Office and computing machinery
17	383-3832	Electrical apparatus, nec.
18	3832	Radio, TV and communication equipment
19	3841	Shipbuilding and -repairing
20	3842+3844+3849	Other transport equipment
21	3843	Motor vehicles
22	3845	Aircraft
23	385	Professional goods
24	39	Other manufacturing
25	4	Electricity, gas and water
26	5	Construction
27	61+62	Wholesale and retail trade
28	63	Restaurants and hotels
29	71	Transport and storage
30	72	Communication services
31	81+82	Finance and insurance
32	83	Real estate and business services
33	9	Community, social and personal services
34		Producers of government services
35		Other producers
36		Statistical discrepancy

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