Real cost reduction and productivity increase in an individual industry: a price-accounting approach in theory and practice

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1. Introduction

The technological roots of wage developments are widely recognized (e.g. Acemoglu, 1999, Card and DiNardo, 2002, Autor, Katz and Kearney, 2006). There is also wide awareness of the 'acceleration in the IT price decline' (Jorgenson, Ho and Stroh, 2005, p. XVIII; see also Autor, Katz and Kearney, 2006, p. 192) and its importance for IT using industries; this decline is obviously traced back to an acceleration of productivity increase in IT producing industries.

Yet the available measures of productivity increase in an individual industry are based not on observable price developments, but on observable input and output developments, according to the growth-accounting logic of Total Factor Productivity. For example, the EU KLEMS indexes of prices are calculated 'ex post', on the basis of quantity indexes, which in turn are built on original sources (see Timmer et al., 2007, p. 17-18). It is quite artificial, then, to think of cost reduction, real wage increase and relative price adjustments via TFP accounts. Harberger (1998), just to consider a notable example, defined Real Cost Reduction (*RCR*) at the industry level as *TFP times* the share of value added in that industry (1998, p. 4). But can we not calculate it *directly* from original data on prices and factor compensation? Can we, perhaps, extract a rate of productivity increase from such data? This paper shows that, in principle, we can; we also provide an illustration of the data sets required, of the qualitative results that can be obtained, and of some practical problems that need to

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be solved in order to extend the analysis and to compare its quantitative results with those of conventional industrial *TFP* analysis.

In Section 2 we define the industrial *RCR* and the industrial rate of productivity increase (*RPI*) for a simplified case, and present the basic methodology for extracting them from real wage change, relative price change and taxation change; in Section 3 we introduce some 'real world' complications; in Section 4 we apply the method to two selected British industries for 1998-2007; Section 5 concludes.

2. Real Cost Reduction and its components. A simple case

Let us consider an industry formed by identical firms characterized by constant returns to scale; they produce a single output by means of skilled and unskilled labour, (labelled s and u, respectively), and an intermediate input, labelled i. For simplicity, we ignore in this Section the presence of fixed capital and assume that the intermediate input is imported at internationally given terms of trade and attracts no interest allowances. In such an industry, all value added consists of wages. Our crucial assumption is that, by competition, each firm earns *net maximum profits of zero*. We remark that this assumption is made also in the growth-accounting literature, but its implications can be worked out more explicitly and with more insight by drawing attention on the 'price side'.

We describe each firm by its *unit cost function*, homogeneous of degree one in input prices. Let the wages paid by the firm (inclusive of the tax wedge) be w_s, w_u, and let the price paid for the intermediate input be $(1+t_i)p_i$, where t_i is an excise tax. Finally, let T be a shift parameter representing technical change. The unit cost function will therefore be $c(w_s, w_u; (1+t_i)p_i; T)$. Now let p be the output price; for simplicity we assume that no tax is levied on output. Maximum profits are null when

$$p = c(w_s, w_u; (1+t_i)p_i; T)$$

By the homogeneity properties of $c(\ )$, we may hereon reinterpret all input prices as *output deflated*, obtaining

$$1 = c(w_s, w_u; (1+t_i)p_i; T) \tag{1}$$

Notice that, by Shephard's Lemma, we have

$$l_{s,u} = \frac{\partial c}{\partial w_{s,u}}, \ a_i = \frac{\partial c}{\partial[(1+t_i)p_i]} \tag{2}$$

as the cost minimizing use *per unit of output* of the two types of labour and of the intermediate input, respectively.

By (1) and (2), we have $1 = w_s l_s + w_u l_u + (1+t_i)p_i a_i$. Therefore we can express $w_s l_s$ etc. as the *shares* of the different inputs on total cost. It simplifies notation if we set

$$w_s l_s = v_s; w_u l_u = v_u; (1+t_i)p_i a_i = v_i.$$

Differentiating (1) and taking (2) into account, we have

$$0 = v_s \frac{dw_s}{w_s} + v_u \frac{dw_u}{w_u} + v_i \left[\frac{dp_i}{p_i} + \frac{dt_i}{(1+t_i)}\right] + \frac{\partial c}{\partial T} dT \tag{3}$$

The rate of cost *reduction* at constant input prices and at constant taxation, is our rate of productivity increase, *RPI*. Let $-(\partial c/dT)dT = RPI$ hereon. Now we may sensibly define the industrial *real cost reduction* (*RCR*), borrowing Harberger's terminology, as

$$RCR = -v_i \left[\frac{dp_i}{p_i} + \frac{dt_i}{(1+t_i)}\right] + RPI \tag{4}$$

We distinguish between three distinct 'sources' or 'components' of *RCR*: a 'relative price component', $-v_i(dp_i/p_i)$, a 'taxation component', $-v_i(dt_i/(1+t_i))$ and a 'productivity increase component', *RPI*. It goes without saying that a negative component makes for a real cost *increase*.

The other side of *RCR* is an increase of the real (i.e. output-deflated) wages. Specifically, we have, by (3)

$$RCR = v_s \frac{dw_s}{w_s} + v_u \frac{dw_u}{w_u} \tag{5}$$

Equation (5) represents the 'outcome' of *RCR* in terms of an increase in a weighted sum of the two real wages. This is an immediate consequence of the zero-profit condition, under competition.

A geometrical interpretation of (5) is useful. Treating p_i, t_i and T as given parameters, we obtain from (1) what may be called the 'industrial real wages frontier', i.e. the possible real wages paid by the firm, subject to the zero-profit condition. A change in the parameters determines, of course, a shift of the frontier itself, which can be decomposed according to equation (3).

When $(dw_s/w_s) = (dw_u/w_u)$, *RCR* is simply a measure of the expansion (contraction) of the frontier on a given ray, equal to this common proportional rate of increase multiplied by the share of value added. But nothing guarantees that an exogenous change is neutral with respect to w_s/w_u ; for instance, skill biased technical change is known to modify the relative wages of skilled and unskilled labour. In such a case, a shift of the frontier is accompanied by a movement on it and one should distinguish between *RCR* and a change in distribution and do that *for any discrete change*. (The reader would certainly notice the analogy between this problem and the problem of distinguishing between *TFP* and a change in input intensity in the framework of growth accounting. An early hint at the 'duality' between measures of productivity increase derived, respectively, from cost functions and production functions is in McCloskey, 1968, p. 290, n. 3; a formal analysis is in Opocher, 2009; see also Opocher, 2010).

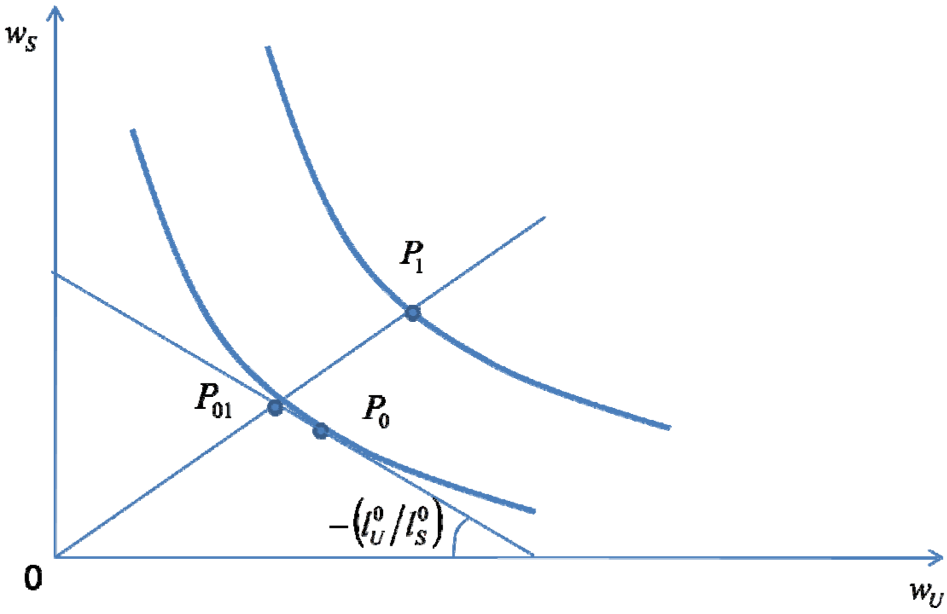

Figure 1 – *Distinguishing between a shift of the frontier and a movement on it*

Let an initial pair $\left(w_s^0, w_u^0\right)$ be at point P_0 in Figure 1, and a second pair $\left(w_s^1, w_u^1\right)$ be at point P_1. It will be noted that, by (1) and (2), the slope of the tangent to the frontier at P_0 is $-\left(l_u^0/l_s^0\right)$ and its intercept with the w_s axis is $\left(\left(v_s^0+v_u^0\right)/l_s^0\right)$. The two pairs differ *both* in the values of the real wages and in the proportions between them. We can find, however, a hypothetical pair $\left(w_s^{01}, w_u^{01}\right)$ at point P_{01} which is a linear approximation of changing proportions along the initial frontier. Now let $\Delta w_{s,u} = w_{s,u}^1 - w_{s,u}^0$. It can be easily shown that

$$RCR = v_s^0 \frac{\Delta w_s}{w_s^0} + v_u^0 \frac{\Delta w_u}{w_u^0} = \left(v_s^0 + v_u^0\right) \frac{w_{s,u}^1}{w_{s,u}^{01}}$$

That is, for *any* discrete variation in the real wages, RCR as defined by (5) still approximates the radial expansion of the frontier multiplied by the share of value added.

Turning now back to (4), it is clear that $\left(\partial C/dT\right)$ is not observable; however RPI can be calculated from observable data. For discrete variations, we have

$$RPI = v_s^0 \frac{\Delta w_s}{w_s^0} + v_u^0 \frac{\Delta w_u}{w_u^0} + v_i^0 \left[\frac{\Delta p_i}{p_i^0} + \frac{\Delta t_i}{\left(1+t_i^0\right)}\right]$$

If the sum in the square brackets is negative (the intermediate input, at the buyer's price, is becoming relatively cheaper) then RPI is the part of *RCR* not accounted for by this source of cost reduction; if it is positive, then RPI *exceeds RCR* by the amount of real cost *increase* brought about by the increasing intermediate input price.

3. Some extensions

The above analysis assumed constant returns to scale. We may remark, however, that only *local*, not 'global', constant returns, are needed. In fact, we may reinterpret $c(\ )$ as an *indirect average cost function* (see, e.g., Silberberg, 1974, p. 735; also Steedman, 1998), calculated at the bottom of a U-shaped average cost curve, and the argument would run as in the case of strictly constant returns, the only difference being that we could determine the long-run output level of the firm as a function of all the parameters and the real wages.

It is not difficult to introduce a positive and variable rate of interest (r) on circulating capital. The rental price of the commodity input becomes $(1+r)(1+t_i)p_i$ and this replaces $(1+t_i)p$ in (1) and (2). The share of the intermediate input *including interest* is $v_i = (1+r)(1+t_i)p_i a_i$. Equation (3) becomes

$$0 = v_s \frac{dw_s}{w_s} + v_u \frac{dw_u}{w_u} + v_i \left[\frac{dr}{(1+r)} + \frac{dt_i}{(1+t_i)} + \frac{dp_i}{p_i} \right] - RPI \qquad (3')$$

Equation (4) remains unaffected, while (5) becomes

$$RCR = v_s \frac{dw_s}{w_s} + v_u \frac{dw_u}{w_u} + v_i \frac{dr}{(1+r)} \qquad (5')$$

Of course, the frontier now becomes a 'real wage-rate of interest frontier'; but is has very similar properties as the two-dimensional frontier discussed in the previous Section. In particular, we notice that $\partial c/\partial r = (1+t_i)p_i a_i$, which is the value of the intermediate input per unit of output (at the purchaser's price). It follows that, for discrete changes, (5') still approximates the expansion of the frontier on a ray.

Similar reasoning can be referred, *under highly simplifying assumptions*, to interest on fixed capital. Let us assume that the industry uses only one durable capital good, subject to a geometric rate of depreciation δ (as assumed in Jorgenson, Ho and Stiroh, 2005, Chapter 5). Denoting by p_k the (parametric) price of the capital good and by k its cost minimizing use per unit of output, the 'real' annuity per unit of output (equal to the share of property compensation) will be $v_k = (\delta + r) p_k k$. For simplicity, we make the heroic assumption that both δ and p_k are not only parametric but also constant; moreover, contrary to the previous paragraph, we assume that no interest allowance is charged on the *intermediate* input. Reformulating the unit cost function with the inclusion of the rental price of fixed capital, $(\delta + r) p_k$, and noting that $(\partial c / \partial r) = p_k k$, (3) now becomes

$$0 = v_s \frac{dw_s}{w_s} + v_u \frac{dw_u}{w_u} + v_k \frac{dr}{(\delta + r)} + v_i \left[\frac{dp_i}{p_i} + \frac{dt_i}{(1+t_i)} \right] - RPI \qquad (3'')$$

By the assumption of constant δ and p_k (4) remains the same, while (5) becomes

$$RCR = v_s \frac{dw_s}{w_s} + v_u \frac{dw_u}{w_u} + v_k \frac{dr}{(\delta + r)} \qquad (5'')$$

Everything we said so far is subject to the condition that p_i and p_k are completely independent of the changes taking place in the industry under consideration, as if the latter belonged to a small open economy facing given terms of trade. Removing this assumption would introduce much more substantial complications, of course. For the relative prices could no longer be treated parametrically: if the input-producing industries, too, make maximum profits of zero, then a change in wages and/or the rate of interest would naturally modify the relative commodity price(s) via changes in relative unit costs. Moreover, taxation changes and productivity increase in *other* *industries* would have an independent effect on relative prices; and so on. It would be beyond the scope of this paper, however, to take all this into account. We shall limit ourselves, therefore, to a simplified framework in which competition exerts its full effects on the industry under consideration, by eliminating profits or losses, in the presence of shocks either internal or external to the industry, but the industry itself does not feed back to the other industries. Apart from noting that this practice is not uncommon in industry-level empirical studies, including *TFP* accounts, we justify the above assumption on the ground of the necessary gradualness and simplicity in conveying some new ideas. The reader wishing to envisage some implications of a fuller analysis (albeit restricted to circulating capital) is referred to Opocher and Steedman (forthcoming, Chapters 7-9).

4. An empirical illustration

We now present some results from the application of the price accounting methodology described in the previous Sections. This exercise has the primary purpose to illustrate our approach for some selected industries.

We derive the following empirical specification of (3''):

$$\sum_l \left(\frac{dw_l}{w_l}\right) v_l + \left(\frac{dr}{\delta + r}\right) v_k = -\sum_i \left(\frac{dp_i}{p_i}\right) v_i - \sum_i \left(\frac{dt_i}{1+t_i}\right) v_i + RPI \qquad (6)$$

where the subscript $l = s,u$ denotes the two types of labour input (skilled and unskilled) and $i = g,e,s$ refers to the category of intermediate inputs (intermediate goods, energy and services). w_l and p_i denote the hourly wage and the producer price index of intermediate inputs, respectively, *as deflated* using the industrial producer price index (PPI, for later reference): they have therefore the nature of 'relative' or 'real' prices in terms of the industrial output. Wages are industry-specific, while the price of each kind of intermediate input is assumed to be identical across industries. The time and industry subscripts have been omitted for simplicity. The real rate of interest r is calculated on long-term maturity corporate bonds and is given by:

$$r = \rho - \frac{dPPI}{PPI}$$

where ρ is the nominal interest rate at time t and $dPPI/PPI$ is the growth rate of the industry-specific producer price index between *t-1* and *t*. Finally, as in the previous Sections, δ is the capital depreciation rate, t_i is the tax rate on intermediate products and *RPI* denotes the industry rate of productivity increase.

The terms on the left-hand side of equation (6) represent the outcomes of *RCR* (labour and capital compensations), while those on the right-hand side denote the sources of *RCR* (terms of trade effects, taxation effects and rate of productivity increase). Following Jorgenson, Ho and Stiroh (2005), all the observable terms are weighted by a two-period average value share of the input in the nominal value of the output. At each time *t* the value shares of labour and intermediate inputs are defined as:

$$v_l = \frac{w_l H_l}{pQ}; v_i = \frac{p_i A_i}{pQ},$$

where $w_l H_l$ is the labour compensation, $p_i A_i$ is the value of intermediate inputs at purchaser's prices and pQ is the value of the output at 'basic prices' (i.e. inclusive of the subsidies received by the producer) . Under the assumption of (local) constant returns to scale, the capital share is derived as $v_k = 1 - v_l - v_i$. It need hardly be said that, by abuse of notation, v_l, v_i, v_k here do *not* denote *two-period moving averages* as in (3) to (6).

The analysis is referred to the United Kingdom over the period 1998-2007. This limited time span is due both to constraints in the data availability of the service producer price index[3] and to the exclusion, for obvious reasons, of the years of the Great Recession. We select two industries from the manufacturing sector, classified according to the NACE nomenclature of economic activities:

[3] We thank the Office for National Statistics (ONS) for making the data available.

manufacture of electrical and optical equipment (subsection DL) and the manufacture of transport equipment (subsection DM) (the divisions which belong to these subsections are shown in the Appendix). In order to emphasize the role of the intermediate inputs and of the change in their relative price, we have selected two industries in the manufacturing sector among those with the highest level of intermediate consumption in the initial years.

Our data come from different sources. From Eurostat we obtain the number of employed individuals aged 16-64 by industry. We then derive the number of employed by labour type by estimating the proportion of skilled and unskilled workers in each industry at each time period using data from the UK Labour Force Survey (LFS)[4]. Skilled workers are defined as those who attained a first or second stage of tertiary education (level of 5 or 6 of the International Standard Classification of Education, ISCED). The LFS is also used to estimate average hourly wages and average annual hours worked by labour type at the industry level, which in turn are used to compute the labour compensation.

From the World Input-Output Database (WIOD) we obtain the use tables for the UK. These are matrices by product and industry which allow to analyse in detail the use of industrial intermediate consumption (see Timmer et al., 2012). For the two industries under consideration, we derive the time series of the output at basic prices, products used as intermediate inputs, and net taxes on these products (taxes minus subsidies). Following the same distinction that EU KLEMS accounts make, we group intermediate inputs into three categories: intermediate goods ('materials'), energy and services.

Data on the industrial producer price index (PPI) in the manufacture of electrical and optical equipment and the manufacture of transport equipment are derived from the Eurostat database. This index, which is available only for some selected activities[5], measures changes in the prices of products from the point of view of the manufacturer. The PPI is also computed by Main Industrial

[4] We thank the UK Data Archive for making the data available.

[5] Mining and quarrying (Section C), Manufacturing (Section D); Electricity, gas and water supply (Section E) of the NACE classification.

Groupings (MIGs). We use the price index of the MIG "Intermediate goods" to measure price changes of the namesake category. From the Organization for Economic Co-operation and Development (OECD) database we derive the time series of the producer price index for the MIG "Energy", while the Office for National Statistics (ONS) provided us with data on the service producer price index.

Next, from the FRED (Federal Reserve Economic Data) of the Federal Reserve Bank of St. Louis we derive data on US corporate bonds with remaining term to maturity greater than or equal to 10 years and less than 15 years[6]. We take this value as a proxy of international bond market conditions.

Finally, we set the depreciation rate δ equal to 0.15. This choice is based on the geometric depreciation rates by asset type employed in Jorgenson, Ho and Stiroh (2005, Chapter 5). Some ICT assets, such as computers equipment and software, have a very high depreciation rate (0.315) compared to those non-ICT, such as metalworking machinery (0.1225) or special industry machinery, n.e.c[7] (0.1031). Other assets, such as industrial buildings, present as expected even smaller numbers (0.0314). In the absence of aggregate values at the industry level, we deem that 0.15 is a reasonable average, although results under alternative scenarios will be also considered.

Some broad stylized facts can be inferred from the change over time of the main variables in the two industries (Table 1). Over the entire period, the nominal hourly wages of unskilled labour increased at about the same rate (nearly 45%) in the two industries, whereas the nominal hourly wages of skilled labour increased some 32% in the electrical and optical industry and some 47% in the transport industry; the real burden of interest on fixed capital decreased in both industries, (albeit at different rates); the nominal prices of all intermediates (and notably energy) increased; finally taxation changes have been broadly neutral in both industries, and perhaps more favourable in the transport industry. At the same time, the producer price index of the first industry *fell* some

[6] We consider the time series of the "BofA Merrill Lynch US corporate 10-15 year effective yield".
[7] Not elsewhere classified.

33% and that of the second industry remained roughly flat. It follows that i) both industries were able to pay increasing real wages and increasing real intermediates' prices; ii) such an increase was (much) bigger in the first industry; iii) the price index of electrical and optical equipment, fell relative to that of transportation equipment. These broad facts suggest that a) there should have been some productivity increase in both industries, and b) the rate of productivity increase should have been higher in the first industry than in the second.

In order to calculate the two rates of productivity increase, one should weight each percentage change in 'real' prices, wages and interest by their respective shares in total cost, according to the conceptual framework developed in Sections 2 and 3. Such shares reflect the structure of costs in the two industries and its evolution though time. Table 2 displays the two-period moving average of such shares; we note that the share of skilled labour has a marked tendency to increase in both industries and that of capital has a marked tendency to decrease, the other shares remaining broadly constant.

In Table 3 we organize the *weighted* percentage change of all variables in the two groups of 'outcomes' and 'sources' of Real Cost Reduction. The definition of the rate of productivity increase as a residual guarantees consistency of the two groups. Over the entire period, the substantial outcome of *RCR* is in terms of labour compensation, whereas intermediates have been a *negative* source, making for real cost *increase* (to a higher rate in the electrical and optical industry): this is why *RPI* exceeds *RCR* in both industries and notably in the electrical and optical industry. Our calculations also confirm a (much) greater *RPI* in the electrical and optical industry.

Table 4 compares *RPI* values in the baseline case (δ =0.15) with two alternative scenarios (δ =0.10 and δ =0.20). As the reader will note, in most of the cases the differences are very small. The last two columns report the *TFP* estimates, both output and value added based, from EU KLEMS data[8]. In some years *TFP* growth is negative for both industries, a figure which is

[8] TFP output based growth is derived from March 2008 release; TFP value added based growth is taken from November 2009 release, updated March 2011.

particularly striking given the industries under consideration. On the contrary, *RPI* values are always positive as one would expect. Our *RPI* calculations are on average higher than the output-based *TFP* and display less variability than the value added version.

5. Concluding remarks

The inter-industry diversity in productivity increase stimulated many studies on the industrial sources of economic growth. Much less efforts have been devoted to the study of the industrial sources of real income increase. Albeit from the standpoint of the economic system these aspects are two sides of the same coin, one can consistently trace back an observable change in real wages (in terms of a certain output) and in capital compensation to its industrial sources only by using data on prices, wages etc. and by fitting them into a 'price-accounting' scheme of the industry. If one is to capture the *long-run* aspects of such sources under competition, then an equality between price and minimum average cost (inclusive of interest allowances) should be postulated. The conceptual framework presented in this paper is centered around the notion of 'Real Cost Reduction', its breakdown into components, and its outcome in terms of increasing labour and capital compensations. Aiming in this paper more at simplicity than generality, we assumed all commodity prices to be parametric from the standpoint of a certain industry and we drastically simplified the treatment of fixed capital.

The results for two selected British manufacturing industries in 1998-2007 should be considered as mere *illustrations* of our conceptual framework and a means for testing the adequacy of the available data. We stress in particular the variety of the required data sets which however, in some cases, may shorten the time series. The application of adequate filters, which would be highly advisable given our emphasis on the long-run, would only exacerbate this problem.

Having said that, some qualitative indications do emerge from our calculations of the industrial *RPI*, as compared to the EU KLEMS calculations of *TFP* growth, if only as hints for further research. First, both *RPI* and *TFP* growth are higher in the 'Manufacture of electrical and optical equipment' than in 'Manufacture of transport equipment' in (almost) all years (as expected), but *RPI* do *not* have negative terms and is generally *higher* in the former industry than *TFP* growth in the gross-output version and much more stable than *TFP* growth in the value-added version. Perhaps this divergence can be explained by a better accounting of 'relative price effects' and 'taxation effects'? Since negative *TFP* growth (especially in well-performing industries) has always been considered a 'problem', more empirical evidence based on 'price accounting' may be helpful.

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Table 1: Main variables (percentage annual rates of change)

Industry	Period	Nominal wages skilled	Nominal wages unskilled	Industry-specific PPI	PPI intermediate goods	PPI energy	PPI services	Tax rate intermediate goods *dt/(1+t)*	Tax rate energy *dt/(1+t)*	Tax rate services *dt/(1+t)*	Real interest rate $dr/(\delta+r)$
Manufacture of electrical and optical equipment	1998-1999	-3.597	6.380	-6.997	-2.780	4.704	0.199	0.112	-1.004	0.078	.
	1999-2000	9.757	3.632	-7.900	1.315	11.314	1.444	-0.198	-1.229	0.046	5.982
	2000-2001	11.775	7.319	-7.706	0.254	-0.598	2.623	0.369	-0.394	-0.067	-3.610
	2001-2002	-0.514	7.393	-2.274	-0.093	-5.263	1.713	0.365	0.053	-0.104	-18.583
	2002-2003	2.474	-0.964	-3.607	2.017	1.905	2.513	0.260	0.904	0.013	-0.279
	2003-2004	7.166	11.521	-5.592	2.409	12.773	1.695	0.215	2.812	-0.062	8.048
	2004-2005	-2.894	6.129	-1.993	3.106	38.122	2.564	0.174	-2.132	-0.006	-13.974
	2005-2006	10.987	-6.733	-0.361	3.248	22.300	2.775	-0.037	-0.770	-0.002	-4.724
	2006-2007	-4.987	4.793	-1.825	4.179	-0.818	2.968	-0.368	-0.373	0.178	7.073
	Av. change	**3.352**	**4.386**	**-4.251**	**1.517**	**9.382**	**2.055**	**0.099**	**-0.237**	**0.008**	**-2.508**
	Tot. change	**32.314**	**45.564**	**-32.597**	**14.308**	**111.324**	**20.051**	**0.893**	**-2.191**	**0.073**	**-21.354**
Manufacture of transport equipment	1998-1999	16.283	10.905	1.161	-2.780	4.704	0.199	0.099	-0.446	-0.045	.
	1999-2000	-3.683	-0.808	-2.417	1.315	11.314	1.444	-0.144	-0.164	0.145	21.059
	2000-2001	-0.521	1.857	-0.422	0.254	-0.598	2.623	0.165	-0.874	-0.061	-11.477
	2001-2002	6.005	6.872	0.183	-0.093	-5.263	1.713	0.126	-0.062	-0.155	-3.139
	2002-2003	6.862	2.696	-3.135	2.017	1.905	2.513	0.160	0.634	-0.054	8.811
	2003-2004	1.347	6.350	0.083	2.409	12.773	1.695	0.013	-0.370	0.053	-13.750
	2004-2005	-0.416	-3.533	0.720	3.106	38.122	2.564	0.029	-4.085	-0.064	-3.363
	2005-2006	7.159	14.866	1.348	3.248	22.300	2.775	0.051	-0.570	-0.008	-0.292
	2006-2007	7.555	-0.159	1.041	4.179	-0.818	2.968	-0.088	0.929	0.110	1.813
	Av. change	**4.510**	**4.338**	**-0.160**	**1.517**	**9.382**	**2.055**	**0.046**	**-0.556**	**-0.009**	**-0.042**
	Tot. change	**46.810**	**44.695**	**-1.533**	**14.308**	**111.324**	**20.051**	**0.410**	**-4.977**	**-0.080**	**-4.433**

Notes: the total percentage rate of change reported in the last column refers to the period 1999-2007 instead of 1998-2007. This comes from the fact that the first year for which the real interest rate, r, is computed is 1999.

Table 2: Two-period average input shares

Industry	Period	Labour shares		Intermediate inputs shares			Capital share
		Skilled	Unskilled	Goods	Energy	Services	
Manufacture of electrical and optical equipment	1998-1999	0.094	0.142	0.361	0.012	0.261	0.130
	1999-2000	0.084	0.132	0.369	0.011	0.267	0.138
	2000-2001	0.101	0.136	0.375	0.011	0.277	0.099
	2001-2002	0.111	0.149	0.371	0.012	0.283	0.073
	2002-2003	0.121	0.154	0.365	0.013	0.277	0.070
	2003-2004	0.135	0.161	0.359	0.013	0.263	0.070
	2004-2005	0.146	0.169	0.353	0.015	0.255	0.062
	2005-2006	0.161	0.164	0.344	0.018	0.259	0.053
	2006-2007	0.156	0.149	0.340	0.018	0.263	0.074
Manufacture of transport equipment	1998-1999	0.059	0.155	0.460	0.013	0.225	0.087
	1999-2000	0.068	0.167	0.453	0.013	0.231	0.068
	2000-2001	0.069	0.161	0.447	0.013	0.241	0.069
	2001-2002	0.068	0.156	0.451	0.012	0.239	0.074
	2002-2003	0.068	0.150	0.452	0.014	0.244	0.072
	2003-2004	0.063	0.142	0.454	0.015	0.249	0.077
	2004-2005	0.065	0.133	0.460	0.016	0.248	0.077
	2005-2006	0.074	0.134	0.460	0.019	0.252	0.061
	2006-2007	0.084	0.139	0.461	0.019	0.252	0.045

Table 3 : Outcomes and Sources of Real Cost Reduction (annual proportional rates of change)

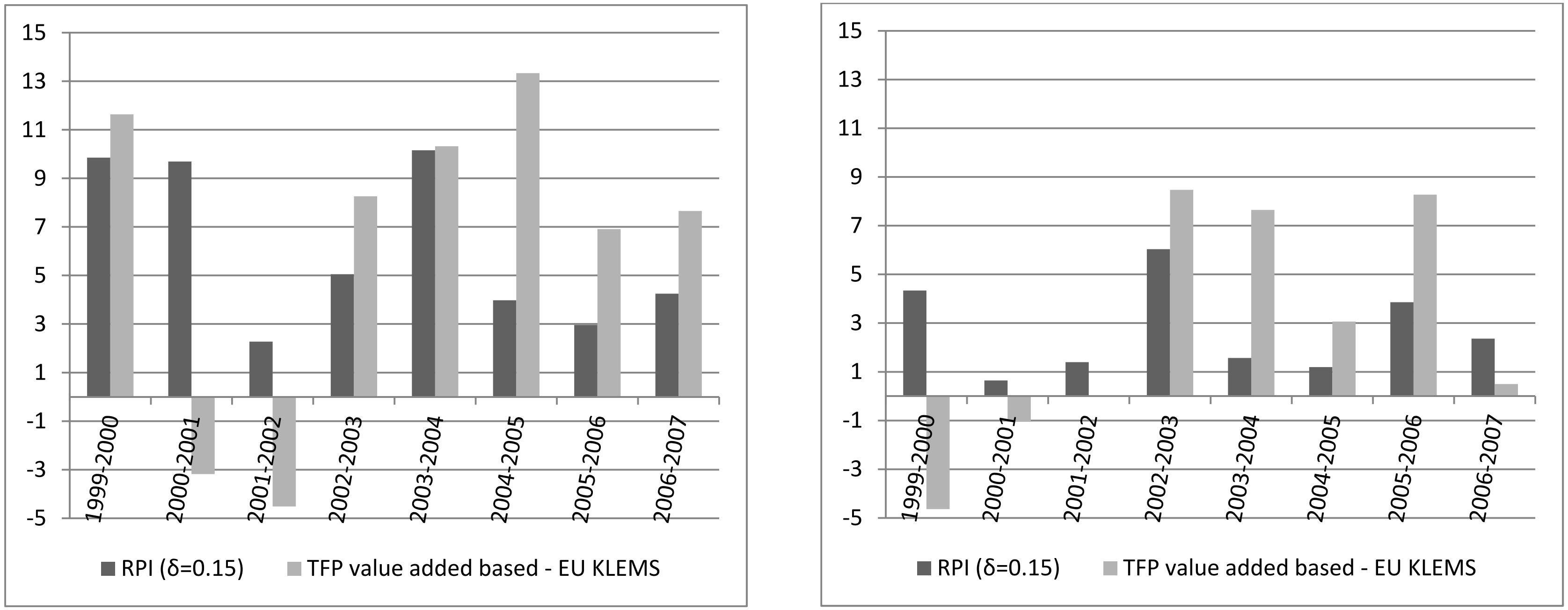
Industry	Period	Skilled labour compensation	Unskilled labour compensation	Capital compensation (δ=0.15)	Total outcomes	Contribution of the relative price of intermediate goods	Contribution of the relative price of energy	Contribution of the relative price of services	Contribution of taxation intermediate goods	Contribution of taxation energy	Contribution of taxation services	Rate of productivity increase (RPI)	Total sources
Manufacture of electrical and optical equipment	1999-2000	1.474	1.520	0.823	3.818	-3.404	-0.212	-2.490	0.073	0.014	-0.012	9.851	3.818
	2000-2001	1.966	2.039	-0.359	3.645	-2.986	-0.081	-2.865	-0.138	0.004	0.019	9.692	3.645
	2001-2002	0.196	1.438	-1.365	0.269	-0.809	0.037	-1.128	-0.135	-0.001	0.029	2.276	0.269
	2002-2003	0.736	0.408	-0.020	1.124	-2.054	-0.070	-1.694	-0.095	-0.012	-0.004	5.052	1.124
	2003-2004	1.720	2.748	0.564	5.032	-2.870	-0.240	-1.915	-0.077	-0.037	0.016	10.153	5.032
	2004-2005	-0.132	1.376	-0.864	0.380	-1.798	-0.609	-1.162	-0.061	0.032	0.001	3.977	0.380
	2005-2006	1.831	-1.047	-0.252	0.531	-1.241	-0.399	-0.814	0.013	0.014	0.000	2.958	0.531
	2006-2007	-0.492	0.988	0.525	1.020	-2.040	-0.019	-1.259	0.125	0.007	-0.047	4.253	1.020
	Av. change	**0.912**	**1.184**	**-0.119**	**1.978**	**-2.150**	**-0.199**	**-1.666**	**-0.037**	**0.003**	**0.000**	**6.027**	**1.978**
	Tot. change	**7.464**	**9.007**	**-2.508**	**13.963**	**-15.683**	**-1.920**	**-12.536**	**-27.119**	**1.780**	**0.123**	**69.318**	**13.963**
Manufacture of transport equipment	1999-2000	-0.087	0.268	1.427	1.609	-1.689	-0.183	-0.892	0.065	0.002	-0.033	4.340	1.609
	2000-2001	-0.007	0.368	-0.795	-0.434	-0.302	0.002	-0.733	-0.074	0.011	0.015	0.647	-0.434
	2001-2002	0.396	1.042	-0.234	1.204	0.125	0.068	-0.365	-0.057	0.001	0.037	1.395	1.204
	2002-2003	0.677	0.876	0.637	2.190	-2.331	-0.069	-1.376	-0.072	-0.009	0.013	6.034	2.190
	2003-2004	0.080	0.888	-1.059	-0.091	-1.055	-0.189	-0.402	-0.006	0.005	-0.013	1.569	-0.091
	2004-2005	-0.073	-0.567	-0.260	-0.901	-1.098	-0.610	-0.458	-0.013	0.067	0.016	1.195	-0.901
	2005-2006	0.428	1.811	-0.018	2.221	-0.875	-0.391	-0.360	-0.023	0.011	0.002	3.858	2.221
	2006-2007	0.549	-0.167	0.082	0.463	-1.446	0.035	-0.485	0.041	-0.017	-0.028	2.364	0.463
	Av. change	**0.245**	**0.565**	**-0.027**	**0.783**	**-1.084**	**-0.167**	**-0.634**	**-0.017**	**0.009**	**0.001**	**2.675**	**0.783**
	Tot. change	**2.245**	**5.085**	**-1.181**	**6.149**	**-9.350**	**-1.619**	**-5.307**	**-14.372**	**7.050**	**0.829**	**28.917**	**6.149**

Table 4: Rate of Productivity Increase (RPI) and Total Factor Productivity (TFP)

Industry	Period	Rate of productivity increase (RPI) (δ=0.15)	Rate of productivity increase (RPI) (δ=0.10)	Rate of productivity increase (RPI) (δ=0.20)	TFP (gross output based) growth from EU KLEMS	TFP (value added based) growth from EU KLEMS	Total sources
Manufacture of electrical and optical equipment	1999-2000	9.851	10.021	9.730	3.823	11.640	3.818
	2000-2001	9.692	9.623	9.742	-1.099	-3.179	3.645
	2001-2002	2.276	2.001	2.473	-1.495	-4.513	0.269
	2002-2003	5.052	5.047	5.056	2.704	8.259	1.124
	2003-2004	10.153	10.301	10.057	3.066	10.325	5.032
	2004-2005	3.977	3.772	4.115	0.116	13.334	0.380
	2005-2006	2.958	2.886	3.004	N.A.	6.909	0.531
	2006-2007	4.253	4.412	4.153	N.A.	7.659	1.020
	Av. change	**6.027**	**6.008**	**6.041**	**1.186**	**6.304**	**1.978**
	Variance	**10.982**	**11.696**	**10.519**	**5.268**	**43.859**	**3.529**
	Tot. change	**69.318**	**68.798**	**69.685**	**7.192**	**60.801**	**13.963**
Manufacture of transport equipment	1999-2000	4.340	4.786	4.065	-1.372	-4.638	1.609
	2000-2001	0.647	0.452	0.777	-0.328	-1.054	-0.434
	2001-2002	1.395	1.329	1.438	-0.003	0.033	1.204
	2002-2003	6.034	6.224	5.915	2.303	8.474	2.190
	2003-2004	1.569	1.286	1.754	2.177	7.648	-0.091
	2004-2005	1.195	1.111	1.246	0.634	3.063	-0.901
	2005-2006	3.858	3.852	3.862	N.A.	8.278	2.221
	2006-2007	2.364	2.392	2.348	N.A.	0.501	0.463
	Av. change	**2.675**	**2.679**	**2.676**	**0.568**	**2.788**	**0.783**
	Variance	**3.530**	**4.235**	**3.138**	**2.099**	**24.127**	**1.441**
	Tot. change	**28.917**	**28.672**	**29.090**	**3.406**	**23.613**	**6.149**

Notes: the total percentage rate of change for the output-based TFP refers to the period 1999-2005 instead of 1999-2007 due to data availability.

Figure 2: Rate of Productivity Increase (RPI) and Total Factor Productivity (TFP)



Notes: Manufacture of electrical and optical equipment (left) and manufacture of transport equipment (right)

Appendix: Industry description

Subsection DL: Manufacture of electrical and optical equipment	
Division	Description
30	Manufacture of office machinery and computers
31	Manufacture of electrical machinery and apparatus n.e.c
32	Manufacture of radio, television and communication equipment and apparatus
33	Manufacture of medical, precision and optical instruments, watches and clocks
Subsection DM: Manufacture of transport equipment	
34	Manufacture of motor vehicles, trailers and semi-trailers
35	Manufacture of other transport equipment

Abstract. The inter-industry diversity in productivity increase stimulated many studies on the industrial sources of economic growth. Much less efforts have been devoted to the study of the industrial sources of real income increase. Albeit from the standpoint of the economic system these aspects are two sides of the same coin, one can consistently trace back an observable change in real wages (in terms of a certain output) and in capital compensation to its industrial sources only by using data on prices, wages etc. and by fitting them into a consistent 'price-accounting' scheme of the industry. The conceptual framework presented in this paper is centered around the notion of 'Real Cost Reduction', its breakdown into components, and its outcome in terms of increasing labour and capital compensations. We also provide an illustration of the data sets required, of the qualitative results that can be obtained, and of some practical problems that need to be solved in order to extend the analysis and to compare its quantitative results with those of conventional industrial *TFP* analysis.