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This paper addresses an important topic. Growth accounting is a fundamental exercise in macroeconomic analysis. It informs us on the sources of growth in a particular country over the medium and the long run. It also highlights the interplay between technological innovations, productivity growth and output growth.

But good growth accounting requires proper measurement of quality improvements. Quality improvements are difficult to measure and this usually proves a major headache for national statistical agencies.

This paper proposes new estimates of euro-area quality-adjusted capital stocks for five disaggregated asset categories. The quality adjustment are constructed by using quality-adjusted price indices obtained from the recent study by Cummins and Violante (2003).

The findings prove quite interesting: properly measured, quality-adjusted capital stocks grew twice as fast in the Euro area between 1980 and 2000 (6% versus 3% unadjusted), quality-adjusted output grew faster by sizeable 0.46% per annum over the same period, and finally, the contribution of aggregate TFP to output growth decreased by 11% (from 79% to 68%).

Taken together, the author’s findings demonstrate that quality adjustment matter for the overall growth estimates as well as the analysis of the sources of growth.

The particular form of quality adjustment adopted here –the use of U.S. based quality-adjusted price-indices implies that the results should be interpreted as tentative, while a definitive answer will have to await the production of Euro-area based price indices. Nonetheless, as the authors stress in the paper, the capital goods subject to quality improvements are all traded goods. While one should not expect the Law of One Price (LOP) to hold exactly, there is also no good reason to expect deviations from LOP to have changed systematically over the period considered.

The basic effects of investment good specific quality-changes can be best appreciated by going back to the standard growth accounting framework set forth by Domar (1961). Denoting \( \dot{x} \) the growth rate of variable \( x \), we obtain the following equation:

\[
\dot{Y} - \dot{l} = \sum_{j} \alpha_j \left( \dot{K}_j - \dot{l} \right) + TFP
\]

Where \( Y \) denotes quality-adjusted output and \( l \) denotes labor input (typically total hours). This formula emphasizes that labor productivity growth (the left hand side of the equation) consists of two terms. The first term on the right hand side represents capital deepening, with \( \dot{K}_j \) representing the growth rate of capital stock of type \( j \) and \( \alpha_j \) the
The income share of capital, $r_j K / pY$. The second represents Total Factor Productivity (TFP). The TFP term can be further broken down into sectoral TFP as follows:

$$TFP = \sum_i \mu_i TFP_i$$

Where TFP\(_i\) represents the TFP of sector i and \(\mu_i\) represents the quality-adjusted income share of sector i, \(p_i Y_i / pY\). Note that this formula sums over both final goods and services sectors as well as intermediate sectors so that the sum of the \(\mu_i\) in general exceeds 1. In fact, this grossing up is necessary if we want to account for TFP growth in intermediate sectors.

In such a framework, embodied technical change means that some sectors—say sector j—experience faster productivity growth, TFP\(_j\) > TFP\(_i\). An essential question is how one would measure sectoral TFP growth, TFP\(_j\). A standard method, called the ‘dual approach’ looks at the cost function and expresses the rate of change of industry specific prices as a function of input prices and industry TFP:

$$\dot{p}_j = \beta_i \dot{w} + \sum_k \beta_{jk} \dot{r}_k - TFP_j$$

where \(\beta_i = w l_j / p_j Y_j\) represents the labor share in sector j, while \(\beta_{jk}\) represents the income share of capital good k in sector j. This expression makes clear that faster TFP growth, for given input prices, leads to faster price declines.

In fact, if the labor and capital shares are equal across sectors, then observing industry price indices provides an estimate of TFP differences relative to some numeraire industry:

$$\dot{p}_j - \dot{p}_0 = TFP_0 - TFP_j$$

To sum up, investment specific technical change generates complex effects on output growth and labor productivity. First, it directly increases aggregate TFP in proportion to the size of the sector in aggregate output. According to the cost equation, it also leads to a decline in the relative price of that investment good, and therefore to an increased use of that type of capital in other industries. The associated increased in \(\tilde{K}_j\) leads to further capital deepening and output growth.

From the preceding discussion, it is clear that accurate measurement of prices is critical to the analysis. And this is where quality adjustments come into play.

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1 One can also allow for changes in labor quality by adding a term \(\alpha_i \dot{q}_h\) where \(\dot{q}_h\) measures the rate of change of labor quality.
Consider the case of the computer industry and suppose that computer specific technical change takes the form that twice as many computers can be produced this year from the same resources used to produce last year’s identical computers. In that case, the price of computers would be halved. A statistical agency that observes the nominal amount spend on computers p_j Y_j together with the price of computers p_j would have no problem computing the real quantity of computers produced in the current year and the associated TFP.

Suppose alternatively that this year’s computers are twice as productive as last year’s computers and as many computers are produced as last year. Computer prices would be unchanged and a statistical agency that observes nominal spending on computers and computer prices would conclude that there is no TFP and no change in the real quantity of computers.

Not adjusting capital leads to a number of biases. First, it leads to a direct underestimate of output and aggregate TFP by $\mu_j TFP_j$ coming from embodied TFP. Second, it leads to an underestimate of capital deepening by $\alpha_j TFP_j$ representing the mis-measurement in the capital stock, as well as an offsetting overestimate of aggregate disembodied TFP by the same amount. The overall effect on aggregate TFP is ambiguous and in general we should not expect it to vary much.

The results presented in the paper and reproduced in the table below support this analysis: quality adjusted output growth and capital growth are both higher while TFP increases modestly. Perhaps the most surprising result that emerges from the table is the extent of the decline in disembodied TFP (line 12) from the 1980s to the 1990s, from 1.61% to 0.82%. This decline of -0.79% explains more than 100% of the decline in output growth over that period and is larger than the decline in TFP in the unadjusted data (-0.58%).

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<tbody>
<tr>
<td>1 Output</td>
<td>2.97</td>
<td>2.49</td>
<td>2.34</td>
<td>1.90</td>
<td>-0.63</td>
<td>-0.59</td>
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<td>2 Capital growth</td>
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<td>3 IT hardware</td>
<td>0.11</td>
<td>0.07</td>
<td>0.11</td>
<td>0.08</td>
<td>0.00</td>
<td>0.01</td>
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<td>4 software</td>
<td>0.07</td>
<td>0.05</td>
<td>0.07</td>
<td>0.05</td>
<td>0.00</td>
<td>0.00</td>
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<td>5 communication equipment</td>
<td>0.08</td>
<td>0.05</td>
<td>0.12</td>
<td>0.05</td>
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<td>0.00</td>
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<td>6 other machinery and equ.</td>
<td>0.43</td>
<td>0.17</td>
<td>0.45</td>
<td>0.17</td>
<td>0.02</td>
<td>0.00</td>
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<td>7 transport equipment</td>
<td>0.04</td>
<td>0.05</td>
<td>0.12</td>
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<td>8 non residential</td>
<td>0.16</td>
<td>0.16</td>
<td>0.09</td>
<td>0.06</td>
<td>-0.07</td>
<td>-0.08</td>
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<td>9 Labor</td>
<td>-0.12</td>
<td>-0.12</td>
<td>-0.07</td>
<td>-0.07</td>
<td>0.05</td>
<td>0.05</td>
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<tr>
<td>10 TFP</td>
<td>2.20</td>
<td>2.04</td>
<td>1.45</td>
<td>1.46</td>
<td>-0.75</td>
<td>-0.58</td>
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<td>11 E&amp;S</td>
<td>0.59</td>
<td>0.63</td>
<td>0.63</td>
<td>0.46</td>
<td>0.04</td>
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<tr>
<td>12 Rest</td>
<td>1.61</td>
<td>0.82</td>
<td></td>
<td></td>
<td>-0.79</td>
<td></td>
</tr>
<tr>
<td>13 Quality (sum of 11 and revision in 3-7)</td>
<td>0.91</td>
<td>1.07</td>
<td></td>
<td></td>
<td>0.16</td>
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This decline in disembodied TFP is bad news for the Euro area. While some of it may be associated with the cyclical component of TFP and the recession of 1993, this is unlikely to account completely for slowdown of that size.

The second result, partly surprising, concerns the size of the gains associated with Equipment and Software (E&S). Line 13 reports the direct (TFP) and indirect (capital deepening) contributions of E&S. We can see a modest increase in the contribution of E&S (0.18%) while the decline in output growth stands at 0.63%.

In fact, both results indicate a general weakness of EU-area total factor productivity growth. Even though E&S contribution to growth goes up, it is surprising that it does not contribute more to total output growth, given the rapid decline in the prices of some of these capital components, especially in the Information and Communications Technology (ICT) industries that underly the strong productivity performance in the US.

In fact, one would wish for the paper to expand in the direction of more comparative work. I can see two dimensions for further research here. First, it would be interesting to present estimates for individual Euro countries. Clearly the authors have the necessary data to perform these calculations, although their Euro sample only consists of four countries, France, Germany, Italy, and the Netherlands. It would be interesting to know whether each of the individual euro-countries experienced similar reductions in disembodied TFP, and whether the breakdown between capital deepening and TFP is also similar.

The other dimension of interest would be a more comparison of the Euro area with the US. In recent years, the U.S. has experienced a ‘productivity revival’ while Euro area productivity growth has stalled. Mc Guckin and Ark (2004), for instance, find a decline in labor productivity of 1.0% between 1990-1995 and 1995-2000 in the euro area, compared to a U.S. labor productivity increase of 0.9% over the same periods (see their Table 1).

Is such difference for real, or does it reflect different measurement methodologies on both sides of the Atlantic? This paper could answer some of these questions by providing a consistent correction for quality adjustment on U.S. and Euro data.

Here, it is important to realize that most estimates for the US (such as Oliner and Sichel) use BLS price series to deflate capital stocks, and not the Cummins and Violante revision of Gordon (1990). Second, this paper proposes a break in 1990. But US productivity growth presents a clear break before and after 1995. Since this paper uses US prices, there should also be a break in embodied technological progress around the same date (one can in fact see such break in the paper’s chart 2).

Furthermore, the influential work of Oliner and Sicher (2000) for the US indicates the importance of ICT industries, with an overall contribution to the change in labor productivity of 0.95% (81% of labor productivity growth) (see Table 2). This number
should be contrasted with the meager 0.18% increase in output growth described above for the Euro-area.

The puzzle for Europe then is why quality-improvements --that manifest themselves mostly in the ICT sectors—do not play a more important role in output growth, as they do in the U.S.

I reiterate that the numbers are not directly comparable since (a) we do not look at the same period breaks, (b) the Oliner and Sichel data looks at labor productivity while this paper looks at output growth (c) Oliner and Sichel only analyzes non farm private output while this paper looks at total output, (d) Oliner and Sichel uses BLS price deflators and not the Cummins Violante quality adjusted prices and finally this paper look at a broader category of quality adjusted assets.

Nevertheless, this paper seems to indicate two possible avenues for understanding the lackluster productivity performance in the euro area since 1980. First, disembodied TFP collapsed by close to 0.8% between the 1980s and the 1990s. By contrast, disembodied TFP growth contributed 0.35% to the increase US labor productivity. Second, E&S contribution to output growth proved relatively small in Europe.

The paper opens with a reference to the Lisbon agenda. A proper assessment of growth policy should identify growth bottlenecks and growth engines. The comparison with the US using a common methodological framework, should prove very useful in that respect.

Such direct comparison would also help address the U.S. part of the productivity puzzle, that the contribution of ICT has remained very strong even after the collapse of the new economy bubble and the sharp drop in ICT investment post 2001.