Europe Economics

Europe Economics' Response to Oxera's Arguments on Embodied Technical Shift

30 April 2020

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1 Introduction

This note responds to a critique by Oxera of our analysis of embodied technical shift contained in our final PR19 report on real price effects (RPEs) and frontier shift (hereafter referred to as "our final PR19 report).[1]

Oxera argues that:

- Embodied technical shift represents movements to the efficiency frontier and therefore double-counts Ofwat's catch-up efficiency assumptions;
- Europe Economics' use of two academic papers to quantify the potential impact is flawed; and
- A downward correction can be considered to TPF growth estimates, as they can include catch-up effects.

In the three sections of this note that follow, we respond to each of these arguments in turn.

[1] Europe Economics, "Real Price Effects and Frontier Shift – Final Assessment and Response to Company Representations", 7 December 2019

2 Embodied Technical Shift and Catch-up Efficiency

2.1 Oxera's argument

Oxera states the following:

> Embodied technical change represents movements towards the efficiency frontier and encapsulates managerial efficiency, industrial organisation, diffusion of new technology, learning effects, etc., whereas disembodied technical change refers to shifts in the known efficiency frontier due to technological progress. Ofwat explicitly measures movements towards the known efficiency frontier using its cost models and, through these, determines efficiency targets for the water companies. Adjusting the frontier shift estimate for 'embodied' technical change is in essence double-counting the potential effect of efficiency change.

A footnote after their first sentence references a paper by Mahadevan published in a journal called Oxford Development Studies. This paper equates embodied technical change to technical efficiency (on p.366), and later states "Technical efficiency represents a movement towards the frontier and refers to the efficient use of inputs and technology due to the accumulation of knowledge in the learning-by-doing process, diffusion of new technology, improved managerial practice etc" (p.372).

2.2 Europe Economics' response

We note first of all that the article that Oxera relies on is taken from a little-known journal. It is therefore far from being a top-level academic source.

Oxera and Mahadevan's assertion that disembodied technical change equates to frontier shift and embodied technical change equates to catch-up efficiency is simply wrong. In particular:

- Disembodied technical change cannot be equated just with frontier shift. Providing that capital and labour inputs have been appropriately quality adjusted, TFP represents only disembodied technical change. It can be shown theoretically that TFP can be decomposed into frontier shift, catch-up efficiency and scale effects, as discussed in Section 3.5 of our final PR19 report. Hence, at a theoretical level, disembodied technical change can include catch-up efficiency as well as frontier shift.
- Embodied technical change cannot be equated just with catch-up efficiency. Embodied technical shift is about better inputs (e.g. better machinery, more educated labour force). The use of these better inputs could in theory be either catch-up efficiency (e.g. if firms are catching up with more efficient peers who were already using better machines) or frontier shift (e.g. if a frontier firm starts to use new machines which embody a new technology).

Further, some of the factors listed by Oxera and Mahadevan are nothing to do with the technical change embodied in capital inputs, which is what our argument focused on. In particular:

- Managerial efficiency can either be seen as an element of disembodied technical change (e.g. if it relates to better company processes) or as technical change embodied in labour (e.g. if a company hires more managers as a proportion of its labour force). In either case, it has nothing to do with better capital inputs.
- Similarly, learning by doing relates to labour inputs rather than capital inputs.

In contrast to the incorrect definition of embodied technical change put forward by Oxera and Mahadevan, here is the definition of embodied and disembodied technical shift put forward by the Organisation for Economic Co-operation and Development (OECD):[2]

> Embodied technological changes are advances in the design and quality of new vintages of capital and intermediate products: machinery and equipment embody the fruits of research performed by the capital goods-producing industry, and other sectors obtain access to the outcome of this research through the purchase of new capital equipment or intermediate goods. Disembodied technical change, on the other hand, relates to the advances in science, to blueprints and formulae and to the diffusion of knowledge of how things are done, including better management and organisational change.

It is clear from this definition that embodied technical change is not the same thing as movements towards the efficiency frontier. Hence, Oxera's argument is based on a false definition of embodied technical change.

We note that another consultancy advising the water industry (NERA) has conceded that TFP data understates frontier shift due to embodied technological change. In particular, NERA states:[3]

> … we agree this factor may cause the EU KLEMS TFP series to understate true productivity growth

As discussed later in Section 4, the methodology we employed addressed the issue of catch-up efficiency by focusing on competitive sectors in which we would not expect catch-up efficiency gains. In the case of embodied technical change, the papers by Uri and Hulten[4] that we used to produce our indicative quantification of the uplift for embodied technical change used data respectively from the US non-residential business sector and US manufacturing industries, which one would expect to largely reflect competitive sectors. Further, the 60 per cent uplift for embodied technical change inferred from these studies was applied in our analysis to base TFP estimates from competitive sectors. Hence, we would expect the uplift for embodied technical shift that we calculated to represent frontier shift rather than catch-up.

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[2] OECD, "Measuring Productivity; OECD Manual; Measurement of Aggregate and Industry-Level Productivity Growth", 2001

[3] NERA, "Review of Ofwat's Proposed Approach to Frontier Shift, Real Price Effects and Output Growth at PR19; Prepared for Bristol Water", 30 March 2019

[4] Uri (1983), "Embodied and disembodied technical change and the constant elasticity of substitution production function". Journal of Applied Mathematical Modelling, Vol. 7(6), pp. 399-404 and Hulten (1992), "Growth Accounting When Technical Change is Embodied in Capital", The American Economic Review, Vol. 82, No. 4 (Sep., 1992), pp. 964-980.

3 Europe Economics' Quantification of Embodied Technical Shift

3.1 Oxera's argument

Oxera goes on to critique the methodology that we used to provide an illustrative quantification of the potential size of the embodied technical change that has not already been included in TFP. In particular, Oxera states:

> The quantification of the impact of quality on frontier shift by Europe Economics is flawed as it is based on isolated, limited research undertaken ten years apart and uses two different datasets to reach its conclusion that embodied technical change stemming from input quality changes could be as high as 60%.

Oxera then describes the two academic articles used in our quantification and how we combined key figures from these two articles to produce our illustrative estimate. However, Oxera does not provide any further detail on exactly why it considers that the approach that it is describing is flawed.

3.2 Europe Economics' response

As best we understand this critique, Oxera seems to be arguing that our approach was flawed because:

- It was based on limited research (i.e. only two academic articles);
- The articles we used were published ten years apart; and
- We combined results from the two articles.

In relation to the first point, we acknowledged the limited nature of the evidence that is available in our final PR19 report. In particular, we stated:

> The evidence base is limited on the issue of embodied technical change and, therefore, the evidence and analysis presented above should be seen only as illustrative of the potential magnitude of efficiency gains from embodied technical change that are excluded from traditional TFP estimates. [p.68]

In recognition of the limitations in the evidence, we did not quantitatively apply the uplift for embodied technical shift that we had calculated to our TFP estimates. Instead, we treated embodied technical change as a qualitative consideration which justified (along with evidence from GVA-based TFP growth) the selection of a point estimate from the upper end of our frontier shift range.

We do not consider the fact that the articles we used by Uri and Hulten were published ten years apart represents a flaw in our approach. There is no reason why results from articles with different publication dates must necessarily be incompatible. Hence, in our view, this represents a wholly spurious criticism on the part of Oxera.

We also consider that it is valid to combine evidence from different sources in order to produce an illustrative estimate of the embodied technical shift that is not already captured in TFP estimates. Uri (1983) shows empirically that embodied technical change is of roughly the same order of magnitude as disembodied technical change.[5] Hulten (1992) shows that 20 per cent of TFP represents embodied technical shift due to inadequate quality adjustment of capital inputs.[6] Taking these two sources together, we therefore infer that TFP would potentially have to be uplifted by 60 per cent to fully account for embodied technical shift (i.e. so that the 20 per cent of TFP already representing embodied technical shift and the 60 per cent uplift would together equate to the 80 per cent of TFP that represents disembodied technical shift, thus achieving the result that the two are equal in magnitude, as suggested by Uri's paper).

We note that the effect of combining results from the two papers is actually to reduce our estimate of the uplift required to account for embodied technical change. If we had instead relied solely on Uri (1983) and assumed that EU KLEMS has already fully accounted for changes in the quality of inputs (such that TFP estimates exclude all embodied technical change), then we would have concluded that embodied technical shift justified a 100 per cent uplift to TFP estimates.

Finally, we note that Oxera does not provide any alternative, better quantification of embodied technical shift.

[5] Uri (1983), "Embodied and disembodied technical change and the constant elasticity of substitution production function". Journal of Applied Mathematical Modelling, Vol. 7(6), pp. 399-404.

[6] Hulten (1992), "Growth Accounting When Technical Change is Embodied in Capital", The American Economic Review, Vol. 82, No. 4 (Sep., 1992), pp. 964-980.

4 Catch-up Efficiency and TFP Estimates

4.1 Oxera's argument

Oxera also says the following:

> Note that the TFP estimates can include catch-up effects as well (e.g. due to random short-term disequilibrium). Hence, a downward correction can be considered to the TFP estimates (rather than an uplift) to account for these effects, as was considered by the Competition Commission in the Bristol Water price inquiry.[7]

A footnote included by Oxera caveats the statement that "a downward correction can be considered to TFP estimates" by saying "Assuming efficiency improves on average".

4.2 Europe Economics' response

In passing, we note the inconsistency between Oxera's arguments. In its first argument (discussed in Section 2), it wrongly equates catch-up efficiency with embodied technical shift, which would mean that catch-up efficiency is excluded from TFP (provided adequate adjustments have been made for the quality of inputs). However, in this argument Oxera alters track and argues that catch-up efficiency is included within TFP.

Putting Oxera's inconsistency to one side, we would agree that conceptually TFP estimates can include catch-up efficiency. We discussed this fact in Section 3.5 of our final PR19 report, where we explained that positive TFP growth can be decomposed into frontier shift, changes in technical and allocative efficiency (i.e. catch-up efficiency), and scale effects.

However, Oxera has not acknowledged the fact that our frontier shift methodology addressed this issue by selecting comparator sectors which are competitive. In competitive sectors, we would not expect inefficient firms to survive in the long run, meaning that surviving firms may only have small efficiency differentials. Alternatively, to the extent that some dispersion in efficiency levels can persist in a (reasonably) competitive market in the long term, there would be no reason to expect the degree of dispersion to vary over time.

Even if TFP growth estimates for competitive sectors do include catch-up effects, any adjustment to take account of this could go in either direction. Oxera's footnote makes clear that a downward correction to TFP estimates for catch-up effects is conditional on the assumption that efficiency improves on average. (By this, Oxera presumably means that it is conditional on the assumption that firms in the sector move closer on average to the efficiency frontier.) However, Oxera also suggests that a reason why TFP estimates may include catch-up effects in the first place is because of "random short-term disequilibrium". For such short-term disequilibrium to exist, a shock must occur which moves the market away from long-term equilibrium (in which there are

[7] Competition Commission (2010), 'Bristol Water plc price determination: Final determinations', 14 September, Annex K, para. 109 and 112.

no inefficient firms). At the point in time at which this shock occurs, levels of catch-up efficiency must actually decrease. For example, there might be a technology shock which leads to a frontier firm becoming more efficient, but due to lags in technology diffusion there might be no immediate change in the efficiency levels of other firms, leading to a decrease in catch-up efficiency in the sector. Hence, there will be periods when any adjustment to remove changes in catch-up efficiency from TFP estimates will actually require an uplift to be applied to TFP estimates, rather than a downward correction.