

# Chapter 3

## Productivity Theory and Drivers

Measuring aggregate productivity accurately and consistently is an important objective for a National Statistical Institute (NSI). Users, however, also want to look behind the statistics to understand the dynamics and determinants of productivity growth.

Increasing productivity is generally considered to be the only sustainable way of improving living standards in the long term. Statistical evidence to help policy makers understand the routes to productivity growth, especially those which can be influenced by government, can help lead to better policy.

This chapter introduces the main determinants – or ‘drivers’ – of productivity growth. It then explains how productivity statistics can be compiled and presented in a way that helps illuminate some of the key determinants. In particular, this chapter gives details of the growth accounting framework that decomposes economic growth into the contributions of capital, labour and other inputs. It does this both for the economy as a whole and for sectors of industry.

## The Relationship between Productivity Theory and Policy

Productivity theory starts with the simple concept of output per unit input to produce the growth accounting framework and many more detailed approaches. A great deal of work and analysis has been carried out in this area by experts around the world.

ONS produces a wide range of productivity estimates. Users, such as other government departments, require this information because it helps them to understand and then design policies to improve productivity within the UK. Productivity is key to living standards (see [Section 1.1](#)) and therefore government policies aim to ensure UK productivity growth is strong, particularly in comparison with other developed countries.

### 3.1 The importance of productivity and competitiveness

Over the long term, increased productivity is the key determinant of economic growth, and together with higher employment is the primary route to higher living standards. Prosperity is usually measured by gross domestic product (GDP) per person: the total output of the economy relative to the UK population. There are essentially two ways of increasing GDP per person:

1. to have a higher level of employment or hours, so that the total labour input in the economy increases
2. to increase the amount of output each person produces: that is, increase their productivity

Given potential limitations on the rise of the UK's labour force, boosting UK productivity growth is generally accepted as the primary route to improving our future standard of living in the long term.

The Government has therefore, for some years, targeted improved UK productivity and competitiveness performance, and currently does so through the joint HM Treasury (HMT) and Department of Trade and Industry (DTI) public service agreement:

Demonstrate progress by 2008 on the Government's long-term objective of raising the rate of UK productivity growth over the economic cycle and improving competitiveness and narrowing the productivity gap with the US, France and Germany.

The emphasis on increasing productivity has been given further focus by recent increased globalisation of the

world economy. Strong productivity growth is essential if UK companies are to be competitive and make the most of opportunities from globalisation – exploiting emerging markets and attracting foreign direct investment. Increased flexibility will also help to facilitate adjustment as globalisation intensifies economic structural change.

### 3.2 The Government's five driver framework

Analysis of the underlying components of economic performance suggests that certain factors are critical for determining productivity growth. The Government's productivity framework identifies five drivers that interact to underlie long-term productivity performance: investment, innovation, skills, enterprise and competition.

**Investment** is in physical capital – machinery, equipment and buildings. The more capital workers have at their disposal, generally the better they are able to do their jobs, producing more and better quality output.

**Innovation** is the successful exploitation of new ideas. New ideas can take the form of new technologies, new products or new corporate structures and ways of working. Such innovations can boost productivity, for example as better equipment works faster and more efficiently, or better organisation increases motivation at work.

**Skills** are defined as the quantity and quality of labour of different types available in an economy. Skills complement physical capital, and are needed to take advantage of investment in new technologies and organisational structures.

**Enterprise** is defined as the seizing of new business opportunities by both start-ups and existing firms. New enterprises compete with existing firms by new ideas and technologies increasing competition. Entrepreneurs are able to combine factors of production and new technologies forcing existing firms to adapt or exit the market.

**Competition** improves productivity by creating incentives to innovate and ensures that resources are allocated to the most efficient firms. It also forces existing firms to organise work more effectively through imitations of organisational structures and technology.

Policies designed to increase productivity are often targeted at these drivers (see [Chapter 10](#) for more details of research work in this area). However, to determine

the success of such action, the accurate measurement of productivity is vital.

### 3.3 Multi-factor productivity

As stated in **Chapter 1**, multi-factor productivity (MFP) is the residual contribution to output growth of an industry or economy after calculating the contribution from all its factor inputs. The MFP measure produced within ONS is labour-capital value added productivity. An explanation of this form of MFP, along with a set of estimates, is given in **Chapter 7**.

MFP is effectively defined from the growth accounting framework. Therefore, to explain MFP fully, an explanation of growth accounting and its history is required.

**Primary inputs (or primary factor inputs)** are resources that go into producing something but are treated as outside (or sometimes described as exogenous to) the production process. This includes labour and capital and may also be called direct inputs.

### 3.4 The growth accounting framework

Growth accounting decomposes growth, but does not explain the process of technological change (HMT, 2006).

The growth accounting framework acts as a mechanism for breaking down the sources of economic growth into the contributions from increases in capital, labour and other factors. When these factors have all been accounted for, what remains is usually attributed to technology. This remainder is often called the Solow residual and, in theory, if all the factors contributing towards productivity were identified and measured correctly then this residual would be zero. There is more information about this residual in the section on MFP in **Chapter 7**.

When using growth accounting it is important to be aware of its limitations as well as its uses. As identified in the quote above, while this decomposition identifies factors that change productivity growth, it is not an explanation in itself of how those factors work.

Growth accounting is a specific, useful way of observing the changing structure of the economy, and assessing the contribution of each sector or industry to the whole. It also provides a very useful framework for the collection of economic statistics. This approach might be called ‘joined up statistics’ because it links various economic growth

and labour measures together to provide a more detailed picture of the economy.

The growth accounting framework is the main framework used internationally and is now more than fifty years old. More on the history of growth accounting is given towards the end of this chapter. The growth accounting approach has been codified in two Organisation for Economic Co-operation and Development (OECD) manuals – OECD (2001a and 2001b) – and is now the primary approach to MFP within National Statistical Institutes (NSIs) across the world. Below is an informal treatment.

#### 3.4.1 The aggregate framework

As stated above, the growth accounting framework decomposes economic growth into the contributions from labour, capital and other factors. This amounts to relating growth in GDP to growth in employment and growth in the various capital services (from buildings, vehicles, computers, and other resources). It also allows for any other factors, such as, for example, technical change. This is easiest to show through equations.

The starting point is the aggregate growth accounting equation:

$$\begin{aligned} \text{Growth of GDP} = & [\text{Capital's share times growth of} & (1) \\ & \text{capital input}] \\ & \text{plus} [\text{Labour's share times growth of} \\ & \text{labour input}] \\ & \text{plus growth of Multi-Factor} \\ & \text{Productivity (MFP)} \end{aligned}$$

where GDP, capital and labour are all chain indices of their respective components.

**Labour input** is a weighted average of the growth rates of the different types of labour, where the weights are the shares of each type in the aggregate wage bill. There is more about defining and estimating the different types of labour input in **Chapter 5**; the labour input series here is effectively a quality-adjusted labour input (QALI) measure.

**Capital input** is defined as aggregate capital services, not capital stock. In this definition, capital services are a direct measure of the flow of productive services from capital assets rather than a measure of the stock of those assets. For example, capital services from computers

refer to the service they provide rather than the value of the computers themselves. The treatment of capital is therefore analogous to the treatment of labour, where each type of labour input is measured by the flow of labour services, for instance hours worked. There is more about defining and estimating capital services in [Chapter 5](#).

**Labour's share** is the proportion of GDP attributable to labour. The largest component of this is the wage bill but it actually comprises all compensation made to labour.

**Capital's share** is the remainder of GDP (ie. attributable to capital).

Note that:

**Labour's share** plus **Capital's share** = 1

**Labour input** grows **either** if hours worked increase **or** if the quality of labour increases; the latter occurs if the composition of the labour force shifts towards better paid workers (Bell, Burriel-Llombart and Jones (2004)). Also see [Chapter 5](#) for more details on increasing labour input for a QALI measure. Likewise **capital input** grows if the amount or the quality increases.

**MFP growth** is calculated as a residual in this equation. It is often regarded as a representation of technology change but, realistically, includes any factors not represented by the **labour input** or **capital input** series. The contribution to growth of improved management structures or practices might be a part of this residual, for example. If technology could be expressed in a similar way to labour and capital then an extra term could be added to the aggregate growth accounting equation. Therefore, if all the factors that affect productivity could be included then the residual would equal zero.

Equation (1) can be rearranged in per hour worked terms as

$$\begin{aligned} \text{Growth of GDP} \\ \text{per hour worked} = & \text{Capital deepening} \\ & \text{plus Labour quality contribution} \\ & \text{plus MFP growth} \end{aligned} \quad (2)$$

where

**Capital deepening** = [Capital's share **times** growth of capital input per hour worked]

**Labour quality contribution** = [Labour's share **times** growth of labour input per hour worked]

Rearranging (1) and (2), MFP can be seen as:

$$\begin{aligned} \text{Growth of MFP} = & \text{growth of GDP} \\ & \text{minus [Capital's share times growth} \\ & \text{of capital input]} \\ & \text{minus [Labour's share times growth} \\ & \text{of labour input]} \end{aligned} \quad (3)$$

$$\begin{aligned} \text{Growth of MFP} \\ \text{per hour worked} = & \text{growth of GDP per hour worked} \\ & \text{minus Capital deepening} \\ & \text{minus Labour's quality contribution} \end{aligned} \quad (4)$$

Equation (3) shows that MFP is the contribution to GDP growth unexplained by the contribution of capital and labour inputs growth.

#### 3.4.1.1 Intermediate inputs

The equations above consider MFP only in terms of the primary inputs, labour and capital, of GDP. Primary inputs are those which are treated as outside (sometimes described as exogenous to) the production process. However it is also common for MFP to be considered in terms of intermediate inputs (materials, energy, business services) of GDP, where intermediates are those inside or used up by the production process. Alternatively, MFP can be considered in terms of direct inputs of GVA.

To describe MFP in terms of primary and intermediate inputs of GDP:

$$\begin{aligned} \text{Growth of MFP} = & \text{growth of GDP} \\ & \text{minus [share of direct inputs times} \\ & \text{growth of direct inputs]} \\ & \text{minus [share of intermediate inputs} \\ & \text{times growth of intermediate inputs]} \end{aligned} \quad (5)$$

To describe MFP in terms of primary inputs of GVA:

$$\begin{aligned} \text{Growth of MFP} = & \text{growth of GVA} \\ & \text{minus [Capital's share times growth} \\ & \text{of capital input]} \\ & \text{minus [Labour's share times growth} \\ & \text{of labour input]} \end{aligned} \quad (6)$$

### 3.4.2 Building up from the industry level

Having considered the growth accounting framework and, consequently, MFP for the whole economy, the next step is to consider how the framework is seen at the industry level. This can be demonstrated by moving from the equations (1) or (2) to corresponding relationships at the industry level.

Measuring the growth of MFP in each industry requires industry data. These data are the price and quantity of total output and the prices and quantities of inputs and outputs for a set of industries covering the whole economy. Using these data, further equations can be produced. Here both primary and intermediate inputs are considered.

For the  $i$ th industry:

Growth of MFP  
in industry  $i$  = Growth of total output in industry  $i$  (7)  
**minus** cost-share-weighted growth  
of capital services, labour and  
intermediate input

### 3.4.3 Aggregation

The crucial link between the industry MFP rates given by **equation (7)** and the aggregate MFP growth rate given by **equation (5)** is provided by the concept of **Domar aggregation** (Domar 1961), named after its creator. This is defined as follows:

Aggregate MFP growth rate = Domar-weighted sum of industry MFP growth rates

where the **Domar weight** for industry  $i$  is

$$\frac{\text{Nominal total output of industry } i}{\text{Nominal GDP}}$$

#### The difference between a 'real' variable and a 'nominal' variable:

A real variable (for example, the real interest rate) is one where the effects of inflation have been factored in.

A nominal variable is one where the effects of inflation have not been accounted for.

Nominal output, or GDP, refers to output or GDP at current prices.

The Domar weights will sum to more than one, reflecting the fact that each industry makes a double contribution to aggregate MFP, once in its own right and once through reducing the costs of industries that buy from it.

#### Box 3.1: The dual approach

MFP growth can also be calculated using prices rather than quantities. This is the so-called dual approach because the framework is seen in terms of prices instead of quantities.

Using this alternative, equation (1) has an equivalent:

Growth of output price = [capital's share **times** growth of rental price] (1a)  
**plus** [Labour's share **times** growth of wages]  
**minus** growth of multi-factor productivity (MFP)

Therefore equation (3) also has an equivalent:

Growth of MFP = [capital's share **times** growth of rental price] (3a)  
**plus** [Labour's share **times** growth of wages]  
**minus** growth of output price

In other words, MFP can also be viewed as the unexplained difference between the growth in cost of the inputs and the growth in cost of the output.

The industry equation can equally be constructed in price terms:

Growth of MFP (7a)  
in industry  $i$  = [growth of price of total output of  $i$ ]  
**minus** [cost-share-weighted growth of prices of capital services, labour and intermediate input]

Provided that the accounting system is consistent, the dual approach of this (7a) must yield exactly the same answer as the one above (7) that uses quantities.

The important element to understanding the Domar weight is considering the ratio between the output of a particular industry and GDP.

This equation can be shown to hold exactly if any given input (for instance university-educated female workers aged 30–34) is paid the same wage in all industries. If this is not the case, then the equation for aggregate MFP growth also contains terms reflecting the reallocation of capital and labour towards or away from higher value uses (Jorgenson *et al* (1987)). But the Domar-weighted sum can still be regarded as the best measure of underlying productivity growth at the aggregate level. Therefore the sources of aggregate MFP growth rates can be traced to their industries of origin. Changes in aggregate MFP can be assigned either to changes in the underlying industry rates or to structural change (changes in the Domar weights).

### 3.4.4 The history of growth accounting

The pioneering growth accounting studies were at the whole economy level. The growth accounting framework was first formalised by Solow (1957), although the earliest empirical applications preceded his seminal paper as shown by Hulten (2000). Subsequently, the framework has been deepened by Jorgenson and his various collaborators (including Domar (1961), Jorgenson and Griliches (1967), Hulten (1978), Jorgenson, Gollop and Fraumeni (1987) and Jorgenson (1989)).

Work has been carried out at the sectoral and industry level as this more closely reflects the interests of policy makers. Consequently, through the work of Domar (1961), Hulten (1978) and Jorgenson *et al* (1987), the growth accounting framework has been extended to the industry level. ‘Best practice’ in this area is the Jorgensonian growth accounting framework, now enshrined in two OECD manuals (OECD (2001a) and (2001b)).

Growth accounting analyses have been employed to inform the UK policy debate (O’Mahony (1999)) and to analyse the failure of Europe or the UK to experience a similar productivity acceleration to the US (Colecchia and Schreyer (2002); van Ark *et al* (2002); O’Mahony and van Ark (2003); Basu *et al* (2003); European Commission (2003)). They have also been very influential in the ongoing debate about the US productivity acceleration of the 1990s, such as in Oliner and Sichel (2000) and Jorgenson and Stiroh (2000a) and (2000b). However, the System of National Accounts 1993 (SNA93) does not refer to growth accounting, probably because SNA93 is not directly concerned with productivity measurement. Where productivity is referred to, it is in terms of labour productivity rather than MFP.

It may seem that growth accounting, being based on the idealistic assumption of perfect competition, is too simplistic to represent the real-life economic picture. But if the data and methods required for growth accounting are not available then it is unlikely that supposedly more sophisticated analyses could be carried out either.

Also, the statistics required for growth accounting can be used as a basis for testing more complex hypotheses going beyond those required for growth accounting itself (for instance as is done by Oulton and Srinivasan, 2005). Another advantage of the growth accounting framework is that implementing it imposes an important discipline: more tests are imposed on the consistency and coherence

of the National Accounts than is the case under our present system. There is more about consistency both within and between output and input in **Chapters 4** and **5**.

### 3.5 Future work

ONS does not currently use the growth accounting framework formally and has not previously produced MFP estimates on a regular basis, although various ad hoc analyses have been carried out (MFP figures are given in **Chapter 7**). However, ONS aims to include the growth accounting framework within the new National Accounts system (there is more information on this in **Chapter 13**). As part of this, MFP estimates will be produced on a regular basis, will be produced, primarily as a diagnostic tool for ensuring that National Accounts and labour market statistics are consistent.

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### 3.6 References

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