Productivity Measurement and R&D Assets

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Abstract

A key feature of the 2008 revision of the System of National was the treatment of R&D expenditure as investment. Measures of R&D capital can now be used in productivity computations and the question arises whether the standard approach towards accounting for their growth contribution is justified given their special nature: R&D assets provide capital services by affecting the working of other inputs *as a whole* - akin to technical change. We model R&D inputs with a restricted cost function and compare econometric estimates of R&D cost elasticities for 20 OECD countries with those derived under a standard index number approach but find no significant differences. However we cannot reject the hypothesis of increasing returns to scale. We de-compose the standard MFP growth into a scale effect and a residual productivity effect, each of which explains about half of overall MFP change. We also compute mark-up rates of prices over marginal cost and find widespread evidence of rising mark-ups for the period 1985-2015..

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1 Introduction

One of the central achievements of the 2008 revision of the System of National Accounts (SNA 2008 – European Commission et al. 2009) was the treatment of research and development expenditure (R&D) as investment that gives rise to knowledge assets. It had long been recognised that such knowledge assets play an important role in firms', industries' and countries' capacity to compete and to penetrate markets. The specifics of measuring R&D expenditure are laid down in detail in the Frascati Manual (OECD 2015). How the intellectual property assets that are the fruit of R&D investment should be measured in practice has been elaborated in OECD (2010). With the completed implementation of the SNA 2008 among OECD countries by end-2016, users of statistics now dispose of sets of estimates for the investment in R&D as well as software (already present before the 2008 revision) along with estimates of the relevant stocks of intellectual property products and other, more traditional non-financial, produced assets (machinery, equipment, structures).

As all these assets provide inputs into production in the form of capital services it is only natural to base productivity estimates on the whole set of assets. Indeed, the economics literature has preceded national accounts standards and embraced an even broader set of intangibles in an attempt to account for new sources of economic growth and competitiveness. The work by Corrado, Hulten and Sichel (2005) measuring intangible capital for the United States and employing it in a new set of productivity estimates was a seminal piece that spawned other work, applying similar or refined concepts to other countries and time periods (OECD 2013, Goodridge et al 2016).

There are, however, several issues when it comes to using R&D assets in productivity measurement. First is that R&D projects often involve sunk costs and upfront investment. These sunk costs need to be recuperated over the economic service life of the R&D asset, requiring a mark-up of average costs over marginal costs of production. Sunk costs also imply a certain degree of increasing returns to scale. There is a longstanding literature (Sena 2004) on externalities and spill-overs that R&D asset generate: "...the level of productivity achieved by one firm or industry depends not only on its own research efforts but also on the level or pool of general knowledge accessible to it." (Griliches 1995, p.63). The implication for measurement is that aggregate returns to scale may not be constant but increasing. A first objective of the analysis here is to test for the presence of increasing returns to scale when R&D assets are included as factor inputs, to measure the evolution of mark-ups and to distinguish those associated with returns to scale from other, ‘pure’ mark-ups. We shall conclude that the hypothesis of increasing returns cannot easily be rejected and there is a pattern of rising mark-ups in nearly all countries of the sample.

A second issue associated with R&D capital is how its services enter the production process and the consequences for productivity measurement. This was highlighted in work by Parham (2007), Pitzer (2004), and Diewert and Huang (2011). Pitzer (2004) observed that R&D capital functions as a source of ’recipes’. Diewert and Huang (2011) start their discussion of R&D assets by explaining that “...we do not treat the stock of R&D capital as an explicit input factor. Rather, we define the stock of R&D capital to be a technology index that locates the economy’s production frontier. An increase in the stock of R&D shifts the production frontier outwards.” (p. 389). R&D assets thus provide capital services by enabling production, for example through licences that permit usage of knowledge or intellectual property (IP) in production. This suggests treating capital services from R&D assets as a technology index that affects the working of all other inputs as a whole so that R&D capital services operate akin to autonomous neutral technical change.

If one adopts this reasoning, production takes place with services from non-R&D inputs conditional on a given stock of R&D assets (and conditional on a given level of other, ‘autonomous’ technical change). This amounts to treating R&D capital as a quasi-fixed input. The theoretical tools to deal with quasi-fixity have long been developed in the form of restricted profit and restricted cost functions (Lau 1976, McFadden 1978, Berndt and Fuss 1986, Schenkerman and Nadiri 1984). When an input is quasi-fix it cannot be adjusted instantaneously – a plausible notion for R&D assets with sometimes long gestation periods. One consequence is that the assumption of period-to-period cost minimising behaviour of producers with regard to the quasi-fixed factor of production no more holds. Then, the user costs for R&D assets as constructed under standard cost-minimising assumptions cannot be used to approximate production elasticities of R&D (or cost elasticities in a dual formulation). Elasticities have to be estimated econometrically.

We use data for 20 OECD countries over the period 1985-2015 and estimate cost elasticities of R&D capital to test whether these diverge significantly from the standard non-parametric elasticities. As it turns out, while there are variations across countries and over time, on average the econometric point estimate lines up rather well with the index number results. This is in particular the case when we allow for non-constant returns to scale at the same time. We will therefore conclude that the theoretical case that can be made in favour of a treatment of R&D assets as quasi-fixed inputs does not outweigh the practical disadvantages that it entails and that can be avoided with an index number approach. There is in particular the need to revert to econometric techniques which reduces reproducibility of results, and the need to accept constancy of R&D elasticities over time and across countries – at least in a case where the number of observations is limited.

A third – and related - issue is how exactly to construct R&D capital stocks. Unlike other assets, market prices for R&D investment are hard to get by, given that much R&D activity is undertaken within firms ('own account' investment) with the consequence that they are valued at cost. Similarly, prices of the capital services from R&D assets are essentially reflective of the price change of the inputs used in their creation, much of it being the wage rate of R&D personnel. This is an added reason for testing whether cost shares are reflective of cost elasticities of R&D, as explained above. Measurement problems do not stop with valuation of the asset, however. There is also an issue of how to determine the rate of depreciation which, in the case of R&D is driven by obsolescence rather than wear-and-tear as with other capital goods. Lastly, because R&D assets are intangible, they can easily be transferred, including across national borders. [1] R&D assets can therefore appear and disappear in lumps, leading to corresponding changes in measured capital stocks and services. Large additions or subtractions from stocks require careful construction of the measures of R&D stocks with attention paid to infra-annual movements: whether an asset appears at the beginning or at the end of an accounting period is no more an ancillary measurement question. Annex A describes at some detail how we proceeded with the measurement of R&D stocks. All our measurement pro-

[1] A widely discussed example is Ireland where trans-border movements of IP assets and the associated production and income flows gave rise to a staggering 25 percent rise in real GDP in 2015 and a similar unusual two-digit growth in labour productivity. While Ireland may have brought the issue of measuring and production and productivity into sharp focus, this constitutes by no means a unique case.

posals are consistent with the 2008 System of National Accounts and fit also with the broader blueprint of productivity measurement in a national accounts framework as developed by Jorgenson and Landefeld (2004).

The paper at hand is organised as follows. Section 2 deals with productivity measurement under non-constant returns to scale and a quasi-fixed R&D input. In Section 3 we follow Diewert et al. (2011) and combine index number and econometric approaches to derive a parsimonious way of testing for quasi-fixity of the R&D input and non-constancy of returns to scale. As our results regarding quasi-fixity are somewhat inconclusive, and in light of many practical considerations, we opt for a treatment of R&D as a standard flexible input. We do, however, maintain the finding of increasing returns to scale and the last part of Section 3 uses these results to decompose the OECD Multifactor productivity (MFP) index into a part that reflects scale effects and into a part that reflects autonomous productivity change. The Section finishes with the dual picture to the MFP decomposition, the measurement of mark-ups over marginal costs and their break down into mark-ups induced by returns to scale and 'pure' mark-ups.

2 IP assets in productivity measurement

We now turn to the theoretical aspects of the use of R&D assets in production. We characterise technology by the following production function where labour and traditional capital inputs are combined with services from a knowledge asset R:

$$Q = f_Q(X, R, t) \tag{1}$$

In (1), Q is the volume of aggregate output; $X \equiv (X_1, X_2, ...)$ is the vector of labour and various types of non-R&D capital employed in producing Q; R is the stock of R&D used in producing Q, and t is a time variable to capture autonomous productivity change. $f_Q(X, R, t)$ is continuous and non-decreasing in inputs X, R and t. No constant returns are imposed here. This is motivated by the desire to maintain a general approach but also by the nature of R&D (and other knowledge-based assets): their creation typically entails large, fixed upfront investment expenditure that need to be recuperated over the economic service life of the asset. The implication is that prices will not be set at short-run marginal costs of production. There may also be mark-ups on marginal costs above and beyond those needed for cost recovery - a point to which we shall return in greater detail below.

In addition to allowing for non-constant returns to scale, we treat R as a quasi-fixed input in the sense of McFadden (1978), Schankerman and Nadiri (1984) or Berndt and Fuss (1986). As a quasi-fixed input, R takes the role of a pre-determined variable that cannot be adjusted instantaneously and in a cost-minimising manner as is usually assumed in productivity measurement. By treating the quantity of R&D as a predetermined, exogenous variable it can easily be interpreted as a 'shifter' to non-R&D input requirements, similar to autonomous productivity change that is captured by the time variable t[2]. For non-R&D inputs X the usual assumption of instantaneous cost-minimising adjustment is maintained.

The production function above characterises technology and can be used as the framework for measuring autonomous technical change. The latter is then measured as the shift of the production function or the extra output that a given input bundle can produce with the passage of time. Alternatively, a cost function can be used to characterize a production unit's technology. Here, autonomous technical change is measured as the shift of the cost function, or the reduction in costs to produce a given output, for given input prices. Primal (production function)-based and dual (cost function)-based productivity measures coincide when production is characterised by constant returns to scale, when production is efficient and when producers minimise costs. Primal and dual measures will divert, however, when one or several of these conditions fail to hold [3]. Similarly, the degree of returns to scale in production can be measured based on the production or on the cost function. Diewert et al (2011) point to the strong intuitive appeal of a cost-based measure of scale elasticity as the percentage change in cost due to a one percent increase in the quantity

[2]Formally, this requires treating R (or t) as separable from X so that the rate by which a change in R (or t) affects output is independent of the rates of substitution between the elements of X. The concept of weak separability is due to Sono (1961) and Leontief (1947). Separability is a rather restrictive assumption but Diewert (1980) offers a way forward with his *Method III* (p.455 ff.) where he shows that price and quantity indices can be constructed using observable prices and quantities only if one is ready to accept that these aggregates are conditional on reference values of variables outside the aggregate (R or t in the case at hand) that are averages of their realisations in comparison periods.

[3]See Balk (1998) for a comprehensive overview of the various primal and dual productivity measures and their relationship.

of output, for a given level of input prices [4]. Further, cost-based productivity measures allow for a simple set-up of producer behaviour on output markets when competition is imperfect. We shall therefore make use of the following restricted (short-term) cost function:

$$C(Q, w_X, R, t) = \min_X (\sum_i w_{Xi} X_i \mid f_Q(X, R, t) \geq Q) = \sum_i w_{Xi} X_i. \qquad (2)$$

The general properties of the restricted cost function were established by Lau (1976) and McFadden (1978). Early empirical references that used the variable cost function include in particular Caves, Christensen and Swanson (1981), Schankerman and Nadiri (1984), Berndt and Fuss (1986) and Morrison (1992). $C(Q, w_X, R, t)$ reflects the minimum variable cost of producing Q, given a vector of input prices w_X, and a level of knowledge assets R as well as autonomous, 'costless' technology t. One notes that (2) assumes cost minimisation by producers only in regards to X, and is conditional on a level of R and t. The second equality in (2) states that minimised variable costs equal observed variable costs $\sum_i w_{Xi} X_i$. We thus abstract from cases of waste or inefficient production where actual costs exceed minimum costs. $C(Q, w_X, R, t)$ captures short-run *variable* costs.

Shepard's (1953) Lemma holds for the variable cost function: for non R&D inputs X_i, $(i = 1, 2, ...)$ factor demand equals marginal cost changes associated with a change in input prices: $\partial C(Q, w_X, R, t)/\partial w_{Xi} = X_i(Q, w_X, R, t)$. For the R&D input, we define a shadow price w_{RS} as the marginal reduction in variable costs due to a marginal increase in R: $\partial C(Q, w_X, R, t)/\partial R \equiv -w_{RS}$. This shadow price (or rather, shadow user cost) of R&D is unknown and may or may not be close to the computable user cost of R&D, w_R, whose evaluation is isomorphic to the user costs of other produced assets (see Annex A). The shadow price w_{RS} can only be evaluated econometrically whereas w_R lends itself to an index number approach.

To derive a measure of technical change, we start by differentiating (2) totally and obtain a continuous time expression for the growth rate of short run variable costs:

[4]While not relevant for the present case where we consider an aggregate measure of output, a cost function-based measure of the returns to scale has the advantage of easily allowing for changes in the composition of output.

$$
\begin{aligned}
&\frac{dlnC(Q, w_X, R, t)}{dt} = \\
&\frac{\partial lnC(Q, w_X, R, t)}{\partial lnQ}\frac{dlnQ}{dt} + \sum_i \frac{\partial lnC(Q, w_X, R, t)}{\partial lnw_{Xi}}\frac{dlnw_{Xi}}{dt} \\
+&\frac{\partial lnC(Q, w_X, R, t)}{\partial lnR}\frac{dlnR}{dt} + \frac{\partial lnC(Q, w_X, R, t)}{\partial t}.
\end{aligned} \tag{3}
$$

The cost elasticity of output is the definition of (inverted) returns to scale and we shall let $\partial lnC(Q, w_X, R, t)/\partial lnQ \equiv 1/\epsilon$. Thus, there are increasing, constant, or decreasing returns to scale in short term variable costs if ϵ exceeds, is equal to, or is smaller than one. The last expression in (3), $\partial lnC(Q, w_X, R, t)/\partial t$, captures the short-run measure of autonomous technical change or the shift of the restricted cost function over time. With Shepard's Lemma and the definition of the R&D shadow price, and using simplified notation by setting $C(Q, w_X, R, t) = C$, (3) is re-written as:

$$
\frac{dlnC}{dt} = \frac{1}{\epsilon}\frac{dlnQ}{dt} + \sum_i \frac{w_{Xi}X_i}{C}\frac{dlnw_{Xi}}{dt} - \frac{w_{RS}R}{C}\frac{dlnR}{dt} + \frac{\partial lnC}{\partial t}. \tag{4}
$$

Next, define a Divisia quantity index of non-R&D inputs, $dlnX/dt$, that equals the Divisia index of deflated input costs:

$$
\frac{dlnX}{dt} \equiv \sum_i \frac{w_{Xi}X_i}{C}\frac{dlnX_i}{dt} = \frac{dlnC}{dt} - \sum_i \frac{w_{Xi}X_i}{C}\frac{dlnw_{Xi}}{dt}. \tag{5}
$$

Combining (4) and (5 gives rise to the following two, equivalent expressions:

$$
\begin{aligned}
\frac{dlnX}{dt} &= \frac{1}{\epsilon}\frac{dlnQ}{dt} - \frac{w_{RS}R}{C}\frac{dlnR}{dt} + \frac{\partial lnC}{\partial t}; \\
\frac{dlnQ}{dt} &= \epsilon\left(\frac{dlnX}{dt} + \frac{w_{RS}R}{C}\frac{dlnR}{dt} - \frac{\partial lnC}{\partial t}\right)
\end{aligned} \tag{6}
$$

The first line in (6) states that non-R&D input growth depends positively on output growth, and negatively on the growth of R&D and time-autonomous technical change ($\partial lnC/\partial t \leq 0$) – fewer inputs are needed for a given output when technology and R&D inputs increase. The second line in (6) reverts this into a growth accounting equation where output growth is explained by the combined growth of non-R&D inputs, R&D inputs and time-autonomous technical change. Combined inputs and technical change are augmented by the degree of short-run returns to scale.

To compare the short-run (restricted) relationships in (6) with their long-run (unrestricted) counterparts, we define an unrestricted cost function $C^*(Q, w_X, w_R, t)$. Here, the shadow price of R&D equals its computable user costs ($w_{RS} = w_R$) and demand for the R&D input $R^*(Q, w_X, w_R, t)$ is always in equilibrium, implicitly defined via

$$\frac{-\partial C(Q, w_X, R, t)}{\partial R} = w_R. \tag{7}$$

The full expression for the unrestricted cost function is

$$C^*(Q, w_X, w_R, t) = C(Q, w_X, R(Q, w_X, w_R, t), t)) + w_R R(Q, w_X, w_R, t). \tag{8}$$

It is now possible to derive the relationship between restricted and unrestricted elasticities (Schankerman and Nadiri 1984) by differentiating (8) and making use of (7):

$$\begin{aligned}
\frac{\partial lnC^*}{\partial lnQ} &= \frac{\partial lnC}{\partial lnQ}\frac{C}{C^*} = \frac{1}{\epsilon}\frac{C}{C^*} \equiv \frac{1}{\epsilon^*};\\
\frac{\partial lnC^*}{\partial t} &= \frac{\partial lnC}{\partial t}\frac{C}{C^*};\\
\frac{\partial lnC^*}{\partial lnw_{Xi}} &= \frac{\partial lnC}{\partial w_{Xi}}\frac{C}{C^*} = \frac{w_{Xi}X_i}{C}\frac{C}{C^*} i = 1, 2, ...\\
\frac{\partial lnC^*}{\partial lnw_R} &= \frac{w_R R}{C^*}
\end{aligned} \tag{9}$$

The passage between unrestricted and restricted cost functions and the associated measures of productivity, returns to scale and cost elasticities of non-R&D inputs is thus rather straight forward and achieved by multiplying the short-term expressions by C/C^*, the share of non-R&D inputs in total costs. For instance, expanding the second line in (6) by C/C^* yields:

$$\begin{aligned}
\frac{dlnQ}{dt} &= \frac{\epsilon}{C/C^*}\left(\frac{C}{C^*}\frac{dlnX}{dt} + \frac{w_{RS}R}{C}\frac{C}{C^*}\frac{dlnR}{dt} - \frac{C}{C^*}\frac{\partial lnC}{\partial t}\right)\\
&= \epsilon^*\left(\frac{C}{C^*}\frac{dlnX}{dt} + \frac{w_{RS}R}{C^*}\frac{dlnR}{dt} - \frac{\partial lnC^*}{\partial t}\right)\\
&= \epsilon^*\left(\frac{dlnZ}{dt} - \frac{\partial lnC^*}{\partial t}\right)
\end{aligned} \tag{10}$$

Here we have defined the short-run Divisia quantity aggregate of all inputs as $\frac{dlnZ}{dt} \equiv (\frac{C}{C^*}\frac{dlnX}{dt} + \frac{w_{RS}R}{C^*}\frac{dlnR}{dt})$. Similarly, we can define an unrestricted, long-run Divisia quantity aggregate of inputs as $\frac{dlnZ^*}{dt} \equiv (\frac{C}{C^*}\frac{dlnX}{dt} + \frac{w_R R}{C^*}\frac{dlnR}{dt})$.

The OECD measures MFP growth as the difference between output and aggregate input growth (OECD 2017, Schreyer et al 2003, Schreyer 2010). This MFP growth can now be broken down into three effects: one that captures the difference between restricted and unrestricted measures of inputs, one that captures the effect of returns to scale and one that captures technical change:

$$\begin{aligned} MFP &\equiv \frac{dlnQ}{dt} - \frac{dlnZ^*}{dt} \\ &= \epsilon^*\left(\frac{dlnZ}{dt} - \frac{\partial lnC^*}{\partial t}\right) - \frac{dlnZ^*}{dt} \text{using (10)} \\ &= \epsilon^*\frac{dlnZ}{dt} - \epsilon^*\frac{\partial lnC^*}{\partial t} - \frac{dlnZ^*}{dt} - \epsilon^*\frac{dlnZ^*}{dt} + \epsilon^*\frac{dlnZ^*}{dt} \\ &= \epsilon^*\left(\frac{dlnZ}{dt} - \frac{dlnZ^*}{dt}\right) + (\epsilon^*-1)\frac{dlnZ^*}{dt} - \epsilon^*\frac{\partial lnC}{\partial t} \\ &= \epsilon^*\left(\frac{w_{RS}R}{C^*} - \frac{w_R R}{C^*}\right)\frac{dlnR}{dt} + (\epsilon^*-1)\frac{dlnZ^*}{dt} - \epsilon^*\frac{\partial lnC}{\partial t}. \quad (11) \end{aligned}$$

When shadow elasticities of R&D equal computable user cost shares ($\frac{w_{RS}R}{C^*} = \frac{w_R R^*}{C^*}$, $\frac{dlnZ}{dt} = \frac{dlnZ^*}{dt}$), the first term in the last line of (11) vanishes and MFP growth is reduced to a scale effect and to a technical change effect. Equation (12) below presents the same MFP decomposition in a slightly different form and confirms that with constant returns to scale ($\epsilon^* = 1$), MFP simply equals the shift in the cost function:

$$\begin{aligned} MFP &= (\epsilon^*-1)\frac{dlnZ^*}{dt} - \epsilon^*\frac{\partial lnC}{\partial t} \text{ for } \frac{w_{RS}R}{C^*} = \frac{w_R R^*}{C^*} \\ &= \left(1 - \frac{1}{\epsilon^*}\right)\frac{dlnQ}{dt} - \frac{\partial lnC}{\partial t} \\ &= -\frac{\partial lnC}{\partial t} \text{ for } \epsilon^* = 1. \quad (12) \end{aligned}$$

Output prices that are equal to marginal variable costs (of non-R&D inputs) are insufficient to recover the fixed costs that were needed to generate or purchase the R&D asset in the first place. Even prices that are equal to total marginal costs may not cover average costs in the presence of longer-term increasing returns to scale. Thus, in order to cover total average costs C^*/Q, there has to be a mark-up over total marginal costs. There may also be an additional mark-up M above and beyond what is needed to avoid losses. Its level will depend on market conditions, and on the degree of competition under which Q is sold. This additional mark-up could also reflect returns to other, unmeasured assets. We shall return to the interpretation of mark-ups when presenting results.

To place M into context we recall the accounting relationship for value-added of aggregate output Q:

$$P_Q Q = \sum_i w_{Xi} X_i + w_{RS} R + M = \sum_i w_{Xi} X_i + w_R R + M^* \tag{13}$$

$P_Q Q$ represents total value-added (GDP at the economy-wide level), and $\sum_i w_{Xi} X_i$ is the value of non-R&D inputs. Both are measurable. In the short-term restricted case where R commands the shadow price w_{RS}, the sum $w_{RS}R+M$ can observed but cannot be broken into its parts. In the unrestricted case the cost of R&D services are measured through $w_R R$ and M^*, the longer-run mark-up over average costs, can be measured residually.

Let the mark-up rate m of prices over marginal costs in the restricted case and let the mark-up rate m^* of prices over marginal costs in the unrestricted case be defined by the following relationship:

$$\begin{aligned}
P_Q &= \frac{\partial C}{\partial Q}(1+m) \text{ from which it follows that} \\
\frac{P_Q Q}{C} &= \frac{\partial C}{\partial Q}\frac{Q}{C}(1+m) = \frac{1}{\epsilon}(1+m) \text{ for the restricted case; and} \\
\frac{P_Q Q}{C^*} &= \frac{1}{\epsilon^*}(1+m^*) \text{ for the unrestricted case such that} \\
(1+m^*) &= \epsilon^* \frac{P_Q Q}{C^*} = \epsilon^* \frac{1}{1 - M^*/P_Q Q}. \qquad (14)
\end{aligned}$$

The last line in (14) reproduces a well-known identity: (one plus) the mark-up rate over marginal costs equals the degree of returns to scale times an expression that rises with the 'pure' profit rate $M^*/P_Q Q$. In the absence of 'pure' profits, ($M^* = 0$), the mark-up rate over marginal costs will equal returns to scale. When $M^* > 0$ and there are constant returns to scale ($\epsilon^* = 1$), all mark-ups will reflect 'pure' profits.

3 Empirical implementation

R&D cost shares – too low, too high, about right?

While the relationships above were derived in continuous time, actual data comes in discrete form – annual observations in the case at hand – and the relevant relationships above need to be expressed in discrete form. We use Törnqvist indices to express equations (6) in discrete time[5]:

$$\begin{aligned}\Delta lnX^t &= \frac{1}{\epsilon}\Delta lnQ^t - 0.5\left(\frac{w^t_{RS}R^t}{C^t} + \frac{w^{t-1}_{RS}R^{t-1}}{C^{t-1}}\right)\Delta lnR^t - \Delta\pi^t \\ \Delta lnQ^t &= \epsilon\left[\Delta lnX^t + 0.5\left(\frac{w^t_{RS}R^t}{C^t} + \frac{w^{t-1}_{RS}R^{t-1}}{C^{t-1}}\right)\Delta lnR^t + \Delta\pi^t\right] \qquad (15)\end{aligned}$$

In (15), $\Delta lnX^t \equiv lnX^t - lnX^{t-1}$ denotes the logarithmic growth rate of X between periods t and $t-1$ and the same notation is used for the other variables. The relations in (15) will constitute the main vehicle to assess shadow prices of R&D inputs, short-run returns to scale and technical change. Note that in (15) the unknown terms are $\epsilon, 0.5\left(\frac{w^t_{RS}R^t}{C^t} + \frac{w^{t-1}_{RS}R^{t-1}}{C^{t-1}}\right)$ and $\Delta\pi^t$ that will need to be estimated. This requires assuming constancy of $0.5\left(\frac{w^t_{RS}R^t}{C^t} + \frac{w^{t-1}_{RS}R^{t-1}}{C^{t-1}}\right)$. The non-R&D input aggregate ΔlnX^t is measured via index numbers, derived from the restricted cost function. This hybrid approach is due to Diewert et al. (2011) who applied it for estimates of returns to scale in Japanese manufacturing, albeit with an unrestricted cost function. Main advantages of the hybrid approach are parsimony in the number of parameters to be estimated and a strong theoretical basis as relations are directly derived from flexible functional forms. Re-formulating (15) for estimation gives:

$$\begin{aligned}\Delta lnX^t &= \alpha_{a0} + \alpha_{a1}\Delta lnQ^t + \alpha_{a2}\Delta lnR^t + \mu^t_a \\ \Delta lnQ^t &= \alpha_{b0} + \alpha_{b1}\Delta lnX^t + \alpha_{b2}\Delta lnR^t + \mu^t_b. \qquad (16)\end{aligned}$$

In (16) we have assumed that time autonomous technical change follows a stochastic process around a long-term average: $-\Delta\pi^t = \alpha_{a0} + \mu^t_a$ in the

[5]This can be justified more rigorously by assuming that the restricted cost function is of the translog form (introduced by Christensen et al. 1971 and generalised by Diewert 1974). As a flexible functional form it approximates an arbitrary cost function to the second degree. As Diewert (1974, 1976) has shown, a Törnqvist index is then an exact representation of the change in the cost function.

first expression of (16) and $\Delta\pi^t/\epsilon = \alpha_{b0} + \mu_b^t$ in the second expression of (16) with productivity shocks μ_a^t and μ_b^t. A well-known and long-standing issue in the estimation of production or cost functions is that productivity shocks are correlated with factor inputs, thus creating an endogeneity problem when the second line in (16) is estimated. Estimation of the reverse regression does not solve the issue – the R&D input still figures as an independent variable with potential correlation with μ_b^t. We use time dummies and country-specific fixed effects in the error term to at least partially address this issue.

Instrumental variables are another avenue towards addressing the endogeneity problem. At the same time, they tend to give rise to other problems. Diewert and Fox (2008) provide an in-depth discussion of estimation in a similar context and note in regards to the use of instrumental variables: "Since different researchers will choose a wide variety of instrument vectors [...], it can be seen that the resulting estimates [...] will not be reproducible across different econometricians who pick different instrument vectors" (p.186). Reproducibility and simplicity are major concerns in the present setting as our work aims at providing guidance for producing periodic productivity statistics, typically by National Statistical Offices. Instrumental variables may also introduce other problems, if they are not completely exogenous, and results may be very sensitive to the choice of instruments (Burnside 1996). Basu and Fernald (1997) find that aggregation effects are important and that these effects are correlated with demand shocks. This may be exacerbated by relatively weak correlation of instruments with the explanatory variables which leads Basu and Fernald (1997) to conclude that "[...] instruments that are both relatively weak and potentially correlated with the disturbance term suggest that instrumental variables may be more biased than ordinary least squares." (p. 258). We therefore follow Diewert and Fox (2008), Basu and Fernald (1997, 2002) and Roeger (1995) and rely on OLS estimates. However, we shall use different OLS estimates to establish boundaries rather than a single point estimate.

Another, related point is that all variables – and in particular the R&D variable - are likely measured with error [6] . When there is a measurement error in the regressor and it is of the classical type, i.e., independent of the true value of

[6]The econometric issues with using R&D in a production function have long been discussed (e;g., Griliches 1998) but never been fully satisfactorily resolved. The work here harks back to a long tradition of analysing R&D in a production context, pioneered by Griliches (1973) and recently reviewed by Ugur et al (2016).

the variable, OLS estimates have been shown to under-estimate the magnitude of the regression coefficient (see, for instance Hyslop and Imbens 2001). When there is classical measurement error in both the regressor and the dependent variable, the OLS bias cannot in general be signed, unless it is assumed that the measurement errors of the regressor and the dependent variable are independent in which case the downward bias in regression coefficients remains. Klepper and Leamer (1984) have demonstrated that with classical measurement error in the two-variable case the true value of the regression coefficient lies between the estimated coefficients [7] from the direct and the reverse regression. Our estimation strategy is to apply OLS to both expressions in (16) and so obtain bounds for the coefficients. Results from an estimation with a panel data set for 20 OECD countries and for the period 1985-2015 are shown in (17) where fixed effects for countries and years have been applied and standard errors are shown in brackets:

$$\begin{aligned} \Delta lnX^t &= \underset{(0.324)}{1.060} + \underset{(0.0264)}{0.520}\,\Delta lnQ^t - \underset{(0.0080)}{0.046}\,\Delta lnR^t; adjR^2 = 0.6422; DF = 546 \\ \Delta lnQ^t &= \underset{(0.403)}{1.027} + \underset{(0.0405)}{0.797}\,\Delta lnX^t + \underset{(0.0088)}{0.121}\,\Delta lnR^t; adjR^2 = 0.7659; DF = 546. \end{aligned} \tag{17}$$

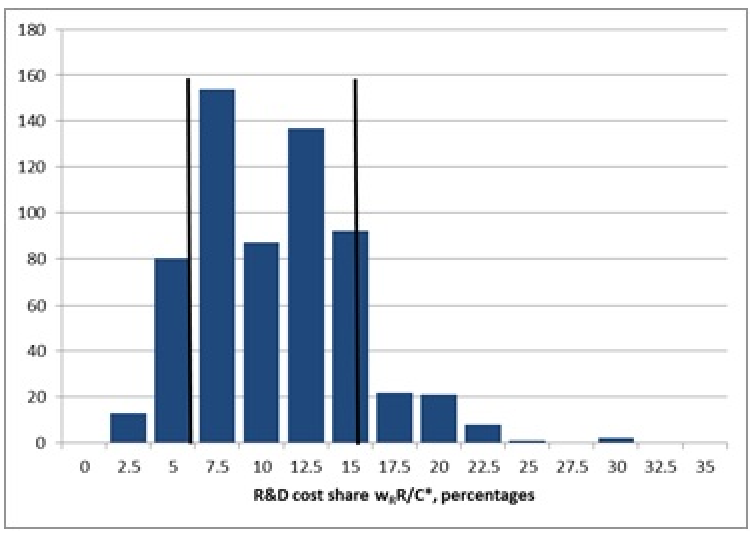
All coefficients are significant and show the right sign. However, as expected, direct and reverse regression lead to very different measures of returns to scale and of shadow prices for the R&D asset. In particular, short-run returns to scale are either 1/0.520 =1.92 when based on the first result in (17) or 0.797 when based on the second result in (17). The cost elasticity of the R&D asset as implied by the first regression equals $w_{RS}R/C^* = (w_{RS}R/C)(C/C^*) = 0.046/(1 + 0.046) = 0.048$ and the cost elasticity of R&D as implied by the second regression equals $w_{RS}R/C^* = [(\epsilon w_{RS}R/C)/\epsilon][C/C^*] = (0.121/0.797)/(1 + 0.121/0.797) = 0.131$. Thus, our lower bound for the cost share as recovered by the estimation is around 5% and the upper bound around

[7] Klepper and Leamer (1984) also demonstrate that in the case of three variables, the true value of the coefficients lies inside the triangular area mapped out by these three regressions. We refrain from formally setting out all three regressions – i.e., also including a specification where R&D is the dependent variable because such a specification would be very hard to justify on economic grounds. It is very unlikely that R&D capital services are driven by contemporaneous output and non-R&D inputs.

13%. We thus find a rather large possible range of cost elasticities for R&D [8].

Compare these point estimates with the descriptive statistics for the cost shares $w_R R/C^*$ that have been computed with a standard index number approach: their mean and median are around 9.5%, with a minimum value of around 2%, the average of the first quartile is around 5%, the average of the third quartile around 12%. Figure (1) below shows the frequency distribution of all $w_R R/C^*$, along with the upper and lower boundaries from the regression results. About 2/3 of all computed values lie within these bounds and we conclude that the econometric results do not offer significant additional insight over the unconstrained index number results.

Figure 1: Cost-elasticities of R&D: distribution of unrestricted measures and econometric results



Source: authors' calculations, based on *OECD Productivity Database October 2017*

Ugur et al (2016) conduct a meta-data analysis of 773 elasticity estimates of R&D capital on output at the firm level and 135 elasticity estimates at the

[8]If the second reverse regression with R&D as the dependent variable is run despite its theoretical implausibility, the implied upper bound to the coefficient is even higher, around 44%

industry level in OECD countries. Their median estimate ranges from 0.008 to 0.313 for elasticities at the industry level. Our own estimates appear to be well within this range, considering in particular that the authors also find that elasticity estimates tend to be higher when R&D capital is constructed with the perpetual inventory method and when output is measured as value added which is the case in our data set.

With the help of equation (12) we can carry out another test for significant differences between estimated cost elasticities and those derived from the unrestricted model. We first express equation (12) in discrete time, and then assume that both restricted and unrestricted cost elasticities are constant, along with the assumption that technical change again follows a simple stochastic process $\Delta\pi^t = \alpha_{c0} + \mu_c^t$:

$$\begin{aligned} MFP^t &= \Delta lnQ^t - \Delta lnZ^{*t} \\ &= \epsilon^*[w_{RS}R/C^* - w_R R/C^*]\Delta lnR^t + (\epsilon^* - 1)\Delta lnZ^{*t} + \Delta\pi^t \\ MFP^t &= \alpha_{c0} + \alpha_{c1}\Delta lnR^t + \alpha_{c2}\Delta lnZ^t + \mu_c^t. \end{aligned} \tag{18}$$

If restricted and unrestricted cost elasticities of R&D are constant and significantly different from each other, the coefficient $\alpha_{c1} = \epsilon^*(w_{RS}R/C^* - w_R R/C^*)$ should be significantly different from zero. A similar specification has been used to test whether output elasticities of knowledge-based capital exceed its factor shares (Roth and Thum 2013, Niebel et al. 2013 and Haines et al., 2017) and, in a somewhat different context, as an estimate for spillovers from ICT and intangibles (Stiroh 2002, Corrado et al. 2014). Estimation of (18) produces insignificant results for α_{c1} and the same holds for the reverse regression.

In light of these outcomes and various other advantages of using unconstrained index numbers – full variability across countries and years, reproducibility and greater ease of applicability in regular statistical production – we conclude that there is no strong reason to prefer the econometric approach over the index number approach. In what follows we shall therefore rely on an unrestricted cost function as set out earlier.

Scale elasticity

We next turn to the estimation of returns to scale. Our workhorse is the growth accounting equation (15) that presents the growth rate of output as a function of the growth rate of combined inputs and technical change, augmented by long-run returns to scale. Transformed into discrete time by repeating the operations in Annex B for an unrestricted cost function, equation (15) reads as follows:

$$\begin{aligned} \Delta lnZ^t &= \frac{1}{\epsilon^*}\Delta lnQ^t - \Delta\pi^t, \\ \Delta lnQ^t &= \epsilon^*\left(\Delta lnZ^{*t} + \Delta\pi^t\right); \end{aligned} \tag{19}$$

where $\Delta lnZ^{*t} \equiv 0.5\left(\frac{C^t}{C^{*t}} + \frac{C^{t-1}}{C^{*t-1}}\right)\Delta lnX^t + 0.5\left(\frac{w_R^t R^t}{C^{*t}} + \frac{w_R^{t-1}R^{t-1}}{C^{*t-1}}\right)\Delta lnR^t$ is the cost-share weighted Törnqvist index of inputs. We have again specified both the direct and the reverse form of the growth accounting equation as the same points about errors in the variables apply that were discussed above. 19 sets up the estimation where productivity $\Delta\pi^t$ is again taken to follow a simple stochastic form with a constant expected value and randomly distributed variations around it: $\Delta\pi^t = \alpha_{d0} + \mu_{dt}$.

$$\begin{aligned} \Delta lnZ^t &= \alpha_{d0} + \alpha_{d1}\Delta lnQ^t - \mu_d^t \\ \Delta lnQ^t &= \alpha_{e0} + \alpha_{e1}\Delta lnZ^{*t} + \mu_e^t. \end{aligned} \tag{20}$$

Our baseline results are the direct and the reverse simple OLS estimate of (20). For each direct and reverse estimate we add country-specific fixed effects and time-specific fixed effects, first separately and then combined. Two types of time effects are tested, one with dummies for all years (bar one), the other with dummies for the crisis years 2008 and 2009 only. Overall, we end up with 12 estimates for long-run returns to scale and productivity growth. The corresponding evaluations of ϵ^* range from around 0.8 to around 1.6. with an unweighted mean of 1.24. With (classical) measurement errors likely present in all variables, the arguments developed earlier apply again, and suggest that the set of direct estimates around the first expression in (20) will produce estimates of $\epsilon^* = 1/\alpha_{d1}$ that are downward biased whereas reverse estimates around the second expression in (20) will produce estimates of $\alpha_{e1} = \epsilon^*$ that are upward biased. As the true coefficient will lie in between each pair of estimates, we take as point estimate – and best guess - for ϵ^* the geometric average of the various results which corresponds to $\epsilon^* = 1.2$.

This is in line with related research. For instance, Diewert and Fox (2008) find a scale elasticity of between 1.2 and 1.5 for U.S manufacturing industry.

Basu and Fernald (1997) produce evidence of scale elasticities of between 1.29 and 1.46 for a comparable aggregate, value-added based measure for the private sector of the US economy.

3.1 De-composing MFP and measuring mark-up

With an estimate for ϵ^* at hand it is now possible to implement (17) empirically and de-compose the MFP growth into an element that reflects returns to scale, $(1-1/\epsilon^*)\Delta lnQ^t$, and into an element of 'residual' productivity growth, $\Delta\pi_S^t$. The qualification 'residual' is important because there are almost certainly other forces than pure technical change that affect this measure.

$$MFP^t = (1-1/\epsilon^*)\Delta lnQ^t + \Delta\pi_S^t. \tag{21}$$

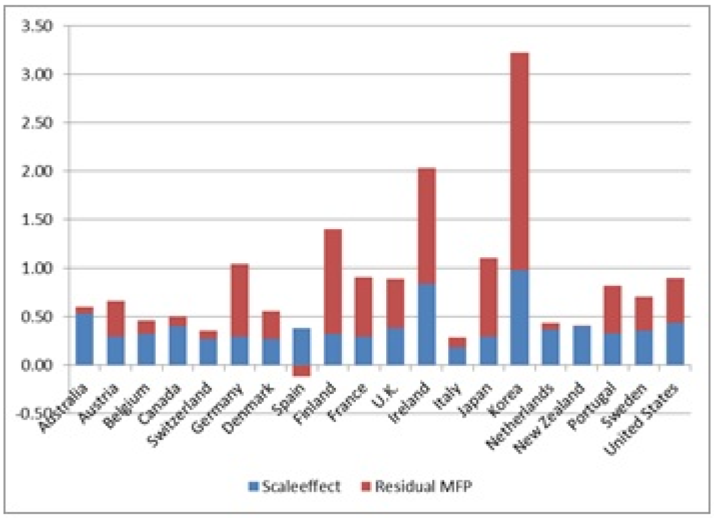
Figure (2) exhibits results of this decomposition for 20 OECD countries over the period 1985-2015. Despite differences between countries, it is apparent that both effects are important, although a look at the annual data shows much greater volatility of the residual MFP component. Overall, and across all countries and periods, the scale effect and the residual MFP effect are approximately equally strong determinants of MFP growth.

A scale effect of some magnitude has policy-relevant consequences. One is the implied effect of demand on productivity – a causality that runs counter to the more standard supply-side interpretation where technology and efficiency improvements affect output. On the one hand, this concerns longer-term demand effects: for instance, rising income inequality may have a dampening effect on demand and consequently on productivity if the average propensity to consume declines (Summers 2015) or if lower income households desire to accumulate precautionary savings in response to the higher income risk associated with persistent inequality (Auclert and Rognlie 2018). In the short-term, the procyclical nature of productivity growth can be explained when demand affects productivity, as has been suggested by Hall (1988) and Basu and Fernald (1997).

A second and related policy-relevant conclusion is that market size matters for MFP. With markets expanding globally, returns to scale come into force and reduce marginal costs. This is one of the positive effects of expanding trade and vice versa, shrinking market size will negatively affect productivity growth. A third consequence is that increasing returns to scale imply the existence of mark-ups over marginal costs and therefore some monopolistic elements. Whether or not these monopolistic elements are further accompanied by 'pure' mark-ups is an important question for competition policy.

Figure 2: Scale effects and residual MFP

Percentages



Source: authors' calculations, based on *OECD Productivity Database October 2017*

Turning to mark-ups over marginal costs, these are measured with the help of equation (19):

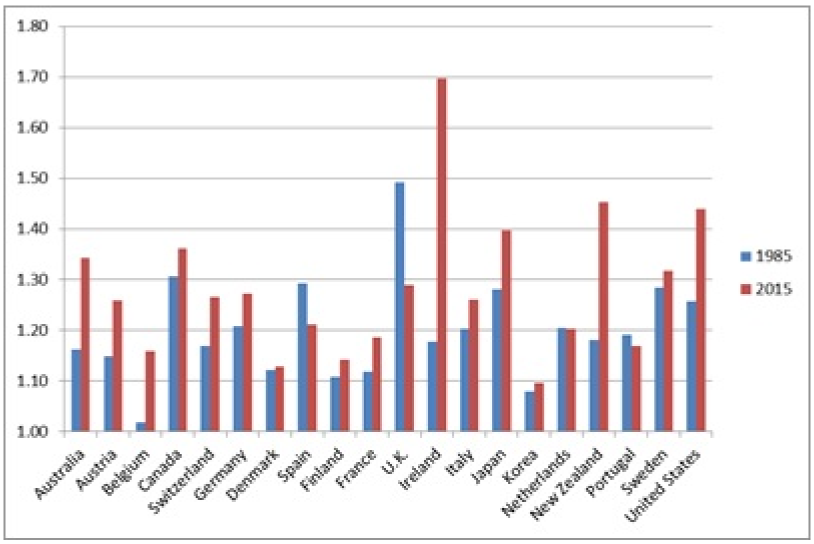
$$1 + m^{*t} = \epsilon^* \left(1 - \frac{M^{*t}}{P_Q^t Q^t}\right) - 1 = \epsilon^* \left(1 + \frac{M^{*t}}{C^{*t}}\right). \tag{22}$$

To measure $1+m^{*t}$, we use the constant average value $\epsilon^* = 1.2$ and the time- and country-varying measure of 'residual' profit rates $M^{*t}/P_Q^t Q^t$. M^{*t} is the difference between labour compensation, user costs of capital and the nominal value of output. The latter is measured at basic prices, so any (other) taxes and subsidies on production are excluded from the residual mark-up M^{*t}. In our sample, the average mark-up factor $1 + m^{*t}$, across all countries and years is around 1.3 or a 30% addition to marginal costs. This is broadly consistent with early work by Oliveira-Martins et al. (1996), Christopoulou and Vermeulen (2012), although the authors assume constant returns and consider the private sector rather the total economy. Diewert and Fox (2008) derive mark-ups between 1.4 and 1.7 for U.S. manufacturing, Devereux et al. (1996) review the literature and estimate that mark-ups of up to 1.5 constitute a plausible value for use in modelling. De Loecker and Warzynski (2012), in a firm-level study of Slovenian manufacturing firms, obtain mark-ups in the range of 1.17–1.28. As in other studies, mark-up levels across countries vary significantly, as can be seen from Figure 3. This reflects a host of factors, including the degree of competition and regulation, differences in the presence and in the returns to other assets such as natural resources or intangibles that have not been explicitly captured; and measurement issues.

It should be recalled here that the level of residual or 'pure' mark-ups $M{*}t$ also reflects assumptions about the longer-run real rate of return to capital that have entered the computation of user costs (Annex A). Indeed, the standard way to proceed (Jorgenson 1985, Jorgenson and Landefeld 2004) is letting the rate of return to capital that enters user cost measures adjust so that M^{*t} vanishes ('endogenous rates of return'). When residual profits disappear, the mark-up over marginal costs equals exactly the degree of returns to scale as can be seen from (22). In this case, time-invariant returns to scale $\epsilon*$ would imply time-invariant mark-ups $1 + m^{*t}$.

Rather than focusing on the level of mark-ups it may thus be more interesting to see how mark-ups develop over time. Under the present methodology all changes in mark-ups $1 + m^{*t}$ are triggered by changes in residual profit rates $M^{*t}/P_Q^tQ^t$. It is of note that over the period 1985-2015, mark-ups increased in virtually all of the 20 countries bar the U.K. and Portugal. A particularly strong hike in mark-ups is measured for Ireland, possibly reflecting supra-normal returns to intellectual property assets. Andrews et al. (2016), albeit with an entirely different firm-level dataset arrive at a similar conclusion of upward trending mark-ups in OECD countries. There is no space for more detailed analysis here but rising mark-ups are certainly consistent with situations where the digital economy and associated network effects lead to 'winner-takes-most' outcomes and reduced competition. Rising mark-ups may also be a reflection of the rising importance and or rising returns to those assets that have not been explicitly recognised in the present computations. When of the intangible kind, these assets include human capital, organisational capital, or marketing assets as investigated by Corrado et al. (2005), OECD (2013) or Goodridge et al (2016). When of the tangible kind, these assets include in particular land whose price has registered an upward trend over the past decades in many OECD countries.

Figure 3: Mark-ups over marginal costs
Percentages



Source: authors' calculations, based on *OECD Productivity Database October 2017*

4 Conclusions

With the implementation of the 2008 System of National Accounts, R&D capital stock measures are now widely available in OECD countries. While it is natural to include R&D capital services into the measurement of productivity, R&D assets are also somewhat special: conceptually, they shape production rather than provide a specific type of service, they are replicable and easily transferable and their production often entails long gestation and sunk costs; and measurement of the value and prices of R&D investment and R&D assets has to rely on more assumptions than is normally the case for other assets. We investigate whether the usual assumption of period-to-period cost-minimising choices of capital inputs is warranted for R&D inputs and conclude that on the whole the traditional index number method cannot be rejected.

We also test for non-constant returns to scale and find econometric evidence for moderately increasing returns at the aggregate economy level, much in line with the available literature. This permits decomposing MFP growth rates into a component that is triggered by returns to scale and into a component of 'pure' or 'residual' technical change. Across the 20 countries examined and over three decades, the two components are approximately equally important. A dependence of MFP on the level of activity both helps explaining cyclical patterns of MFP growth and points to the importance of long-term demand, market size and international trade as supporting factors of productivity.

The dual picture of imperfect competition and increasing returns to scale is mark-ups over marginal costs. We measure mark-ups and distinguish between those that arise in conjunction with increasing returns and those that are 'pure' or 'residual' profit rates above and beyond what is needed to cover average costs. We find that mark-up rates have trended upwards in nearly all countries investigated. This chimes well with effects associated with globalisation and digitalisation where some markets may have become less competitive. Extra profits may also reflect returns to assets not measured in our set of inputs, including intangibles other than R&D, R&D capital services that are provided from abroad within a Multinational enterprise and tangibles such as land and natural resources.

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Annex A Measurement and Data Sources

R&D assets

The measurement of capital requires a number of methodological choices that, more often than not, suffer from weak empirical support and require more or less well-founded assumptions by statisticians. Examples include the choice of service lives (or depreciation rates), retirement distributions and the form of the age-efficiency function (OECD 2009). Some of these choices matter little for the final productivity measure. But with large and lumpy shifts of the asset base as observed recently with intellectual property products, they may become important.

We start with a representation of the production of the IP asset itself. In line with the 2008 SNA, R&D is an investment activity that adds to final demand and GDP. Investment may happen as a result of own-account production in the functional unit of a larger enterprise or in a separate corporation. Statistical practice now introduces several simplifications to deal with missing information in regards to R&D.

Absent market observations on the value of own-account research, a first constraint is that the gross value of research output at current prices has to be measured by summing costs – compensation of employees, user costs of capital employed in R&D and (other) taxes on production. Current price value-added (gross output net of intermediate inputs) is then measured by summing the value of primary inputs labour and capital. Thus, the value-added created in R&D firms or production units in period t equals

$$P_R^t I_R^t = \sum_i w_{Xi}^t X_{Ri}^t. \tag{A.1}$$

In (A.1), I_R^t is the volume of R&D output (in value-added terms) in period t and $X_R \equiv [X_{R1}, X_{R2}, ...]$ captures volumes of labour and capital services purchased at prices $w_X \equiv [w_{X1}, w_{X2}, ...]$. Although we specify price and volume components P_R^t and I_R^t for R&D output, these are not in general separately observable. A second assumption is necessary here, namely that the volume change of research output is measured by the volume change of its inputs. By implication, productivity growth in R&D production is zero and the price index of research output moves in tandem with the price index of research inputs [9] .

[9]The implied production function is $I_R = f_R(X_R)$. Note that this reflects a statistical

Absence of an independent measure of the price P_R and its movements over time also implies that the usual assumption that P_R is the equilibrium price generated on the market for capital goods does not necessarily hold. Such an equilibrium price connects the (marginal) cost of producing a unit of R&D investment with the discounted stream of future revenues that is expected from using R&D in production. There is no guarantee that the input-based price that is imputed by statisticians reflects such an equilibrium price. However, a valuation by private asset owners may be observable when assets are sold or transferred. As will be seen below, this raises an issue of consistency of valuation of capital measures.

A third element of statistical practice - indeed, needed for most types of assets and not only for R&D - is that measures of stocks are constructed by cumulating measures of flows of investment volumes over time after correcting for depreciation and retirement:

$$P_R^t R^t = \lambda_0 P_R^t I_R^t + \lambda_1 P_R^t I_R^{t-1} + \lambda_2 P_R^t I_R^{t-2} + ... \tag{A.2}$$

The sequence $1 \geq \lambda_0 \geq \lambda_1 \geq \lambda_N > 0$ captures the depreciation, retirement and obsolescence patterns for a service life of N periods. One issue is the choice of service lives N and the implied rates of depreciation. We shall devote little space to this question here although we note that depreciation of IP assets reflects obsolescence or patent expiration rather than physical wear-and-tear. This complicates the estimation of depreciation rates. Diewert and Huang (2011) and Li (2012) show how N and the sequence of λ can be derived.

In (A.2), the sequence of $\left[P_R^t I_R^{t-i}\right]$ was somewhat loosely referred to as investment flows. This requires some precision. Capital formation does not only consist of newly produced investment products but may also include existing or second-hand assets that are being acquired. Another, less frequent, source of additions to capital is the 'appearance' of assets. This may arise with discoveries of natural resources or with the transfer of an asset within a (multinational) corporation. Both acquired existing assets and appearing assets need to be added to a country's or industry's capital stock if they generate capital services. Thus, for any period t, the addition to the capital stock is $\lambda_i(P_R^t I_R^{t-i} + P_R^t I_{RA}^{t-i})$

constraint rather than economic reasoning. If independent volume measures or deflators for research output are available, the zero productivity growth assumption is not needed as the growth rate of IR can be estimated independently from the volume of inputs. In this case, the production function would read as $I_R = f_{R1}(X_R, t)$.

where $P_R^t I_{RA}^{t-i}$ is the volume of the appearing stock I_{RA}^{t-i}, valued in prices P_R^t of year t. If the source of information for the appearing asset is a company balance sheet, this creates a potential inconsistency as companies may have have applied a different valuation from P_R^t, call it P_{RA}^t. Unless a revaluation is undertaken, there is a danger of inconsistency if $P_{RA}^t I_{RA}^{t-i}$ rather than $P_R^t I_{RA}^{t-i}$ enters the computation of the capital stock. Consistent revaluation requires also that information is available about the remaining service life of the appearing asset. Such a revaluation and adjustment for the age of the appearing asset is not always possible absent relevant information. The analyst faces a trade-off between an inconsistency in valuation as well as an inaccurate depreciation profile and not accounting for the appearing (or disappearing) asset at all. It would seem that the latter likely constitutes a worse choice than the former.

There is also the selection of the depreciation pattern. A common choice is a geometric pattern where a cohort of assets loses value and productive capacity at a constant rate. Another, widely used sequence is the hyperbolic age-efficiency profile for $\lambda : \lambda_i = \frac{N-i}{N-bi}; i = 0, 1, 2, ...N; 0 < b \leq 1$ implying that the service flows from assets decline little at first and more rapidly towards the end of the service life. An extreme case of the hyperbolic profile arises with $b = 1$ for $i = 1, 2, ...N$ so that $\lambda = 1$ throughout the asset's service life and dropping to zero thereafter ('one-hoss shay'). In the case of knowledge assets it stands to reason that service flows follow a hyperbolic or one-hoss shay profile: absent any wear and tear, there is a non-diminished flow of services during the asset's service life coupled with a rapid decline at the end of the service life. However, things may be different if one reasons in terms of cohort of assets rather than a single asset. For whole cohorts, it is necessary to introduce a retirement distribution unless it is assumed that N is identical for all individual assets within the same cohort. The sequence of service flows for an entire cohort may look quite different from that for an individual asset (Hulten 1990).

The treatment of appearing assets that are lumpy and large requires also careful attention to infra-annual patterns (assuming that observations are annual) so that large additions to the capital stock appear when they actually provide capital services and affect output. Note that in line with national accounts conventions, investment flows or appearance of assets (I_R^t, I_{RA}^t) are measured in terms of average values of the period. Whether they affect productive stocks R^t and associated service flows at the beginning, in the middle or at the end of period t does not normally matter but may become important when I_R^t or I_{RA}^t are large, discrete flows.

In summary, then, while the principles of measuring R&D capital are aligned with other types of assets (OECD 2010), there are some major complications that are specific to R&D (and other knowledge-based assets):

- It is often difficult to obtain independent observations on the value and price of R&D investment, which requires applying an input-based approach. There is also greater uncertainty about the accuracy of rates of depreciation – or obsolescence – than with many other fixed assets.

- As intellectual property assets can easily be transferred across borders, there is the possibility of large appearances of such assets on countries' balance sheets. These additions to the capital stock should be recognised in the measurement of capital services although they raise further issues of valuation and estimation of their remaining service lives.

The *OECD Productivity Database* uses the perpetual inventory method as in (A.2) to compute stocks of R&D capital. The age-efficiency pattern is hyperbolic with a service life of 10 years and the retirement function follows a normal distribution with a standard deviation of 25% of the average service life. Investment data on R&D is augmented by the value of appearing assets where this plays a sizable role, for example in Ireland. National deflators for R&D investment are applied which in general reflect price changes of inputs in R&D activity.

4.1 Capital services

More generally, in the OECD Productivity Database capital services provided to production by each type of capital good are estimated by the rate of change of their productive capital stocks. Estimates of productive capital stock are computed using the perpetual inventory method on the assumption that the same service lives and retirement functions are applicable for any given asset irrespective of the country. Productive capital stocks and the respective flows of capital services are computed separately for eight non-residential fixed assets. The following average service lives are currently assumed for the different assets: 7 years for computer hardware, 15 years for telecommunications equipment, transport equipment, and other machinery and equipment and weapons systems, 40 years for non-residential construction, 3 years for computer software and databases, 10 years for R&D and 7 years for other intellectual property products. The approach further uses harmonised deflators for computer hardware, telecommunications equipment and computer software and databases, for all countries, to sort out comparability problems that exist in national practices for deflation for this group of assets (Schreyer, 2002; Colecchia and Schreyer, 2002). The overall volume measure of capital services is computed with a Törnqvist index by aggregating the volume change of capital services of all individual assets using asset specific user cost shares as weights. Further details can be found in Schreyer et al (2003) as well as in the *OECD Productivity Compendium* ([45]).

4.2 Labour inputs

The preferred measure of labour input in the OECD Productivity Database, and hence the labour input measure used in this paper, is the total number of hours worked by all persons engaged in production (i.e. employees plus self-employed). While the preferred source for total hours worked in the database is countries' national accounts, in the case of Japan and New Zealand, for which national accounts data on hours worked are not available at the time of writing this paper, other sources have been used, i.e. data from labour force surveys as published in the OECD Employment and Labour Market Statistics.

Annex B Tables by Country

Australia

Year	GDP (volume) annual % change (ΔlnQ)	Non-R&D inputs annual % change (ΔlnX)	R&D input annual % change (ΔlnR)	R&D user costs % of total cost of inputs (w_R)	All inputs annual % change (ΔlnZ)	Multi-factor productivity annual % change (MFP)	Residual productivity effect	Scale effect	Mark up over marginal costs (1+m*)
1985	4.02	4.74	5.07	2.24	4.75	-0.73	-1.403	0.673	1.16340
1986	2.55	3.19	7.15	2.36	3.21	-0.67	-1.097	0.427	1.18140
1987	5.62	3.90	6.83	2.38	3.93	1.69	0.750	0.940	1.20061
1988	3.81	4.37	7.97	2.33	4.40	-0.59	-1.227	0.637	1.18900
1989	3.47	3.70	7.41	2.34	3.73	-0.26	-0.841	0.581	1.14799
1990	-0.38	-0.21	6.68	2.52	-0.15	-0.22	-0.156	-0.064	1.12769
1991	0.44	0.01	7.65	2.78	0.08	0.36	0.286	0.074	1.17128
1992	3.98	0.96	9.30	3.05	1.04	2.94	2.274	0.666	1.21501
1993	3.97	2.56	9.35	3.44	2.63	1.34	0.676	0.664	1.24364
1994	3.82	4.03	9.05	3.89	4.09	-0.27	-0.909	0.639	1.25147
1995	3.87	2.66	9.24	4.31	2.75	1.13	0.483	0.647	1.26650
1996	3.87	1.47	6.96	4.83	1.54	2.33	1.683	0.647	1.27975
1997	4.34	2.25	5.62	5.04	2.29	2.05	1.324	0.726	1.30007
1998	4.89	2.21	4.68	4.74	2.24	2.64	1.822	0.818	1.29364
1999	3.79	3.47	3.76	4.73	3.47	0.32	-0.314	0.634	1.28631
2000	1.91	1.34	4.03	4.96	1.38	0.53	0.210	0.320	1.27553
2001	3.78	0.91	5.06	5.03	0.97	2.81	2.178	0.632	1.28867
2002	3.02	3.20	5.21	5.09	3.23	-0.21	-0.715	0.505	1.28859
2003	4.06	2.73	5.56	5.36	2.78	1.29	0.611	0.679	1.31637
2004	3.15	3.01	5.49	5.70	3.05	0.11	-0.417	0.527	1.34756
2005	2.93	3.17	6.19	5.92	3.22	-0.28	-0.770	0.490	1.37753
2006	3.68	3.53	6.76	6.03	3.58	0.10	-0.516	0.616	1.38358
2007	3.63	3.83	7.16	6.00	3.89	-0.25	-0.857	0.607	1.35425
2008	1.80	2.35	5.73	6.21	2.40	-0.61	-0.911	0.301	1.39719
2009	1.99	1.52	5.14	6.28	1.59	0.40	0.067	0.333	1.36138
2010	2.35	3.26	4.82	6.29	3.29	-0.94	-1.333	0.393	1.37331
2011	3.57	2.80	5.34	6.37	2.85	0.72	0.123	0.597	1.37708
2012	2.54	1.81	4.40	6.80	1.86	0.67	0.245	0.425	1.37458
2013	2.58	1.74	3.59	6.82	1.78	0.80	0.368	0.432	1.37385
2014	2.39	1.64	3.19	6.95	1.67	0.72	0.320	0.400	1.36458
2015	2.73	1.93	2.78	7.03	1.95	0.78	0.323	0.457	1.34161

Source: authors' calculations, based on *OECD Productivity Database October 2017*

Austria

Year	GDP (volume) annual % change ($\Delta \ln Q$)	Non-R&D inputs annual % change ($\Delta \ln X$)	R&D input annual % change ($\Delta \ln R$)	R&D user costs % of total cost of inputs (w_R)	All inputs annual % change ($\Delta \ln Z$)	Multi-factor productivity annual % change (MFP)	Residual productivity effect	Scale effect	Mark up over marginal costs (1+m*)
1985	2.47	n.a.	7.27	3.87	n.a.	n.a.	n.a.	n.a.	1.14929
1986	2.28	n.a.	7.06	4.10	n.a.	n.a.	n.a.	n.a.	1.15366
1987	1.35	n.a.	6.61	4.71	n.a.	n.a.	n.a.	n.a.	1.17604
1988	3.24	n.a.	6.49	5.05	n.a.	n.a.	n.a.	n.a.	1.18421
1989	3.81	n.a.	6.55	5.07	n.a.	n.a.	n.a.	n.a.	1.18326
1990	4.25	n.a.	6.52	5.26	n.a.	n.a.	n.a.	n.a.	1.18901
1991	3.38	n.a.	6.42	5.57	n.a.	n.a.	n.a.	n.a.	1.18403
1992	2.07	n.a.	6.17	5.63	n.a.	n.a.	n.a.	n.a.	1.16481
1993	0.53	n.a.	5.65	6.05	n.a.	n.a.	n.a.	n.a.	1.15737
1994	2.37	n.a.	5.41	6.31	n.a.	n.a.	n.a.	n.a.	1.16529
1995	2.63	n.a.	6.47	6.46	n.a.	n.a.	n.a.	n.a.	1.20544
1996	2.37	2.44	6.29	6.79	2.51	-0.14	-0.536	0.396	1.20689
1997	2.18	1.69	6.13	7.02	1.77	0.41	0.045	0.365	1.21232
1998	3.50	0.81	5.85	7.14	0.90	2.60	2.014	0.586	1.21741
1999	3.53	2.33	5.67	7.30	2.39	1.14	0.549	0.591	1.20442
2000	3.31	1.89	5.47	7.19	1.96	1.36	0.806	0.554	1.21114
2001	1.34	1.17	5.44	7.44	1.25	0.09	-0.134	0.224	1.21707
2002	1.64	0.83	5.00	7.83	0.92	0.73	0.456	0.274	1.21674
2003	0.75	1.04	4.80	8.18	1.13	-0.38	-0.505	0.125	1.22296
2004	2.67	1.35	3.84	8.69	1.41	1.26	0.813	0.447	1.24845
2005	2.12	0.53	4.11	9.39	0.61	1.50	1.145	0.355	1.27227
2006	3.30	1.11	4.78	9.98	1.20	2.09	1.538	0.552	1.29978
2007	3.56	1.56	5.13	10.67	1.66	1.90	1.304	0.596	1.32929
2008	1.54	1.75	4.58	11.21	1.83	-0.30	-0.558	0.258	1.30974
2009	-3.87	-2.38	4.69	11.24	-2.17	-1.70	-1.053	-0.647	1.25330
2010	1.91	0.75	4.53	11.07	0.87	1.05	0.730	0.320	1.25260
2011	2.77	2.10	4.62	11.07	2.17	0.60	0.137	0.463	1.25732
2012	0.74	0.27	4.98	11.09	0.42	0.33	0.206	0.124	1.23169
2013	0.12	0.12	5.24	11.26	0.28	-0.15	-0.170	0.020	1.22772
2014	0.64	0.63	4.40	11.75	0.75	-0.11	-0.217	0.107	1.24056
2015	0.96	-0.11	3.88	12.12	0.03	0.93	0.769	0.161	1.25865

Source: authors' calculations, based on *OECD Productivity Database October 2017*

Belgium

Year	GDP (volume) annual % change (ΔlnQ)	Non-R&D inputs annual % change (ΔlnX)	R&D input annual % change (ΔlnR)	R&D user costs % of total cost of inputs (w_R)	All inputs annual % change (ΔlnZ)	Multi-factor productivity annual % change (MFP)	Residual productivity effect	Scale effect	Mark up over marginal costs (1+m*)
1985	1.64	1.77	-0.54	6.00	1.73	-0.09	-0.364	0.274	1.01918
1986	1.81	0.85	-0.39	4.91	0.83	0.98	0.677	0.303	1.02305
1987	2.28	1.04	2.03	4.98	1.06	1.22	0.839	0.381	1.03367
1988	4.62	2.12	1.49	7.44	2.11	2.51	1.737	0.773	1.12789
1989	3.41	2.12	2.37	6.97	2.13	1.28	0.710	0.570	1.17350
1990	3.09	2.83	4.65	5.31	2.86	0.23	-0.287	0.517	1.17594
1991	1.82	-0.17	2.61	4.61	-0.13	1.95	1.646	0.304	1.15274
1992	1.52	0.01	2.72	4.98	0.05	1.47	1.216	0.254	1.17047
1993	-0.97	-1.39	-1.23	6.20	-1.38	0.42	0.582	-0.162	1.15225
1994	3.18	0.89	-2.25	6.82	0.84	2.34	1.808	0.532	1.12564
1995	2.36	3.99	-2.02	7.69	3.87	-1.52	-1.915	0.395	1.17384
1996	1.58	0.37	-1.74	11.22	0.31	1.27	1.006	0.264	1.17096
1997	3.64	2.57	-1.38	11.55	2.46	1.19	0.581	0.609	1.18386
1998	1.96	3.31	-1.37	12.14	3.18	-1.22	-1.548	0.328	1.21017
1999	3.50	2.41	-0.65	11.35	2.33	1.17	0.584	0.586	1.18737
2000	3.57	3.62	-0.93	10.41	3.50	0.07	-0.527	0.597	1.19007
2001	0.81	2.19	0.64	10.46	2.15	-1.34	-1.476	0.136	1.18532
2002	1.76	0.73	1.32	10.55	0.74	1.02	0.726	0.294	1.17510
2003	0.77	0.70	1.37	10.28	0.71	0.06	-0.069	0.129	1.17625
2004	3.57	1.55	2.17	10.75	1.56	2.01	1.413	0.597	1.20784
2005	2.07	1.82	2.76	11.40	1.84	0.23	-0.116	0.346	1.22651
2006	2.47	2.19	2.22	10.84	2.19	0.28	-0.133	0.413	1.20691
2007	3.34	2.55	2.31	10.35	2.54	0.80	0.241	0.559	1.20223
2008	0.74	2.06	2.64	10.69	2.08	-1.33	-1.454	0.124	1.18501
2009	-2.31	-0.45	2.76	10.89	-0.36	-1.95	-1.564	-0.386	1.15628
2010	2.66	1.06	2.25	10.73	1.10	1.56	1.115	0.445	1.16401
2011	1.78	2.41	2.57	10.84	2.41	-0.63	-0.928	0.298	1.16227
2012	0.14	0.92	2.21	11.41	0.96	-0.82	-0.843	0.023	1.15360
2013	-0.07	0.10	1.99	11.48	0.15	-0.22	-0.208	-0.012	1.14221
2014	1.64	0.68	3.28	11.61	0.76	0.88	0.606	0.274	1.13952
2015	1.49	0.90	4.84	12.06	1.02	0.47	0.221	0.249	1.15996

Source: authors' calculations, based on *OECD Productivity Database October 2017*

Canada

Year	GDP (volume) annual % change (ΔlnQ)	Non-R&D inputs annual % change (ΔlnX)	R&D input annual % change (ΔlnR)	R&D user costs % of total cost of inputs (w_R)	All inputs annual % change (ΔlnZ)	Multi-factor productivity annual % change (MFP)	Residual productivity effect	Scale effect	Mark up over marginal costs (1+m*)
1985	4.63	3.76	3.95	5.07	3.76	0.86	0.085	0.775	1.30655
1986	2.14	3.10	2.84	5.26	3.10	-0.96	-1.318	0.358	1.29012
1987	4.01	3.56	1.69	5.52	3.53	0.49	-0.181	0.671	1.29867
1988	4.33	3.62	2.98	5.71	3.61	0.73	0.006	0.724	1.28450
1989	2.30	2.63	2.61	5.40	2.63	-0.34	-0.725	0.385	1.23371
1990	0.15	1.21	2.10	5.24	1.23	-1.07	-1.095	0.025	1.22860
1991	-2.15	-1.26	1.78	5.89	-1.21	-0.94	-0.580	-0.360	1.20582
1992	0.88	-0.15	0.96	6.28	-0.13	1.01	0.863	0.147	1.21302
1993	2.62	1.09	1.81	5.94	1.10	1.52	1.082	0.438	1.23504
1994	4.40	2.55	1.97	7.16	2.54	1.86	1.124	0.736	1.30962
1995	2.64	1.81	3.03	7.20	1.83	0.81	0.368	0.442	1.33237
1996	1.60	2.15	3.74	6.68	2.18	-0.58	-0.848	0.268	1.35044
1997	4.19	2.28	2.05	6.91	2.28	1.92	1.219	0.701	1.32272
1998	3.81	2.67	2.15	6.47	2.67	1.14	0.503	0.637	1.29421
1999	5.03	3.09	2.86	6.29	3.09	1.95	1.109	0.841	1.31206
2000	5.05	2.70	4.04	6.74	2.72	2.33	1.485	0.845	1.34170
2001	1.76	1.43	4.89	6.50	1.49	0.27	-0.024	0.294	1.32311
2002	2.97	1.87	4.72	7.19	1.92	1.04	0.543	0.497	1.31972
2003	1.79	2.14	4.41	8.22	2.19	-0.40	-0.699	0.299	1.36103
2004	3.04	2.76	4.45	8.95	2.80	0.24	-0.269	0.509	1.40017
2005	3.15	1.75	4.23	9.41	1.80	1.35	0.823	0.527	1.42983
2006	2.59	2.28	3.39	10.70	2.30	0.29	-0.143	0.433	1.45716
2007	2.04	2.55	2.20	10.62	2.54	-0.50	-0.841	0.341	1.45289
2008	1.00	1.80	2.31	9.91	1.81	-0.82	-0.987	0.167	1.46081
2009	-2.99	-2.31	1.29	9.51	-2.22	-0.77	-0.270	-0.500	1.35791
2010	3.04	2.16	1.00	9.57	2.13	0.91	0.401	0.509	1.39256
2011	3.09	1.75	0.81	8.97	1.73	1.36	0.843	0.517	1.39790
2012	1.73	2.16	0.19	8.68	2.11	-0.38	-0.669	0.289	1.38321
2013	2.44	1.46	0.53	8.49	1.44	1.01	0.602	0.408	1.38934
2014	2.53	0.83	0.19	8.43	0.81	1.72	1.297	0.423	1.40880
2015	0.94	1.31	-0.11	7.87	1.28	-0.34	-0.497	0.157	1.36147

Source: authors' calculations, based on *OECD Productivity Database October 2017*

Denmark

Year	GDP (volume) annual % change (ΔlnQ)	Non-R&D inputs annual % change (ΔlnX)	R&D input annual % change (ΔlnR)	R&D user costs % of total cost of inputs (w_R)	All inputs annual % change (ΔlnZ)	Multi-factor productivity annual % change (MFP)	Residual productivity effect	Scale effect	Mark up over marginal costs (1+m*)
1985	3.93	2.41	3.25	4.98	2.42	1.50	0.843	0.657	1.12216
1986	4.79	3.49	4.43	4.88	3.50	1.29	0.489	0.801	1.08487
1987	0.25	0.19	5.18	5.00	0.26	-0.01	-0.052	0.042	1.07494
1988	-0.01	-0.27	6.13	5.35	-0.18	0.17	0.172	-0.002	1.07422
1989	0.64	0.20	6.50	5.97	0.30	0.34	0.233	0.107	1.11311
1990	1.46	0.11	6.37	6.14	0.21	1.25	1.006	0.244	1.12300
1991	1.38	0.23	5.84	6.49	0.32	1.06	0.829	0.231	1.14377
1992	1.94	1.08	5.96	6.82	1.16	0.77	0.445	0.325	1.15966
1993	0.01	-0.54	5.17	6.97	-0.44	0.45	0.448	0.002	1.15073
1994	5.20	0.26	4.86	7.31	0.35	4.84	3.970	0.870	1.16820
1995	2.98	2.19	4.98	7.66	2.25	0.73	0.231	0.499	1.16744
1996	2.86	1.48	4.95	7.89	1.55	1.31	0.832	0.478	1.14780
1997	3.21	3.14	5.17	8.33	3.19	0.02	-0.517	0.537	1.14718
1998	2.19	3.08	4.67	8.61	3.11	-0.92	-1.286	0.366	1.10909
1999	2.91	2.65	4.41	9.02	2.70	0.21	-0.277	0.487	1.11165
2000	3.68	2.20	4.72	9.32	2.27	1.41	0.794	0.616	1.15688
2001	0.82	1.88	5.65	9.71	1.98	-1.16	-1.297	0.137	1.13389
2002	0.47	0.75	2.10	10.04	0.79	-0.33	-0.409	0.079	1.12348
2003	0.39	-0.08	2.93	10.64	0.01	0.38	0.315	0.065	1.13103
2004	2.63	0.49	2.23	10.82	0.55	2.09	1.650	0.440	1.14177
2005	2.31	1.47	3.84	11.62	1.54	0.77	0.384	0.386	1.13866
2006	3.84	2.95	2.64	12.21	2.94	0.90	0.258	0.642	1.15149
2007	0.91	1.53	1.86	10.93	1.54	-0.63	-0.782	0.152	1.09671
2008	-0.51	1.59	4.94	10.71	1.70	-2.21	-2.125	-0.085	1.08698
2009	-5.03	-2.49	5.71	11.83	-2.22	-2.82	-1.979	-0.841	1.05962
2010	1.85	-1.05	4.78	12.11	-0.84	2.69	2.381	0.309	1.08611
2011	1.33	0.93	3.26	11.91	1.02	0.31	0.087	0.223	1.07747
2012	0.23	-0.96	3.32	13.31	-0.79	1.02	0.982	0.038	1.10796
2013	0.93	0.39	2.81	13.83	0.49	0.44	0.284	0.156	1.11928
2014	1.66	0.40	2.72	13.88	0.50	1.16	0.882	0.278	1.13190
2015	1.59	1.08	3.11	13.91	1.16	0.43	0.164	0.266	1.12835

Source: authors' calculations, based on *OECD Productivity Database October 2017*

Finland

Year	GDP (volume) annual % change (ΔlnQ)	Non-R&D inputs annual % change (ΔlnX)	R&D input annual % change (ΔlnR)	R&D user costs % of total cost of inputs (w_R)	All inputs annual % change (ΔlnZ)	Multi-factor productivity annual % change (MFP)	Residual productivity effect	Scale effect	Mark up over marginal costs (1+m*)
1985	3.48	1.10	10.03	5.52	1.22	2.26	1.678	0.582	1.10832
1986	2.69	-0.15	9.76	6.00	-0.01	2.70	2.250	0.450	1.11178
1987	3.50	1.72	9.24	6.61	1.83	1.66	1.074	0.586	1.10667
1988	5.08	2.28	8.85	7.13	2.39	2.69	1.840	0.850	1.09670
1989	4.96	1.88	8.35	6.85	1.99	2.97	2.140	0.830	1.08297
1990	0.67	-0.50	6.57	6.44	-0.37	1.05	0.938	0.112	1.03909
1991	-6.10	-4.29	5.50	6.74	-4.09	-2.00	-0.980	-1.020	0.97519
1992	-3.38	-4.45	4.53	7.12	-4.26	0.88	1.445	-0.565	0.98904
1993	-0.74	-4.00	3.91	7.10	-3.81	3.08	3.204	-0.124	1.02866
1994	3.86	-0.06	4.37	7.78	0.05	3.82	3.174	0.646	1.08682
1995	4.12	1.78	4.39	9.06	1.85	2.27	1.581	0.689	1.15670
1996	3.59	1.40	5.86	9.82	1.52	2.07	1.469	0.601	1.16295
1997	6.06	2.58	7.12	10.50	2.70	3.36	2.346	1.014	1.18434
1998	5.29	1.62	7.07	11.37	1.78	3.51	2.625	0.885	1.21673
1999	4.35	2.59	9.11	12.48	2.79	1.56	0.832	0.728	1.22325
2000	5.48	1.55	8.99	13.04	1.80	3.68	2.763	0.917	1.24109
2001	2.55	0.81	7.82	13.84	1.06	1.49	1.063	0.427	1.25896
2002	1.67	0.79	6.72	14.81	1.01	0.65	0.371	0.279	1.25203
2003	1.97	0.15	5.90	16.21	0.39	1.59	1.260	0.330	1.25156
2004	3.85	0.92	5.33	17.34	1.11	2.74	2.096	0.644	1.26650
2005	2.74	1.21	4.26	19.57	1.35	1.39	0.932	0.458	1.26391
2006	3.98	1.66	3.46	20.20	1.75	2.23	1.564	0.666	1.26147
2007	5.05	2.22	3.48	19.38	2.28	2.77	1.925	0.845	1.29173
2008	0.72	2.02	3.22	18.25	2.08	-1.36	-1.480	0.120	1.23684
2009	-8.63	-2.56	1.52	18.47	-2.35	-6.28	-4.836	-1.444	1.13932
2010	2.95	0.06	1.14	18.87	0.12	2.83	2.336	0.494	1.15683
2011	2.54	1.05	0.01	18.77	0.99	1.54	1.115	0.425	1.13763
2012	-1.44	0.45	-1.21	18.95	0.36	-1.79	-1.549	-0.241	1.10611
2013	-0.76	-0.82	-1.85	19.88	-0.88	0.12	0.247	-0.127	1.12545
2014	-0.63	-0.29	-2.48	19.62	-0.41	-0.22	-0.115	-0.105	1.13739
2015	0.27	0.17	-2.93	18.45	0.01	0.26	0.215	0.045	1.14212

Source: authors' calculations, based on *OECD Productivity Database October 2017*

France

Year	GDP (volume) annual % change ($\Delta \ln Q$)	Non-R&D inputs annual % change ($\Delta \ln X$)	R&D input annual % change ($\Delta \ln R$)	R&D user costs % of total cost of inputs (w_R)	All inputs annual % change ($\Delta \ln Z$)	Multi-factor productivity annual % change (MFP)	Residual productivity effect	Scale effect	Mark up over marginal costs ($1+m^*$)
1985	1.61	-1.10	4.30	9.89	-0.96	2.57	2.301	0.269	1.11925
1986	2.32	0.85	4.02	10.51	0.93	1.40	1.012	0.388	1.15904
1987	2.54	1.98	4.22	10.67	2.04	0.50	0.075	0.425	1.16763
1988	4.63	2.08	4.29	11.09	2.14	2.49	1.715	0.775	1.19294
1989	4.26	1.62	4.62	11.01	1.71	2.55	1.837	0.713	1.21044
1990	2.87	1.54	5.33	10.46	1.64	1.23	0.750	0.480	1.20462
1991	1.03	0.70	4.47	10.40	0.81	0.23	0.058	0.172	1.18839
1992	1.59	0.50	4.08	10.76	0.60	0.98	0.714	0.266	1.20260
1993	-0.61	-0.82	3.53	10.87	-0.68	0.07	0.172	-0.102	1.20034
1994	2.32	0.55	3.12	11.09	0.63	1.69	1.302	0.388	1.19964
1995	2.06	0.23	2.59	11.61	0.30	1.76	1.415	0.345	1.21126
1996	1.38	1.21	2.14	12.04	1.24	0.14	-0.091	0.231	1.21339
1997	2.31	0.89	1.49	12.34	0.91	1.40	1.014	0.386	1.23625
1998	3.49	1.61	1.20	12.80	1.59	1.90	1.316	0.584	1.26616
1999	3.35	2.37	1.21	12.85	2.33	1.02	0.460	0.560	1.26630
2000	3.80	1.18	1.05	12.83	1.17	2.63	1.994	0.636	1.27851
2001	1.94	1.71	1.39	12.85	1.70	0.23	-0.095	0.325	1.28406
2002	1.11	-0.84	1.72	12.97	-0.76	1.87	1.684	0.186	1.28074
2003	0.82	0.51	1.31	12.96	0.53	0.28	0.143	0.137	1.27689
2004	2.75	2.21	1.38	13.38	2.19	0.56	0.100	0.460	1.29313
2005	1.59	0.86	1.18	13.49	0.87	0.72	0.454	0.266	1.29303
2006	2.35	0.29	1.40	13.85	0.32	2.03	1.637	0.393	1.28970
2007	2.33	2.70	1.51	13.36	2.66	-0.33	-0.720	0.390	1.30374
2008	0.20	1.48	1.87	12.70	1.49	-1.30	-1.333	0.033	1.29252
2009	-2.99	-1.43	1.94	12.74	-1.33	-1.66	-1.160	-0.500	1.25422
2010	1.95	0.75	2.09	12.59	0.79	1.15	0.824	0.326	1.24009
2011	2.06	1.12	2.32	11.84	1.16	0.90	0.555	0.345	1.21945
2012	0.18	0.40	2.22	11.63	0.46	-0.27	-0.300	0.030	1.19308
2013	0.57	-0.31	2.26	11.62	-0.23	0.80	0.705	0.095	1.18790
2014	0.63	0.27	1.99	11.33	0.33	0.31	0.205	0.105	1.18385
2015	1.27	0.97	2.06	11.13	1.01	0.26	0.048	0.212	1.18698

Source: authors' calculations, based on *OECD Productivity Database October 2017*

Germany

Year	GDP (volume) annual % change ($\Delta \ln Q$)	Non-R&D inputs annual % change ($\Delta \ln X$)	R&D input annual % change ($\Delta \ln R$)	R&D user costs % of total cost of inputs (w_R)	All inputs annual % change ($\Delta \ln Z$)	Multi-factor productivity annual % change (MFP)	Residual productivity effect	Scale effect	Mark up over marginal costs ($1+m^*$)
1985	2.30	0.82	8.68	8.06	0.99	1.31	0.925	0.385	1.20786
1986	2.26	1.33	8.91	8.65	1.49	0.77	0.392	0.378	1.22802
1987	1.39	0.75	9.01	9.04	0.93	0.46	0.227	0.233	1.20793
1988	3.64	1.61	8.86	9.87	1.78	1.86	1.251	0.609	1.23897
1989	3.82	1.11	9.30	10.21	1.33	2.50	1.861	0.639	1.24180
1990	5.12	2.13	9.21	10.12	2.32	2.80	1.943	0.857	1.23761
1991	4.98	2.14	8.58	9.80	2.31	2.67	1.837	0.833	1.20428
1992	1.91	0.39	7.33	9.70	0.58	1.33	1.010	0.320	1.18354
1993	-0.96	-1.52	5.83	9.39	-1.32	0.36	0.521	-0.161	1.16489
1994	2.43	0.36	4.53	9.01	0.48	1.95	1.543	0.407	1.16156
1995	1.72	0.42	3.89	8.99	0.51	1.21	0.922	0.288	1.16627
1996	0.81	-0.26	3.28	9.33	-0.16	0.98	0.844	0.136	1.17615
1997	1.83	0.02	2.54	9.44	0.09	1.75	1.444	0.306	1.19367
1998	1.96	1.29	2.52	9.51	1.32	0.64	0.312	0.328	1.19606
1999	1.97	1.26	2.84	9.82	1.30	0.66	0.330	0.330	1.18243
2000	2.92	1.23	2.78	9.87	1.28	1.64	1.152	0.488	1.17354
2001	1.68	0.04	3.02	9.99	0.12	1.56	1.279	0.281	1.18858
2002	0.00	-0.39	2.77	10.43	-0.30	0.30	0.300	0.000	1.19748
2003	-0.71	-0.76	2.28	10.78	-0.67	-0.04	0.079	-0.119	1.19334
2004	1.16	0.43	2.18	11.34	0.48	0.68	0.486	0.194	1.22737
2005	0.70	-0.24	1.90	12.23	-0.17	0.88	0.763	0.117	1.24955
2006	3.63	1.79	2.18	12.68	1.80	1.83	1.223	0.607	1.27617
2007	3.21	1.83	2.35	12.91	1.85	1.36	0.823	0.537	1.29086
2008	1.08	1.18	2.49	13.11	1.23	-0.15	-0.331	0.181	1.27712
2009	-5.78	-2.30	2.35	13.24	-2.13	-3.65	-2.683	-0.967	1.22225
2010	4.00	1.39	2.14	13.01	1.42	2.58	1.911	0.669	1.24564
2011	3.59	1.49	2.21	13.30	1.51	2.08	1.479	0.601	1.25058
2012	0.49	0.07	2.56	13.48	0.16	0.33	0.248	0.082	1.23766
2013	0.49	-0.10	2.04	13.87	-0.02	0.51	0.428	0.082	1.25039
2014	1.58	1.07	2.38	14.10	1.11	0.47	0.206	0.264	1.25973
2015	1.71	0.89	2.41	14.46	0.95	0.76	0.474	0.286	1.27291

Source: authors' calculations, based on *OECD Productivity Database October 2017*

Ireland

Year	GDP (volume) annual % change ($\Delta \ln Q$)	Non-R&D inputs annual % change ($\Delta \ln X$)	R&D input annual % change ($\Delta \ln R$)	R&D user costs % of total cost of inputs (w_R)	All inputs annual % change ($\Delta \ln Z$)	Multi-factor productivity annual % change (MFP)	Residual productivity effect	Scale effect	Mark up over marginal costs ($1+m^*$)
1985	3.04	0.59	9.81	3.72	0.67	2.37	1.861	0.509	1.17706
1986	-0.43	1.29	8.70	4.65	1.37	-1.79	-1.718	-0.072	1.20732
1987	4.56	0.09	8.53	5.16	0.18	4.38	3.617	0.763	1.24630
1988	5.09	0.83	8.63	5.34	0.92	4.17	3.318	0.852	1.27235
1989	5.65	0.78	8.86	5.74	0.88	4.77	3.825	0.945	1.30489
1990	8.13	3.68	9.13	6.33	3.75	4.38	3.020	1.360	1.33478
1991	1.91	-1.20	8.71	6.22	-1.07	2.99	2.670	0.320	1.33410
1992	3.29	-0.90	8.68	6.47	-0.77	4.06	3.510	0.550	1.29088
1993	2.66	0.48	8.05	7.08	0.59	2.07	1.625	0.445	1.33974
1994	5.60	3.04	7.86	7.57	3.10	2.49	1.553	0.937	1.33819
1995	9.20	4.33	9.69	7.96	4.41	4.79	3.251	1.539	1.40540
1996	8.70	4.15	9.57	8.58	4.23	4.47	3.015	1.455	1.38137
1997	10.21	3.36	9.54	9.49	3.45	6.75	5.042	1.708	1.45926
1998	7.91	4.48	10.87	9.73	4.58	3.33	2.007	1.323	1.54640
1999	10.31	6.35	12.93	10.30	6.46	3.85	2.125	1.725	1.52671
2000	9.45	4.74	9.50	10.46	4.83	4.62	3.039	1.581	1.54786
2001	5.88	3.47	22.44	10.78	3.86	2.02	1.036	0.984	1.52570
2002	5.43	1.63	24.83	11.47	2.19	3.23	2.322	0.908	1.53275
2003	3.61	2.01	17.66	12.76	2.45	1.16	0.556	0.604	1.50571
2004	6.51	3.43	17.56	14.47	3.88	2.63	1.541	1.089	1.45756
2005	5.61	5.63	17.78	14.95	6.05	-0.45	-1.389	0.939	1.42749
2006	5.70	5.08	13.94	13.91	5.40	0.31	-0.644	0.954	1.39067
2007	3.73	4.51	10.51	13.89	4.73	-1.01	-1.634	0.624	1.36828
2008	-4.47	0.11	7.26	14.60	0.39	-4.86	-4.112	-0.748	1.26825
2009	-4.67	-6.10	8.99	15.65	-5.42	0.75	1.531	-0.781	1.22845
2010	2.01	-2.52	7.51	17.38	-1.99	4.00	3.664	0.336	1.33121
2011	-0.04	-3.63	8.29	20.47	-2.95	2.91	2.917	-0.007	1.40605
2012	-1.11	0.88	9.22	24.94	1.44	-2.55	-2.364	-0.186	1.43064
2013	1.09	3.38	3.94	27.74	3.42	-2.32	-2.502	0.182	1.49054
2014	8.12	2.91	6.14	28.14	3.15	4.98	3.622	1.358	1.58531
2015	23.33	3.49	153.21	65.27	28.95	-5.62	-9.523	3.903	1.69640

Source: authors' calculations, based on *OECD Productivity Database October 2017*

Italy

Year	GDP (volume) annual % change (ΔlnQ)	Non-R&D inputs annual % change (ΔlnX)	R&D input annual % change (ΔlnR)	R&D user costs % of total cost of inputs (w_R)	All inputs annual % change (ΔlnZ)	Multi-factor productivity annual % change (MFP)	Residual productivity effect	Scale effect	Mark up over marginal costs (1+m*)
1985	2.76	1.51	7.12	3.13	1.56	1.20	0.738	0.462	1.20370
1986	2.82	1.89	7.01	3.50	1.94	0.88	0.408	0.472	1.25344
1987	3.14	2.04	7.02	3.67	2.09	1.05	0.525	0.525	1.25693
1988	4.11	2.16	7.15	3.59	2.21	1.90	1.212	0.688	1.25286
1989	3.33	1.03	6.98	3.81	1.09	2.24	1.683	0.557	1.26911
1990	1.97	1.80	6.42	4.06	1.85	0.12	-0.210	0.330	1.24928
1991	1.53	2.03	6.06	4.13	2.07	-0.55	-0.806	0.256	1.22508
1992	0.83	0.37	5.71	4.24	0.43	0.40	0.261	0.139	1.21472
1993	-0.86	-1.60	5.16	4.25	-1.52	0.66	0.804	-0.144	1.23471
1994	2.13	-0.98	5.07	4.55	-0.90	3.03	2.674	0.356	1.25792
1995	2.85	0.60	4.96	5.18	0.66	2.18	1.703	0.477	1.28772
1996	1.28	1.57	5.01	5.12	1.62	-0.34	-0.554	0.214	1.29910
1997	1.82	0.75	4.56	5.17	0.80	1.02	0.716	0.304	1.28534
1998	1.60	2.10	4.47	5.77	2.14	-0.54	-0.808	0.268	1.32063
1999	1.55	1.55	4.37	5.67	1.59	-0.04	-0.299	0.259	1.31655
2000	3.64	1.63	4.63	5.53	1.68	1.96	1.351	0.609	1.32702
2001	1.76	1.86	5.14	5.46	1.91	-0.16	-0.454	0.294	1.33642
2002	0.25	1.72	4.86	5.63	1.76	-1.52	-1.562	0.042	1.33597
2003	0.15	1.38	4.42	5.69	1.42	-1.27	-1.295	0.025	1.33530
2004	1.57	1.09	3.51	5.85	1.13	0.44	0.177	0.263	1.33654
2005	0.95	0.91	3.43	6.17	0.95	-0.01	-0.169	0.159	1.33194
2006	1.99	2.13	2.91	6.43	2.14	-0.16	-0.493	0.333	1.31420
2007	1.46	1.83	2.82	6.55	1.85	-0.39	-0.634	0.244	1.31838
2008	-1.06	0.24	3.21	6.65	0.29	-1.35	-1.173	-0.177	1.30668
2009	-5.64	-2.29	3.43	7.06	-2.18	-3.46	-2.516	-0.944	1.27819
2010	1.67	-0.15	2.80	7.02	-0.09	1.76	1.481	0.279	1.24774
2011	0.57	0.26	2.33	6.61	0.30	0.28	0.185	0.095	1.23815
2012	-2.86	-1.79	1.66	6.48	-1.72	-1.14	-0.662	-0.478	1.22848
2013	-1.74	-1.99	1.45	6.51	-1.92	0.17	0.461	-0.291	1.23293
2014	0.11	-0.19	0.94	6.24	-0.16	0.28	0.262	0.018	1.23025
2015	0.78	0.55	0.85	6.35	0.55	0.23	0.100	0.130	1.26039

Source: authors' calculations, based on *OECD Productivity Database October 2017*

Japan

Year	GDP (volume) annual % change ($\Delta\ln Q$)	Non-R&D inputs annual % change ($\Delta\ln X$)	R&D input annual % change ($\Delta\ln R$)	R&D user costs % of total cost of inputs (w_R)	All inputs annual % change ($\Delta\ln Z$)	Multi-factor productivity annual % change (MFP)	Residual productivity effect	Scale effect	Mark up over marginal costs (1+m*)
1985	6.14	1.46	6.80	8.63	1.58	4.56	3.533	1.027	1.28055
1986	2.79	2.09	6.74	9.11	2.20	0.60	0.133	0.467	1.30225
1987	4.03	1.78	6.92	9.70	1.90	2.12	1.446	0.674	1.34858
1988	6.90	2.42	7.08	10.15	2.54	4.37	3.216	1.154	1.37375
1989	5.23	2.05	7.46	10.30	2.19	3.04	2.165	0.875	1.37155
1990	5.42	1.58	7.17	10.60	1.73	3.69	2.783	0.907	1.36732
1991	3.27	2.05	6.67	10.27	2.18	1.09	0.543	0.547	1.35072
1992	0.82	1.10	6.01	9.96	1.24	-0.42	-0.557	0.137	1.32903
1993	0.17	-0.74	4.32	10.44	-0.59	0.77	0.742	0.028	1.31176
1994	0.86	0.88	3.69	10.55	0.96	-0.10	-0.244	0.144	1.30733
1995	2.71	0.87	3.27	10.50	0.94	1.76	1.307	0.453	1.29920
1996	3.05	1.70	3.33	10.64	1.75	1.30	0.790	0.510	1.30754
1997	1.07	0.78	3.14	10.50	0.86	0.21	0.031	0.179	1.29952
1998	-1.14	-0.58	2.98	10.74	-0.47	-0.67	-0.479	-0.191	1.30778
1999	-0.25	-1.13	2.26	10.81	-1.02	0.76	0.802	-0.042	1.31062
2000	2.74	0.96	2.02	10.88	1.00	1.74	1.282	0.458	1.32660
2001	0.41	0.20	1.89	11.24	0.26	0.15	0.081	0.069	1.33256
2002	0.12	-0.59	1.67	11.76	-0.51	0.63	0.610	0.020	1.37938
2003	1.52	0.66	1.45	12.17	0.69	0.83	0.576	0.254	1.39670
2004	2.18	0.45	1.26	12.59	0.48	1.70	1.335	0.365	1.42629
2005	1.65	0.63	1.60	13.09	0.67	0.98	0.704	0.276	1.43894
2006	1.41	1.37	1.64	13.82	1.38	0.03	-0.206	0.236	1.44436
2007	1.64	1.09	1.87	14.00	1.12	0.52	0.246	0.274	1.44318
2008	-1.10	-0.34	1.53	13.63	-0.26	-0.84	-0.656	-0.184	1.38725
2009	-5.57	-3.17	0.77	13.62	-3.01	-2.56	-1.628	-0.932	1.36772
2010	4.11	0.64	0.17	13.68	0.62	3.49	2.802	0.688	1.39250
2011	-0.12	-0.27	0.10	13.50	-0.25	0.14	0.160	-0.020	1.35006
2012	1.48	0.45	-0.02	13.57	0.43	1.06	0.812	0.248	1.36561
2013	1.98	0.05	0.26	13.61	0.06	1.92	1.589	0.331	1.37223
2014	0.34	0.33	0.79	13.36	0.35	-0.01	-0.067	0.057	1.36037
2015	1.21	-0.07	1.32	13.58	-0.01	1.22	1.018	0.202	1.39637

Source: authors' calculations, based on *OECD Productivity Database October 2017*

Korea

Year	GDP (volume) annual % change (ΔlnQ)	Non-R&D inputs annual % change (ΔlnX)	R&D input annual % change (ΔlnR)	R&D user costs % of total cost of inputs (w_R)	All inputs annual % change (ΔlnZ)	Multi-factor productivity annual % change (MFP)	Residual productivity effect	Scale effect	Mark up over marginal costs (1+m*)
1985	7.46	4.37	19.22	3.93	4.47	2.99	1.742	1.248	1.08000
1986	10.64	5.93	19.99	4.09	6.03	4.60	2.820	1.780	1.08481
1987	11.75	6.01	19.98	4.29	6.12	5.63	3.664	1.966	1.10465
1988	11.25	3.76	19.68	4.47	3.89	7.36	5.478	1.882	1.10157
1989	6.79	2.94	18.25	4.86	3.08	3.72	2.584	1.136	1.09058
1990	9.36	3.58	17.77	5.62	3.72	5.63	4.064	1.566	1.09289
1991	9.85	4.67	14.91	6.09	4.79	5.06	3.412	1.648	1.10378
1992	5.99	3.42	13.72	6.34	3.55	2.44	1.438	1.002	1.08873
1993	6.62	3.84	12.55	6.78	3.96	2.66	1.553	1.107	1.07791
1994	8.81	4.77	12.61	6.91	4.89	3.92	2.446	1.474	1.09027
1995	9.14	5.27	13.91	7.58	5.40	3.74	2.211	1.529	1.08639
1996	7.32	4.00	11.73	7.90	4.13	3.19	1.965	1.225	1.06025
1997	5.75	1.94	11.39	8.50	2.11	3.64	2.678	0.962	1.07839
1998	-5.63	-6.35	7.85	8.68	-6.06	0.43	1.372	-0.942	1.08713
1999	10.71	3.40	7.36	8.89	3.49	7.22	5.428	1.792	1.07886
2000	8.55	5.88	8.30	8.97	5.94	2.61	1.180	1.430	1.09134
2001	4.43	2.86	9.82	9.42	3.02	1.40	0.659	0.741	1.07653
2002	7.17	2.61	8.70	9.82	2.76	4.41	3.210	1.200	1.08863
2003	2.89	0.00	8.08	9.68	0.21	2.68	2.197	0.483	1.07770
2004	4.78	1.71	8.35	9.79	1.89	2.89	2.090	0.800	1.09737
2005	3.85	0.92	7.39	9.99	1.09	2.75	2.106	0.644	1.07290
2006	5.05	1.95	6.78	11.21	2.09	2.96	2.115	0.845	1.09027
2007	5.32	0.79	7.44	11.66	0.99	4.33	3.440	0.890	1.11652
2008	2.79	-0.58	7.51	12.31	-0.32	3.11	2.643	0.467	1.12805
2009	0.71	0.13	7.42	12.56	0.38	0.33	0.211	0.119	1.13430
2010	6.29	0.52	8.04	12.61	0.79	5.51	4.458	1.052	1.15329
2011	3.62	-0.87	7.57	11.50	-0.56	4.17	3.564	0.606	1.12226
2012	2.27	4.78	7.80	11.54	4.90	-2.63	-3.010	0.380	1.08715
2013	2.86	-0.57	7.40	12.18	-0.26	3.11	2.632	0.478	1.09074
2014	3.29	3.97	7.34	12.52	4.11	-0.82	-1.370	0.550	1.08264
2015	2.58	1.62	6.47	12.93	1.83	0.75	0.318	0.432	1.09711

Source: authors' calculations, based on *OECD Productivity Database October 2017*

Netherlands

Year	GDP (volume) annual % change ($\Delta \ln Q$)	Non-R&D inputs annual % change ($\Delta \ln X$)	R&D input annual % change ($\Delta \ln R$)	R&D user costs % of total cost of inputs (w_R)	All inputs annual % change ($\Delta \ln Z$)	Multi-factor productivity annual % change (MFP)	Residual productivity effect	Scale effect	Mark up over marginal costs (1+m*)
1985	2.55	1.82	0.85	10.82	1.79	0.76	0.333	0.427	1.20522
1986	2.75	2.33	0.89	11.33	2.29	0.46	0.000	0.460	1.21232
1987	1.91	1.68	0.88	10.96	1.66	0.26	-0.060	0.320	1.18988
1988	3.38	2.33	1.10	10.92	2.30	1.08	0.515	0.565	1.20422
1989	4.33	3.04	1.48	10.46	2.99	1.33	0.606	0.724	1.21993
1990	4.10	3.36	1.77	9.62	3.32	0.78	0.094	0.686	1.18753
1991	2.41	2.29	1.77	9.33	2.27	0.14	-0.263	0.403	1.17796
1992	1.69	2.59	1.66	9.12	2.57	-0.88	-1.163	0.283	1.14682
1993	1.25	0.91	1.49	9.23	0.92	0.33	0.121	0.209	1.14363
1994	2.92	1.88	1.49	9.71	1.87	1.05	0.562	0.488	1.16931
1995	3.07	4.43	1.64	10.12	4.36	-1.29	-1.804	0.514	1.17572
1996	3.50	3.46	1.53	10.38	3.41	0.09	-0.496	0.586	1.18540
1997	4.21	2.79	2.23	10.70	2.77	1.44	0.736	0.704	1.21065
1998	4.43	3.06	1.81	10.78	3.03	1.39	0.649	0.741	1.22206
1999	4.93	3.71	2.75	10.62	3.69	1.24	0.415	0.825	1.21095
2000	4.15	2.06	2.55	10.60	2.07	2.08	1.386	0.694	1.22025
2001	2.10	2.10	2.49	10.63	2.11	0.00	-0.351	0.351	1.20995
2002	0.10	0.39	1.75	10.70	0.43	-0.33	-0.347	0.017	1.20515
2003	0.28	-0.18	1.54	10.71	-0.13	0.42	0.373	0.047	1.19824
2004	2.01	0.89	1.75	10.88	0.91	1.10	0.764	0.336	1.21368
2005	2.14	0.51	1.57	10.96	0.54	1.60	1.242	0.358	1.23412
2006	3.46	2.39	1.24	11.06	2.36	1.10	0.521	0.579	1.25779
2007	3.63	3.20	0.88	10.89	3.14	0.49	-0.117	0.607	1.26616
2008	1.68	2.20	0.35	10.78	2.15	-0.47	-0.751	0.281	1.25620
2009	-3.84	-0.55	0.00	10.50	-0.54	-3.30	-2.658	-0.642	1.19581
2010	1.39	-0.07	0.38	10.22	-0.06	1.45	1.217	0.233	1.21158
2011	1.65	1.28	0.60	10.01	1.26	0.39	0.114	0.276	1.20010
2012	-1.06	-0.19	0.32	9.81	-0.17	-0.89	-0.713	-0.177	1.18480
2013	-0.19	-0.28	0.55	9.53	-0.26	0.07	0.102	-0.032	1.17003
2014	1.41	0.79	0.72	9.54	0.79	0.62	0.384	0.236	1.17176
2015	1.93	0.87	0.94	9.54	0.87	1.06	0.737	0.323	1.20248

Source: authors' calculations, based on *OECD Productivity Database October 2017*

New Zealand

Year	GDP (volume) annual % change (ΔlnQ)	Non-R&D inputs annual % change (ΔlnX)	R&D input annual % change (ΔlnR)	R&D user costs % of total cost of inputs (w_R)	All inputs annual % change (ΔlnZ)	Multi-factor productivity annual % change (MFP)	Residual productivity effect	Scale effect	Mark up over marginal costs (1+m*)
1985	1.60	n.a.	3.55	4.01	n.a.	n.a.	n.a.	n.a.	n.a.
1986	2.67	n.a.	4.88	4.10	n.a.	n.a.	n.a.	n.a.	n.a.
1987	-4.38	1.92	4.81	4.11	1.96	-6.35	-5.617	-0.733	1.18199
1988	1.98	-1.09	4.27	4.04	-1.01	2.99	2.659	0.331	1.18041
1989	0.51	-1.19	3.52	4.23	-1.11	1.62	1.535	0.085	1.19736
1990	0.66	-0.76	3.17	4.49	-0.69	1.35	1.240	0.110	1.22243
1991	-1.65	0.48	2.30	5.21	0.51	-2.17	-1.894	-0.276	1.31046
1992	1.25	-1.30	2.89	5.55	-1.23	2.48	2.271	0.209	1.34664
1993	6.32	3.40	2.65	5.79	3.39	2.94	1.883	1.057	1.41443
1994	5.09	4.37	2.67	5.89	4.34	0.74	-0.112	0.852	1.42821
1995	4.51	3.65	2.60	5.68	3.64	0.87	0.116	0.754	1.43310
1996	3.33	3.27	2.70	5.65	3.26	0.07	-0.487	0.557	1.41960
1997	2.95	0.91	4.20	5.68	0.96	1.99	1.496	0.494	1.41402
1998	1.05	3.03	3.00	6.04	3.03	-1.98	-2.156	0.176	1.44307
1999	5.02	4.14	2.68	6.41	4.11	0.90	0.060	0.840	1.50523
2000	2.23	0.67	3.57	6.46	0.72	1.50	1.127	0.373	1.53632
2001	3.78	2.73	3.70	6.00	2.75	1.03	0.398	0.632	1.51396
2002	4.94	3.37	3.53	6.51	3.37	1.57	0.744	0.826	1.51573
2003	4.42	3.39	3.44	6.47	3.39	1.03	0.291	0.739	1.50563
2004	3.19	4.22	4.04	6.52	4.22	-1.03	-1.564	0.534	1.49322
2005	3.28	4.18	3.11	6.46	4.16	-0.89	-1.439	0.549	1.45594
2006	2.56	2.19	2.90	7.11	2.20	0.36	-0.068	0.428	1.46896
2007	3.67	1.24	3.82	6.86	1.28	2.39	1.776	0.614	1.46202
2008	-1.55	2.36	3.21	6.60	2.37	-3.92	-3.661	-0.259	1.39884
2009	1.91	-1.72	3.52	6.54	-1.62	3.54	3.220	0.320	1.39589
2010	0.95	2.34	3.01	6.24	2.35	-1.40	-1.559	0.159	1.39344
2011	2.66	1.48	2.72	6.32	1.50	1.16	0.715	0.445	1.35754
2012	2.47	-0.02	1.26	7.36	0.01	2.46	2.047	0.413	1.37919
2013	1.87	3.83	2.12	7.37	3.80	-1.93	-2.243	0.313	1.46748
2014	3.02	3.75	1.76	7.43	3.71	-0.70	-1.205	0.505	1.45317
2015	3.27	2.09	1.75	8.53	2.08	1.19	0.643	0.547	n.a.

Source: authors' calculations, based on *OECD Productivity Database October 2017*

Portugal

Year	GDP (volume) annual % change (ΔlnQ)	Non-R&D inputs annual % change (ΔlnX)	R&D input annual % change (ΔlnR)	R&D user costs % of total cost of inputs (w_R)	All inputs annual % change (ΔlnZ)	Multi-factor productivity annual % change (MFP)	Residual productivity effect	Scale effect	Mark up over marginal costs (1+m*)
1985	2.77	-0.48	-0.22	2.03	-0.48	3.25	2.787	0.463	1.19135
1986	4.06	0.08	0.90	2.07	0.08	3.97	3.291	0.679	1.12427
1987	6.19	3.05	2.87	2.10	3.05	3.14	2.104	1.036	1.14848
1988	7.22	2.54	4.64	2.05	2.55	4.67	3.462	1.208	1.15224
1989	6.24	3.11	4.79	2.09	3.12	3.12	2.076	1.044	1.16573
1990	3.87	2.23	5.42	2.08	2.25	1.62	0.973	0.647	1.19831
1991	4.28	0.75	5.46	2.19	0.78	3.50	2.784	0.716	1.12890
1992	1.08	-0.47	5.98	2.33	-0.43	1.51	1.329	0.181	1.12551
1993	-2.06	-0.47	4.58	2.57	-0.44	-1.63	-1.285	-0.345	1.17806
1994	0.96	1.29	4.39	2.73	1.31	-0.35	-0.511	0.161	1.18249
1995	4.19	2.97	5.23	2.88	2.98	1.21	0.509	0.701	1.20948
1996	3.44	2.42	5.46	2.91	2.44	1.00	0.425	0.575	1.18443
1997	4.33	3.15	5.84	2.88	3.17	1.16	0.436	0.724	1.18962
1998	4.68	4.47	7.32	2.97	4.49	0.19	-0.593	0.783	1.16936
1999	3.81	2.99	8.32	3.10	3.03	0.78	0.143	0.637	1.16007
2000	3.72	3.82	9.80	3.04	3.86	-0.14	-0.762	0.622	1.15144
2001	1.92	2.28	9.22	3.26	2.33	-0.40	-0.721	0.321	1.14614
2002	0.77	1.40	7.49	3.41	1.45	-0.68	-0.809	0.129	1.14611
2003	-0.94	0.17	5.63	3.42	0.21	-1.15	-0.993	-0.157	1.13462
2004	1.80	0.84	5.63	3.56	0.88	0.92	0.619	0.301	1.15407
2005	0.76	0.80	5.43	3.56	0.84	-0.08	-0.207	0.127	1.13168
2006	1.54	0.84	7.91	3.88	0.90	0.64	0.382	0.258	1.14795
2007	2.46	1.78	9.15	4.06	1.85	0.61	0.198	0.412	1.17028
2008	0.20	0.88	11.49	4.67	1.00	-0.80	-0.833	0.033	1.15973
2009	-3.02	-1.17	9.77	4.83	-1.02	-2.00	-1.495	-0.505	1.16429
2010	1.88	-0.10	8.07	5.18	0.02	1.86	1.545	0.315	1.15145
2011	-1.84	-1.75	4.86	6.70	-1.63	-0.21	0.098	-0.308	1.12933
2012	-4.11	-3.41	2.79	7.18	-3.27	-0.84	-0.152	-0.688	1.13259
2013	-1.14	-1.55	3.64	6.59	-1.43	0.30	0.491	-0.191	1.15504
2014	0.89	1.43	2.88	7.80	1.46	-0.57	-0.719	0.149	1.16924
2015	1.58	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Source: authors' calculations, based on *OECD Productivity Database October 2017*

Spain

Year	GDP (volume) annual % change (ΔlnQ)	Non-R&D inputs annual % change (ΔlnX)	R&D input annual % change (ΔlnR)	R&D user costs % of total cost of inputs (w_R)	All inputs annual % change (ΔlnZ)	Multi-factor productivity annual % change (MFP)	Residual productivity effect	Scale effect	Mark up over marginal costs (1+m*)
1985	2.29	-0.57	3.45	4.39	-0.53	2.82	2.437	0.383	1.29270
1986	3.20	2.18	3.36	4.35	2.19	1.01	0.475	0.535	1.28550
1987	5.40	4.23	3.82	4.25	4.22	1.18	0.277	0.903	1.29763
1988	4.97	3.68	4.26	4.13	3.68	1.29	0.459	0.831	1.30949
1989	4.71	3.65	4.69	4.43	3.66	1.05	0.262	0.788	1.34009
1990	3.71	4.34	5.07	4.40	4.34	-0.63	-1.251	0.621	1.32252
1991	2.51	2.61	4.97	4.52	2.63	-0.12	-0.540	0.420	1.31070
1992	0.92	-0.37	4.67	4.76	-0.31	1.24	1.086	0.154	1.27665
1993	-1.04	-1.90	3.80	4.69	-1.84	0.80	0.974	-0.174	1.27441
1994	2.36	0.33	3.18	4.67	0.36	1.99	1.595	0.395	1.27095
1995	2.72	2.34	4.65	4.98	2.36	0.36	-0.095	0.455	1.30372
1996	2.64	2.08	4.11	4.81	2.11	0.53	0.088	0.442	1.29263
1997	3.62	3.95	4.11	4.80	3.96	-0.33	-0.936	0.606	1.28491
1998	4.22	4.89	4.06	5.04	4.88	-0.67	-1.376	0.706	1.29432
1999	4.39	5.02	3.37	4.89	5.00	-0.61	-1.344	0.734	1.28266
2000	5.15	4.91	4.39	4.63	4.90	0.25	-0.612	0.862	1.28244
2001	3.92	4.22	4.30	4.77	4.22	-0.30	-0.956	0.656	1.30396
2002	2.84	3.22	6.00	4.85	3.25	-0.41	-0.885	0.475	1.31428
2003	3.14	3.33	8.80	4.86	3.39	-0.25	-0.775	0.525	1.30094
2004	3.12	3.42	7.37	5.16	3.46	-0.35	-0.872	0.522	1.30097
2005	3.66	3.77	7.69	5.19	3.82	-0.16	-0.772	0.612	1.28882
2006	4.09	4.02	8.62	5.06	4.08	0.01	-0.674	0.684	1.26760
2007	3.70	3.35	8.44	4.82	3.41	0.29	-0.329	0.619	1.26337
2008	1.11	1.87	8.53	4.89	1.96	-0.85	-1.036	0.186	1.26489
2009	-3.64	-3.61	7.84	5.13	-3.45	-0.19	0.419	-0.609	1.26070
2010	0.01	-0.81	7.76	5.18	-0.68	0.69	0.688	0.002	1.20370
2011	-1.01	-0.97	6.05	5.32	-0.86	-0.15	0.019	-0.169	1.20389
2012	-2.97	-2.85	4.58	5.74	-2.72	-0.25	0.247	-0.497	1.21471
2013	-1.72	-1.65	4.62	5.98	-1.53	-0.19	0.098	-0.288	1.21381
2014	1.37	1.26	4.15	6.04	1.32	0.05	-0.179	0.229	1.21124
2015	3.15	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Source: authors' calculations, based on *OECD Productivity Database October 2017*

Sweden

Year	GDP (volume) annual % change ($\Delta \ln Q$)	Non-R&D inputs annual % change ($\Delta \ln X$)	R&D input annual % change ($\Delta \ln R$)	R&D user costs % of total cost of inputs (w_R)	All inputs annual % change ($\Delta \ln Z$)	Multi-factor productivity annual % change (MFP)	Residual productivity effect	Scale effect	Mark up over marginal costs (1+m*)
1985	2.14	2.41	1.78	12.51	2.38	-0.25	-0.608	0.358	1.28507
1986	2.66	1.72	2.03	12.73	1.74	0.92	0.475	0.445	1.27555
1987	3.30	2.51	2.36	13.51	2.50	0.80	0.248	0.552	1.25690
1988	2.53	3.40	2.50	13.60	3.36	-0.83	-1.253	0.423	1.24586
1989	2.62	2.77	2.62	13.06	2.76	-0.14	-0.578	0.438	1.19583
1990	0.75	2.00	2.40	13.34	2.02	-1.27	-1.395	0.125	1.15510
1991	-1.15	-0.56	1.93	14.49	-0.44	-0.72	-0.528	-0.192	1.10949
1992	-1.17	-1.63	1.50	14.38	-1.47	0.30	0.496	-0.196	1.10967
1993	-2.09	-2.23	-0.38	14.12	-2.14	0.05	0.400	-0.350	1.11065
1994	4.01	1.89	0.39	14.49	1.81	2.19	1.519	0.671	1.16411
1995	3.95	2.48	1.40	14.62	2.42	1.52	0.859	0.661	1.24582
1996	1.51	1.12	1.10	15.49	1.12	0.39	0.137	0.253	1.26432
1997	2.86	0.38	1.50	16.59	0.43	2.43	1.952	0.478	1.29068
1998	4.14	2.53	2.08	16.69	2.51	1.63	0.937	0.693	1.33650
1999	4.43	3.53	1.92	17.64	3.45	0.98	0.239	0.741	1.33994
2000	4.63	2.45	3.42	18.52	2.50	2.12	1.345	0.775	1.32483
2001	1.55	1.70	4.28	18.87	1.84	-0.29	-0.549	0.259	1.28413
2002	2.05	-0.24	2.91	20.02	-0.05	2.10	1.757	0.343	1.28897
2003	2.36	-0.42	2.55	20.73	-0.24	2.60	2.205	0.395	1.30429
2004	4.23	1.28	2.63	20.89	1.37	2.86	2.152	0.708	1.31914
2005	2.78	1.12	1.87	21.02	1.17	1.61	1.145	0.465	1.31629
2006	4.58	2.08	1.70	20.73	2.05	2.53	1.764	0.766	1.34740
2007	3.35	3.43	1.92	20.23	3.34	0.01	-0.550	0.560	1.34187
2008	-0.56	1.99	1.39	19.98	1.95	-2.51	-2.416	-0.094	1.31033
2009	-5.32	-1.65	0.73	19.66	-1.51	-3.81	-2.920	-0.890	1.24092
2010	5.82	2.47	1.08	19.64	2.38	3.43	2.456	0.974	1.28567
2011	2.63	2.21	0.81	19.37	2.13	0.50	0.060	0.440	1.27979
2012	-0.29	0.57	0.34	19.11	0.55	-0.84	-0.791	-0.049	1.25311
2013	1.23	0.83	1.22	19.14	0.85	0.38	0.174	0.206	1.25959
2014	2.57	1.52	2.66	19.75	1.59	0.98	0.550	0.430	1.28366
2015	4.00	1.77	3.26	19.84	1.86	2.15	1.481	0.669	1.31661

Source: authors' calculations, based on *OECD Productivity Database October 2017*

Switzerland

Year	GDP (volume) annual % change (ΔlnQ)	Non-R&D inputs annual % change (ΔlnX)	R&D input annual % change (ΔlnR)	R&D user costs % of total cost of inputs (w_R)	All inputs annual % change (ΔlnZ)	Multi-factor productivity annual % change (MFP)	Residual productivity effect	Scale effect	Mark up over marginal costs (1+m*)
1985	3.61	n.a.	7.21	5.74	n.a.	n.a.	n.a.	n.a.	n.a.
1986	1.84	n.a.	6.99	6.35	n.a.	n.a.	n.a.	n.a.	n.a.
1987	1.57	n.a.	6.86	7.08	n.a.	n.a.	n.a.	n.a.	n.a.
1988	3.23	n.a.	7.07	7.07	n.a.	n.a.	n.a.	n.a.	n.a.
1989	4.24	n.a.	7.44	6.96	n.a.	n.a.	n.a.	n.a.	n.a.
1990	3.61	n.a.	7.71	7.05	n.a.	n.a.	n.a.	n.a.	n.a.
1991	-0.92	n.a.	7.16	7.04	n.a.	n.a.	n.a.	n.a.	n.a.
1992	-0.04	0.41	6.78	7.33	0.57	-0.61	-0.603	-0.007	1.16915
1993	-0.13	0.13	6.33	7.77	0.29	-0.41	-0.388	-0.022	1.16054
1994	1.26	1.22	6.12	8.31	1.35	-0.09	-0.301	0.211	1.18020
1995	0.48	0.06	4.38	9.04	0.18	0.30	0.220	0.080	1.18033
1996	0.60	-0.31	4.34	9.99	-0.17	0.77	0.670	0.100	1.20213
1997	2.29	0.44	4.14	10.52	0.56	1.73	1.347	0.383	1.20400
1998	2.90	2.46	4.06	11.36	2.51	0.39	-0.095	0.485	1.23130
1999	1.63	2.76	3.86	11.98	2.80	-1.17	-1.443	0.273	1.21985
2000	3.87	1.67	4.16	12.05	1.76	2.11	1.463	0.647	1.23337
2001	1.44	0.43	4.67	12.08	0.57	0.87	0.629	0.241	1.20051
2002	0.14	0.37	5.19	12.51	0.54	-0.39	-0.413	0.023	1.18480
2003	0.05	0.85	5.58	13.05	1.02	-0.97	-0.978	0.008	1.19611
2004	2.80	2.08	6.32	13.76	2.25	0.56	0.092	0.468	1.22007
2005	2.99	0.82	5.48	14.90	1.02	1.98	1.480	0.500	1.25206
2006	3.93	1.77	5.18	15.79	1.91	2.02	1.363	0.657	1.28500
2007	4.06	2.26	4.87	15.69	2.37	1.69	1.011	0.679	1.29773
2008	2.25	2.11	4.33	15.73	2.21	0.04	-0.336	0.376	1.29151
2009	-2.15	0.37	3.09	16.20	0.49	-2.64	-2.280	-0.360	1.25259
2010	2.91	0.75	2.77	16.06	0.84	2.07	1.583	0.487	1.26930
2011	1.79	1.92	2.33	16.08	1.93	-0.15	-0.449	0.299	1.26003
2012	1.04	0.97	2.18	16.68	1.02	0.02	-0.154	0.174	1.25212
2013	1.76	0.52	1.76	16.94	0.58	1.19	0.896	0.294	1.25480
2014	1.98	1.43	2.32	17.00	1.47	0.51	0.179	0.331	1.26726
2015	0.84	2.08	1.97	17.06	2.08	-1.24	-1.381	0.141	1.26635

Source: authors' calculations, based on *OECD Productivity Database October 2017*

United Kingdom

Year	GDP (volume) annual % change ($\Delta \ln Q$)	Non-R&D inputs annual % change ($\Delta \ln X$)	R&D input annual % change ($\Delta \ln R$)	R&D user costs % of total cost of inputs (w_R)	All inputs annual % change ($\Delta \ln Z$)	Multi-factor productivity annual % change (MFP)	Residual productivity effect	Scale effect	Mark up over marginal costs ($1+m^*$)
1985	4.10	3.04	2.12	7.78	3.02	1.09	0.404	0.686	1.49120
1986	3.10	1.12	2.29	8.06	1.14	1.96	1.441	0.519	1.48372
1987	5.22	2.15	2.74	9.35	2.17	3.06	2.187	0.873	1.53970
1988	5.63	5.66	3.22	8.21	5.61	0.02	-0.922	0.942	1.48757
1989	2.55	2.97	3.24	6.21	2.98	-0.43	-0.857	0.427	1.34588
1990	0.71	1.17	3.00	5.81	1.20	-0.49	-0.609	0.119	1.28309
1991	-1.13	-0.94	2.51	6.03	-0.87	-0.25	-0.061	-0.189	1.25748
1992	0.36	-1.70	2.24	5.77	-1.63	1.99	1.930	0.060	1.24235
1993	2.48	0.36	2.23	6.19	0.40	2.08	1.665	0.415	1.32065
1994	3.81	2.31	2.38	8.54	2.31	1.50	0.863	0.637	1.48860
1995	2.48	2.17	2.32	9.68	2.17	0.30	-0.115	0.415	1.40878
1996	2.52	1.73	2.27	9.02	1.75	0.77	0.348	0.422	1.41404
1997	3.08	1.18	2.31	10.75	1.21	1.87	1.355	0.515	1.43364
1998	3.14	2.37	2.73	11.06	2.38	0.76	0.235	0.525	1.39253
1999	3.23	1.50	3.75	9.77	1.55	1.68	1.140	0.540	1.32459
2000	3.68	1.14	3.62	10.45	1.19	2.49	1.874	0.616	1.33417
2001	2.69	1.41	2.66	10.39	1.44	1.25	0.800	0.450	1.30300
2002	2.37	0.47	2.63	10.20	0.51	1.86	1.464	0.396	1.31739
2003	3.41	0.81	2.44	10.46	0.85	2.56	1.990	0.570	1.32689
2004	2.50	0.69	2.15	10.57	0.72	1.78	1.362	0.418	1.31711
2005	2.93	2.26	2.74	10.44	2.27	0.66	0.170	0.490	1.32755
2006	2.47	1.06	2.50	10.73	1.09	1.38	0.967	0.413	1.32312
2007	2.52	1.38	3.46	11.15	1.43	1.10	0.678	0.422	1.30889
2008	-0.63	0.16	3.78	10.31	0.24	-0.87	-0.765	-0.105	1.28990
2009	-4.42	-1.28	2.53	9.74	-1.19	-3.23	-2.491	-0.739	1.24400
2010	1.90	0.04	2.91	10.40	0.10	1.79	1.472	0.318	1.22125
2011	1.50	1.43	2.14	10.66	1.45	0.05	-0.201	0.251	1.20957
2012	1.30	2.01	1.73	10.38	2.00	-0.69	-0.907	0.217	1.21739
2013	1.89	1.83	1.93	11.27	1.84	0.06	-0.256	0.316	1.25257
2014	3.02	2.66	1.77	12.02	2.63	0.39	-0.115	0.505	1.28559
2015	2.17	0.99	1.60	11.93	1.01	1.16	0.797	0.363	1.28950

Source: authors' calculations, based on *OECD Productivity Database October 2017*

United States

Year	GDP (volume) annual % change ($\Delta\ln Q$)	Non-R&D inputs annual % change ($\Delta\ln X$)	R&D input annual % change ($\Delta\ln R$)	R&D user costs % of total cost of inputs (w_R)	All inputs annual % change ($\Delta\ln Z$)	Multi-factor productivity annual % change (MFP)	Residual productivity effect	Scale effect	Mark up over marginal costs ($1+m^*$)
1985	4.15	3.03	5.74	12.42	3.12	1.03	0.336	0.694	1.25744
1986	3.45	2.06	5.63	13.10	2.18	1.27	0.693	0.577	1.26248
1987	3.40	3.10	5.49	13.74	3.18	0.22	-0.349	0.569	1.26051
1988	4.12	3.26	4.90	14.09	3.32	0.80	0.111	0.689	1.25267
1989	3.61	3.14	4.46	13.77	3.19	0.42	-0.184	0.604	1.25207
1990	1.90	1.11	4.16	13.59	1.22	0.68	0.362	0.318	1.23961
1991	-0.07	-0.26	3.56	13.97	-0.11	0.04	0.052	-0.012	1.22345
1992	3.49	0.86	2.78	14.43	0.93	2.57	1.986	0.584	1.23948
1993	2.71	2.59	2.02	14.43	2.57	0.14	-0.313	0.453	1.26683
1994	3.96	3.23	1.47	14.54	3.17	0.79	0.128	0.662	1.28114
1995	2.68	2.84	1.31	14.85	2.78	-0.10	-0.548	0.448	1.29413
1996	3.73	2.06	1.59	14.75	2.04	1.68	1.056	0.624	1.31097
1997	4.39	3.56	1.69	14.49	3.49	0.90	0.166	0.734	1.41149
1998	4.35	3.11	1.86	14.15	3.07	1.29	0.562	0.728	1.38925
1999	4.58	2.91	2.21	14.17	2.89	1.69	0.924	0.766	1.39556
2000	4.01	2.48	2.55	14.30	2.49	1.52	0.849	0.671	1.37984
2001	0.97	0.13	2.72	13.87	0.22	0.75	0.588	0.162	1.37635
2002	1.77	-0.06	2.67	14.18	0.03	1.74	1.444	0.296	1.39926
2003	2.77	0.52	2.79	15.48	0.60	2.17	1.707	0.463	1.43689
2004	3.72	1.67	2.85	16.16	1.71	2.01	1.388	0.622	1.46274
2005	3.29	1.87	3.17	16.13	1.92	1.37	0.820	0.550	1.48623
2006	2.63	2.31	3.41	16.05	2.35	0.29	-0.150	0.440	1.48197
2007	1.76	1.42	3.59	15.80	1.50	0.26	-0.034	0.294	1.47185
2008	-0.29	-0.17	3.46	14.33	-0.04	-0.25	-0.201	-0.049	1.42710
2009	-2.81	-4.03	2.85	13.38	-3.78	0.97	1.440	-0.470	1.41372
2010	2.50	0.15	2.69	13.56	0.24	2.26	1.842	0.418	1.42702
2011	1.59	1.44	2.31	13.62	1.48	0.11	-0.156	0.266	1.42508
2012	2.20	1.96	1.98	13.54	1.96	0.24	-0.128	0.368	1.42310
2013	1.66	1.55	1.92	13.92	1.56	0.10	-0.178	0.278	1.44284
2014	2.34	2.09	1.62	14.02	2.07	0.27	-0.121	0.391	1.44752
2015	2.56	1.97	1.57	13.90	1.95	0.61	0.182	0.428	1.43824

Source: authors' calculations, based on *OECD Productivity Database October 2017*