Getting Rental Prices Right for Computers

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Abstract

It is well established that there are three key components in the capital rental price formula: rate of return, depreciation and capital gain/loss. In applying this formula to national accounts investment data, statisticians face a variety of choices. In terms of the depreciation term for computers, the choice is often made between the time series depreciation and the cross section depreciation, as defined by Hill (1999). In terms of the capital gain/loss term, the choice is between price indexes for new computers and general price indexes, such as CPI. In this paper, we argue that obsolescence is the common element contained in both the time series depreciation term and the computer price indexes. A combination of the time series depreciation and the computer price indexes for imputing rental prices for computers leads to double counting of obsolescence and hence results in upward biased estimates of their capital services. To solve the double counting issue, we propose a combination of the time series depreciation with CPI as a general inflation measure. Our empirical findings demonstrate that the new approach will significantly improve the stability and analytical quality of computer rental prices.

1 Introduction

It is well established that there are three key components in the capital rental price formula: rate of return, depreciation and capital gain/loss. In applying this formula to national accounts investment data, statisticians face a variety of choices.[1]These choices in calculating the price of capital services can make substantial differences to the estimates of capital input, as demonstrated in the recent debate between Diewert &Yu (2012) and Gu (2012). In his comment to the two papers, Schreyer (2012) notes that '*At this stage, there is no single method that constitute an international recommendation or standard. The current debate shows that it may be worth pursuing this objective and to go beyond the recent achievement of having capital services officially recognised as part of the UN System of National Accounts*'.

In this paper we contribute to this literature by considering the case of imputing rental prices for computers. Our focus on computers is mainly due to two factors. First, computer capital is the prevalent driver of rapid growth of capital input both in official productivity statistics and hundreds of productivity studies. An enhanced understanding of the measurement issues for computer rental prices is an important step towards producing more robust and relevant productivity statistics in the information age. Second, the impact of alternative choices in implementing the theoretical user cost formula on practical estimates of capital rental prices appears the largest for computers.

To simplify things further, we confine our considerations to choices relating to depreciation and capital gain/loss terms. In terms of the depreciation term for computers, the choice is often made between the time series depreciation and the cross section depreciation, as defined by Hill (1999). In terms of capital gain/loss term, the choice is

[1] Diewert (2008) points out 'there is still no agreement on the precise form for each term' and provides a summary of a few important issues in relation to 'what is the exact form of the user cost formula?' (p.23)

between price indexes for new computers and general price indexes, such as CPI. This latter choice is concerned with the view of either ex-ante expectations of future price changes or ex-post price movements. In this paper, we argue that obsolescence is the common element contained in both the time series depreciation term and the computer price indexes. A combination of the time series depreciation and the computer price indexes for imputing rental prices for computers leads to double counting of obsolescence and hence results in upward biased estimates of their capital services.

The common practice used by statistical agencies in compiling capital services is to adopt time series depreciation (the traditional national accounts approach) combined with asset-specific price indexes. These choices make practical rental prices for computers appear too high. For example, among the three elements in estimating rental price for computers, depreciation is set around 25%-30%, which includes both physical decay and obsolescence, and capital loss (calculated using quality-adjusted computer price index) is about 30%, which also largely reflects obsolescence. If internal rate of return is 10%, the rental prices for computers represent about 70% of the computer stock values. We argue that these imputed rental prices are excessive because obsolescence is accounted twice here.

To solve the double counting issue, we propose a combination of the time series depreciation with CPI as a general inflation measure. This recommendation is made mainly on pragmatic grounds. First, the alternative choice of the cross section depreciation, though more consistent with the original theory of capital user cost, would represents a departure with the traditional national accounting convention, and the resulted two series of depreciation estimates would add another layer of complexity to the already complex investment and capital statistics. Second, computer price indexes are often volatile and the capital gain/loss term is the major contributor to unstable rental prices for computers, which is at odds with observed behaviour of market computer rental prices. The new approach will significantly improve the stability and analytical quality of computer rental prices.

The rest of this paper is structured as follows. Section 2 discusses some related conceptual issues. Section 3 presents empirical results and Section 4 concludes.

2 Issues in the Implementation of the User Cost Formula: How to Treat Obsolescence

2.1 Basic National Accounting Identity

In a basic aggregate model of a closed economy without taxes or subsidies, the Gross Domestic Product (GDP) accounting identity can be written as ,

$$P_t Q_t = w_t L_t + r_t K_t \tag{1}$$

Where p_t, w_t and r_t represent the general price level, average wage rate and rental price of capital respectively. Q_t, L_t and K_t represent the volume of real value added output produced in the economy, labour employed and capital utilised in the production respectively. Collectively, p_tQ_t stands for the aggregate output produced in the economy, w_tL_t is labour services, which is referred to as the compensation of employees (COE) in national accounts and r_tK_t is capital services, which is referred to as the gross operating surplus (GOS) in national accounts.

It is worth noting that measures of capital services from the capital stock in compiling MFP statistics are model-based and do not rely on the observed gross operating surplus (GOS) component within the national accounts. To transform capital assets into flows of capital services, an assumption has to be made regarding the time for new capital investment to provide productive services. In the case of no time lag between new investments and the provision of productive services - which is the usual assumption made by official statistical agencies including the ABS - estimates of capital services are obtained by weighting individual capital assets using the rental price of each asset in the weight. In this sense, capital services are essentially weighted capital stocks.

The series of weighted capital stocks representing capital services can be significantly different from unweighted capital stocks. For example, the relative importance of information and communication technology (ICT) assets to non-ICT assets has increased in recent years. Since ICT assets deliver more services per unit of capital stock, their capital service input growth rates are much higher than their capital stock growth rates. However, if only their capital stock is used to measure capital input, the impact of this shift in capital composition would not be accounted for, leading to underestimated contributions of ICT capital to output growth.

2.2 The Standard User Cost Formula

In estimating the value of labour services, statisticians can directly observe labour rental prices as wage rates paid to workers. In the case of capital the rental prices for capital have to be imputed. A standard specification for the capital rental price in the absence of taxes is the arbitrage equation presented by Jorgenson, Ho and Stiroh (2005), in which the rental price reflects the price at which an investor is indifferent between two alternatives: (1) earning a nominal rate of return on a different investment, and (2) buying a capital asset, renting it out, collecting rent and selling it in the next period:

$$p_t(1 + i_{t+1}) = r_{t+1} + p_{t+1}(1 - \delta) \tag{2}$$

where i_t is the nominal interest, p_t is the acquisition price of capital, r_t is the rental price, p_{t+1} is the end of period price of capital and δ is the rate of economic depreciation.

This can be rearranged into the expression

$$r_t = i_t p_{t-1} + \delta p_t - \pi_t \tag{3}$$

where $\pi_t = p_t - p_{t-1}$ is the asset specific capital gains term.

Capital gain/loss, π_t, is measured by the change in the value of the asset in time t relative to its value in time $t-1$. This item contains two effects: one is the relative price changes among capital goods, with the other reflecting general inflation environment in the economy.

The interpretation and empirical estimation of the above rental price formula has been the source of confusion, debates and controversies in the productivity measurement literature for several decades. It is useful to put this formula in the context of the basic economic theory. We can express Q_t in the national income equation, (1), as a production function linking output to labour and capital; that is,

$$Q_t = A_t F(L_t, K_t) \tag{4}$$

where K_t is the productive capital stock.

Using the perpetual inventory method, the productive capital stock can be expressed as a sum of linear combination of present and past investments (Hulten 1990); that is,

$$K_t = \phi_0 I_t + \phi_1 I_{t-1} + ... + \phi_T I_{t-T} \tag{5}$$

where I_t is a capital asset purchased at time t and the efficiency sequence, $\phi_0, \phi_1 ... \phi_T$, is defined to be between zero and 1 to make it possible to convert all capital assets of different ages and vintages into the common efficiency unit and hence total capital stock is derived as the sum of weighted investment series. Through these efficiency coefficients the productive capacity of older capital goods still in use can be expressed in units of new capital goods.

Substituting (5) into (4), we have

$$Q_t = A_t F(L_t, \{\phi_0 I_t + \phi_1 I_{t-1} + ... + \phi_T I_{t-T}\}) \tag{6}$$

Now we need to introduce the age dimension of capital assets to establish the linkage between asset age and its relative efficiency. We use the second subscript to denote the age dimension. Under certain neoclassical assumptions, $r_{t,s}$, the rental price for capital asset in time t at age s, is equal to the value of its marginal product, that is

$$r_{t,s} = P_t \frac{dQ_t}{dI_{t,s}} \tag{7}$$

Similarly, we have the rental price for v-year-old capital asset as

$$r_{t,v} = P_t \frac{dQ_t}{dI_{t,v}} \tag{8}$$

where $s < v$.

If we divide (7) by (8) and express the productive capacity of v-year-old capital asset in terms of efficiency unit of s-year-old capital asset, we have

$$\frac{r_{t,s}}{r_{t,v}} = \frac{dQ_t/dI_{t,s}}{dQ_t/dI_{t,v}} = \frac{dQ_t/dI_{t,s}}{\phi_{s,v} dQ_t/dI_{t,s}} \tag{9}$$

Equation (9) establishes the linkage between rental prices and the productive capacity of capital assets. The price for s-year-old capital asset is equal to the sum of discounted present value of rental income stream; that is,

$$p_{t,s} = \sum_{\tau=0}^{T} \frac{r_{t+\tau,s+\tau}}{(1+i)^{\tau+1}} \tag{10}$$

Expressing the rental price for s-year-old capital asset in terms of the rental price for a new asset, we can rewrite (10) as

$$p_{t,s} = \sum_{\tau=0}^{T} \frac{\phi_{s+\tau} r_{t+\tau,0}}{(1+i)^{\tau+1}} \tag{11}$$

Similarly we have

$$p_{t,s+1} = \sum_{\tau=0}^{T} \frac{\phi_{s+\tau+1} r_{t+\tau,0}}{(1+i)^{\tau+1}} \tag{12}$$

Now the second term in the user cost formula, specified in (3), is estimated as the difference between (11) and (12); that is,

$$\begin{aligned} \delta_{t,s} p_{t,s} &= p_{t,s} - p_{t,s+1} \\ &= \sum_{\tau=0}^{T} \frac{(\phi_{s+\tau} - \phi_{s+\tau+1}) r_{t+\tau,0}}{(1+i)^{\tau+1}} \end{aligned} \tag{13}$$

The depreciation term in the user cost formula is defined as cross section depreciation. That is, the price change is defined as the price difference between capital assets of two successive ages in the same period, reflecting both the current decline in efficiency and the present value of future declines in efficiency. Put differently, the cross section depreciation is due to the pure aging effect.[2] Hulten and Wykoff (1996) point out that *'it is also the definition of economic depreciation: the amount of capital financial value that must be "put back" in order to keep the real value of the wealth intact'* (p. 14).

The cross section depreciation, the economic definition of depreciation, is different from the SNA definition of depreciation, which is defined as *'the decline, between the beginning and the end of the accounting period, in the value of the fixed assets..., as a result of their physical deterioration and normal rates of obsolescence and accidental damage'* (pp. 10.156, SNA 2008). Clearly, the SNA depreciation includes both cross-section and time dimensions.

Hulten (1990) and OECD (2001) show the theoretical linkage between depreciation and the decline in asset efficiency. Hill (1999) notes that *'cross section depreciation can be interpreted as the loss in value attributable to the aging of the asset and the consequential loss in productive potential which is often loosely described as wear and tear'* (pp. 11).

[2]Wykoff (2003) explains that 'the pure aging effect (deterioration) actually results from several different forces. Some services are used or, in the language of national income accounts, consumed. The asset has fewer periods of service to deliver (unless it has an infinite life). The likelihood of down time may have increased. The cost of repairs may have increased (or decreased). The quality of the service flow may have degenerated and the cost of operations may have increased (pp. 20-21).

The relative efficiency of a capital good depends on the age of the good and not on the time it is acquired. The role of obsolescence in the capital decay process is not obvious in the traditional representation of rental price formula. The obsolescence is associated with the emergence of new improved capital assets, not with aging per se. A quotation from Wykoff (2003) helps to shed light on how depreciation was confined to the loss of productive capacity formulated by a prominent figure in the capital measurement literature:

> *Zvi Griliches frequently expressed concern about reducing the value of the stock of capital by depreciating it based on obsolescence. Griliches reasoned that even if an asset becomes relatively obsolete because new technology generates a superior one, the value of the used asset should not be reduced. The older vintage asset remains as productive as it was before the new one came on line. Put another way, if obsolescence is the cause of the fall in asset price, the value of the used asset does not fall. The new asset may be worth relatively more, but the old one's in-use value is undiminished. As Griliches used to express the point, if an econometrics professor does not know the new cutting-edge ideas, his teaching is no less valuable. It simply means someone else is teaching something new. (Griliches adds the caveat that the old professor must not be teaching material that is wrong.) I suspect this argument is at the heart of a lot of debates about measuring capital stocks, especially the debates about gross and net stocks. I hope to sharpen the debate a bit.* (p. 12)

In this context, the standard method of applying the user cost formula to impute rental prices is to include the impact of obsolescence in the third term, that is, the capital loss/gain term, measured by asset specific price indexes. In the following discussion, we argue that the obsolescence is inherently included in the depreciation term and if the asset specific price indexes are used in the third term, then the impact of obsolescence is counted twice in imputing rental prices of capital assets. This is particularly the case for computers.

2.3 Obsolescence, Asset Life and Depreciation

When statisticians apply the user cost formula to national accounts capital data to obtain estimates of capital services, a problem arises from the fact that depreciation is defined differently by SNA, It seems that the double counting problem of obsolescence could be avoided by adopting the physical decay interpretation of depreciation term and accounting for obsolescence in the capital gain/loss term. Official statisticians need to stand by the SNA definition and measures of depreciation, which contains obsolescence. As capital gain/loss is measured by constant quality price indexes of investment goods, which also contain obsolescence, the resulting estimates of capital services for computers count obsolescence twice and hence the computer rental prices are too high.

The depreciation rates in the Australian System of National Accounts are derived based upon the assets' age-efficiency and age-price profiles. From a study of capital asset lives, the age-efficiency profiles are calculated using retirement weighted hyperbolic age-efficiency functions up to the maximum life for each asset type, which is based upon empirical evidence of the assets' wear and tear, and obsolescence. The assets' age-price profiles and the depreciation functions (percentage changes in the present discounted value of an asset as it ages) are calculated based on discounted age-efficiency profiles.

A numerical example is useful to illustrate our point. Let us assume that the asset life of a computer is expected to be 4 years and its efficiency profile is one-hoss-shay pattern. That is, the efficiency vector is given by $(1, 1, 1, 1, 0)$ and hence the quantity of capital services is represented by the vector $(1, 1, 1, 1, 0)$, regardless of the computer age. The present value of a computer is discounted present value of capital services. For ease of calculation, let us assume that discount rate is 10 per cent and the rent is paid at the beginning of the period. Then we have the price vector for our computer as $(3.49, 2.74, 1.90, 1.0, 0)$, the value of depreciation vector is given by $(0.75, 0.83, 0.91, 1)$ and the associated depreciation rate vector is given by $(0.22, 0.30, 0.48, 1.00)$. Is the obsolescence factor built into the computer efficiency profile? The answer is clearly yes, through the impact of obsolescence on the short asset life of the computer.

Now let us calculate the computer rental price using the formula as specified in equation (3). Suppose the rate of return is 10 per cent and the compute prices decline at an average annual rate of 25 per cent. The rental price vector for the computer at different ages, expressed as cents per dollar is given by $(0.57, 0.65, 0.83, 1.35)$. It is clear that the imputed computer rental prices appear to be too high. For example, the rental price for the 4-year-old computer is \$1.35 for per dollar worth of computer. The renter would be better off to buy the computer rather than renting it. Assuming that annual general inflation rate is 2 per cent and correcting the double counting problem, we can revise the rental price vector as $(0.34, 0.42, 0.60, 1.12)$, which makes much more sense.

Returning to the above case of the impact of knowledge obsolescence on the econometrics professor' human capital, we can argue that the professor's obsolete knowledge of econometrics does reduce the economic value of his human capital. If the professor did not stay at the knowledge frontier, he would find increasingly difficult to get his work published and demand for his teaching service would also be likely to decline. In a competitive academic labour market, he would find it harder and harder to renew his employment contract and therefore his future labour earnings would decrease and hence his lifetime labour income, the measure of economic value of his human capital, would be lower.

3 Empirical Results

This section presents our empirical results of comparing alternative computer rental prices and their impact on capital input and MFP figures between the current method and our proposed new method of calculating capital gains/loss term. Figures 1, 2, and 3 show the time series of computer rental prices for the three selected industries from 1985-86 to 2011-12. The current series are calculated using industry computer deflators as the estimates for the capital gain/loss term, whereas the proposed series were compiled using CPI. The computer rental prices are expressed as how many cents it costs for using one dollar value of computers. We find that the substitution of CPI for computer deflators significantly reduces the size of computer rental prices throughout the entire period of interest. Unlike current computer rental prices, the proposed figures range from 40c to 60c per dollar of computers in all three industries.

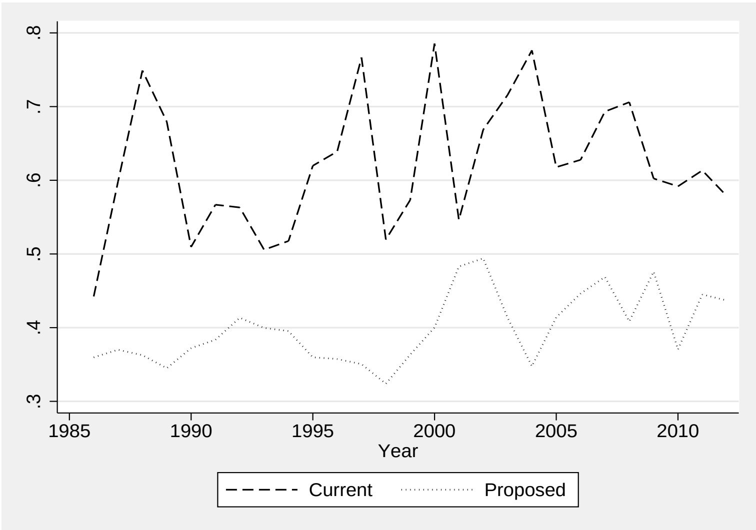

Figure 1: Corporate Computer Rental Prices: Mining

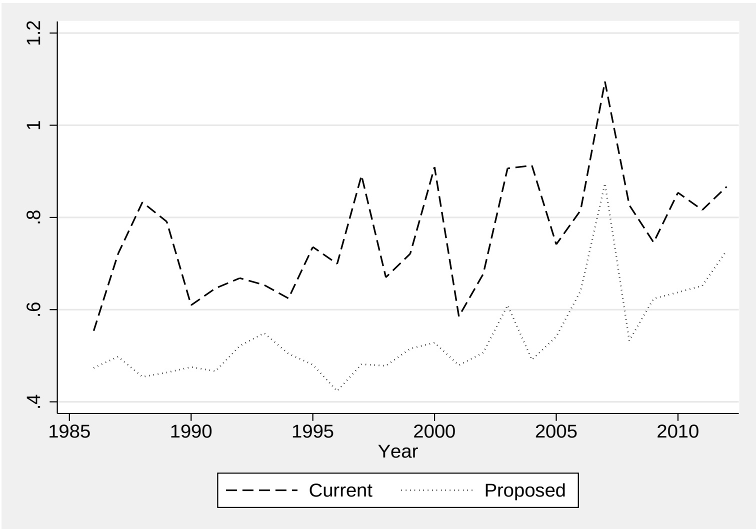

Figure 2: Corporate Computer Rental Prices: Construction

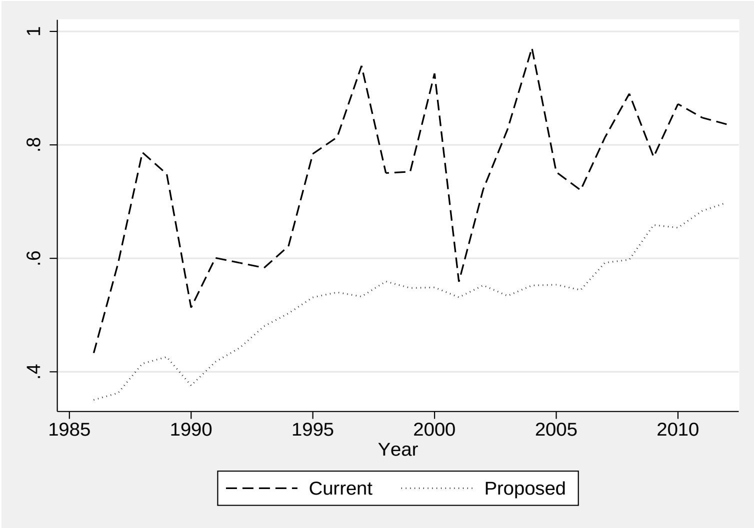

Figure 3: Corporate Computer Rental Prices: Finance

Table 1 shows the impact of the proposed method on the estimated annual growth rates of industry capital services from 1995-96 to 2003-04, and 2003-04 to 2011-12. The estimated annual capital services growth rates are calculated as the sum of weighted logarithmic growth of all asset types. The weights used are the (two-period moving average) shares of each capital asset type in total industry capital income, $\frac{rK}{\sum rK}$, from both the corporate and unincorporated sectors within an industry). The estimated capital growth rates are then expressed as annual averages over the two aforementioned sub-periods.

The impact is most significant for the computer-intensive Financial & Insurance Services Industry, with its annual growth rates of capital services revised down by -0.6% and -0.35% from 1995-96 to 2011-12 and 2003-04 to 2011-12 respectively. The revisions to capital services growth for the Construction Industry are also noticeable, with -0.35% and -0.25% over the same sub-periods. In contrast, the equivalents in the Mining industry are minor, as it is the least computer-intensive industry among the three.

Table 1: Differences in Annual Industry Capital Services Growth

	Period	
	1995-96 to 2003-04 (%)	2003-04 to 2011-12 (%)
Mining	-0.06	-0.03
Construction	-0.35	-0.25
Finance and Insurance	-0.58	-0.35
Market Sector	-0.42	-0.24
12 Selected Industries	-0.37	-0.21

Table 1 also shows the impacts of the proposed method on the estimated annual growth rates of capital services for the market sector and the 12 selected industries from 1995-96 to 2003-04, and 2003-04 to 2011-12. The annual growth rates of capital services for the market sector are revised down by over -0.4% and nearly -0.25% from 1995-96 to 2011-12 and 2003-04 to 2011-12 respectively. The corresponding downward revisions for the 12 selected industries are over -0.35% and over -0.2%.

Table 2 shows the impacts of the proposed method on the estimated annual growth rates of MFP for the market sector and the 12 selected industries from 1995-96 to 2003-04, and 2003-04 to 2011-12. The annual growth rates of capital services for the market sector are revised up by over 0.16% and 0.1% from 1995-96 to 2011-12 and 2003-04 to 2011-12 respectively. The corresponding upward revisions for the 12 selected industries are over 0.15% and nearly 0.1%.

Table 2: Differences in Annual Industry MFP Growth

	Period	
	1995-96 to 2003-04 (%)	2003-04 to 2011-12 (%)
Mining	0.04	0.02
Construction	0.09	0.07
Finance and Insurance	0.29	0.16
Market Sector	0.16	0.10
12 Selected Industries	0.16	0.10

4 Concluding Remarks

In this paper we revisit the issue of imputing rental prices for computers. Compared with observed prices in computer rental markets, the current ABS estimates appear too high. The key factor is the treatment of obsolescence in the user cost formula. We argue that obsolescence is counted twice, both in the depreciation as well as capital gain/loss terms. Capital losses are typical for computers. This causes user costs of computers to be overstated. Overstated weight of computer capital leads to biased results of MFP estimates. We demonstrate that this mismeasurement partly explains the MFP slowdown seen in recent years in Australia.

Our empirical results show that the impact is significant on MFP estimation of double-counting obsolescence for computers. Research into capital measurement issues is promising to bear fruits.

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