The Measurement of Business Capital, Income and Performance

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IV. Constructing a Capital Stock for R&D Investments

1. Introduction

It is likely that the next international version of the System of National Accounts (SNA) will contain recommendations that national expenditures on Research and Development (R&D) be capitalized and then depreciated over subsequent periods. This is quite appropriate from the viewpoint of economic theory, since the R&D expenditures in the present period usually give rise to benefits that are realized in the future periods and hence, these R&D expenditures have the nature of a capital input to production.

R&D expenditures are an example of an *intangible* expenditure. Other examples of expenditures on intangible assets are *advertising and marketing expenses* and *expenditures on training*. All of these categories of expenditures have the character that the present period outlays will create incremental revenues in the future for the firm that undertakes them. These current period expenditures on intangible assets have a different character than expenditures on tangible durable inputs, which can be used for a number of periods and then sold to other users.[1] The problem is how to *allocate* the cost outlays on intangible investments over future periods. Thus these accounting problems in have a different character than in the treatment of reproducible capital, where a straightforward

[1] In some cases, the stream of future revenues created by an intangible investment can be sold on the marketplace (e.g., patents, trademarks and franchises), but if it is not sold, we still have the problem of how to distribute the intangible investment costs over future periods. If it is sold, then the purchaser has the problem of allocating the purchase cost to future periods.

opportunity cost approach can be taken. In the present chapter, the approach taken is one of *matching* current costs with future expected revenues.[2]

The problem of intertemporally allocating intangible investment expenditures to future periods when the benefits might be realized is similar to other intertemporal cost allocation problems that are associated with *prepaid expenses* and *transactions costs*. It is often the case that when a business unit purchases a nonresidential structure, there are substantial transactions costs associated with this purchase. From one viewpoint, these costs are sunk and should be written off immediately; i.e., these expenditures should be treated as a business intermediate or primary input expense. However, from the point of view of constructing period by period estimates of the income of the business unit, it is more appropriate to take these transactions costs, capitalize them and then distribute them over the future periods that the associated asset is expected to be held, ensuring that the discounted value of these future cost distributions is equal to the current period transactions costs incurred.[3] Prepaid expenses[4] can also be given a similar treatment. In both of these cases, the transactions costs and the prepaid expenses can be given an accounting treatment that is similar to our suggested treatment of R&D expenses.

In section 2, we present a reasonably general cost allocation model that assumes a constant structure of real and nominal interest rates. We relate this model to the usual models of depreciation for reproducible capital. In sections 3 and 4, we relax this simplifying assumption.

In section 3, we present the details involved in making various cost imputations for a simple 4 period model, while in section 4, we present the algebra of the general model, along with a discussion of the data requirements for implementation of the model.

Section 5 concludes with a discussion of some of the difficult conceptual and practical issues that are involved in capitalizing R&D expenditures.

2. The Basic Cost Matching Methodology

To fix ideas, suppose that as of at the beginning of period t, a firm has made expenditures on creating an intangible asset, which are equal to C^t:[5]

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[2] Paton and Littleton (1940; 123) argued that the primary purpose of accounting is to match costs and revenues. For an excellent early discussion on the importance of matching costs to future revenues, see Church (1917; 193).

[3] In the Australian national accounts, household transactions expenses on the purchase of residential housing units are capitalized and distributed over the average length of life that a dwelling unit is held by a single owner in Australia.

[4] Prepaid expenses as an accounting asset class occurred quite early in the history of accounting. Thus Hatfield (1927; 16) gave several examples of this type of "asset", including insurance payments which apply to multiple accounting periods, the stripping away of surface rock for a strip mine and prepaid expenses in general. Hatfield (1927; 18) correctly noted that this type of asset is different from the usual sort of tangible asset since this type of asset cannot readily be converted into cash; i.e., it may have no opportunity cost value.

[5] Much of the material in this section is taken from section 11 in Diewert (2005a). C^t could represent the cumulated costs over a number of periods that it has taken to develop a useful product or process.

(1) $C^t \equiv \sum_{m=1}^{M} P_m^t Q_m^t$

where P_m^t is the period t price for the mth type of input that is used to create the intangible asset and Q_m^t is the corresponding quantity purchased. These expenditures in period t are expected to generate a future stream of incremental revenues for the firm. Let R_0^t denote the immediate period t incremental revenues (which could be zero) and let R_n^t denote the incremental revenues that the period t expenditures C^t are *expected* to generate n periods from the present period t, for n = 1,2,… Let r^t be the (nominal) period t opportunity cost of financial capital. Then the discounted value of these expected incremental revenues is:[6]

(2) $R^t \equiv R_0^t/(1+r^t) + R_1^t/(1+r^t)^2 + R_2^t/(1+r^t)^3 + R_3^t/(1+r^t)^4 + \ldots$

The problem is to allocate the current period cost C^t over future periods. Thus let C_n^t be the allocation of C^t to the accounting period that is n periods after period t for n = 0,1,2,… At first sight, it seems reasonable that these future cost allocations C_n^t should sum to C^t. However, this turns out *not* to be so reasonable: costs that are postponed to future periods must be escalated by the (nominal) interest rate r^t, so that the present value of discounted future costs is equal to the actual period t costs C^t. Thus the intertemporal cost allocations C_n^t should satisfy the following equation:[7]

(3) $C^t = C_0^t/(1+r^t) + C_1^t/(1+r^t)^2 + C_2^t/(1+r^t)^3 + C_3^t/(1+r^t)^4 + \ldots$

To see why discounting is necessary, consider the following simple example where we have a cumulated investment equal to C^t at the beginning of period t and we anticipate the revenue R_1^t at the end of period 1, which is two periods from the beginning of period 0. The expected discounted profits that this investment will generate are:

(4) $\Pi \equiv -C^t + R_1^t/(1+r^t)^2$.

The period by period cash flows for this project are $-C^t$, 0, R_1^t. In general, we want to *match* the beginning of period t cost C^t with the end of period t+1 revenue flows. Thus we want to convert the cash flow stream $-C^t$, 0, R_1^t into an equivalent cash flow stream 0, 0, $-C_1^t + R_1^t$. If we choose

(5) $C_1^t \equiv C^t(1+r^t)^2$,

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[6] Thus R_0^t is the revenue that the R&D project is expected to generate over the course of period t (and this revenue is not expected to materialize until the end of period 0), R_1^t is the revenue that the R&D project is expected to generate over the course of period t+1, and so on. At the beginning of period t, the present value of these expected revenue contributions is R^t. At the beginning of period t+1, the expected asset value will decline (if expectations do not change) to $R_2^t/(1+r^t) + R_3^t/(1+r^t)^2 + \ldots$ and so on. Thus as the revenues are realized, the asset value will decline.

[7] We are assuming that the period t+n cost allocation, C_n^t, is written off at the end of period t+n.

then it can be seen that these two cash flow streams have the same present value and C_1^t is the "right" period t+1 cost allocation. Put another way, if we simply carried forward the period t costs C^t and set C_1^t equal to C^t, we would be neglecting the fact that the costs were in place at the beginning of period t while the return on the investment was deferred until the end of period t+1 and hence, we need to charge the opportunity cost of financial capital for two periods on the initial investment (for two periods) until it is expensed in period t+1.

How should the intertemporal cost allocations C_n^t be chosen? It is natural to make these cost allocations proportional to the corresponding period anticipated revenues. Thus choose the number α so that the following equation is satisfied:

(6) $C^t = \alpha R^t$.

Thus we set the observed period t cost associated with the intangible investment C^t equal to the constant α times the discounted value of the anticipated incremental revenue stream R^t that the investment is expected to yield.[8]

Typically, α will be equal to or less than one, since otherwise, the period t intangible investment expenditures C^t should not be undertaken. If α is less than one, then there will be an expected profit above the opportunity cost of capital, which could be some form of monopoly profit or a reward for risk taking.

Once α has been determined by solving (6), then the intertemporal cost allocations C_n^t can be defined to be proportional to the corresponding anticipated incremental revenues R_n^t for future periods:

(7) $C_n^t \equiv \alpha R_n^t$; $\qquad n = 0,1,2,\ldots$

We can convert the nominal cost allocation factors C_n^t into constant (period t) dollar cost allocations q_n^t as follows:

(8) $q_n^t \equiv C_n^t/(1+\rho^t)^n$; $\qquad n = 0,1,2,\ldots$
$\quad = \alpha R_n^t/(1+\rho^t)^n$

where ρ^t is the period t consumer price inflation rate, which is expected to persist into the future.[9] The q_n^t defined by (8) are the constant (beginning of period t) dollar counterparts to the period t nominal cost allocation factors C_n^t that occurred in (3). The corresponding future expected spot prices P^{t+n} of the q_n^t are defined to be the expected cumulated consumer price inflation rates; i.e, define the P^{t+n} as follows:

[8] Of course, the practical problem that the national income accountant will face is: how can the future stream of incremental revenues be estimated?

[9] This expectational assumption could be relaxed at the cost of more notational complexity; see section 4 below. It should be noted that the use of the CPI as a price for converting a financial cost into a real cost is not without controversy as we have seen in the previous chapter.

(9) $P^{t+n} \equiv (1+\rho^t)^n$; $\quad$ n = 0,1,2,… .

Thus the nominal cost allocation factors $C_n{}^t$ and the $q_n{}^t$ and the P^{t+n} satisfy the following equations:

(10) $C_n{}^t = P^{t+n}q_n{}^t$; $\quad$ n = 0,1,2,… .

We can define the period t real interest rate r^{t*} in terms of the period t nominal rate r^t and the period t general inflation rate ρ^t as follows:

(11) $1+r^{t*} \equiv (1+r^t)/(1+\rho^t)$.

Substituting (8)-(11) into (3) shows that the constant dollar cost allocations $q_n{}^t$ satisfy the following equation:

(12) $C^t = q_0{}^t/(1+r^{t*}) + q_1{}^t/(1+r^{t*})^2 + q_2{}^t/(1+r^{t*})^3 + q_3{}^t/(1+r^{t*})^4 + \ldots$

We can define a *real capital stock* that corresponds to the R&D asset at the beginning of period t by K^t by setting K^t equal to C^t defined above by (12). If expectations about future prices and revenues are realized, then we can define the corresponding real R&D capital stock at the start of period t+1 by K^{t+1}, at the start of period t+2 by K^{t+2}, and so on, where these stocks are defined to be the expected discounted future real cost allocations; i.e., we have:

$$
\begin{aligned}
(13)\ K^t &\equiv q_0{}^t/(1+r^{t*}) + q_1{}^t/(1+r^{t*})^2 + q_2{}^t/(1+r^{t*})^3 + q_3{}^t/(1+r^{t*})^4 + \ldots \\
K^{t+1} &\equiv q_1{}^t/(1+r^{t*}) + q_2{}^t/(1+r^{t*})^2 + q_3{}^t/(1+r^{t*})^3 + q_4{}^t/(1+r^{t*})^4 + \ldots \\
K^{t+2} &\equiv q_2{}^t/(1+r^{t*}) + q_3{}^t/(1+r^{t*})^2 + q_4{}^t/(1+r^{t*})^3 + q_5{}^t/(1+r^{t*})^4 + \ldots \\
&\ldots
\end{aligned}
$$

If expectations about future prices and revenues are realized, then K^t defined by the first line in (13) represents the beginning of period t constant dollar R&D capital stock, K^{t+1} defined by the second line in (13) represents the beginning of period t+1 constant dollar R&D capital stock and so on. The corresponding prices for the K^{t+n} are taken to be the CPI prices P^{t+n} defined by (9) above.

Thus accounting for R&D stocks at first glance seems to be relatively straightforward. Given our expectations about the future revenue flows $R_n{}^t$ that the R&D asset is expected to generate, we use equations (7) to calculate our nominal sequence of future cost allocations, the $C_n{}^t$. Given the $C_n{}^t$ and expectations about the future course of the CPI, we form the constant dollar cost allocations $q_n{}^t$ using equations (8). Then $q_n{}^t$ gives us the expected constant dollar charge that we should make at the end of period t+n as an R&D real cost for period t. This can be converted into the nominal period t+n cost, $P^{t+n}q_n{}^t$, where P^{t+n} is defined by (9). The corresponding beginning of period t+n real R&D capital stock K^{t+n} is defined by the appropriate equation in (13) and this can be converted into the corresponding nominal beginning of period t+n value of the R&D capital stock, $P^{t+n}K^{t+n}$.

There is one more useful relationship that we can develop in this accounting method for allocating a fixed cost over future time periods when the cost produces a benefit. Look at the first two equations in (13). Substituting the second equation into the first, we obtain the following equation:

(14) $K^t = q_0^t/(1+r^{t*}) + K^{t+1}/(1+r^{t*})$.

This equation can be solved for the period t constant dollar cost allocation flow variable, q_0^t, in terms of constant dollar capital stocks as follows:

(15) $q_0^t = r^{t*}K^t + K^t - K^{t+1} = r^{t*}K^t + D_0^t$.

The remaining equations in (13) lead to similar formulae for the remaining constant dollar allocations q_n^t in terms of R&D capital stocks, K^{t+n}, and the real interest rate r^{t*}:

(16) $q_1^t = r^{t*}K^{t+1} + K^{t+1} - K^{t+2} = r^{t*}K^{t+1} + D_1^t$;
$q_2^t = r^{t*}K^{t+2} + K^{t+2} - K^{t+3} = r^{t*}K^{t+1} + D_2^t$;
...

where the anticipated *real time series depreciation amounts* D_n^t for period t+n are defined in terms of the constant dollar capital stocks as follows:[10]

(17) $D_n^t \equiv K^{t+n} - K^{t+n+1}$; $n = 0,1,2, \ldots$.

Equations (15) and (16) are counterparts to equations (7) in chapter I, except in chapter I, we held the quantity fixed and allowed the user costs by age to change, whereas in the present chapter, we are fixing the price of the R&D asset (if there is no general inflation) and allowing the quantity flow R&D charges q_n^t to vary with n.

Equations (15) and (16) allow us to decompose the period t real R&D flow charge q_0^t into a constant dollar depreciation component D_n^t and a real interest rate charge, $r^{t*}K^t$.[11]

It should be noted that the cost allocation model outlined above can be applied to other forms of "assets"; namely, deferred charges, prepaid expenses and transfer fees when a reproducible asset is acquired. The one hoss shay form of revenue matching is probably the preferred method for dealing with this type of transfer fee "asset".

Of course, the practical problem with all of the above algebra is that it is entirely driven by the pattern and magnitudes of expected future incremental revenues but the statistician will not have very good information on these expected revenues. Moreover, it is not

[10] These definitions are the counterparts to definitions (11) in chapter I, which defined cross sectional depreciation. Obviously the depreciation amounts D_n^t can be transformed into depreciation rates as follows: $\delta_n^t \equiv 1 - [K^{t+n+1}/K^{t+n}] = D_n^t/K^{t+n}$; $n = 0,1,2,\ldots$.

[11] If it is necessary to keep track of nominal interest flows (including imputed interest), then the algebra does not work out so nicely; see the example in the following section.

clear what would be a "good" rough approximation to these expected revenues.[12] This is an important area for future research.

Finally, if we want to construct measures of *real R&D (flow) input*, we need *additional* information on the prices and quantities of the inputs that are used to create the R&D asset. Thus in addition to information on R&D costs, we need to be able to collect information on the price and quantity components that went into this R&D cost, in order to construct measures of real R&D input.[13] Hence in addition to information on the projected future period revenue flows that will materialize as a result of the R&D investment, we need some additional information in order to construct measures of real R&D input:

- Information on the prices and quantities of the flow inputs that comprise the period 0 cost, C^0; i.e., these are the $P_m{}^t$ and $Q_m{}^t$ that appeared in equation (1) above.

We agree with Pitzer (2004) that R&D investments are *fundamentally different* from investments in reproducible capital. Pitzer (2004; 2) regards R&D investments as producing "recipes" but a recipe is not the usual type of "productive" input. Pitzer defines "productive" inputs as follows:

"Fundamental to production is the notion that inputs are proportional in some sense to outputs. Outputs are created by combining a particular collection of inputs in a particular manner. … If more outputs are desired, then more inputs are necessary, and usually, more of all inputs. It may not be necessary to double the inputs to double the outputs, but more inputs are necessary to produce more outputs." John Pitzer (2004; 2).

We also agree with Pitzer that the asset value of a marketable R&D investment is a discounted monetary flow of payments that will usually have some form of monopoly element to it:

"A patented entity is an asset that permits the owner to levy an assessment, much like a tax, on other units for the use of a recipe. In some cases, the assessment is paid by another producing unit to acquire the right to produce outputs based on the recipe. In other cases, the owner will produce the outputs and levy the assessments on its customers by charging a monopoly price. The market value of the asset is the present value of the future assessments that are expected to be collected by the asset's owner." John Pitzer (2004; 5).

Thus the treatment of R&D assets will necessarily be quite different in some respects from the treatment of reproducible capital assets. In particular, the treatment of R&D assets involves *two* separate deflation problems:

[12] Thus the practical measurement problems are much harder in the intangible context compared to the case of reproducible capital where a straightforward capital expenditures survey that includes information on the age of retired capital assets (or their age and sale price if the reproducible assets are sold before they are worthless) will enable the statistician to construct somewhat accurate depreciation rates and user costs.

[13] On a national basis, it is important to be able to construct measures of real R&D input so that the resulting real measure can be used as an explanatory variable in regressions that regress measures of economy wide performance (like Total Factor Productivity Growth) on various explanatory variables.

- The deflation of expenditures on R&D inputs at a point in time into price and quantity components. This requires information on the price and quantity components of the inputs into the creation of the R&D asset.
- The deflation of the nominal intertemporal cost allocation of the current R&D flow expenditures into constant dollar cost allocations. The deflator to be used here is a general purchasing power deflator.

There are some additional complications in dealing with intangible assets in a national income accounting framework that can be best illustrated by a "concrete" example. Thus we consider a simple example in the following section and look at the various accounting transactions that will be necessary to implement the cost matching model outlined in this section.

3. A Simple Example

We consider a special case of the model outlined in the previous section where the current period t is set equal to 0, R&D costs equal to C^0 are incurred at the beginning of period 0 and this project has no further nonfinancial costs in future periods but it is expected to yield nominal revenues of R_1^0 and R_2^0 in periods 1 and 2. Thus there are no revenues generated by the project during period 0. All costs and revenues are transacted at the end of each period. The one period nominal (bond) expected interest rate (or cost of capital) at the beginning of period 0 is r_0, at the beginning of period 1 is r_1 and at the beginning of period 2 is r_2, with all expectations being formed at the beginning of period 0.[14] We assume that the project is funded by one period bonds and no dividends are paid out so that as the firm gathers revenues, bond debt is retired at the end of periods 1 and 2. From the perspective of the beginning of period 0, the firm's *expected discounted profits* are:

(18) $\prod^0 \equiv -C^0 + R_1^0/(1+r_0)(1+r_1) + R_2^0/(1+r_0)(1+r_1)(1+r_2) \geq 0.$

From the perspective of the end of period 2, the firm's expected profits are:

(19) $\prod^0(1+r_0)(1+r_1)(1+r_2) = -C^0(1+r_0)(1+r_1)(1+r_2) + R_1^0(1+r_2) + R_2^0 \equiv A^3$

where A^3 is the firm's net asset value at the end of period 3.

The counterpart to equation (3) in the previous section is the following equation:

(20) $C^0 = C_0^0/(1+r_0) + C_1^0/(1+r_0)(1+r_1) + C_2^0/(1+r_0)(1+r_1)(1+r_2)$

[14] Thus our model is slightly more general than in the previous section in that we are no longer assuming that the term structure of interest rates is constant.

where the C_n^0 are the cost allocations of the actual beginning of period 0 cost, C^0, to periods n = 0,1,2.[15] Since there are no expected revenues in period 0, it is natural to set the period 0 cost allocations, C_0^0, equal to 0. We shall also impose inequalities on the period 1 and 2 cost allocations so that the allocated costs do not exceed the corresponding revenues for those periods. Thus we assume that the 3 cost allocations C_n^0 satisfy (20) and the following equations and inequalities:

(21) $C_0^0 = 0;\ 0 < C_1^0 \le R_1^0;\ 0 < C_2^0 \le R_2^0.$

This is all of the information that we need to set up a set of (expected) accounts for the firm for the 4 periods under consideration. Table 1 below does this. Note that (−) means that the corresponding item is a current period cost to the firm. D^t denotes the net debt of the firm at the end of period t. D^0 is equal to C^0 and so the beginning of period 0 net asset value, counting just debt (negatively) and realized cash flow (positively) is $A^0 \equiv -D^0 = -C^0$.

Table 1: **Abbreviated Income and Balance Sheet Accounts for the R&D Firm**

Line 0: (Beginning of) Period t; t =	0	1	2	3
Line 1: Revenues at t, R_t^0	0	0	R_1^0	R_2^0
Line 2: Nonfinancial costs C^t (−)	$-C^0$	0	0	0
Line 3: Interest paid (−)	0	$-r_0D^0$	$-r_1D^1$	$-r_2D^2$
Line 4: Deferred nonfinancial costs	C^0	0	0	0
Line 5: Deferred interest	0	r_0D^0	r_1D^1	r_2D^2
Line 6: Allocated costs C_n^0 (−)	0	0	$-C_1^0$	$-C_2^0$
Line 7: Period t income π^t	0	0	$R_1^0 - C_1^0$	$R_2^0 - C_2^0$
Line 8: Period t debt D^t	$D^0 = C^0$	D^1	D^2	0
Line 9: Period t net asset value A^t	$A^0 = -D^0$	A^1	A^2	A^3

The beginning of period 0 debt level, D^0, is equal to the end of period 0 expenditures on R&D, C^0. In this example, there are no further real expenditures on R&D in periods 0,1 and 2. If there were, we would have to set up tables similar to Table 1 and combine the resulting tables by summing up expenditures in the various categories.[16]

The beginning of period 1 and 2 debt levels are given by:

$$(22)\quad D^1 \equiv (1+r_0)D^0 = (1+r_0)C^0\ ;$$
$$D^2 \equiv (1+r_1)D^1 - R_1^0 = (1+r_0)(1+r_1)C^0 - R_1^0.$$

[15] Think of C^0 as being the market component of Gross Expenditures on Research and Development (GERD). For now, we exclude the non market component of GERD from our simple model because there are no identifiable revenue streams that are associated with non market R&D, which is given away freely to all who want to use it. Thus there are no future revenues that current costs can be matched to.

[16] Thus Table 1 sets out the basic accounting framework for capitalizing the costs pertaining to a single period, period 0. A similar Table can be constructed if there are additional R&D expenditures in period 1 that generate identifiable incremental future revenues.

The *beginning of period t net realizable asset values* A^t, counting only beginning of the period debt (negatively) and cash flows (positive for revenues, negative for costs), turn out to equal the negative of the end of period debt levels:

$$(23)\ A^1 \equiv -(1+r_0)D^0 = -(1+r_0)C^0\ ;$$
$$A^2 \equiv R_1^{\ 0} - (1+r_1)D^1 = R_1^{\ 0} - (1+r_0)(1+r_1)C^0\ ;$$
$$A^3 \equiv R_2^{\ 0} - (1+r_2)D^2 = R_2^{\ 0} + (1+r_2)R_1^{\ 0} - (1+r_0)(1+r_1)(1+r_2)C^0.$$

Lines 1-3 and 8-9 in Table 1 correspond to real transactions whereas lines 4-6 represent the imputations that are necessary to get the sum of the first 6 lines to equal an appropriate *matched income* π^t for each period t, line 7, which matches costs with revenues in each period. Note that since there are no project revenues within periods 0 and 1, the corresponding matched incomes, π^0 and π^1, are set equal to zero by our imputation scheme.[17]

Note that the *net present value of the matched incomes*, π^2 and π^3, *equals the discounted present value of the revenues generated by the R&D investment in period 0*, Π^0, defined by (18); i.e., we have:[18]

$$(24)\ \Pi^0 = \pi^2/(1+r_0)(1+r_1) + \pi^3/(1+r_0)(1+r_1)(1+r_2).$$

We now work through the lines in Table 1 for period 0. The firm undertakes R&D expenditures prior to the beginning of period 0 that sum to the value C^0. These expenditures show up as a negative entry in line 2.[19] Since there are no period 0 revenues associated with these R&D expenditures, the expenditures C^0 are capitalized at the beginning of period 0 and these capitalized expenditures show up in line 4. These capitalized expenditures are formally identical to an investment, and thus are an imputed output of the firm for period 0. At the beginning of period 0, the firm borrows financial capital of the amount D^0 equal to C^0 (in order to finance the payments associated with the R&D expenditures) and this shows up in the firm's balance sheet at the beginning of period 0 as debt;[20] see line 8. There is no deferred or capitalized interest at the beginning of period 0 because the borrowing took place at the beginning of the period. Also, there are no allocated costs to set against revenue in period 0, because the R&D project has yet to generate any revenues, and so line 6 has a 0 entry for the beginning of period 0. The

[17] Thus π^t is the income at the beginning of period t or at the end of period t−1. There is no income during period 0 and none until the very end of period 1 so we only recognize positive income at the beginning of period 2 or at the end of period 1.

[18] We need to use the matched income entries in Table 1 and (18) and (20) to establish this result.

[19] This input value aggregate can be decomposed into a price and quantity component if prices for R&D employees, R&D intermediate input purchases and R&D capital service inputs are available; see de Haan and van Rooijen-Horsten (2004; 19) for an outline of the methodology for setting up an R&D input price index.

[20] For the sake of simplicity, we have only a single interest rate to measure the opportunity cost of capital in each period; i.e., we have not dealt with the complications due to a mixture of debt and equity financing.

sum of the first 6 lines gives us the firm's income for period 0, π^0, and it turns out to be 0 (as desired using our matching principle).

Turning now to the beginning of period 1 and the entries in the beginning of period 1 column, there are still no project revenues at the beginning of period 1, so the entry in line 1 is 0. We assume that there are no additional nonfinancial costs that were incurred in period 0,[21] so that the entry in line 2 is also 0. However, the firm has period 0 interest expenses equal to r_0D^0, and these interest expenses appear as a negative entry in line 3. These interest costs are also associated with the project and since we still have no project revenues to offset these costs, our matching principle forces us to capitalize these interest expenses as well; see the offsetting entry in line 5 of the period 1 column. Since there were no project revenues in period 0, we still do not allocate any costs to this period, so that line 6 has a 0 entry for the beginning of period 1. The sum of the first 6 lines for the period 1 entries gives us the firm's income for period 0, π^0, and it also sums to 0. Line 8 gives us the total (net) debt of the firm at the beginning of each period, assuming that any revenues received during the previous period are used to reduce debt at the end of that period. The sequence of net beginning of period t debts, D^t, are defined by (22). The net debt at the end of period 2 or the beginning of period 3, D^3 is 0 because we assumed that the R&D project was intertemporally profitable. For periods t = 0,1,2, the negative of D^t is equal to A^t, which is the realizable net asset value of the firm; i.e., it is an asset value that recognizes all costs (with a negative sign) but it recognizes revenues only when they occur; i.e., when they are realized.

Turning now to the entries in the beginning of period 2 column, there are project revenues in period 1, so the entry in line 1 is R_1^0. Again, we assume that there are no additional nonfinancial costs in period 1, so that the entry in line 2 is 0. However, the firm has period 1 interest expenses equal to r_1D^1, and these interest expenses appear as a negative entry in line 3. It turns out that our matching principle forces us to capitalize these interest expenses as well;[22] see the offsetting entry in line 5 of the period 2 column. Since there are project revenues in period 2, we allocate the cost C_1^0 to this period, so that line 6 has the entry $-C_1^0$ for period 2. The sum of the first 6 lines for the period 2 entries gives us the firm's income for period 1, π^1, and it sums to end of period 1 revenues, R_1^0, less the allocated cost C_1^0. The entries in the beginning of period 3 column are analogous to the period 2 columns.

4. A Summary of the Information Needed to Implement the Capitalization Procedure

Examining the example in the previous section, it can be seen that R&D cost capitalization procedure (in nominal terms) has the following informational requirements:

- Information on current period 0 R&D costs in nominal terms, C^0 say.

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[21] If there were additional R&D research expenditures, we would set up another table similar to Table 1, which would distribute these costs over future periods.

[22] This capitalization of interest is required in order to ensure that the present value equation (24) will hold.

- Information on the expected future stream of incremental revenues generated by the R&D investment in period 0 in nominal terms, say R_0^0, R_1^0, R_2^0,…
- Information on the one period nominal interest rates r_1^0, r_2^0, r_3^0, that are expected to prevail in future periods 1, 2, 3, …

Given the above information, first find the parameter α by solving the following equation:

$$(25)\ C^0 = \alpha[\ R_0^0/(1+r_0^0) + R_1^0/(1+r_0^0)(1+r_1^0) + R_2^0/(1+r_0^0)(1+r_1^0)(1+r_2^0)\ + \dots\ ].$$

The *matched end of period n cost* C_n^0 that should be allocated to the end of period n for the R&D project that was finished at the beginning of period 0 can now be defined as follows, once we have determined α:

$$(26)\ C_n^0 \equiv \alpha R_n^0\ ; \qquad n = 0,1,2,\dots\ .$$

This gives us enough information to fill out all of the real and imputed transactions that correspond to the transactions in the Table 1 example. Thus the entire cost matching procedure is driven by our assumptions about the future nominal anticipated incremental revenues, the R_n^0, and our assumptions about future nominal one period interest rates (or opportunity costs of capital), the r_n^0.

In order to get constant dollar cost allocations q_n^0 as in section 2 above, we need some additional information on expected future rates of general inflation. Thus to the above information set, add:

- Information on expected future rates of CPI inflation for periods 1,2,3, …, say, ρ_1^0, ρ_2^0, ρ_3^0, … .

Finally, if we want to construct measures of real R&D (flow) input, we need information on the prices and quantities of the inputs that are used to create the R&D asset. Thus, add to the above information set:

- Information on the prices and quantities of the flow inputs that comprise the period 0 cost, C^0; i.e., these are the P_m^t and Q_m^t that appeared in equation (1) above.

Thus there are 5 separate informational components that are required in order to do a complete accounting for R&D investments.

5. Discussion of Some Difficult Issues

Pitzer (2004) and de Haan and van Rooijen-Horsten (2004) raise a number of difficult issues that arise if we attempt to capitalize R&D expenditures in the National Accounts or in the accounts of any production unit. In this section, we look at some of these difficulties in the light of the algebra presented in the previous sections.

- How exactly do the various imputations outlined in section 2 fit into standard national accounting categories?

At least some new lines to the system of input output framework will have to be created to accommodate some of the imputations. The details need to be worked out.

- What is the "best" set of "standard" assumptions that we can make about the pattern of future expected revenues for market R&D?

There is some review of the empirical literature on R&D depreciation rates[23] in De Haan and van Rooijen-Horsten (2004; 20-24) but it would seem that a more extensive discussion of these issues is required before the Canberra Group can make concrete recommendations to the National Accounts community. Although life is simplest if we assume geometric rates of revenue decay, there may well be more realistic "standard" models for the pattern of future incremental revenues that are quite different from our usual set of assumptions about depreciation for reproducible capital.

- What is the "best" deflator for converting current dollar values into constant dollar values?

De Haan and van Rooijen-Horsten (2004; 20) mention that the Frascati Manual recommends the use of the GDP deflator for constant price comparisons, but Kohli (1982; 211) (1983; 142) and Diewert (2002; 556) argue against this choice, since the GDP deflator has negative weights for imports and this can cause the deflator to *decrease* if the price of imports *increases* enough.[24] Hill (1996; 94-97) and Diewert (2002; 557) discuss some alternative choices to the GDP deflator.

- What is the "best" set of assumptions to make about interest rates and future inflation rates?

Should we work with the assumption of a constant real interest rate as is convenient in studies of depreciation for reproducible capital? If so, how should we choose this real rate?

- Should Non Market R&D be capitalized?

Aspden (2003) argues that all research potentially provides benefits to society that can accrue over long periods of time. Hence, he advocates capitalizing both private and public R&D. There is no doubt that publicly funded research that is made freely available provides benefits to society. However, there are no "straightforward" market

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[23] A rather critical review of this literature is contained in Diewert (2005b).

[24] Diewert (2002; 556) gave a recent US example of perverse behavior of the GDP deflator, where the chain type price indexes for C, I, X and M for the third quarter of 2001 decreased over the previous quarter (at annual rates) by 0.4%, 0.2%, 1.4% and 17.4% respectively, but yet the overall US GDP deflator increased by 2.1%.

transactions that can provide us with guidance on the future distribution of these benefits. The problem is that the freely given benefits may show up in the form of lower output prices, higher input prices or higher profits. To work out the exact nature of the improvements due to the freely available R&D would require some complicated general equilibrium modeling along with many assumptions. Moreover, the cost matching methodology explained above will not work in this context because there will be no easily identifiable revenues that the deferred costs can be matched to. These considerations suggest that it would be simpler to *not* capitalize publicly available R&D expenditures. This is the position taken by de Haan and van Rooijen-Horsten (2004; 18) and provisionally by Pitzer (2004; 9). However, current National Accounts conventions simply put the non market R&D expenditures into government consumption (i.e., an artificial output is created out of these input expenditures and added to GDP). This is essentially the same treatment that is done for other difficult to measure general government "outputs" but I am not sure that it is completely satisfactory. However, given that these non market R&D expenditures have been shunted over to the government sector, there is nothing to prevent us from inventing a method that would essentially spread this government "output" over future periods.[25] The exact details of how this should be done need to be worked out.

- Should unsuccessful R&D ventures be capitalized?

De Haan and van Rooijen-Horsten (2004; 24) discuss this issue. They note that some experts argue that unsuccessful ventures should be immediately expensed or "written off", while other experts argue that all R&D activities, whether successful or not, contribute to acquiring a commercially valuable knowledge stock.[26] Both points of view are justifiable but it seems to me that the first point of view is more in line with market realities. This issue requires further discussion.

- Is the proposed method of R&D capitalization consistent with the national accounts treatment of other intangible assets, such as mineral exploration, advertising and franchising?

This is an issue for national accounting experts to discuss. However, in my opinion, all (market sector) current period expenditures on any of the above intangible assets have the same character as (market sector) current expenditures on R&D: expenditures are made now in the hope of "creating" future period incremental revenues. Hence, essentially the

[25] This possibility was noted by Pitzer (2004; 9): "If unpatented entities were to be treated as assets, then an accounting treatment needs to be created for them. At first glance, it would appear that unpatented entities should be given the same accounting treatment as patented entities because both affect future income in the same way. The lack of assessments for unpatented entities prevents use of any of the treatments discussed in the previous section, which means that either different treatments should be accorded patented and unpatented entities or a new methodology applicable to both should be developed."

[26] De Haan and van Rooijen-Horsten(2004; 24) also note the analogy of unsuccessful R&D ventures to unsuccessful oil wells: "For mineral exploration, the SNA 1993 recommends that all mineral exploration should be treated as gross fixed capital formation (#166) since both successful and unsuccessful exploration efforts are needed to acquire new reserves. In a similar way, one may conclude that the value of the knowledge capital stock should include both the costs of successful and unsuccessful R&D."

same matching of costs to future revenues methodology used above could be applied to these activities and overall consistency could be achieved.[27]

- How should taxes and subsidies and subsidies be treated?

Again, de Haan and van Rooijen-Horsten (2004; 12) discuss this issue. They point out that in the Netherlands, subsidies for R&D are quite substantial. In Canada, there is a favorable business income tax treatment for R&D investments of an approved type. It is not completely clear how to deal with these tax and subsidy complications.

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[27] The same matching methodology will work for transfer costs (i.e., transactions costs of whatever form) as well.

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