OBSOLESCENT TECHNOLOGY AND THE TIME HORIZON FOR BENEFITS IN BENEFIT-COST ANALYSIS

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Obsolescent Technology and the Time Horizon for Benefits in Benefit-Cost Analysis

The purpose of this paper is to demonstrate the incorrectness of imposing a truncated time horizon for estimating the benefits of research in a situation where technological obsolescence is likely to occur. The comparison of the 'with research' and 'without research' situations forms the basis for estimating the benefits of research in benefit-cost analysis. This approach is consistent with the premise that research users will not adopt the results of research unless they receive a benefit additional to the one received from use of existing technology. However it is not consistent with the view taken by some analysts and incorporated in some software packages that technological obsolescence will limit the time horizon for the benefits of a new technology to some finite number of years. There are a number of factors which will limit the time horizon of benefits but technological obsolescence is not one of them

Introduction

The magnitude of the estimated benefits in benefit-cost analysis can depend critically on the time horizon selected for the analysis. Generally, the greater the number of years over which benefits are received, i.e. the more distant the time horizon, the greater will be the magnitude of the present value of the benefits (PVB). Conversely, the shorter the time horizon, the lower will tend to be the magnitude of PVB.

There are of course other factors which may be more or less influential such as the annual value of the gross potential benefits or the adoption rate. In the case of the evaluation of research which is not yet completed, the values assigned to the probability of the research being successful and the probability of success of the technology transfer process will also influence the magnitude of PVB.

In the present paper, consideration will be limited to the use of benefit-cost analysis (BCA) in research evaluation, and in particular to obsolescent technology as a factor which limits the time horizon of benefits.

Factors Influencing the Time Horizon of Benefits

A number of factors have been identified as reasons for limiting the time horizon of benefits in the evaluation of research. These factors include:

- technological obsolescence due to the appearance of a new superior technology (ABARE (1991), Alston *et al* (1995); Coelli (1991), Coelli *et* al

(1991), Grains Research and Development Corporation (1995), Lindner (1989), Marshall and Brennan (1993));

- biological decay (Alston *et al* (1995), Marshall and Brennan, (1993)),

- a 'without research' scenario in which the production of the same technology is expected by a competing research agency (Collins and Johnston (1992), Marshall and Brennan (1993)),

- the leakage of benefits to competing producers overseas or in other regions resulting in increased supply and lower product prices (Edwards and Freebairn (1982,1984), Davis, Oram and Ryan (1987)) and

- the effect of discounting (Young (1992))

The impact of these factors is taken account of in different ways in the benefit-cost formula. The model generally used for benefit-cost analysis in the evaluation of research takes the following form

$$NPV = \Sigma_t [p\ a_t\ B_t - C_t]\ (1+i)^{t}$$

where	NPV	= net present value of benefits
	p	= probability of success of R&D
	a	= adoption rate
	B	= gross value of benefits
	C	= costs of R&D
	i	= rate of discount
	t	= year(s)

The estimation of the annual benefits to society from a given piece of research may therefore be based on the expression $p\ a_t\ B_t$ taken from this formula

It has become 'conventional' (see for example Alston *et al* (1995), Marshall and Brennan (1993)) to reflect the impact of technological obsolescence through the value of a_t - the adoption rate will decline as producers replace the obsolete technology with the new superior technology.

Biological decay will be reflected in a declining value of annual gross benefits, and may also be associated with a declining adoption rate.[1] For example, if a new variety becomes susceptible to disease, or a pesticide becomes less effective because of growing resistance among target pests then the benefits will decline. Producers may continue to use the technology if no better alternative is available. If a better alternative is available, then the adoption rate will also decline

[1] The endogenous nature of adoption was noted by Vere *et al* (1992)

If the same new technology is being developed by another research agency, then the 'without research' situation should take account of this so that the benefits of the research being evaluated are limited to the time period up to the point when the competing technology becomes available to producers. In this situation, the impact is directly on 't'

The impact of a price decline, caused by the leakage of the technology to overseas suppliers and resulting supply increase, will generally be reflected directly in the value of gross annual benefits, and may also influence the adoption rate as producers seek a more profitable alternative

In the case of the discount rate impacting on the time horizon, the value of 't' will generally be limited only to those years for which significant positive PVB's are generated by the research. For example, with a 10% discount rate and a stream of benefits extending to perpetuity, there is usually no significant addition to PVB beyond a time horizon of 50 years because the present value of benefits accruing beyond that point are not significantly different from zero

The aim of the present paper is to focus on the treatment of the benefits generated by a technolo^r y which becomes obsolete. This issue is the topic of discussion for the remainder of the paper

The Case of Technological Obsolescence

There have been a few dissenting observations about the 'conventional' treatment of the benefits of a technology which is expected to become obsolete. For example Johnston *et al* (1992), Carter and Young (1993), and Collins and Johnston (1993) argue that technological obsolescence is not relevant to a determination of the time horizon of benefits from project research. Their arguments are presented in terms of the benefits from a new technology being incremental to the benefits received by producers from use of the existing technology and hence the benefits of the existing technology continue in perpetuity. The comments of these analysts are made by and large as passing observations without the support of any detailed analysis. The essence of their argument is that whilst the technology may become obsolete, the benefits of that technology do not disappear with technological obsolescence

What might be described as a 'middle course' has been taken by Marshall and Brennan (1993). They accept the validity of the conventional treatment of technological obsolescence imposing a limit on the time horizon of benefits as producers replace an obsolete technology with a new superior technology. However they also acknowledge the possibility of technological obsolescence not having an impact on the time horizon of benefits. The choice of the analyst as to which alternative treatment to use will depend, they argue, on the nature of the problem being solved. If the current 'genus' of solutions to a problem is expected to remain economically superior in the foreseeable future, then no truncation of the time horizon of benefits via disadoption would apply. The diesel-fuelled tractor is cited as a technology for which benefits would continue in perpetuity "because it is likely that the innovation will be incorporated, probably with further refinement, in all future 'species' of tractor design." If however, "the current genus of solutions to a problem may be expected to be rendered extinct by imminent progress with another genus of solutions", then the conventional treatment of technological obsolescence would apply. They conclude that the use of one or other of the two alternative treatments of technological obsolescence as a uniform approach could be expected to "result in calculation of misleading benefit-cost ratios, both for assessing any single innovation and for choosing among opportunities to develop various possible innovations."

The use of the 'genus of solutions' argument by Marshall and Brennan is itself innovative but is essentially a supply side view. The benefits of a technology accrue to the users of the technology. The decision as to whether to adopt a new technology, regardless of genus or species, will be determined by whether it is profitable for the producer to do so. In other words the demand side rather than the supply side will prevail. And the profit or benefit from adopting the new technology will be in addition to those benefits received from using the existing technology i.e. the increment. If that increment is not positive in NPV terms, then it is not in the producer's economic interest to adopt the new technology.[2]

It is therefore concluded that the correct treatment for the case of obsolescent technology is to assume that the benefits of the existing technology continue in perpetuity, and that application of the 'conventional' treatment may lead to underestimation of benefits. In the next section, the results of a simulation exercise are presented to illustrate the validity of this conclusion.

A Simulation Exercise

The part of the benefit-cost formula given earlier which is of concern here is $p.a_t.B_t$, the measure of the annual benefits from research. For ease of exposition and without affecting the outcome of the analysis in a way that is relevant to the issue being considered, it is assumed that p = 1. Accordingly we are primarily concerned with the impact of technological obsolescence on the values of a, B and t.

The scenario for the simulation exercise is as follows:

- the time period for the simulation is 20 years.

[2] There may of course be situations in which research results are complementary, and that the adoption of one component only may result in loss, whereas the adoption of the package may be profitable. Such a view might, in the present context, lead to a debate about the definition of 'technology', an issue which is not considered in this paper.

- as a result of research, a new technology, T1, becomes available in year 5 after completion of the research in year 4.
- the potential gross annual benefits aggregated over the target group of producers is $2m per annum
- the adoption of T1 follows the traditional S-curve pattern and reaches a ceiling rate of 50% in year 10. and continues at that level until year 14
- in year 14 research on a new superior technology, T2, is completed and becomes available in year 15 to the same target group of producers as for T1
- the gross annual benefits for T2 aggregated over the same target group of producers is $2 per annum
- from year 15, producers adopt T2 following the same S-curve pattern as characterised the earlier adoption of T1, up to a maximum rate of 50% in year 20
- reflecting the adoption of T2, a disadoption pattern is recorded for T1 as from year 15 mirroring the adoption pattern of T2 in reverse
- the only factor determining the disadoption of T1 is its replacement by T2 In other words, T1 has been made technologically obsolete by T2

The data used to represent the foregoing scenario and the simulation analysis are shown in the Appendix Table

The cumulative values for the gross annual social benefits for T1 and T2 are shown in Figure 1. These benefit estimates represent the anticipated maximum annual benefits if all producers in the target group of research beneficiaries adopt the new technologies, T1 and T2. The incremental nature of the benefits from T2 compared with the 'without research' situation characterised by T1 is clearly evident.

The adoption patterns of the two technologies are shown in Figure 2. The disadoption pattern for T1 is represented as a reverse S-curve, mirroring in reverse the S-shaped adoption curve for T2.

The data underlying the values for B_t in Figure 1 and a_t in Figure 2 are combined in the product $a_t.B_t$ to generate estimates of annual benefits for each of T1 and T2 respectively - see Figure 3. Not surprisingly, the respective patterns of the annual benefits for the two technologies closely resemble that for the corresponding adoption patterns.

In Figure 3, the outcome is shown of the 'conventional' treatment of benefits being applied to a case of technological obsolescence. Benefits cease in year 20 and in effect the time horizon for the benefits from T1 has been truncated to 15 years

The paradox which the 'conventional' approach causes is illustrated when the annual cumulative benefits for the T1 and T2 are computed The sum of the annual benefits for the two technologies for each year of the 20 year simulation period is shown in Figure 4 It can be seen that the maximum level of aggregated benefits for T1 +T2 never exceeds the maximum level achieved by T1 in year 10 In other words, under the 'conventional' approach, the benefits generated by T2 merely replace the benefits lost by T1 through the disadoption process

This result is surprising because it suggests that the adopters of T2 have received no incremental benefit from adopting T2 and that they may just as well have continued with T1 and ignored T2 In the simulation, the aggregate incremental benefits gained from using T2 are assumed to be the same as for T1, viz $2m If the incremental gain from T2 had been less than $2m, then the annual cumulative benefits from the two technologies would have declined from year 15 onwards This is in sharp contrast to the situation shown in Figure 1 It may be concluded that such a situation is quite unrealistic and application of the conventional treatment of the impact of technological obsolescence results in a substantial understatement of the benefits for T1

To overcome the problem of the 'missing' benefits in Figure 4, it is necessary to assume that the benefits of the existing technology, T1, continue in perpetuity Thus, even although in reality there may be disadoption of the obsolete technology, for the purpose of computing benefits, it is necessary to assume that disadoption does not occur And the reason for this is because of the way research benefits are calculated as an increment over the 'without research' situation Such an approach seems to be in accord with the perceptions of the beneficiaries who adopt the new technology

The effect of assuming that benefits continue in perpetuity for an existing technology, even when it becomes obsolete, are shown in Figure 5. In this representation of the benefits, the 'missing' benefits have been made visible and the incremental nature of the benefits made clear. The 'real' benefits from adopting each technology are shown as successive increments In the analysis therefore, the effect of disadoption of an existing technology due to obsolescence is not to reduce the benefits from the obsolescent technology, but to provide a mechanism which enables producers to adopt the new superior technology and thereby achieve the incremental benefits of the new technology, and these benefits represent an addition to the benefits received from the obsolete technology. For computational purposes, it is necessary to treat the benefits of the obsolete technology as if they continued indefinitely.

It should be stressed that the foregoing treatment of benefits from research applies only to the case of technological obsolescence. As was pointed out earlier, for situations where the time horizon may be truncated for other reasons including disadoption because of biological decay, the treatment of benefits will be different

Concluding Comments

A number of factors were identified which result in the truncation of the time horizon of benefits in the benefit-cost model as it is applied in the economic evaluation of research. Included amongst these factors is technological obsolescence. The conventional approach in estimating research benefits for a technology which becomes obsolete is to impose disadoption of the obsolete technology, reflecting the adoption of the new superior technology by producers. The effect is to limit the number of years of benefits of a technology which becomes obsolete and is replaced by a new technology.

The paradox resulting from the introduction of the disadoption mechanism is that incremental benefits from the adoption of the new technology merely replace the benefits associated with the obsolete technology. The incremental nature of the benefits from the new technology is lost.

Yet it seems clear that producers will only adopt a new technology if the benefits exceed those of the existing technology. The treatment of research benefits as incremental in the economic evaluation of research is consistent with this user perception.

For computational purposes, to retain the incremental nature of the benefits from adopting a new technology, it is necessary to treat the benefits from the obsolete technology as if they continue in perpetuity. In this way, the paradox of the 'missing' benefits arising from use of the conventional approach to technological obsolescence can be overcome and the risk of the gross underestimation of research benefits avoided.

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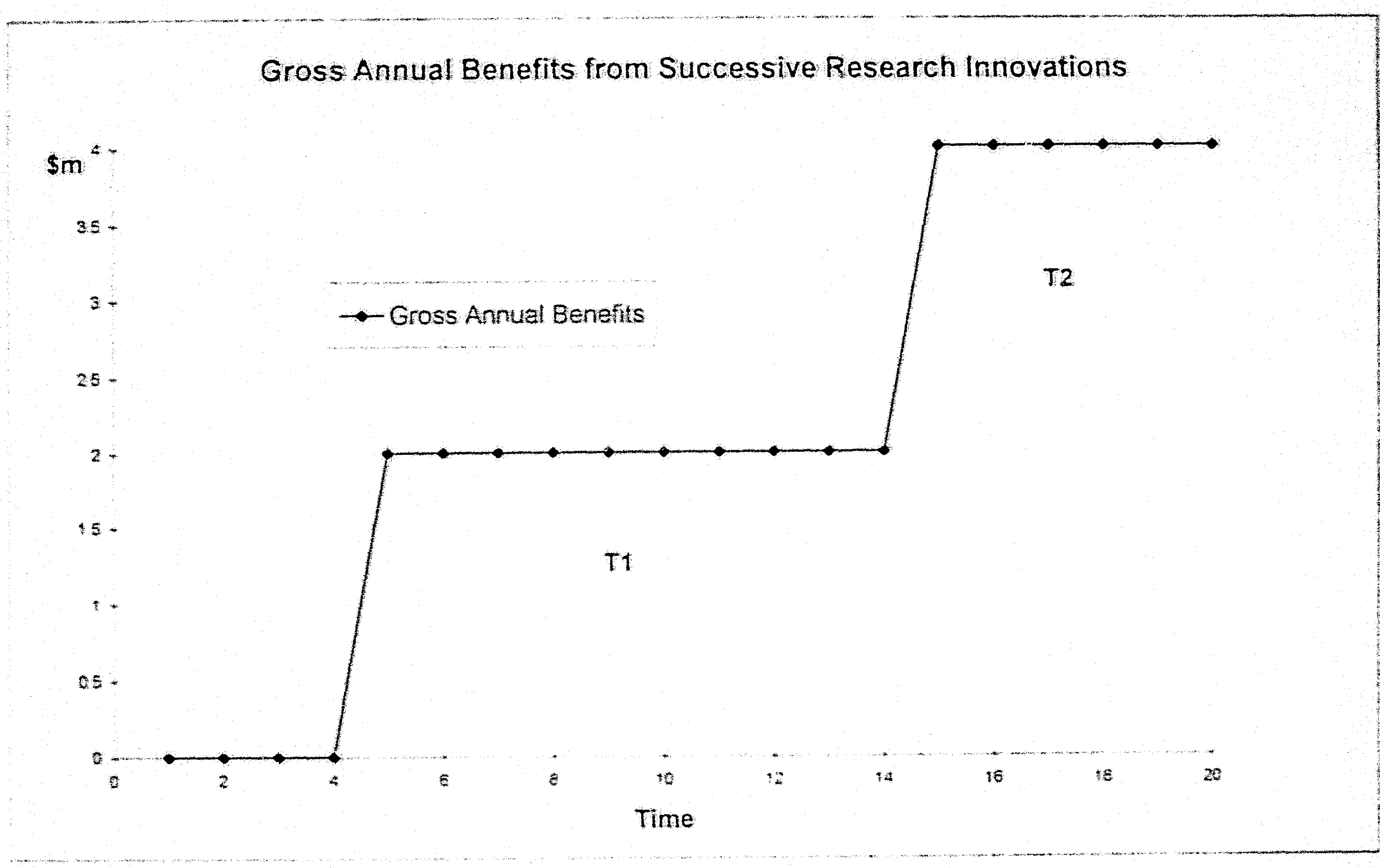
APPENDIX TABLE: DATA USED FOR SIMULATION EXAMPLE

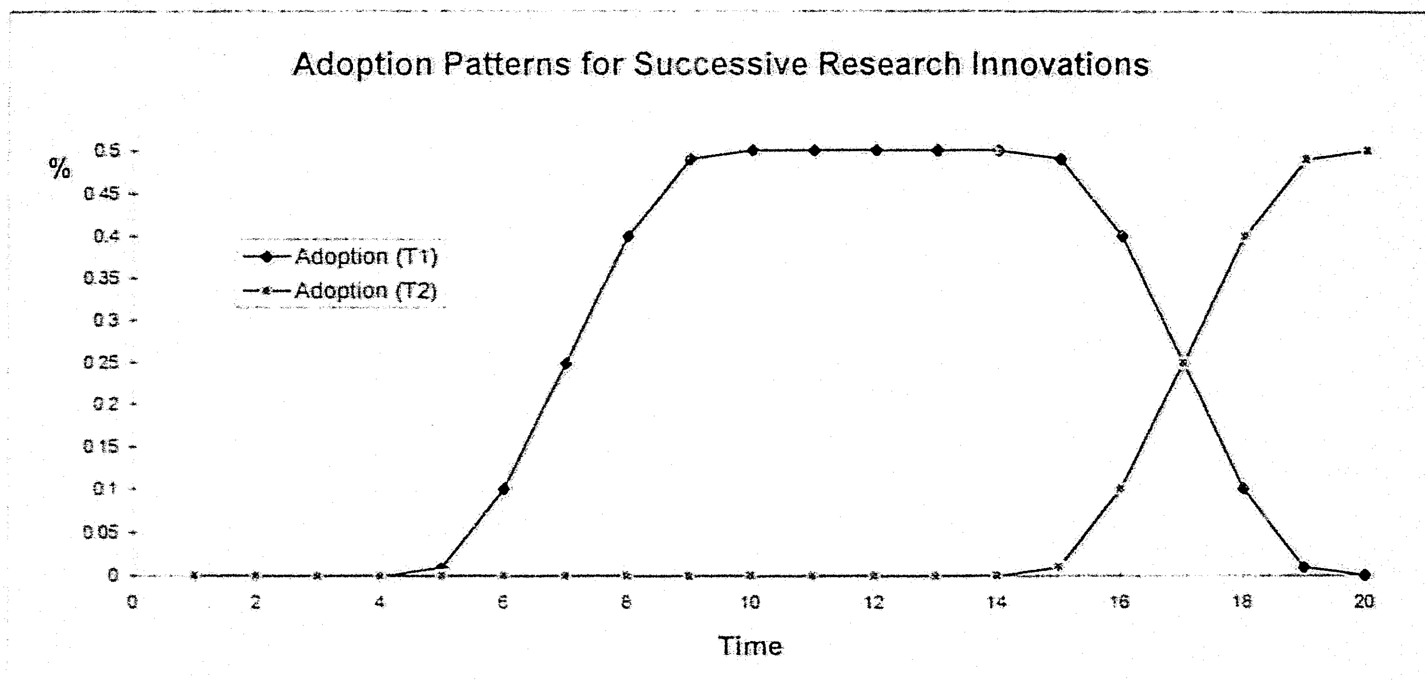
Time (Years)	Gross Annual Benefits ($m)	Adoption (T1) (%)	Adoption (T2) (%)	Annual Benefits (T1) ($m)	Annual Benefits (T2) ($m)	Annual Cumulative Benefits (T1+T2) ($m)	Real Annual Cumulative Benefits (T1+T2) ($m)
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0
5	2	0.01	0	0.02	0	0.02	0.02
6	2	0.1	0	0.2	0	0.2	0.2
7	2	0.25	0	0.5	0	0.5	0.5
8	2	0.4	0	0.8	0	0.8	0.8
9	2	0.49	0	0.98	0	0.98	0.98
10	2	0.5	0	1	0	1	1
11	2	0.5	0	1	0	1	1
12	2	0.5	0	1	0	1	1
13	2	0.5	0	1	0	1	1
14	2	0.5	0	1	0	1	1
15	4	0.49	0.01	0.98	0.02	1	1.02
16	4	0.4	0.1	0.8	0.2	1	1.2
17	4	0.25	0.25	0.5	0.5	1	1.5
18	4	0.1	0.4	0.2	0.8	1	1.8
19	4	0.01	0.49	0.02	0.98	1	1.98
20	4	0	0.5	0	1	1	2

FIGURE 1



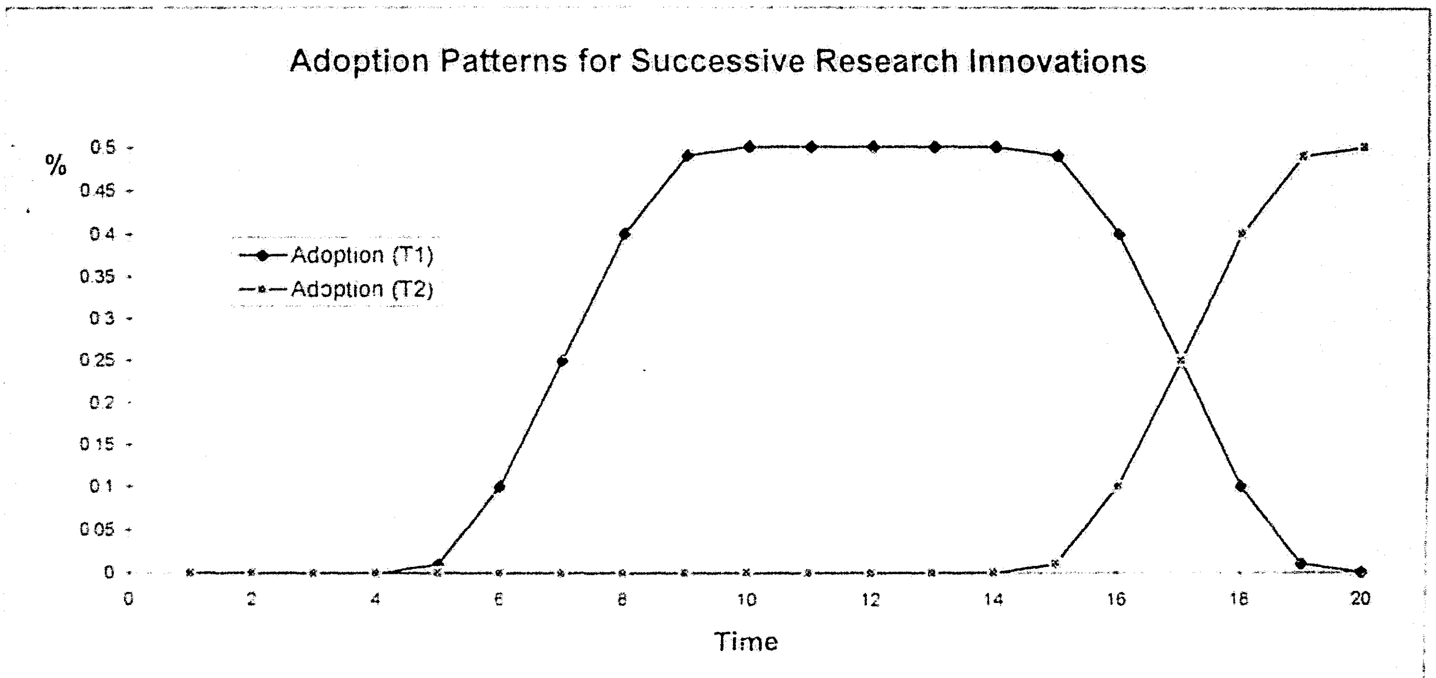
Gross Annual Benefits from Successive Research Innovations
$m
4
3.5
3
2.5
2
1.5
1
0.5
0
0
2
4
6
8
10
12
14
16
18
20
Time
Gross Annual Benefits
T1
T2

FIGURE 2



Adoption Patterns for Successive Research Innovations
%
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Adoption (T1)
Adoption (T2)
0
2
4
6
8
10
12
14
16
18
20
Time

FIGURE 2



Adoption Patterns for Successive Research Innovations
%
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Adoption (T1)
Adoption (T2)
0
2
4
6
8
10
12
14
16
18
20
Time

FIGURE 3

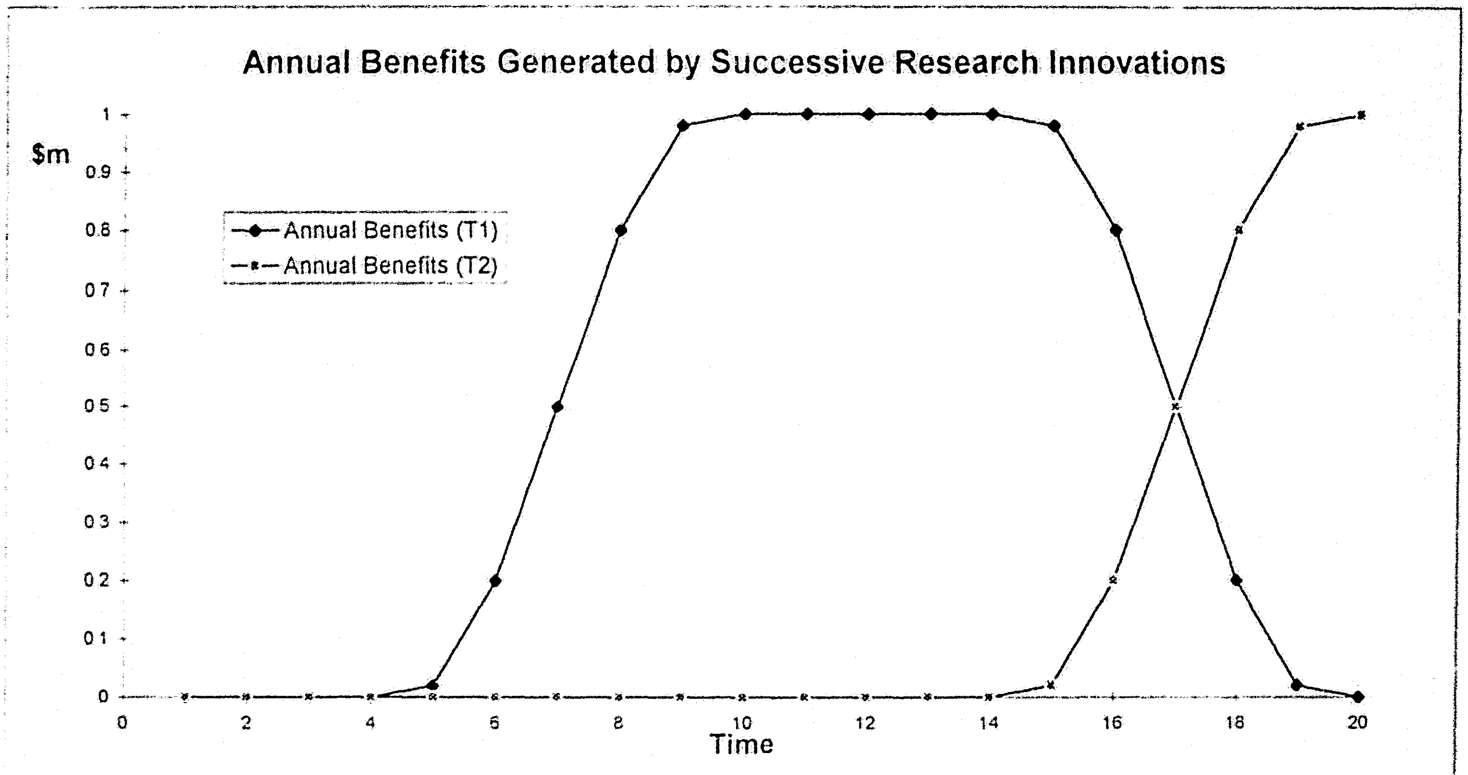
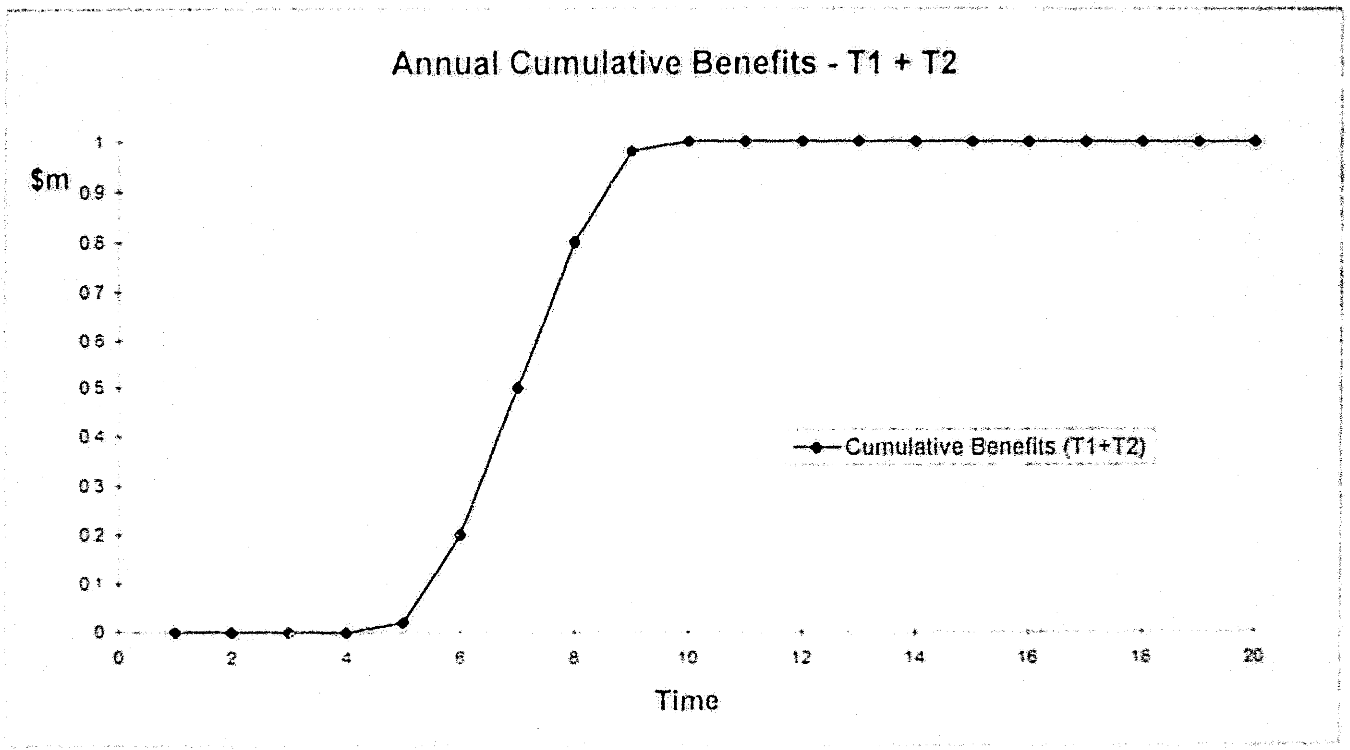
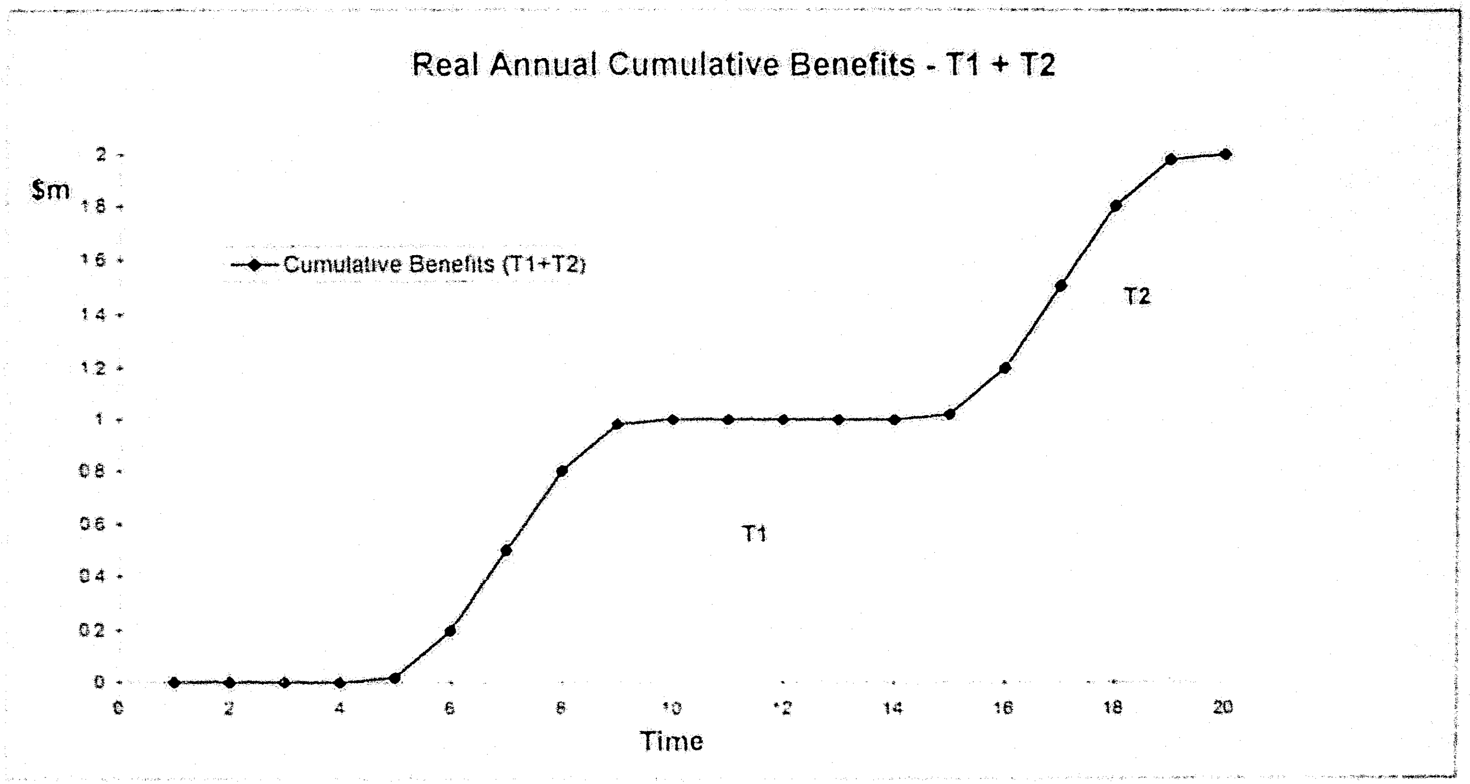

Annual Benefits Generated by Successive Research Innovations
$m
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Annual Benefits (T1)
Annual Benefits (T2)
0
2
4
6
8
10
12
14
16
18
20
Time

FIGURE 4



Annual Cumulative Benefits - T1 + T2
$m
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2
4
6
8
10
12
14
16
18
20
Time
Cumulative Benefits (T1+T2)

FIGURE 5


Real Annual Cumulative Benefits - T1 + T2
$m
Cumulative Benefits (T1+T2)
T1
T2
Time
0
2
4
6
8
10
12
14
16
18
20