Evaluating the Economic Impacts of Accelerated R&D

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Abstract

A key part of any economic impact assessment study is the specification of a counterfactual scenario. Sometimes, the most likely counterfactual for a research project is that the same, or equivalent research, would be carried out by someone else, albeit at a later date. Alternatively, the research impacts might simply "spill-in" without any further research, and at little or no cost. Either way, the material impact of the research being evaluated is simply to bring forward in time realisation of the consequential economic benefits. However, which of the above two alternative scenarios is applicable does have important implications for the treatment of costs in the counterfactual scenario. An economic impact assessment study of an ACIAR funded project on the development and uptake of a mud crab hatchery innovation in Vietnam is used to illustrate some of the issues involved.

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Ex Post Economic Impact Assessment of Accelerated R&D and Innovation Adoption

Introduction

Since the pioneering study by Schultz (1953), the assessment of the economic impact of agricultural R&D has become a sizeable industry. After a concerted search, (Alston et. al., 2000) assembled 292 published impact assessment studies reporting a total of 1,886 individual estimates for a comprehensive meta-analysis of all the available evidence on estimated rates of return to agricultural R&D.

Findings from these studies that estimated returns to investment in agricultural R&D are typically quite high, often almost unbelievably so, is one of the reasons for ongoing resourcing of what is quite an arcane sub-field. For instance, typical rates of return reported in Alston et. al. (2000) were in the range of 40–60 percent per year. Not surprisingly, such results are seized upon by the agricultural science industry as objective evidence that funding should at least be maintained, and preferably increased.

Despite the solid weight of evidence, debate continues over the validity of at least some of these findings. In particular, it has been argued that some estimates of large returns to agricultural R&D might be inflated due to quirks in the methods used to assess the economic impacts. For instance, it has been common practice to assume, sometimes explicitly but more often implicitly, that the state of technology in the counterfactual "without R&D" scenario is static. In particular, there is often no recognition in the counterfactual scenario of the possibility of adoption of a substitute innovation for that developed by the agricultural R&D project or program being evaluated. If the agricultural R&D being evaluated had not been undertaken, but the same innovation, or an equivalent substitute, did become available subsequently, then the true R&D benefits will be overestimated by assuming in the counterfactual scenario that productivity will never improve. In these circumstances, the real impact of funding a specific agricultural R&D project will be to bring forward in time the realisation of economic benefits, rather than to generate benefits that would never be realised in the absence of the R&D funding. This possibility has been recognised in a number of recent economic impact studies. An early example cited by Maredia et. al. (2000) was a study by Martinez and Sain (1983), and more recent examples include Morris, Dubin and Pokhrel, (1994), Ryan (1998) and Van Bueren (2004).

The purpose of this paper is to note that the means by which an innovation might become available under the counterfactual scenario will vary from one case to another, and that the appropriate analytical method to use will depend on which possibility is most likely to occur. Hence, the key to correct treatment of this methodological issue in economic impact assessment studies is explicit and precise specification of the counterfactual scenario.

Ex post economic impact assessment

Details of the conceptual framework, as well as the types of information needed, and the method of analysis for ex post evaluation of agricultural R&D using the economic surplus approach are clearly spelt out in Alston, Norton, and Pardey (1995), and will not be repeated here. In essence, ex post estimation of the economic impacts of any R&D project involves quantifying the economic outcomes of the "with R&D"

scenario, as well as those of the counterfactual “without R&D” scenario, and then taking the difference between them. Hence, the first step in any assessment of the economic impacts of a R&D project is to specify both these scenarios.

In this paper, it will be assumed that the key output of the R&D being evaluated is a process innovation that improves productivity, and/or saves input costs, because this is the most common source of beneficial impacts from agricultural R&D. Rational and fully informed primary producers will only adopt such a process innovation if it reduces their unit cost of production, so the consequence of innovation adoption is a downward shift of the supply curve relative to its position in the counterfactual scenario, hereafter referred to as the counterfactual supply curve.

For a truly ex-post impact assessment, the “with R&D” scenario can be specified in a relatively straightforward way so long as the outcomes are more or less observable. While some impacts may need to be predicted when there is a short time lag between the completion of the research, the main problem is partitioning changes over time in observed outcomes between those attributable to diffusion of the innovation, and those due to other exogenous causes.

Prior to the time of first adoption of the innovation, the “with R&D” and the “without R&D” supply curves will be coincident, but subsequently the “with R&D” supply curve will shift downward relative to the “without R&D” supply curve. Moreover, the broad array of factors that determine the position of both supply curves will rarely, if ever, be static. As Alston, Norton, and Pardey (1995, p31) note, one quite common reason why the counterfactual supply curve might shift up over time is deceasing productivity due to increasing resistance in weeds, pests, and diseases to current methods of control. More generally, productivity may decline, and the counterfactual supply curve might shift up due to depreciation in the stock of knowledge, and/or to the deteriorating quality of natural resources that are inputs to agricultural production.

Alternatively, the counterfactual supply curve may shift down over time, albeit more slowly than the “with R&D” supply curve, because of increasing productivity for reasons other than adoption of the innovation. Alternatively, even in the “without R&D” scenario, the innovation may become available and be adopted at a later date. This possibility will be discussed in more detail in the next section.

Trying to take account of all of these possibilities when envisioning how the counterfactual supply curve would have shifted over time in the absence of the specific research project or program being evaluated, can present a conceptual challenge for analysts undertaking impact assessment studies. Since the “without R&D” scenario is hypothetical by definition, specifying it is necessarily subjective, and consequently more problematic than the “with R&D” scenario. Nevertheless, specification of a counterfactual scenario should be a key part of any ex post economic impact assessment study. It should be inferred from the best available information, and the necessarily subjective underlying assumptions should be made explicit.

This is often not the case in practice. As Alston, Norton, and Pardey (1995) point out, while the comparative static approach should compare situations with and without research, the fact that time–subscripted data are often used for the comparison can result in “before and after” research scenarios being compared instead of “without and with” research scenarios. As a result, it is not uncommon for there to be no explicit consideration of the counterfactual scenario, and for a tacit assumption to be made in the impact assessment study that the counterfactual supply curve does not shift over time.

The state of technology in the counterfactual scenario

When specifying the “without R&D” scenario in economic impact assessment studies of agricultural R&D, the possibility of changes to the counterfactual state of technology are often overlooked. As a result the “without R&D” scenario is synonymous with a “without innovation” scenario.

However, in many cases, it is implausible to assume that no substitute innovation would have been developed if the particular R&D project being assessed had not taken place. As the Centre for International Economics (CIE 1997) pointed out, the counterfactual state of technology during the period when benefits of the R&D project are being realised will not necessarily be the same as that prevailing before the research commenced. In fact, it is more likely that many potential sources of technological change, including spill-ins of equivalent technology from other regions, substitute research outputs from other organisations, and endogenous farmer experimentation, will shift the counterfactual supply curve (Alston and Pardey 2001). Consequently, as Maredia et. al. (2000, p10) note, “Large errors, usually overestimates, are possible from a lack of rigor in thinking about the "with" and especially, the "without" situation.”

Clearly, alternative sources of equivalent technology to the research outputs being assessed should be considered when specifying the counterfactual scenario. For instance, the innovation or a close substitute may already exist elsewhere. In the absence of the assessed R&D, eventually this substitute innovation would become available for adoption in the country where the impacts are being assessed. In other words, the research impacts might simply “spill-in” exogenously from other research programs without any further research by the agency or funding body being evaluated, and at little or no opportunity cost. Alternatively, the most likely counterfactual might be that someone else would fund and/or carry out other R&D that would generate the same, or an equivalent innovation, albeit at a later date.

Either way, the impact of the research being evaluated can be conceived of as shortening the time lag to adoption, and thus bringing forward in time the realisation of the consequential economic benefits. In those studies that have recognised the above possibilities, the most common approach has been to specify a counterfactual scenario in which innovation adoption is some lagged transformation of adoption in the “with R&D” scenario. Thus, an innovation diffusion profile is embedded in the counterfactual scenario as well as in the “with R&D” scenario. According to Maredia et. al. (2000, p10), for such cases, the major challenge is to estimate the timing of the without-research adoption curve, but this overlooks another issue that does not seem to have been widely recognised.

While guesstimating the time lag from realisation of economic benefits for the “with R&D” scenario to that for the “without R&D” scenario is unquestionably difficult, another issue which seems to have received less attention is the treatment of costs in the counterfactual scenario. The appropriate treatment of costs should depend on which of the above two alternative scenarios for changes to the counterfactual state of technology is applicable.

So long as the substitute innovation would have become available exogenously at some future date, and at no cost to the relevant countries, the sole or principal benefit of the particular R&D project being evaluated will be the earlier realisation of the benefits from innovation adoption (Ryan and Garrett 2003). In other words, if the innovation would in any case spill-in spontaneously at some time in the future, the only thing that the assessed R&D achieves is to enable earlier adoption of the process innovation. The difference between the research benefits realised at observed or predicted rates, and a counterfactual scenario of lagged benefit realisation, is an appropriate measure of this benefit for the particular R&D project. Hence, there is no need to include any costs in the counterfactual scenario.

Conversely, where some other organisation would need to finance equivalent R&D in order to develop the same or an equivalent substitute innovation, the impact of the R&D being evaluated would be to bring forward in time BOTH the costs of the R&D and the economic benefits of adoption of the innovation.

The logically consistent way to do so is to first specify both a "without innovation" scenario and a "with innovation" scenario. The latter includes the R&D costs of development of the innovation, while the former scenario does not. Estimates of the annual economic outcomes of each scenario can then be quantified, and the difference between them is a measure of net economic benefits from innovation development and adoption. It is also the time profile of economic outcomes for the "with R&D" scenario. The time profile of economic outcomes for the "without R&D" scenario is simply the same annual values of both costs and benefits lagged by the assumed delay before some other organisation carries out the necessary R&D.

An example – The impact assessment of mud crab hatchery technology in Vietnam

An economic impact study of an ACIAR funded project on the development and uptake of a mud crab hatchery innovation in Vietnam is used below to illustrate how the method advocated above can be applied.

Until recently, all mud crab aquaculture operations in Vietnam relied on crab seed collected from the wild to stock farm ponds. However, this source of seed is finite, and Allan and Fiedler (2004) expressed concerns that further expansion of mud crab aquaculture will need an alternative source of supply, as the maximum sustainable yield from wild stocks has been reached. Potentially, hatchery-reared mud crablets are an alternative source of seed, and are the obvious solution to this supply constraint if the potential for expansion of mud crab aquaculture is to be realised.

The lack of reliable hatchery technology for production of juveniles to stock ponds, and the need to improve pond yield, had been identified previously as two of the most important constraints to further development of the industry. The perceived need for reliable hatchery technology was based on a belief that the traditional supply of wild caught crab seed would:

- shrink because of the loss of mangrove forests
- not be sustainable due to over-exploitation of wild crab stocks
- not be sufficient to support expanded production to meet increased demand.

Starting in 1995, ACIAR funded projects designed to develop technology for hatchery and nursery production of mud crab, and to identify ways to increase pond productivity in the grow-out phase. When the ACIAR funded projects commenced, there was no known financially viable method for producing commercial quantities of mud crab seed. Consequently, exogenous spill-in to Vietnam of this innovation without further R&D was not a plausible possibility in the foreseeable future. Even less likely is the possibility that mud crab farmers, or operators of hatcheries for other aquaculture species, could overcome these impediments by trial and error within any meaningful time frame. Hence, new scientific knowledge had to be acquired to enable consistent spawning and hatching of good-quality larvae and increased survival of larvae to crab stage.

While no successful method for commercial scale hatchery production of mud crab seed existed at the time when these ACIAR projects commenced, its feasibility had been demonstrated in experiments. Moreover, hatchery technology did exist for other aquaculture species of crustaceans, such as shrimp, and the need to develop such an innovation for mud crab aquaculture had been recognised. Furthermore, significant research into the feasibility of larval rearing of mud crabs had taken place before the inception of the ACIAR mud crab projects. Therefore, it was assumed that development of the commercial scale mud crab hatchery technology would have been funded by another organisation had ACIAR not funded the assessed projects, but that the development of the innovation, and its adoption, would have been delayed by three years.

The “without innovation” scenario

This scenario is predicated on the assumption that crab farmers would continue to rely indefinitely on the traditional supply of wild-caught crablets to stock their ponds in the absence of the innovation. As discussed above, the sustainable supply of mud crab seed from the wild is limited, and thus extremely inelastic. As demand grows in the future, prices for crab seed would increase, thereby constraining future development and expansion of mud crab aquaculture in Vietnam.

Currently, wild-caught crab seed is purchased mainly for semi-intensive and intensive grow-out of mud crabs, and only infrequently for more extensive operations. There are no statistics for the area of semi-intensive and intensive culture of mud crabs, and the 11,839 ha recorded for culture of blue swimmer and mud crabs in Vietnam in 2004 clearly underestimates the actual area by a significant margin.

For the purpose of projecting future production from semi-intensive and intensive aquaculture, it was assumed that this form of mud crab culture covered 947 ha (8% of 11,839 ha.) of ponds in 2003. Because of the constraining effect of limited supply of crab seed, this area is predicted to grow at an annual rate of only 3%. The average of yield from semi-intensive ponds (700 g/ha) and intensive ponds (1120 g/ha) was assumed to be 910 g/ha. Conversely, the area of extensive mud crab aquaculture was assumed to not use any crab seed, and to grow at 5% per year from a base of 9,708 ha yielding 350 g/ha.

As far as could be determined, there are no studies of the demand for mud crabs. It is known that there are large potential markets in China, and that supply in other exporting countries also is projected to expand. Therefore, it was assumed that the export demand is highly elastic, and will ensure that, in the long run, prices will be more or less independent of production in Vietnam. Of course, prices inevitably will fluctuate, but on average they are likely to remain close to current levels of about VND70 million per tonne in real terms.

The "with innovation" scenario

The innovation in question is a commercial-scale mud crab hatchery technology for *Scylla paramamosain*. By the time of completion of the ACIAR projects at the end of June 2003, this innovation was ready and available for adoption.

For potential benefits from this innovation to be realised, mud crab aquaculture farms must adopt the practice of purchasing hatchery-reared crab seed rather than relying on the supply of crablets from the wild stock of mud crabs. They will do so if hatchery-reared crab seed is cheaper than wild-caught seed and/or if grow-out productivity is greater.

Hatchery-reared crab seed is best suited to semi-intensive and intensive mud crab aquaculture, while relying on wild-caught crab seed to stock grow-out ponds constrains stocking, survival and growth rates. Estimates of productivity of grow-out of hatchery-reared crab seed as compared to wild-caught seed in pond culture in Vietnam were based on anecdotal evidence collected during a visit to Vietnam in 2005 to study the development of mud crab aquaculture.

The following budget (Table 1) for grow-out of mud crabs in semi-intensive and intensive ponds is based on conservative assumptions, including that hatchery seed is more expensive than wild-caught seed, even though this price differential is likely to turn round over time. Also, it was assumed that productivity gains from stocking with hatchery-reared crab seed are limited to increased stocking rate (by 25%), and higher survival rates (45% rather than 40%). For both sources of seed, it was assumed that final crab live weight is the same, and that only two crops per year are feasible.

Table 1. Budget for semi-intensive and intensive grow out of mud crabs in Vietnam, assuming two crops per year

	Semi-intensive monoculture		Intensive monoculture	
	Hatchery seed	Wild seed	Hatchery seed	Wild seed
Stocking rate (m^2/crablet)	1.6	2.0	1.0	1.25
Price of seed (VND/crablet)	650	400	650	400
Survival rate (%)	45	40	45	40
Number of crabs harvested/ha/crop	2,813	2,000	4,500	3,200
Production (kg/ha/crop)	**984**	**700**	**1,575**	**1,120**
Revenue (VND/ha/crop)	**68,906,250**	**49,000,000**	**110,250,000**	**78,400,000**
Cost of seed (VND/ha/crop)	4,062,500	2,000,000	6,500,000	3,200,000
Cost of feed (VND/ha/crop)	13,331,250	10,125,000	21,330,000	16,200,000
Cost of marketing (2%)	1,378,125	980,000	2,205,000	1,568,000
Interest on operating expenditure	1,877,188	1,310,500	3,003,500	2,096,800
Variable costs (VND/ha/crop)	**20,649,063**	**14,415,500**	**33,038,500**	**23,064,800**
Number of crops /year	2	2	2	2
Fixed costs (VND/ha/year)	**69,169,000**	**69,169,000**	**110,670,400**	**110,670,400**
Total cost (VND/ha/year)	**110,467,125**	**98,000,000**	**176,747,400**	**156,800,000**
Total revenue (VND/ha/year)	**137,812,500**	**98,000,000**	**220,500,000**	**156,800,000**
Profit (VND/ha/year)	**27,345,375**	**0**	**43,752,600**	**0**
Average cost (VND/kg)	56,110	70,000	56,110	70,000
% Reduction in average cost (K)	20%		20%	

Source: Data collected by Economic Research Associates.

In the budget in Table 1, the fixed costs per hectare per year were imputed by assuming that farmers using wild-caught seed just break even if they grow two crops of crabs per year. The budget clearly demonstrates the potential for greater profitability when farmers stock their ponds with hatchery-reared crab seed rather than wild caught seed. It also indicates that unit cost reductions attributable to uptake of the mud crab hatchery technology could be at least 20%, even if there are no realised benefits from higher growth rates. These are conservative estimates because the potential for higher growth rates of hatchery-reared crab seed were ignored in estimating potential benefits from uptake of the innovation.

Semi-intensive and intensive mud crab farms were assumed to be the sole potential adopters of the purchase of hatchery-reared crab seed in lieu of wild-caught seed. Again, this form of crab culture was assumed to cover 947 ha in 2003, but was projected to grow at a much higher rate of 15% per year, in part due to the higher profitability of buying hatchery seed, and in part because the price of wild seed will be held down by the availability of a competitively priced substitute. Conversely, compared to the counterfactual "without innovation" scenario, the area of extensive crab aquaculture is projected to grow more slowly at 3% per year from a base of 9,708 ha yielding 350 g/ha, as at least some extensive crab farmers will upgrade to more-intensive production. Overall, the total area of crab farms is projected to grow to 35,886 ha by 2024, as compared to 28,808 ha for the "without innovation" scenario.

For adopting farmers, the average yield from semi-intensive ponds and intensive ponds was assumed to be 1280 g/ha, reflecting the higher productivity of hatchery seed. Due to the large profits to be earned, adoption of the purchase of hatchery seed is projected to grow by 10% per year of the total production from semi-intensive and intensive grow-out ponds until a ceiling of 80% is reached. It was assumed that the remaining 20% will continue to purchase wild-caught seed.

The "with R&D" scenario for Vietnam

As already noted, the principal output of the two ACIAR-funded projects was a fully developed and commercial-scale mud crab hatchery technology for *Scylla paramamosain*. Support from the national government in Vietnam enabled the key collaborator in Vietnam to work with hatcheries on adoption of the innovation. For potential benefits from this innovation to be realised, two necessary and interdependent conditions need to be met. First, investors need to establish mud crab hatcheries that can supply seed to mud crab farms at competitive prices. Second, farmers need to purchase hatchery-reared crab seed in preference to wild-caught crablets.

To date, 14 mud crab hatcheries are known to have been established. Government support has been important in the early stage of development. The national government made a significant investment to upgrade the original experimental hatchery so that it could produce commercial quantities of seed. The government also built another commercialised government hatchery in Bac Lieu Province in the lower Mekong Delta. However, it was the Hai Phong provincial government that provided some key infrastructure support to establish the first commercial-scale hatchery, and produced a trial batch of seed crablets in 2003. A number of hatcheries produced significant numbers of crab seed in 2004, including several private shrimp hatcheries that have adopted the mud crab hatchery technology and are either converting existing facilities to produce crablets or building extra capacity. Details of 2004 production and estimated production at full capacity for these 14 existing hatcheries are detailed in Table 2.

Table 2. Hatchery capacity and production of crab seed in Vietnam in 2004

Location		Hatchery	**2004**	**Production**	**Ownership**
Red River Delta					
	Hai Phong		300,000	1,000,000	PPT[a]
	Nam Dinh		20,000	500,000	100% private
	Ninh Binh		25,000	500,000	100% private
North Central Coast					
	Thanh Hoa			300,000	PPT
	Ha Tinh		0	300,000	PPT
	Quang Tri		0	700,000	PPT
	TT Hue		520,000	700,000	100% private
South Central Coast					
	Khanh Hoa	RIA3	350,000	1,000,000	PPT
	Khanh Hoa	Family	400,000	1,000,000	100% private
Mekong River Delta					
	Tra Vinh		200,000		Not known
	Bac Lieu	RIA2		1,500,000	PPT
	Ca Mau				
	Kien Giang				
	Can Tho		na	na	PPT
Total			**1,815,000**	**7,500,000**	

- PPT = commercialised government

Source: Nguyen Co Thach (pers. comm.)

Initial outcomes were modest. Fewer than 2 million crablets were produced in 2004. Sales of hatchery-reared seed to mud crab aquaculture farms were reportedly even less, due mainly to the low level of awareness of availability and potential profitability of using this source of crab seed. This low level of output can be attributed to production constraints during the start-up phase of a new technology rather than to a lack of demand by mud crab farms.

At a stocking rate of 8,000 crablets per ha, estimated sales of 1.6 million crablets would have been sufficient to stock about 200 ha of ponds, and total output in 2004 from hatchery-reared seed would have been about 200 t. Total production in that year was 10,000 t, according to Ministry of Fisheries statistics. When all of these 14 hatcheries are operating at full current capacity, the supply of hatchery seed should substitute for most of the supply of wild-caught seed currently purchased by semi-intensive and intensive mud crab farms.

Further expansion of hatchery capacity will depend on growing demand from mud crab farmers. However, the rapid expansion in capacity of private shrimp hatcheries suggests that the current capacity of mud crab hatcheries will grow in a similar manner, so long as growth in demand for hatchery-reared crab seed matches the impressive expansion in demand for shrimp seed. MOFI (2004) notes that there are now more than 5,000 shrimp hatcheries, mostly private small-scale enterprises, and that annual shrimp larvae production in 2004 exceeded 25 billion shrimp seed.

Besides, only a relatively small part of total output will be produced from hatchery-reared seed for many years. Although it is possible that improved extensive mud crab farms might benefit from purchasing small quantities of hatchery-reared crab seed rather than wild seed to top-up stocking rates, it was assumed in this impact assessment study that all extensive crab farmers will continue to rely exclusively on wild-caught crab seed.

The "without R&D" scenario for Vietnam

This without R&D scenario covers the economic outcomes for Vietnam if ACIAR had not funded the two projects. It is necessarily hypothetical, because it is the counterfactual scenario to what has in fact happened.

As noted above, no successful method for commercial-scale hatchery production of mud crab seed existed at the time when the ACIAR projects began. While the development of larval rearing of mud crablets had been demonstrated in experiments before the start of these projects, the rate and reliability of survival from eggs to crablets fell far short of the levels necessary for commercial operations. Hatchery technology did exist for other aquaculture species of crustaceans, such as shrimp, but real resources still had to be committed by someone to develop a financially viable hatchery technology for production of mud crab seed stock. Specifically, R&D was necessary to identify the critical success factors to promote consistent spawning and hatching of good-quality larvae, and how to overcome several bottlenecks in hatchery and nursery culture techniques to ensure consistent and increased survival of larvae to crab stage.

Nevertheless, the need to develop such an innovation had been recognised for many years. Significant research into the feasibility of larval rearing of mud crabs had taken place before the inception of the ACIAR mud crab projects, and the expertise and resources required to independently develop such an innovation existed in a number of countries.

The most likely "without R&D" scenario for this impact assessment study is that some other organisation would subsequently have funded the R&D needed to yield a comparable innovation. Other aid donors were working in Vietnam on mud crab aquaculture but, in the absence of funding from these sources, it is quite conceivable that the Vietnamese Government would have funded the necessary R&D. In any case, it is almost certain that this process innovation would become available for adoption in Vietnam sooner or later.

Therefore, it was assumed in this scenario that development of the innovation would have been funded by another organisation had ACIAR not funded the two assessed projects, but that the development of the innovation, and its adoption, would be delayed by 3 years. In particular, note that, because the necessary R&D to develop the mud crab hatchery innovation was assumed to have been merely delayed under this scenario, the required expenditure of real resources must be included in the time profile of costs and benefits, even though lagged by 3 years. In other words, **all** of the estimated costs and benefits for the "with R&D" scenario first need to be lagged by 3 years, and then included in this scenario. It follows that the benefits of the ACIAR-funded projects that developed the mud crab hatchery technology include both the future R&D costs avoided, as well as the earlier realisation of innovation adoption benefits.

Estimates of net annual innovation and research project benefits

Estimates of projected area and production from mud crab aquaculture under a "without innovation" scenario and a "with innovation" scenario plus assumptions about supply and demand elasticities and innovation-induced supply shifts outlined above were used to calculate annual benefits, in VND, from uptake of the mud crab hatchery innovation in Vietnam. The total nominal value of annual innovation benefits was estimated to be VND757,624 million. This estimate does not include the costs of the development and uptake of the mud crab hatchery technology innovation in Vietnam.

The conventional time horizon for the analysis of the economic impacts of ACIAR-funded projects is 30 years, and benefit–cost measures for the mud crab projects were calculated for the 30 years from the start of the project in 1995. In this case, the benefit of the ACIAR-funded project is simply to bring forward in time both the costs and benefits from development and uptake of an innovation. Hence, a slightly longer time frame is justified for the "without R&D" scenario so that the same number of years of benefits are assessed for both the "without R&D" and "with R&D" scenarios. Consequently, benefit–cost measures were calculated for a "with R&D" scenario from 1995 to 2024, and a "without R&D" scenario from 1998 to 2007. In both cases, real values in 2004 Australian dollars were converted to present values using a discount rate of 5%.

Estimates of the annual net benefits from the two ACIAR-funded mud crab R&D projects are provided in Table 3. Real net annual innovation benefits in 2004 Australian dollars in column 3 are lagged by 3 years in column 4 to provide a profile of annual net economic benefits for the "without R&D" scenario. These annual values of net innovation benefits and lagged net innovation benefits in these two columns are discounted, and the discounted net benefit flows are shown in columns 5 and 6 respectively. Column 5 is the estimate of the discounted annual net benefits for the "with ACIAR funded R&D" scenario, and column 6 is the corresponding estimate for the "without ACIAR funded R&D" scenario. The values in column 7 are the discounted net annual economic benefit from the ACIAR projects calculated by taking the difference between columns 5 and 6.

Table 3: Annual net benefits to Vietnam of ACIAR-funded mud crab projects

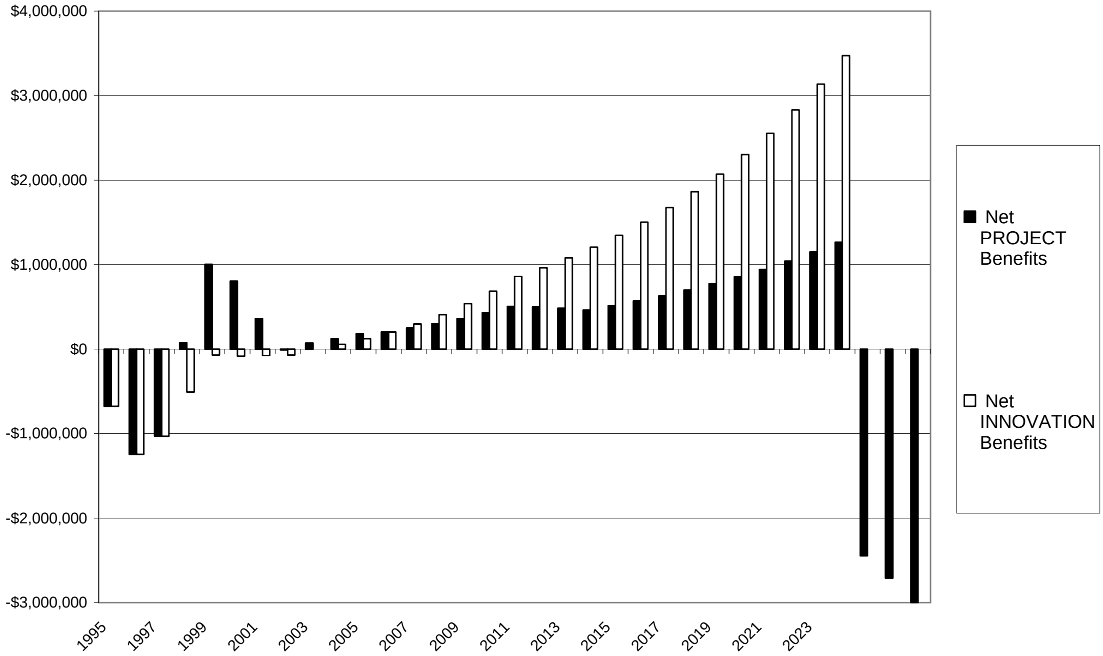
Year no.	Year	Net annual *innovation* benefits in A$'000 (real)	Lagged net annual *innovation* benefits in A$'000 (real)	Discounted net annual *innovation* benefits in A$'000	Discounted lagged net annual *innovation* benefits in A$'000	Discounted net annual *ACIAR project* benefits in A$'000
1	1995	–458		–677		–677
2	1996	–886		–1,246		–1,246
3	1997	–768		–1,030		–1,030
4	1998	–398	–458	–507	–584	77
5	1999	–59	–886	–72	–1,077	1,005
6	2000	–72	–768	–83	–889	806
7	2001	–69	–398	–76	–438	362
8	2002	–68	–59	–71	–62	–9
9	2003	–6	–72	–6	–72	66
10	2004	53	–69	50	–66	116
11	2005	130	–68	118	–62	179
12	2006	235	–6	203	–5	208
13	2007	362	53	298	43	254
14	2008	521	130	408	102	307
15	2009	720	235	537	175	362
16	2010	967	362	687	257	430
17	2011	1,271	521	860	353	507
18	2012	1,495	720	964	464	500
19	2013	1,757	967	1,079	593	485
20	2014	2,063	1,271	1,206	743	463
21	2015	2,419	1,495	1,347	833	515
22	2016	2,834	1,757	1,503	932	571
23	2017	3,315	2,063	1,674	1,042	632
24	2018	3,875	2,419	1,864	1,164	700
25	2019	4,523	2,834	2,072	1,298	774
26	2020	5,276	3,315	2,302	1,446	855
27	2021	6,148	3,875	2,554	1,610	945
28	2022	7,157	4,523	2,832	1,790	1,042
29	2023	8,326	5,276	3,138	1,988	1,149
30	2024	9,677	6,148	3,474	2,207	1,267
31	2025		7,157		2,447	–2,447
32	2026		8,326		2,711	–2,711
33	2027		9,677		3,001	–3,001
TOTAL		**60,340**	**60,340**	**25,402**	**21,943**	**3,459**
NPV over 30 years to 2024				25,402	13,785	11,617
NPV to time of assessment				–3,601	–3,250	–351

Compared to results from many other impact assessment studies of economic returns to R&D, the values in Table 3 are quite modest. Over a 30-year time frame, the net present value of benefits to the ACIAR projects in 2004 Australian dollars was $3.46 million. At the time of assessment in 2005, discounted real costs still exceeded realised discounted real benefits by A$351,000, and a final positive outcome will depend on continued uptake of the innovation in Vietnam. The benefit–cost ratio of the ACIAR projects is only 1.9, and the corresponding internal rate of return is 16%.

Like all research projects, net returns in the early years are negative because project costs are incurred at the outset. However, positive benefits in the years 1998 to 2002 are not due to benefits from uptake of results from these projects, but to the assumed cost savings of avoided R&D by some other organisation.

One key reason for these modest outcomes is the assumption that some other organisation would have developed the mud crab hatchery technology 3 years later if ACIAR had not funded projects. If this either never happened, or did not happen for many years, then the benefit from the ACIAR these projects would be much greater. For instance, if the "without R&D" scenario was that the innovation was never developed, the net present value of R&D is estimated to be A$25.40 million rather than A$3.46 million. The difference between discounted net annual innovation benefits, and discounted net annual ACIAR R&D benefits, is illustrated in Figure 1.

Figure 1. Discounted net annual innovation and project benefits of ACIAR-funded research on mud crab hatchery technology



The sensitivity of key estimates of economic impacts to the assumed length of the lag to innovation development under the counterfactual scenario is tabulated below.

Table 4: Sensitivity to the assumed length of the lag to innovation development of key measures of economic impacts.

Assumed project start date for counterfactual scenario	Net present value	Benefit–cost ratio	Internal rate of return
1998	A$3.46 million	1.92	16%
2001	A$6.45 million	2.71	16%
Never	A$25.4 million	7.74	16%

Conversely, if the mud crab hatchery technology had already been developed elsewhere, and would have spontaneously spilled into Vietnam at no cost, then there would be no avoided R&D costs to count as a benefit of ACIAR funding. As the present value of these avoided cost was estimated to be $3.256 million, the NPV of ACIAR funding for a counterfactual that included spontaneous spill in of a substitute hatchery innovation would be only A$0.20 million. Hence, the counterfactual scenario specified in this study was neither the most conservative, not the least conservative assumption that could be made about the state of technology in the counterfactual scenario.

Summary

In ex post economic impact assessment studies, sometimes, the most plausible counterfactual "without R&D" scenario is that a similar innovation, or an equivalent substitute, subsequently would have became available if the agricultural R&D being evaluated had not been undertaken. In these circumstances, it is now widely recognised that the principal impact of funding a specific agricultural R&D project will be to bring forward in time the realisation of economic benefits, rather than to generate benefits that would never be realised in the absence of the R&D funding. It is less widely recognised that for such cases, it is important when specifying the counterfactual scenario for the analyst to consider how the substitute innovation is most likely to become available.

One possibility is that the innovation, or a close substitute, may already exist elsewhere, and eventually will "spill-in" exogenously without any further research or expenditure by the research agency or funding body being evaluated. Alternatively, the same, or an equivalent innovation, might only become available after another agency has subsequently carried out the same, or equivalent research, albeit at a later date. Which of the above two alternative scenarios is deemed to be more plausible does have important implications for the treatment of costs in the counterfactual scenario. Hence, the key to correct treatment of this methodological issue in economic impact assessment studies is explicit and precise specification of the counterfactual scenario.

If the innovation would spill-in spontaneously at some time in the future, the only thing that the assessed R&D achieves is to enable earlier adoption of the process innovation, and earlier realisation of the consequential benefits. Hence, there is no need to include any research costs in the counterfactual scenario. Conversely, where some other organisation would need to finance equivalent R&D in order to develop the same or an equivalent substitute innovation, the impact of the R&D being evaluated would be to bring forward in time BOTH the costs of the R&D and the economic benefits of adopting the innovation.

The latter situation was judged to be the more plausible counterfactual supply curve in an economic impact assessment study of an ACIAR funded project on the development and uptake of a mud crab hatchery innovation in Vietnam. To ensure consistent treatment of costs, both a "without innovation" scenario and a "with innovation" scenario were specified first, and with the R&D costs of innovation development included in the latter scenario. Annual economic outcomes for each scenario were quantified, and the difference between them used as a measure of annual net economic benefits from innovation development and adoption, as well as a time profile of economic outcomes for the "with R&D" scenario. The time profile of economic outcomes for the "without R&D" scenario was obtained simply by lagging the same annual values of both costs and benefits by three years.

Given this specification of the counterfactual scenario, the net present value of the ACIAR projects was estimated to be A$3.46 million, the benefit–cost ratio was 1.9, and the corresponding internal rate of return was 16%. However, relative to a "without innovation" scenario, the net present value from development and uptake of the mud crab hatchery innovation was estimated to be A$25.4 million. Alternatively, if the innovation would spontaneously spill in, the estimated NPV was only A$0.20 million. This illustrates the potential for under or over estimation of returns to research if the counterfactual scenario is not correctly specified.

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