Template for Economic contribution of new technologies generated in NARS

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Preamble

Quantifying the economic contribution of agricultural innovations has been a challenging task for economists and generators of technology especially when the policy makers seek information on macro level impacts. Most often a linear extrapolation of benefits obtained on small experimental research plots is made to reflect the macro level benefits. Such a linear extrapolation of micro level experimental results realized per plot discounts the operation of the most crucial law of economics - the law of diminishing marginal returns to land. Such an extrapolation of benefits from new technology is fraught with constraints as the impact depends factors *inter alia*, probability of performance of innovation or technology in the field, rate of adoption of the technology by farmers (as farmers may not fully adopt the new technology and may make on farm adjustments), rate of depreciation of technology.

Transfer of Technology

Economists are often asked to find the economic impact of new technologies in SAU/ICAR context. The discipline of economics provides the rationale and the methodology to compute the impacts considering tangible and intangible benefits of research. Valuation of intangibles continues to be a challenging task due to externalities, asymmetric information and transaction costs. Policy makers seek answers from recipients of research funds like the SAUs / ICAR institutes for a reflection of economic impact of their technologies / innovations. Scientists endeavor in generating new technologies and upon generation, release them following the official codes of research procedures through their respective Zonal Research and Extension Councils. However, on the other hand, farmer acceptance and adoption rates seem to be lower than expected. Often it is said that around 70% of innovations are yet to move from the lab to the land, due to factors *inter alia* lack of extension efforts, lack of investment in diffusion of innovations, including sustained economic viability of technologies.

Under estimation of costs and over estimation of returns

The causes for the widening gap in the transfer of technologies includes*inter alia* the economic viability on a farm and the economic impact of new technologies on all the farms. The scientists often use direct costs and benefits of their technologies and use the BC Ratio for the findings from their experiments conducted and extrapolated to the district or State level. Here the costs are underestimated since implicit costs and opportunity costs such as return to land, family labor, capital, management, risk premium are not accounted. In addition, the public / private investment on research and extension, the probability of adoption of new technology, probability of performance of new technology, depreciation of technology involved are not accounted for. In the linear extrapolation of yields or benefits, the returns are obviously overestimated and the costs are underestimated, since the law of diminishing marginal returns, a major limiting factor in agriculture is discounted in estimation.

Quantification of research benefits is complex

The benefits from research may be from a new variety, or new method of cultivation, or new practice of soil and water conservation, product processing, a new product, a new market, a new value chain, a new service in banking or extension, or a new institution. Some research may be basic in nature and may not have immediate application. Also the research benefits and costs are spread horizontally over areas, and vertically over years and hence time lags in quantification exist. There may be externalities generated in the process. Some research may aim at capacity building, Integrated farming systems, and social science research, which are not easily quantifiable. The time length of benefits from research is often indicated arbitrarily by scientists and there are no proven theories to estimate the same. This introduces bias in the estimation of rate of return to research investment.

Further, the uncertainty and variations in the (1) impact and adoption of research, (2) political, natural and economic environments which influences commodity supplies, (3) the market conditions such as cob-webs, (4) the availability of quality infrastructure over time and space in adequate quantity, (5) availability of extension to meet client needs, (6) impact of technology at different locations, farm situations, adoption patterns, (6) efficiency of extension system, (7) receptivity of farmers exist.

There are also aggregation problems, as the researchers and extension specialists are simultaneously and over time involved in several studies / projects, and hence the research and extension costs are available at aggregate level and are not available crop wise, technology and innovation wise. In addition, there are synergies in research and extension system, responsible for adoption, which is also difficult to quantify. Intervening variables such as literacy, awareness, proactive role, leadership, education, capacity building, substantially contribute to adoption, difficult to quantify and measure.

Limitations of the existing methods

The common methodology used in economic contribution of research innovations or economic impact of technologies is (1) economic surplus approach of Alston, Norton and Pardey[1] and (2) The total factor productivity (TFP) approach [2]. The 'economic surplus' approach widely used is not transparent to scientists and is limited largely to new seed innovation since it uses the concept of elasticity of demand and supply. Since the elasticity of demand and supply used in estimation is pertinent to products / crops and not for an improved method or service, or an innovative institution policy technology or innovation, this method cannot be applied for all innovations from SAU/ICAR system. Also it uses constant elasticities of demand and supply across different income and land holding classes of farmers and consumers which is untenable.

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[1]Alston, J., G. Norton and P. Pardey, *Science under Scarcity: Principles and Practices for Agricultural Research and Priority Setting*, Cornell University Press, Ithaca,NY, 1995

[2]Kumar, P, A. Kumar and S. Mittal, Total Factor Productivity of Crop Sector in the Indo-Gangetic Plain of India: Sustainability Issues revisited", *Indian Economic Review*, Vol.39, No. 1, 2004, pp. 169-201.

The method thus hides more than what it reveals and makes too much of an approximation in the contribution of research and extension.

The Total Factor Productivity (**TFP**) method accounts for impacts not caused by conventional inputs such as seeds,fertilizers, labor, plant protection chemicals. For example, technology growth, infrastructure, markets, institutional innovations also contribute to growth and impact. Thus, TFP cannot be measured directly but is measured as a (Solow) residual, which accounts for effects in total output not caused by inputs. If Y is a (Cobb Douglas) function of capital input (K), labor input (L), and α and β (=1- α) are input share of contribution for K and L respectively, an increase in either A, K or L leads to output increase. Here, capital and labor input are tangible. The TFP is more intangible as it can be due to technology, knowledge (human capital), infrastructure.

The TFP method quantifies the portion of output not explained by the amount of conventional inputs used in production. If r_o is the growth rate of aggregate output, $r_k$is the growth rate of aggregate capital, r_l is the growth rate of aggregate labor, TFP is given by the Solow residual = $r_o - \alpha r_K - \beta r_{l.}$ For accurate measurement of TFP, the assumptions are that (1) the production function is neoclassical,(ii) there is perfect competition in factor markets, and (iii) growth rates of the inputs are accurately measured. Thus, the TFP also is specific to crops and does not help in quantifying research benefits for an improved method or innovation. Thus, both Economic surplus approach and TFP approach are having limitations of applications, and hide more than what they reveal.

Partial budgeting: for measuring economic contribution of research innovations

In this paper an alternative, easy to use methodology which could be used by all non economists, is proposed, for the benefit of quantifying economic benefits of farm innovations from the NARS - SAU/ICAR system. This approach involves a healthy blend of economists and scientists and only with their synergistic involvement, proper quantification of research benefits is possible. Partial budget template is simple, transparent, easy to understand by non economists hiding nothing and not using concepts of elasticity of demand / supply which are product specific. The method uses standard partial budgeting methodology incorporating opportunity costs of inputs and research costs, extension costs, probability of field performance, the factor of Law of diminishing marginal returns (LDMR), depreciation of technology and rate of adoption. This paper provides the following steps in finding the economic contribution of new technologies.

The seven steps of arriving at the economic contribution of new technology are highlighted as u

Step1: The research costs incurred in the generation of specific technology need to be obtained over time. The research costs include the salaries paid to the scientists and staff for say a decade or even longer. The salaries paid each year along with operation costs incurred need to be compounded from the year of incurring expenditure till the present year, when the economic contribution is measured. For instance, if work on a new technology commenced in the year 1991 and went on upto 2000, then each year the expenditure on research as well as extension (such as demonstrations conducted and other costs involved in diffusion of innovations, including salaries paid to extension personnel and their staff) need to be compounded till the year 2012, if the year 2012 is the year in which economic contribution is computed. The expenditure is compounded at around 2 percent to reflect the actual costs incurred in 2012 or the latest year where the economic contribution is computed.

Step 2: The total compounded value of research and extension costs need to be amortized over say n=10 years, at 2 percent, assuming that the scientist/s believe that their technology will have active life of around a decade, which is reasonable. If the life of the technology generated is 5 years, the costs need to be amortized over five years.The total area of adoption of new technology need to be estimated or obtained from secondary sources / primary sources

Step 3: The amortized cost of research and extension obtained in step 2 needs to be divided by the total area of adoption (mentioned in step 3), to obtain the estimate of current cost of research and extension per hectare of new technology adoption.

Step 4: The probability of adoption of new technology needs to be provided by the scientist/s. The probability of adoption refers to what proportion of the new technology recommendation is adopted by the farmers. This is both subjective and objective. For example, it is likely that the farmers would adopt only 50 percent of the recommended technology, or 75 percent of the recommended technology.

Step 5: The probability of performance of new technology needs to be provided by the scientists/researchers/extension personnel involved. The probabilty of performance would again be both subjective / objective since this depends upon the field conditions, field diversity and field reality. If all is well, the probability of performance can be even 1, or if climate is not favorable, the probability may drop to 0.6.

Step 6: The depreciation of technology needs to be provided by the scientists/researchers. Technology also has its depreciation which can be due to use of technology over time similar to wear and tear as well as obsolescence which is due to arrival of newer technologies, which makes the current technology obsolete. If there is no depreciation, then this value is 1.0, if the depreciation is 10%, then this figure can be 0.9 and so on.

Step 7: The partial budgeting format needs to be used to find the benefit from new technology generated. An example is provided below (Table 1). For economic worthiness of any new technology or innovation or service or method, the Credit minus Debit should be more than zero.

Table 1. Estimated **Economic Impact of Tur (Variety BRG 2) in Karnataka using partial budgeting framework (Rs. per ha), 2012**

Debit Side (A + B)				**Credit Side (C + D)**			
A. ADDED COSTS DUE TO BRG 2 variety of Tur				**C. Reduced costs due to use of BRG 2 Tur**			
Added cost due to new seed	**Price/ kg**	**qty used**	**Cost Rs**	**Savings due to BRG2 tur (in terms of fertilizers, FYM, water…)**	**Price/ kg**	**qty used**	**Cost Rs**
i. Seed cost of check variety (TTB7)	80	15	1200	**C. Reduced costs due to new technology**			0
ii. Seed Cost of BRG 2 (new var)	80	15	1200	Savings in PPC /agro chemicals			0
Added cost due to use of BRG 2 seed			0	Savings in weeding, pesticide application			0
Added Labour cost due to improved yield of BRG 2	**Wage**	**Mand ays**	**Cost Rs**	**D. Added returns due to BRG 2 Tur**	qty in qtl	Price/ qtl	Gross return Rs
Extra labor cost to harvest, thresh, increased yield due to BRG 2	150	5.0	750	Value of litter fall from BRG 2 variety			500
Additional cost of labour			**750**	Value of Woody biomass			500
Total additional cost due to seed and labour (additional working capital)			750	Value of nutrition to farm family			500
Interest on additional working capital @ 5% per year for 6 months			19				
Risk premium @ 10% of additional working capital			75	Added yield of Tur due to BRG 2 variety	1.5		
Management cost @10% of additional working capital			75				
Research cost per ha			9.50	Added returns due to new technology	1.5	3200	4800
Extension cost per ha			**1.37**				
Total of research and extension costs per ha			10.87				
Total of added costs			930				
B. Reduced Returns by using BRG 2 variety:			0				
Total Debit side:			930	Total credit side			**6300**
Economic worthiness of BRG 2 variety: Credit minus Debit = 6300-930 = Rs. 5370 per hectare							

Notes: The rental value of land has not been considered as there is no provision to lease out land in Karnataka due to the Karnataka Land Reforms Rules of 1974; Management cost is an extra cost due to the new variety; Risk premium is the extra cost due reflecting the risk taking cost of farmer for adopting new technology or variety

Estimated annual economic contribution of new variety of Tur BRG 2 in Karnataka, 2012

1. Product life cycle of this technology (years)	10.0
2. Probability of performance of this technology = 0.75	0.75
3. Rate of adoption of this technology = 0.80	0.80
4. Depreciation of technology (if 1, no depreciation) (=10%)	0.9
5.Economic impact of BRG 2 Variety considering field conditions per hectare and the operation of the law of diminishing marginal returns = 5370*0.75*0.8*0.9 = Rs. 2900 per hectare	Rs. 2900
6. Total area adopted =72300 ha	72300 ha
7. Total economic impact on 225900 ha in Rs. = 2900 *72300 =	Rs. 20.97 crores
8. No. of years for developing BRG 2 tur variety	11 years
9. Cost of salaries of researchers plus staff for 11 years (Rs)	Rs. 6171000
10 Amortized research cost of project per year Rs at interest rate of 2%	Rs. 686996
11. Cost of extension per demonstration (Rs)	Rs. 5000
12. Total cost of demonstrations (Rs) for 50 demonstrations	Rs. 500000
13. Amortized cost of demonstration per year (Rs) at interest rate of 2 %	Rs. 55663
14. Salaries of extension workers plus staff (Rs) for 5 years	Rs. 43500
15. Area under tur in Karnataka ha (2010-11)	753000 ha
16. Estimated area under the new technology variety BRG 2 Tur is 9.6%	72300 ha
17. Research cost per ha is	Rs. 9.50
18. Extension cost per ha is	Rs. 1.37
19. Total research and extension cost per ha is	Rs. 10.87

The estimated annual economic contribution of BRG 2 variety of tur in Karnataka using partial budget framework, incorporating the weightage for law of diminishing returns reflected by the probability of performance, rate of adoption and depreciation of technology, and accounting for research costs, extension costs and the opportunity cost of all inputs is Rs. 20.97crores.