SELF-LEARNING MANUAL

on

Assessing Social Gains from Investment in Agricultural Technologies

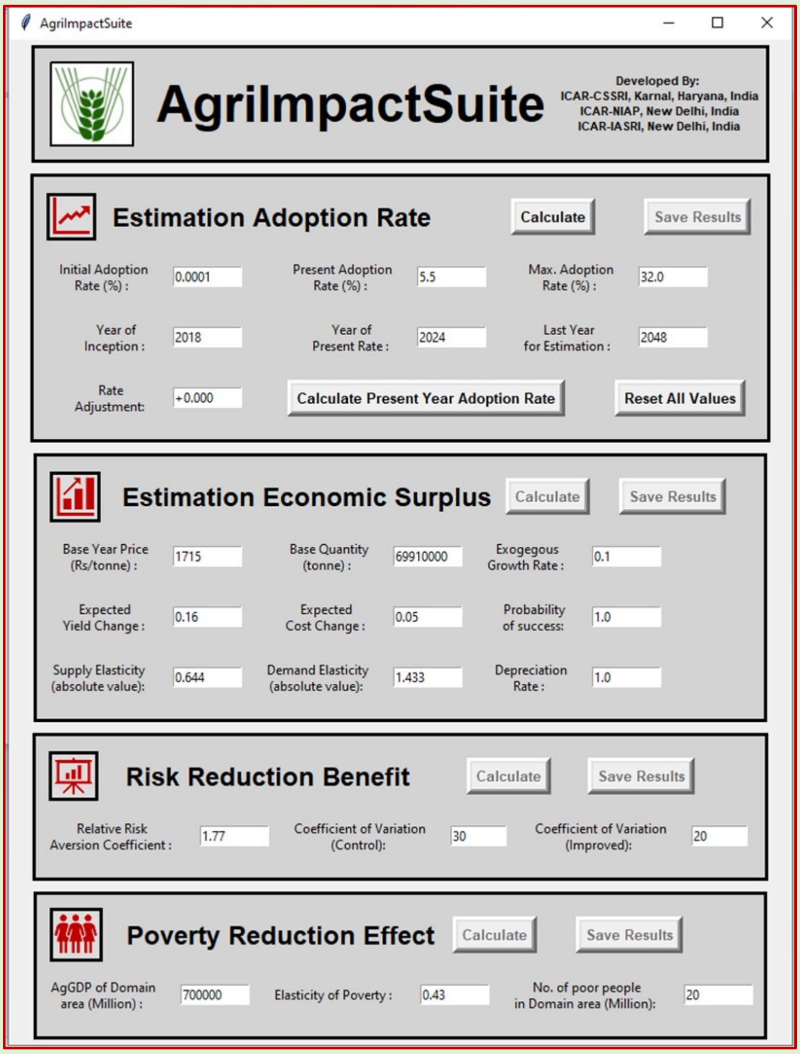

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Table of Contents

1. INTRODUCTION

1.1.Overview

Agricultural research is crucial in enhancing productivity, promoting food security, and supporting sustainable economic development. However, measuring the economic impact of such research is a complex task, as the benefits often materialize over extended periods and across diverse part of populations covering both producers and consumers. This manual serves as a comprehensive guide for students, researchers, policymakers, and decision-makers who are interested in assessing the economic contributions of agricultural research/ technologies and practices. This manualprovides a practical and user-friendly to facilitate the impact assessment by practitioners with expertise in economics.

Through a step-by-step approach, the manual explains how to calculate the economic returns from agricultural research investments. It also includes computer exercises to facilitate hands-on learning. In doing so, the document empowers readers to not only understand the theorical aspects of impact assessments but also to apply these methods to real-world scenarios in the agricultural sector.

The primary objective of this manual is to provide a structured framework for evaluating the economic impact of agricultural research, particularly in the context of agricultural technologies (here, crop varietal technologies). Utilizing real case studies and field data, the document guides users through the necessary steps to calculate research impacts, emphasising accessibility for those without an economic background. To support this, practical exercises are integrated, enabling users to apply the concepts and methodologies in real-time as they proceed through the manual.

1.2 Intended Users of the Manual

The manual is primarily developed for researchers within the National Agricultural Research and Education System (NARES) who conduct impact assessments of crop varietal technologies. Additionally, it aims to support research managers and policymakers in interpreting these assessments, offering valuable insights into the broader implications of agricultural research on national and international levels. The guide also benefits decision-makers involved in the design and funding of agricultural research programs, helping them understand the value of the investments they oversee.

1.3 Importance of Measuring Agricultural Research Impact

The need to measure the impact of agricultural research arises from the constraints posed by limited financial and natural resources. Governments and foreign aid donors must ensure that their investments yield significant returns. However, the quantification of benefits of agricultural research can be challenging because they often accrue gradually over time and are distributed across a wide range of beneficiaries. Economic impact assessments serve as a vital tool in demonstrating the worth of these investments. By comparing the benefits of research against its costs, these assessments help in identifying which areas of research deliver relatively higher returns. In turn, this enables scientists and research institutions to better allocate their resources and focus on research that maximizes positive outcomes for society. Moreover, documented evidence of research benefits is essential for securing sustained public funding and maintaining policy support for long-term research initiatives.

1.4 The Role of Agricultural Research in Development

At the heart of economic growth lies technological innovation, which is often the result of scientific research outputs addressing practical problems. In agriculture, particularly in India, advancements in technology are critical to meeting the challenges posed by population growth, food insecurity, and natural resource depletion. Through agricultural research, farmers are equipped with improved technologies—such as new crop varieties, fertilizers, and farming equipment—that enable them to do more with fewer resources.

Agricultural research serves multiple objectives that go beyond increasing productivity. It helps to improve overall living standards, enhance food security, reduce poverty by creating jobs and lowering food prices, and protect natural resources like water and soil. The public sector plays a major role in conducting and funding this research, especially in areas where private investment is lacking, such as research into staple crops and open-pollinated varieties.

A significant portion of agricultural research produces what economists refer to as "public goods." These are goods that, once created, are available to everyone and cannot be restricted to a particular group. Since the benefits of public goods are widely shared, private firms often have little incentive to invest in such research. Consequently, research into areas like staple crops or agronomic techniques is typically funded by the government.

Because the benefits of agricultural research are not always immediately apparent, regular impact assessments are necessary to ensure proper support and funding. These assessments help demonstrate accountability for past funding, attract new resources, and align research activities with national development priorities. Without clear evidence of the economic returns from research, it is unlikely that public investments will continue at levels necessary to sustain long-term growth and innovation.

1.5 Methods of Impact Assessment

Impact assessments are broadly divided into two categories: *ex-post* and *ex-ante*. *Ex-post* assessments analyse the impacts of technologies that have already been adopted, whereas *ex-ante* assessments estimate the potential impacts of technologies yet to be implemented. In both cases, some data may be directly observed, while other information must be inferred indirectly from secondary sources. This manual provides a detailed guide on the appropriate methods for sourcing and utilizing data in both *ex-post* and *ex-ante* assessments. *Ex-post* assessments, which typically involve data collected through actual surveys, are generally more reliable than ex-ante assessments, which depend on trials/assumptions and projections. However, the success of both approaches ultimately relies on the researcher's ability to accurately gather and analyse data.

Several methodologies can be employed for conducting impact assessments using field data, which are usually grouped into three primary categories: econometric approaches, programming methods, and economic surplus methods. Econometric approaches aim to estimate the marginal returns of research over extended periods and across various research activities. Programming methods focus on identifying the optimal technologies or research strategies from a set of alternatives. The economic surplus method, which quantifies the total social benefits generated by a specific research initiative, is the most commonly applied. This method is particularly favoured because it requires less data and can be applied across a wide range of research contexts. Its relatively simple application also makes it accessible to those with minimal technical training. Therefore, this manual primarily emphasizes the economic surplus method, while also offering concise reviews of the econometric and programming approaches.

1.6 Structure and Use of the Manual

This manual is organized to facilitate a deep understanding of the economic surplus approach and its practical application. The first section provides an introduction to the concept of impact assessment, followed by a detailed explanation of the economic surplus method. Subsequent chapters offer practical guidelines for data collection and utilization, along with case studies and exercises to reinforce the material covered.Throughout the manual, examples drawn from real-world research projects, such as the case study on rice research in India, are used to illustrate key concepts. Additionally, self-paced computer exercises are provided, enabling readers to practice applying these methods. By the end of the manual, readers will have gained both the analytical skills and practical knowledge needed to conduct their impact assessments. Additionally, the manual will also demonstrate the use of

AgriImpact Suitsoftware developed by ICAR-National Institute of Agricultural Economics and Policy Research for estimating the economic surplus from adoption of technologies.

In brief, this manual serves as both a theoretical guide and a practical toolkit for understanding and evaluating the economic impact of agricultural research. It equips researchers and decision-makers with the skills necessary to measure the returns on research investments, helping ensure that agricultural research continues to drive economic development and improve livelihoods.

2. THE ECONOMIC SURPLUS METHOD: THEORY TO PRACTICE

Assessing the economic impact of agricultural research is essential for understanding its contribution to societal welfare. One widely used approach for such assessments is the economic surplus method, which provides a robust framework for estimating the value of research by comparing scenarios with and without it. This chapter explores how the economic surplus approach applies core economic principles—supply, demand, and equilibrium—to quantify the effects of research on producers and consumers. By examining shifts in supply and demand curves, it measures the social gains resulting from technological innovations. These gains are captured as changes in economic surplus, which reflect the improvements in production efficiency and cost reduction brought about by research interventions. Through a detailed discussion of how research affects both producer and consumer surpluses, this chapter provides a foundation for understanding how economic surplus analysis can guide policy decisions, allocate resources, and demonstrate the overall societal benefits of agricultural innovations.

2.1 Supply and demand as a basis for economic surplus

The economic surplus method utilizes the concepts of supply, demand, and market equilibrium to estimate the value of research. Supply represents producers' costs, while demand reflects consumers' valuation of the product. The equilibrium point is where supply meets demand, determining both the quantity produced and the price at which it is sold. However, economic welfare is not just a function of the observed price and quantity; it is also influenced by the entire supply and demand curves, which reflect the full range of production costs and consumption values.

2.2 Supply curve: relationship between production and costs

Production is influenced by various inputs such as land, labour, seeds, fertilizers, and other inputs. As the price of the product increases, producers are incentivized to use more inputs, thereby increasing production. This relationship is captured by the supply curve, which slopes upward, indicating that higher prices lead to higher quantities supplied (Fig 1A). The supply curve can shift due to changes in production costs, such as labour prices or technological advancements, including the introduction of new crop varieties (Fig. 1B).The basic supply curve equation is expressed as:

$$P_s = \alpha_s + \beta_s Q_s$$

Where, P_s is the supply price, α_s is the intercept, and $\beta_s$is the slope of the curve. Changes in production techniques, such as those resulting from research, can shift the supply curve, reducing production costs and increasing output.

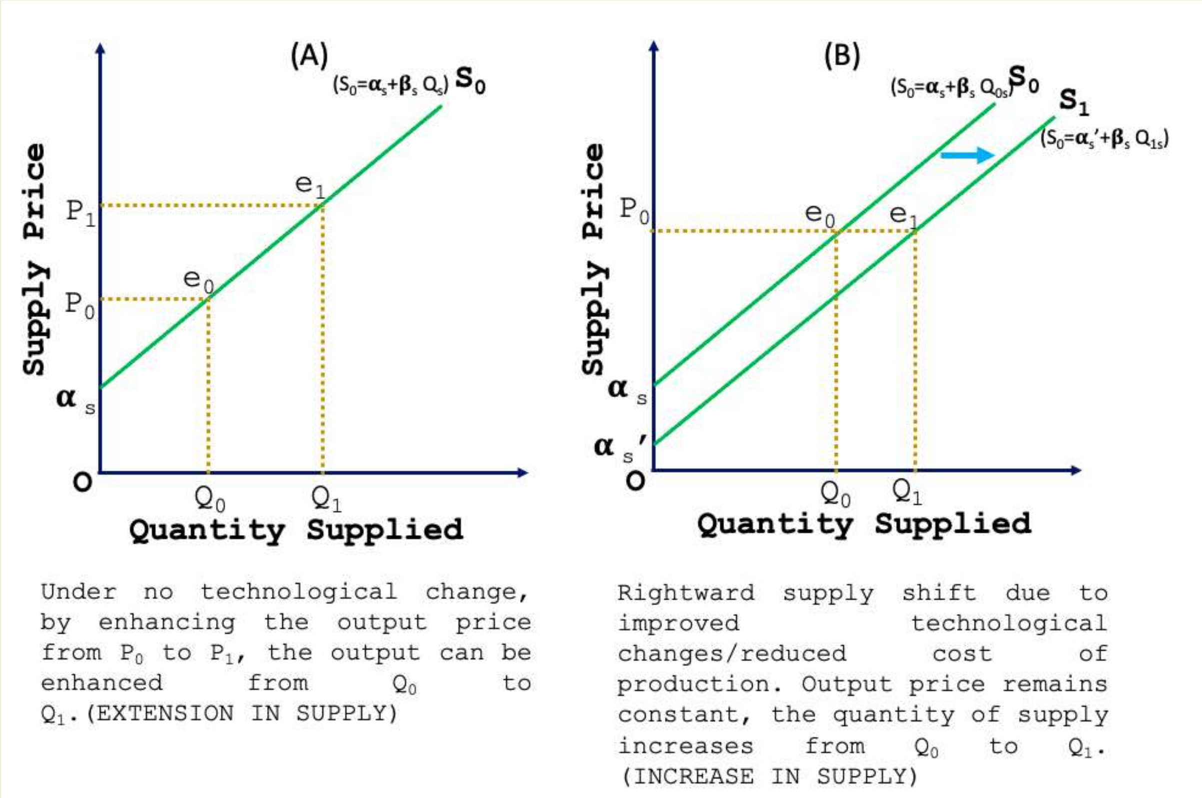


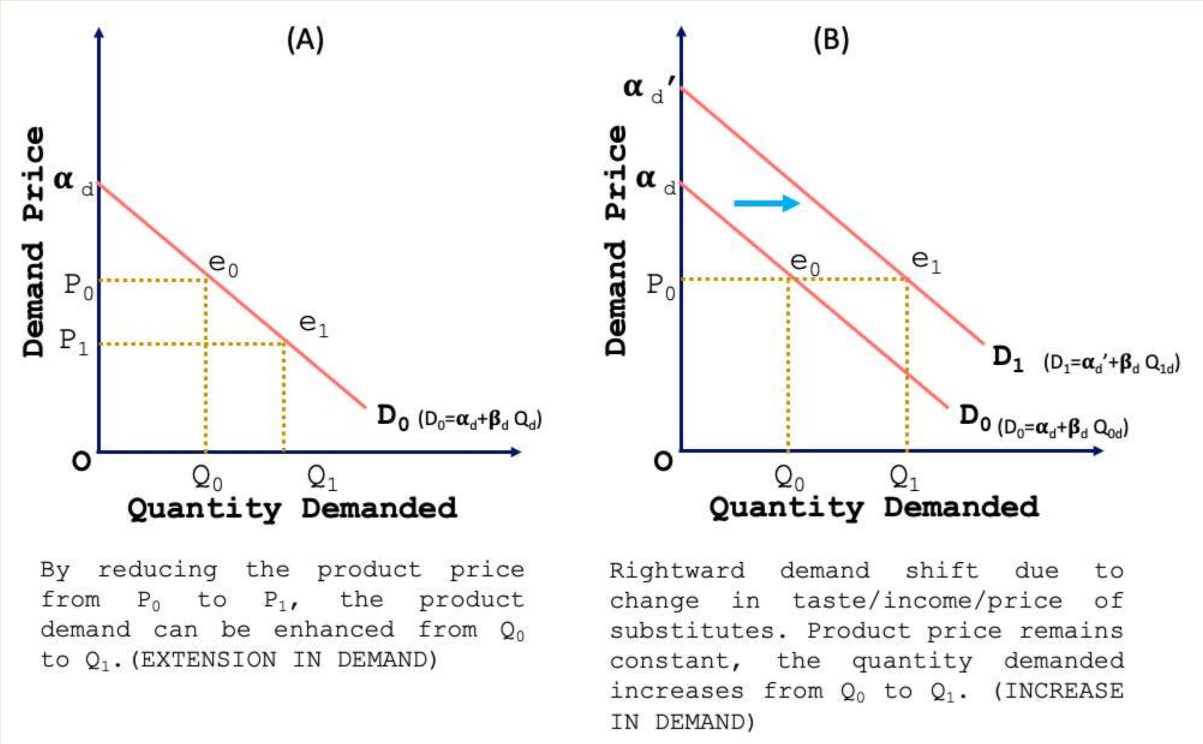
Figure 1: A linear supply curve depicting the relationship between supply price and quantity supplied (A) and shift in linear supply curve due to either cost reduction or new method of production or technological changes (B)

2.3 Demand Curve: consumer behaviour and price sensitivity

On the demand side, the quantity consumed typically decreases as prices rise, as consumers may switch to substitute goods or face budget constraints. This relationship is represented by a downward-sloping demand curve (Fig 2A):

$$P_d = \alpha_d + \beta_d Q_d$$

Where P_d is the demand price, α_d is the intercept, and β_d is the slope. Like the supply curve, the demand curve can also shift due to changes in consumer preferences, incomes, or the prices of substitute goods (Fig 2B). The slope of the demand curve reflects how sensitive consumers are to price changes, which is a key consideration in determining the overall impact of research on economic surplus.



2.4 Equilibrium and Economic Surplus

At any given point, an equilibrium is achieved when the quantity supplied matches the quantity demanded, and the price paid by consumers equals the price received by producers (Fig 3).

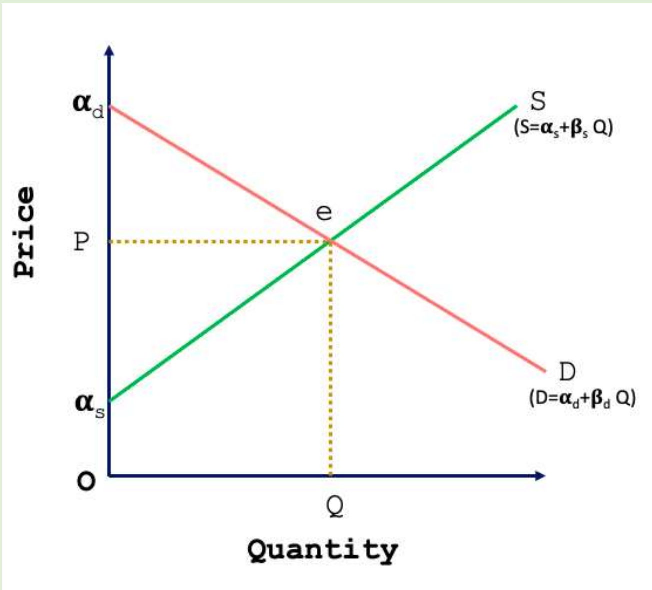


Figure 3: Supply curve, demand curve and market equilibrium

While the observed price and quantity provide insights into the economic situation, the true measure of economic welfare is captured by the "economic surplus," which is the area between the supply and demand curves (Fig 4).

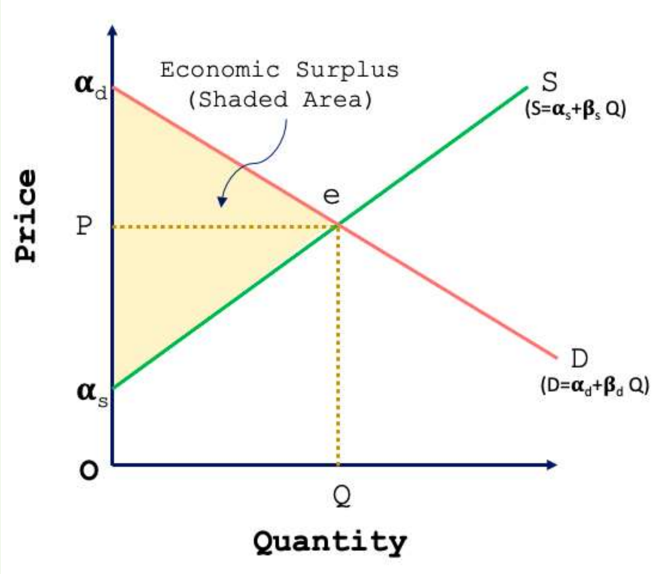


Figure 4: Economic surplus (shaded region before equilibrium point between the demand and supply curve)

Since the surplus earned in one market is spent in the other market, the economic surplus is divided into two components: a) consumer surplus (the area between the demand curve and the market price) and b) producer surplus (the area between the supply curve and the market price) (Fig 5).

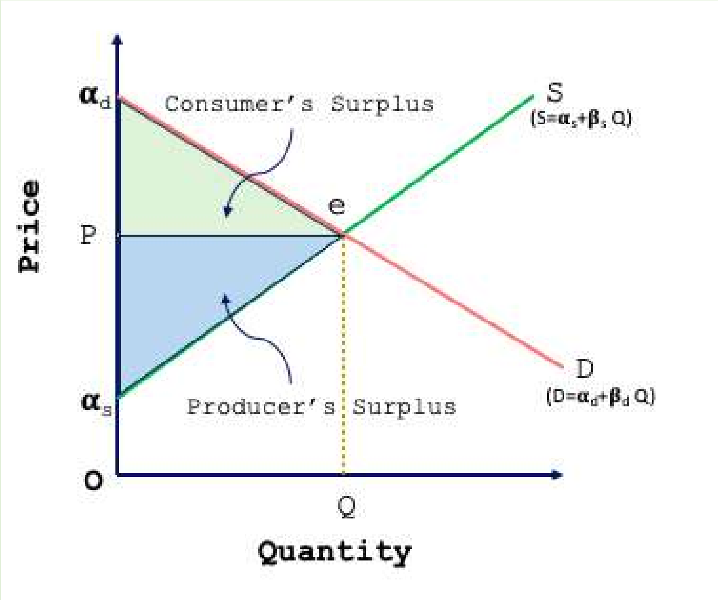


Figure 5: Consumer's and Producer's surplus together constitute the economic surplus

The primary focus in most impact assessments is on the total economic surplus or the area between the supply and demand curves.

2.5 The Role of Research in Shifting Supply Curves and Generating Economic Surplus

Research can impact economic surplus by shifting the supply curve, either reducing production costs or increasing output. A successful research output shifts the supply curve to the right, lowering the price while increasing the quantity produced. This shift creates a new equilibrium with a lower price (P_1) and higher quantity (Q_1) (Fig 6).

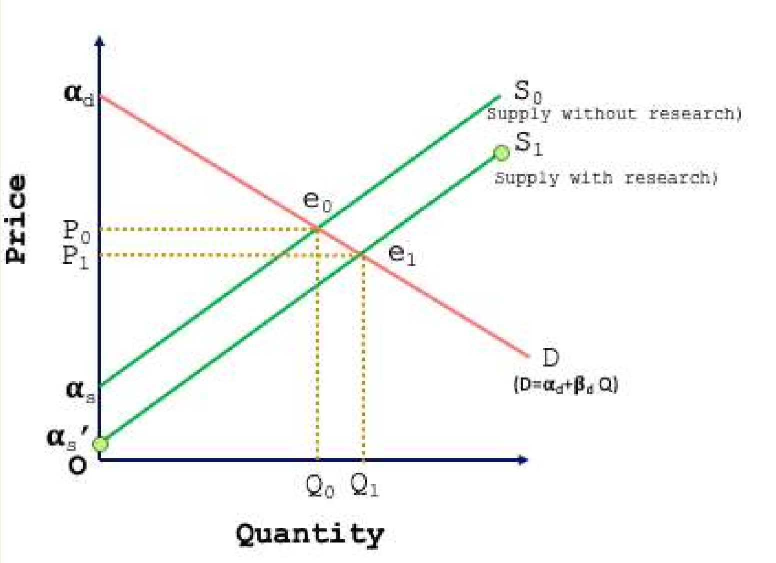


Figure 6: Significance of research in rightwards shift of supply curve

For producers, research can lower production costs, represented by an increase in area (A) (the area between the old and new supply curves). However, the reduced price may decrease producer surplus by area (B). Whether producers experience a net gain (area A - B) (Fig 7) depends on the elasticity of demand. If demand is elastic (i.e., consumers are highly responsive to price changes), producers can still benefit despite lower prices because the increase in quantity demanded outweighs the price reduction.

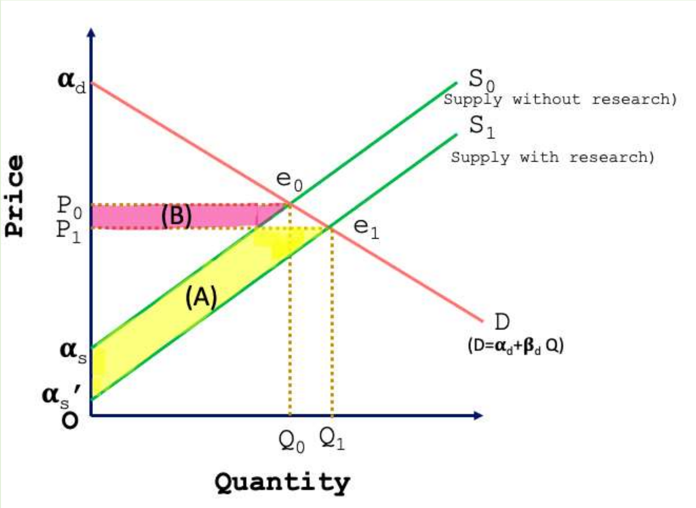


Figure 7: Change in producer surplus due to research

Conversely, if demand is inelastic (i.e., consumers are less responsive to price changes), producers may experience a net loss.

Consumers, on the other hand, always benefit from research, as they gain from both lower prices (area B) and increased consumption (area C) (Fig 8). The net gain to consumers (B+C) supports the earlier assertion that, generally, consumers derive the greatest benefits from research on staple foods, which tend to have relatively inelastic demand and a steep demand curve. Conversely, producers typically benefit more from research on high-value/exportable crops, where demand is more elastic and the demand curve is flatter. This pattern is often reflected in practice, where producers or marketing organisations frequently subsidize research on export crops, while research on staple foods is more commonly funded by taxpayers through government support.

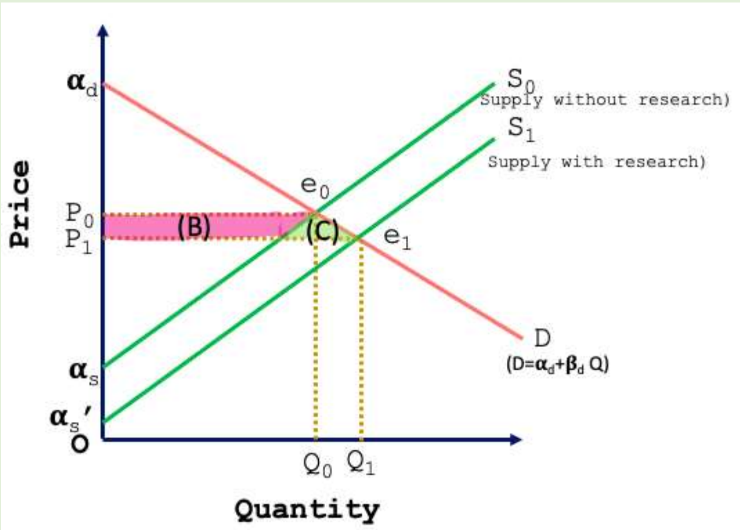


Figure 8: Change in consumer surplus due to research

For the overall economy, the net gain from research is the sum of areas A and C. Area B is merely redistributed from producers to consumers, and thus does not contribute to a net economic gain. Area A represents the benefits of reduced production costs, while area C reflects the benefits of lower consumer prices. The total social gain / total economic surplus from research is the sum of these areas, and the goal of this method is to estimate this net social gain using available data.

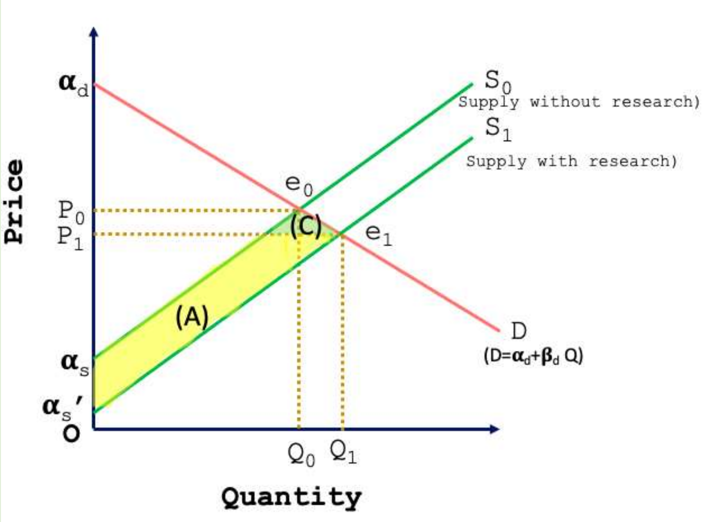


Figure 9: Social gain from the research

2.6 Measuring Social Gains from Research

In practical applications, the total social gain is typically divided into two components: the reduction in production costs (area R) and the increase in production levels (area T). The majority of benefits from research tend to come from reduced production costs, as shown by the larger area (R) compared to the area (T). This suggests that the primary value of research lies in cost reductions rather than increased output (Fig 10).

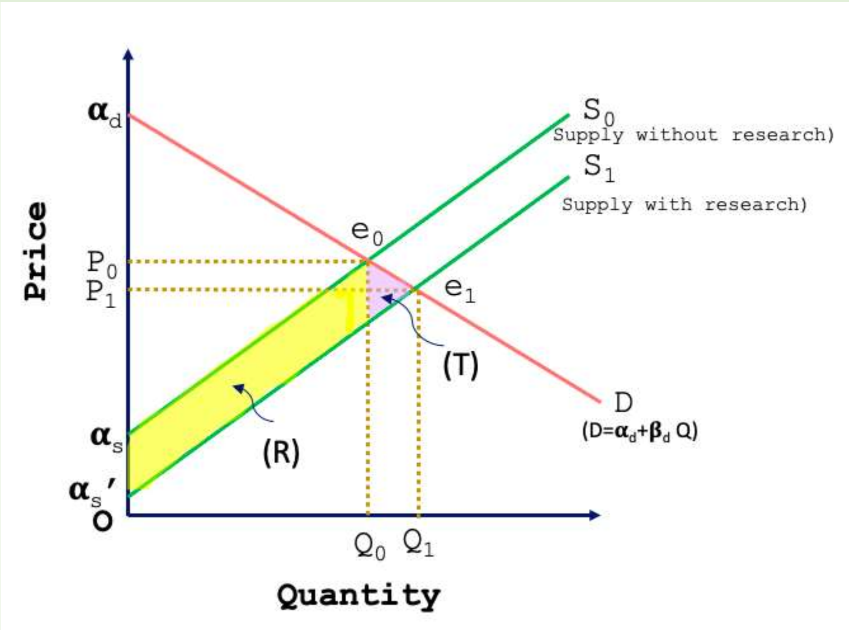


Figure 10: Ex-ante impact of research

In ex-ante studies, where the research results have not yet been adopted, the observed price and quantity reflect the without-research scenario, and the task of impact assessment is to estimate the unobserved situation with research i.e. P_1 and Q_1. In this case,the social gain is the sum of area R and area T, representing the reduction in production costs and the increase in output, respectively.

In ex-post studies, where the research has already been adopted, the observed price and quantity reflect the with-research scenario, and the without-research scenario must be estimated. The social gain is then area (R) (including area T), minus area (T), representing the reduction in production costs.Area R represents thesocial gain due to the decrease inproduction costs at the observed level ofproduction (Q_1), while area T represents acorrection for the change in quantitycaused by the research (Fig. 11).

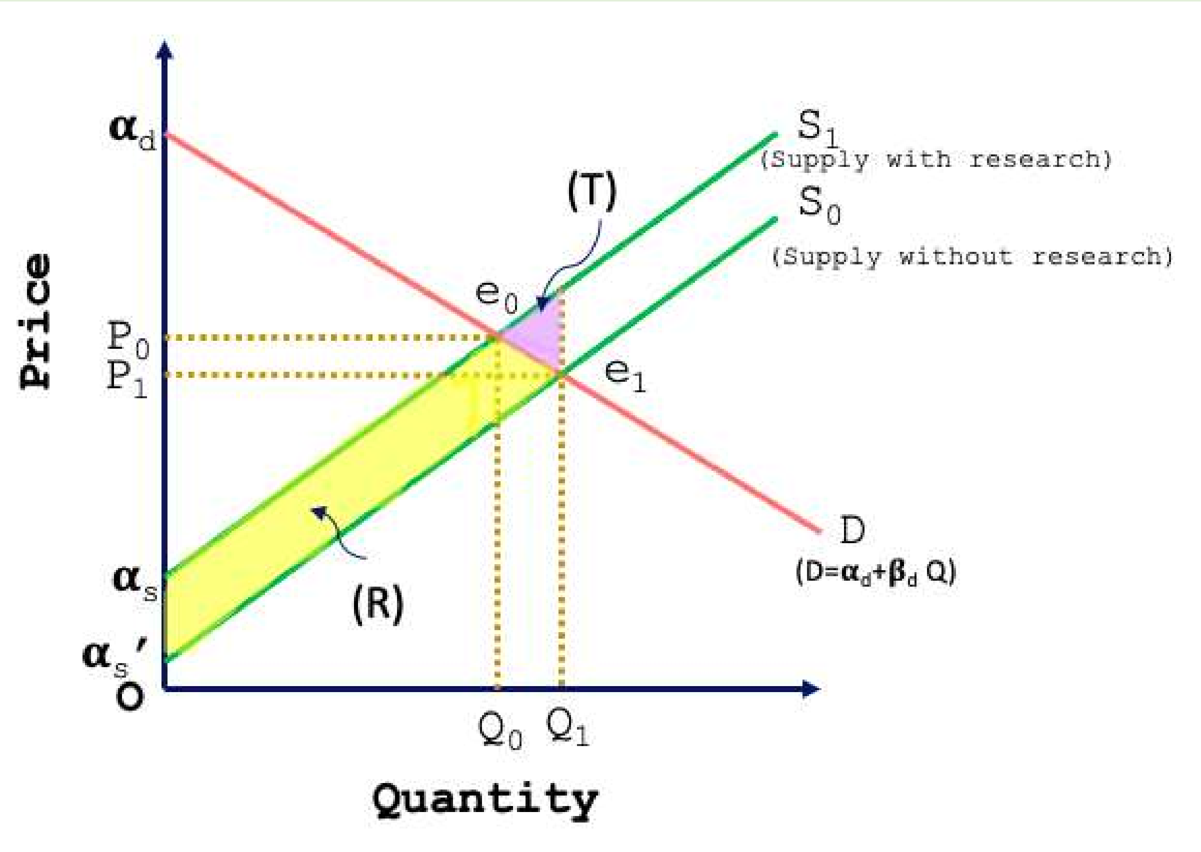


Figure 11: Ex-post impact of research

2.7 Estimating the Supply Shift

The key challenge in using the economic surplus method is estimating the magnitude of the supply shift or the reduction in production costs. This is represented by the parameter (K), which reflects the vertical shift in the supply curve. Typically, research results are observed in terms of increased output per unit of input, such as higher crop yields per hectare. The net shift in the supply curve is determined by combining changes in output (a horizontal shift) and changes in input costs (a vertical shift).

Figure 12 demonstrates how different types of data can be combined in a typical impact assessment. It showcases a successful research project that increases output for the same inputs by quantity J, moving the supply curve from S_0 to S_0 +J. This increase is often measured as yield per hectare (e.g., kg/ha). To calculate J, the yield gain (kg/ha) is multiplied by the area planted with the new technology (ha). For instance, if a climate-resilient rice variety increases yields by 50 kg/ha, and 1,00 hectares are planted with it, then J would be 5,000 kg (50 kg/ha x 1,00 ha). If the adoption of this variety came at no cost, the new supply curve would be S_0+J. However, adoption usually requires investment in inputs like certified seeds or additional labour. The vertical distance I represent these "adoption costs" per unit (e.g., Rs/kg) is calculated by dividing the added cost per hectare by the average yield (kg/ha). For example, if adoption costs Rs. 50/ha more and average yields are 500 kg/ha, the per-unit cost is Rs. 0.10/kg (Rs. 50 ÷ 500 kg/ha). This shift in the supply curve from S_0 to S_1 (including both J and I) reflects the net reduction in production costs, represented by the vertical distance K, which signifies the "shift" or "K parameter." In the case of climate-resilient rice varietal technology, such an impact assessment could show the increase in rice yields under stress conditions and the reduction in production costs as farmers adopt this more resilient technology despite some initial input costs.

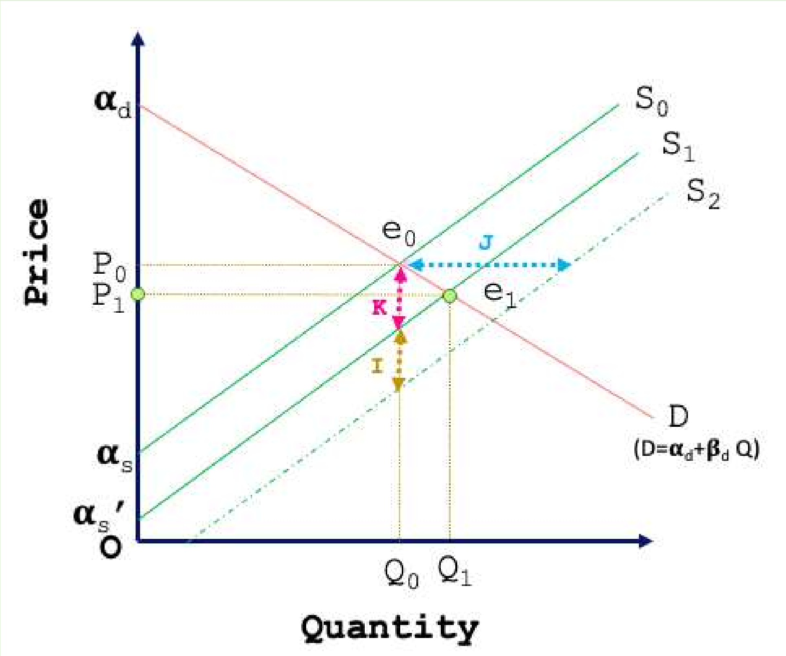


Figure 12: Estimating supply shift using observed data

2.8 Mathematical Approach for Estimating Economic Surplus/ Social Gain

For estimation of the social gain depicted in Figures 10 and 11, we need the area of a parallelogram plus or minus the area of a triangle. Defining the variable Q_0 to be the quantity of produce without research, ΔQ to be the change in the quantity caused by the research (i.e. Q_0-Q_1 in ex-ante studies or Q_1-Q_0 in ex-post studies), and K to be the vertical shift in supply, then we have the social gains expressed in the following simple formula, using addition in ex-ante studies and subtraction in ex-post studies.

$$\textbf{Social Gain} = K*Q \pm \tfrac{1}{2} K * \Delta Q$$

The Q is directly observed through the varietal release document or from the technology profile of the particular variety. The unknown variables that need to be estimated in the impact assessment are K and ΔQ. To estimate these values, we will first need to estimate J and I.

The parameters J, I, K and ΔQ are not directly observable but can be estimated using the available data. In particular, we need estimates of the results of research, in termsof yield increases (ΔY), adoption costs(ΔC), adoption rates (t), total acreage plantedto the crop (A), total production (Q) and the overall average yield (Y = Q/A).

The J parameter can be defined as the total increase in production caused by adopting the new technology, in the absence of any change in costs orprice. It can readily be estimated based on three kinds of observable data:

- the yield increase (ΔY) caused by adopting the new technology, expressed in terms of physical units (e.g. kg/ha);
- the adoption rate (t), expressed as the proportion of total area under the new technology;
- the total area (A) in the crop (often measured in ha).

Thus, we have:

$$J = \Delta Y \times t \times A$$

Note that the adoption rate in terms of area planted may be very different from theadoption rate in terms of the number of farmers, since different farmers plant differentareas. It is essential to try to estimate adoption carefully, using the best possibleinformation on area planted.

For many applications, it is more practical to compute the J parameter in proportionalterms,as the increase in quantity produced as a share of total quantity:

$$j = J/Q$$

This transformation permits us to estimate the supply shift parameter (j) in terms ofthe yield gains, adoption rates, and the overall average yield level (Y):

$$j = (\Delta Y \times t) / Y$$

Note that this simplified formula is valid only if the denominator (Y) is defined as theoverall average yield level (Y=Q/A). It is often convenient to check the consistencyof this sort of formula with the units of analysis. For example, in this formula, wehave:

$$\mathbf{j = J(kg)/Q(kg) = \Delta Y(kg/ha) \times t/Y(kg/ha)}$$

Since all the units cancel out, this formula is consistent with calculating a ratio.

The I parameter may be defined as the increase in per-unit input costs required toobtain the given production increase (J). It can be calculated on the basis of thefollowing parameters:

- the adoption costs (ΔC), per unit of area switched to the new technology;
- the adoption rate (t), in terms of area; and
- the overall average yield (Y).

The complete formula is:

$$\mathbf{I = \Delta C \times t / Y}$$

Typically, the units involved might be:

$$\mathbf{(Rs/kg) = (Rs/ha) / (kg/ha)}$$

Often it is more convenient to do our calculations in proportional terms, as theincrease in production costs (I) as a share of the observed product price (P). Thisproportional cost-increase parameter (c) is:

$$\mathbf{c = I/P = (\Delta C \times t) / (Y \times P)}$$

A unit analysis yields:

$$\mathbf{c} = \frac{I\left(\frac{Rs}{kg}\right)}{P\left(\frac{Rs}{kg}\right)} = \frac{\Delta \mathrm{C}\left(\frac{\mathrm{Rs}}{\mathrm{ha}}\right) \times \mathrm{t}}{\mathrm{Y}\left(\frac{kg}{ha}\right) \times \mathrm{P}\left(\frac{\mathrm{Rs}}{\mathrm{Kg}}\right)}$$

Once more the units cancel out indicating that c is a proportion without units.

The K parameter may be defined as the net reduction in production costs induced bythe new technology, combining the effects of increased productivity (J) and adoptioncosts (I). It corresponds to a vertical shift in the supply curve, given J and I, andcould be computed using the slope of the supply curve (bs) as follows:

$$\mathbf{K = [J \times bs] - I}$$

In practice, the slopes of supply curves (bs) are not generally used in calculations,because they are associated with specific units of measurement. Researchers prefer touse the supply elasticity (ε), which is independent of the units of measurement:

$$\varepsilon = \frac{\%\Delta\ \mathbf{Q}}{\%\Delta\ \mathbf{P}}$$

$$\varepsilon = \frac{\Delta\, Q/Q}{\Delta\, P/P}$$

$$\varepsilon = \left(\frac{\Delta Q}{\Delta P}\right) \times (\frac{P}{Q})$$

$$\varepsilon = \left(\frac{1}{b_s}\right) \times (\frac{P}{Q})$$

$$b_s = \varepsilon \times (\frac{Q}{P})$$

$$K = \frac{J}{\{\varepsilon \frac{Q}{P}\}} - I$$

$$K = \frac{JP}{\{\varepsilon Q\}} - I$$

Using proportional terms (i.e. the net reduction in production costs as a proportion ofthe product price), we have:

$$k = \frac{K}{P}$$

$$k = [\frac{JP}{\varepsilon QP}] - I/P$$

$$k = [\frac{j}{\varepsilon}] - c$$

This formulation shows clearly that, when supply is “inelastic” (0 is less than 1), thenthe elasticity amplifies the k-parameter (k> j-c). In this case, a given yield increasecaused by research has a relatively high economic value--perhaps because there islittle available land on which to expand production. On the other hand, when supplyis "elastic" (0 is greater than 1), perhaps because land is abundant, then the elasticitydampens the k parameter (k<j-c). This corresponds to a situation in which it isrelatively easy to expand production, so the gains from research have a relatively loweconomic value.

The change in quantity actually caused by research (ΔQ) depends on the shift in supply and the responsiveness of supply and demand. The equilibrium situation without research would be that price and quantity which satisfy both demand and supply:

$$Qs = Qd$$

$$a_d + b_d P = a_s + b_s P$$

$$P = (a_s - a_d)/(b_d - b_s)$$

With research, the equilibrium must be on a new supply curve, that is shifted in the direction of a price increase:

$$\mathbf{Q's = Qd}$$

$$\mathbf{a_d + b_d P' = a_s + b_s K + b_s P'}$$

$$\mathbf{P' = (a_s - a_d + b_s K)/(b_d - b_s)}$$

The resulting change in price is:

$$\mathbf{\Delta P \quad = -b_s K/(b_d - b_s)}$$

$$\mathbf{= b_s K / (b_d + b_s)}$$

And hence the change in quantity is:

$$\mathbf{\Delta Q \quad = b_d \Delta P}$$

$$\mathbf{= b_d b_s K / (b_d + b_s)}$$

To substitute elasticities for slopes, we need the elasticity of demand (e), expressed inabsolute value:

$$\varepsilon = \frac{\%\Delta\ \mathbf{Q}}{\%\Delta\ \mathbf{P}}$$

$$\varepsilon = \frac{\Delta\ \mathbf{Q/Q}}{\Delta\ \mathbf{P/P}}$$

$$\varepsilon = \left(\frac{\Delta \mathbf{Q}}{\Delta \mathbf{P}}\right) \times \left(\frac{\mathbf{P}}{\mathbf{Q}}\right)$$

$$\varepsilon = \left(\frac{\mathbf{1}}{\mathbf{b_d}}\right) \times \left(\frac{\mathbf{P}}{\mathbf{Q}}\right)$$

$$\mathbf{b_d} = \varepsilon \times \left(\frac{\mathbf{Q}}{\mathbf{P}}\right)$$

Thus,

$$\mathbf{\Delta Q = (eQ/P)\times(\varepsilon Q/P)K/[(eQ/P)+(\varepsilon Q/P)]}$$

$$\mathbf{\Delta Q = e\varepsilon K(Q^2/P^2)/[(e+\varepsilon)\times(Q/P)]}$$

In proportional terms, this simplifies to:

$$\mathbf{\Delta Q = Qe\varepsilon k/(e+\varepsilon)}$$

2.9 Computation of relative change/reduction in price (Z)

$$Z = \frac{K\varepsilon_s}{\varepsilon_s+\varepsilon_d} \ldots\ldots\ldots\ldots (6)$$

Where,

ε_s and ε_d is the absolute value of the price elasticity of supply and demand, respectively.

K-shift parameter

2.10 Computation of incremental changes in producer surplus (ΔPS) and consumer surplus (ΔCS)

$$\Delta PS = P_0Q_0(K - Z)\ (1{+}0.5\varepsilon_d Z) \ldots\ldots (7)$$

$$\Delta CS = ZP_0Q_0(1 + 0.5\varepsilon_d Z) \ldots\ldots\ldots (8)$$

$$TS = P_0Q_0K(1 + 0.5\varepsilon_d Z) \ldots\ldots\ldots (9)$$

Where,

P_0 is the pre-adoption or base-price produce;

K is K-shift parameter;

Z is relative change/reduction in price;

Q_0 is the pre-adoption level of production;

ε_d is the price elasticity of demand

2.11Exogenous Output Change

The exogenous output change is the anticipated proportionate change in output not due totechnology adoption or research in each year (Alston et al., 1995).It can be calculated by summing the growth rates of yield and area. In the model, it is used to adjust production (Qt) inyear t

$$Q_t = Q_0(1 + g)^t$$

Where, g=Growth rate in output.

2.12Estimation of the Current rate of adoption

To get the current adoption rate and the maximum adoption rate required as inputs for estimating the technology adoption path the users can obtain this information from the technology generating institute or the expert opinion or through the surveys. Usually, the surveys are reliable but a costlier effort. Hence, using the breeder seed supplied by the institute/ technology generator for a technology under consideration one can estimate the area under the technology using the following equation:

$$\textbf{Area}_{Formal}(\textbf{Mha}) = \left[\frac{(\textbf{BS} * \textbf{ Seed multiplication factor}) \times \textbf{Correction Factor}}{\textbf{Seed Rate}}\right] \times \frac{\textbf{1}}{\textbf{Conversion factor}}\Bigg]$$

$$\textbf{Area}_{Informal}(\textbf{Mha}) = \frac{\left[\left\{\frac{(\textbf{1}^{\textbf{st}}\textbf{ generation output of technology })\times \textbf{ Output kept as seed } (\%) \times \textbf{Correction Factor}}{\textbf{Seed Rate}}\right\} \times \{\textbf{100} - \textbf{SRR} - \textbf{technology discontinuance } (\%)\}\right]}{\textbf{Conversion factor}}$$

Gross area under the technology = $\textbf{Area}_{\textit{Formal}}$ + $\textbf{Area}_{\textit{Informal}}$

Using the estimated area under the technology (crop variety) and the gross area under crop in the domain states, one can calculate the current adoption rate using the given formula:

$$\text{Adoption Rate}_{\ Current} = \frac{\text{Area under the technology (crop variety)}}{\text{Area under crop in the domain states}} \times 100$$

2.13Estimation of the Adoption path

Among the different functional forms (e.g., logistic, Weibull, exponential and lognormal), the most commonly used function for fitting new technology diffusion curves is the logistic function (Jabbar et al., 2003). It is in accordance with two empirical regularities found in diffusion data, namely, it is sigmoid shaped, and right-handskewed (Davies, 1979). Therefore, Generally, a "S" shaped logistic curve is used to estimate and depict the adoption process of agricultural technology (Griliches, 1957). The sigmoid shape implies that the rate of diffusionbegins slowly followed by a period of rapid growth and then reaches a plateau or maximum level of adoption (ceiling limits or equilibrium value) adoption level. However, a small number of farmers may lag far behind or never adoptthe new technology, causing the diffusion curve's right-handed skewness (Fuglie and Kascak, 2001). A typical logistic function can be given as follows:

$$A_t = \frac{A_{max}}{1 + e^{-(\alpha+\beta t)}} \dots \dots . (1)$$

where,

A_t is the proportion of adopted area under technology t^{th} year; A_{max} is the maximum rate of the adoption. For A_{max},the most common practice, particularly in case of ex-ante impact assessment studies, is to consult with the experts (Hareau et al., 2006). Experts may factor-in changing socio-economic and climate conditions, for projected future rate of adoption.Another way could be, use of the logit model for predicting the future rate of adoption (Krishna and Qaim, 2008).β is rate of growth coefficient and α is constant which position the curve on the time scale. Key properties of logistic curve are: (a) asymptotic to zero and ceiling limit; (b) symmetric around the point of inflection, which occur at $-\left(\alpha/_{\beta}\right)$ time correspondent to 50% adoption (Jabbar et al., 2003); and (c) rate of growth is proportional to the growth already achieved and to the distance from the ceiling limit (Griliches, 1957). For tracking the adoption path, which is pre-requisite for estimating the economic surplus model, the value of these coefficients (α, β) are to be estimated. If have the time series data on the adoption rate of a particular technology, then estimating the value of β and α is easy. However, in the practical sense, usually, time series on the adoption rate a particular technology are rarely available for estimating the value of the β and α. Another way, to find the value of these coefficients is solving the equation 1 for two periods.

2.13.1 Estimation of parameters of logistics function

Re-arrange the equation 1 as follows (details are given the appendix A).

$$\beta = \left[\ln\left(\frac{A_t}{(A_{max} - A_t)}\right) - \alpha\right] * \frac{1}{t} \ldots\ldots\ldots\ldots (2)$$

Now the equation 2 can be written to two period to find the value of β andα, let say for period t_1 and t_n, the equations are 2.1 and 2.2, respectively.

$$\beta_1 = \left[\ln\left(\frac{A_0}{(A_{max} - A_0)}\right) - \alpha\right] * \frac{1}{t_1} \ldots\ldots\ldots\ldots (2.1)$$

$$\beta_2 = \left[\ln\left(\frac{A_t}{(A_{max} - A_t)}\right) - \alpha\right] * \frac{1}{t_n} \ldots\ldots\ldots\ldots (2.2)$$

Now, equating the equation 2.1 and 2.2 is similar to imposing the restriction as

$$\beta_1 - \beta_1 = 0$$

Parameters like t_1, t_n, A_t, $A_0$and A_{max} of the equation 2.1 and 2.2 are known. Therefore, there are two equations in two unknowns. Then, we find the value of α provided that $\beta_1 - \beta_1 = 0$ using the solver function of MS Excel. Further, the solution of either equation 2.1 or 2.2 gives the value of the β.

The advantage of this approach is that annual adoption rates over time (the diffusion pathway) can be generated using as few as two data points and an assumption of the maximum potential adoption ceiling (Mooney et al., 2022). By using the survey and/or secondary data adoption rate at particular point of time $(A_{t)})$, let say, t_n can be estimated. Further, $t_1$year of inception of technology i.e., first year, for the sake of simplicity, it can be assumed that adoption rate $(A_{0)})$ is close to zero but not zero, let say, 0.001. This method of estimation of adoption rate was used by various researchers, for instance, Song and Swinton(2009) used for estimating the ex-ante net benefitsfrom adoption of an IPM (Integrated pest management) against Aphid in soybean in USA and Mooney et al., (2022) assessed the return to research for pest resistant cultivars.

2.14 Risk reduction benefits of the climate resilient technologies

In the view of increasing climate variability, yield variance reduction is a key objective of the crop improvement programs. To estimate the benefits of the reduction, following method was used. The coefficient of relative risk aversion for a producer with Von-NewmanMorgestern utility function of income ($U(Y)$)can be given as below:

$$R = -Y_1 \frac{U''(Y_1)}{U''(Y_1)}$$

Now, le us assume that introduction of the climate resilient variety affects both the mean and variation of yield of a crop. Let distribution of yield before and after introduction of climate resilient crop variety can be depicted by $\tilde{Y}_1$and$\tilde{Y}_2$, respectively.Now, introduction of climate resilient crop variety assumed to change the mean yield from $\bar{Y}_1$ to $\bar{Y}_2$, and coefficient of variation from σ_{y1} to σ_{y2}.

The money value M for this reduction in income variation canbe estimated employing the following equation

$$EU(\tilde{Y}_1) = EU(\tilde{Y}_2 - M)$$

Expanding the left-hand side using a Taylor series approximation

$$EU(\tilde{Y}_1) \cong U(\bar{Y}_1) + \tfrac{1}{2}U''(\bar{Y}_1)E(\tilde{Y}_1 - \bar{Y}_1)^2 \text{.....(a)}$$

Expanding the Right-hand side using a Taylor series approximation

$$EU(\tilde{Y}_2 - M) \cong U(\bar{Y}_1) + (\Delta Y - M)U'(\bar{Y}_1) + \tfrac{1}{2}U''(\bar{Y}_1)E(\tilde{Y}_2 - \bar{Y}_1 - M)^2$$

Now, equating equation a and b and dividing by $\bar{Y}_1 U'(\bar{Y}_1)$

$$\frac{M}{\bar{Y}_1} = \frac{\Delta Y}{\bar{Y}_1} - \frac{1}{2}R(\bar{Y}_1)\left\{\sigma_{Y2}^2\left(\frac{\bar{Y}_1}{\bar{Y}_2}\right) - \sigma_{Y1}^2\right\}$$

where the first term on the right-hand side is what Newbery and Stiglitz (1981) refer to as transfer benefits and the second term is the risk benefit. If we focus solely on yield variance reductions, assuming no change in mean yield, then producer risk benefits can be measures as

$$\frac{M}{\bar{Y}_1} = \frac{\Delta Y}{\bar{Y}_1} - \frac{1}{2}R(\bar{Y}_1)\{\sigma_{Y2}^2 - \sigma_{Y1}^2\}$$

2.15Poverty reduction benefits of technology adoption

Number of people who escape poverty at the current level of technology adoption is estimated as follows (Alene et al., 2009)

$$\Delta P_n = \left(\left(\frac{CS + PS + \boldsymbol{RRB}}{AgGDP}\right) * \varepsilon_p\right)$$

Where,

CS is estimated consumer surplus in (million)

PS is estimated producer surplus in (million)

RRB is the estimated risk reduction benefits (million)

AgGDP is GDP from agriculture crops in domian area (million)

ε_p is elasticity of poverty to agricultural productivity growth

N is Number of poor people in the domain area (million)

ΔP_n is Change in poverty (number of people that escaped poverty due to adoption) (million)

3 DATA COLLECTION AND USE

The previous section outlined the fundamental formulas and the types of data required to estimate the economic benefits from adopting a new technology. Now, we turn our attention to the equally challenging task of gathering the right data and using it effectively. The data needed to estimate social gains can be grouped into three main categories:

1. Market data: This includes observed prices and quantities.
2. Agronomic data: Information on yields and the costs associated with adopting the new technology.
3. Economic parameters: This capture how the market responds to changes.

Additionally, it is crucial to consider the costs of research and extension activities that led to the development of the new technology. Each of these data types comes from distinct sources, requiring careful evaluation and tailored approaches for their proper use.

3.1 Market Data on Prices and Quantities

The most essential data for conducting an impact assessment are the price (P) and quantity (Q) of the product influenced by technological change. The economic value of a given technological advancement (e.g., a 10% reduction in production costs) increases when it applies to a high-volume, high-priced product. Conversely, for low-volume, low-priced products, similar economic impacts can only be achieved through either greater proportional cost reductions or lower research and extension expenses.

When markets operate with minimal government intervention or monopoly influence, market prices typically approximate the social opportunity costs. However, in cases where market distortions exist, researchers must estimate border prices, marketing costs, and equilibrium exchange rates. This often requires collaboration with economists from outside the agricultural research system, such as those in Ministries of Finance or Planning, Central Banks, or donor agencies involved in economic policy.

Data for quantities (Q) are usually obtained from the same sources as price data. What is typically needed is the total quantity produced in the region or country where the technological change is occurring. This data is often collected at the national level, as this is generally the focus of policymakers. However, an impact assessment can be carried out at any level of the market, as long as all data corresponds to the defined area under study.

For ex-post studies using historical price data, it is necessary to adjust prices for inflation, a process referred to as "deflation." This is usually done by dividing the observed prices by a consumer price index (CPI), normalized so that the index value is 1 at a reference year (e.g., 1990). This method transforms observed prices into "real" prices based on 1990 values.

For ex-ante studies that forecast future prices, the common assumption is that real prices will remain close to the average of recent years. Although prices may fluctuate, it is difficult to predict future trends in terms of direction or magnitude. Price data (P) is typically available from Ministries of Agricultureor statistical agencies. However, researchers may encounter different types of prices and may need to conduct their own price surveys. The goal is to obtain the marginal price, which reflects the price that would be paid for any additional production resulting from technological change. In most cases, an average of wholesale prices from key rural or peri-urban markets is appropriate.

To evaluate the impact of technological change in terms of economic surplus for the broader economy, prices should reflect the opportunity costs for the entire economy. If market prices do not align with social opportunity costs due to trade restrictions or other market distortions, it is necessary to estimate these opportunity costs. This typically involves calculating the export or import price of the product at the country's border in foreign currency, adjusting for marketing costs to reach local wholesale markets, and converting domestic prices to foreign currency using an equilibrium exchange rate rather than the prevailing market rate.

3.2 Agronomic Data on Yield Gains and Adoption Costs

Assessing the impact of research is impossible without data on the technologies it produces. In most cases, this information is captured through production increases and the costs associated with adoption.Production increases are typically measured as proportional gains, represented by the parameter "j." These gains are the result of two key factors: the yield improvements from the new technology and the rate at which the technology is adopted. Both factors are essential for any impact assessment.

For example, consider a new technology that boosts a crop's average yield by 0.33 metric tonnes per hectare in an environment where the current average yield is 1.5 metric tonnes per hectare. This results in a proportional yield gain of 22% (calculated as 0.33 ÷ 1.5). If the technology has an adoption rate of 50%, the overall production increase will be 11% (0.22 × 0.5).

This calculation can be expressed as:

$$\mathbf{c = (\Delta C \times t) / (Y \times P)}$$

where:

- C represents the additional cost of adopting the technology,
- t is the adoption rate,
- Y is the current average yield,
- P is the market price.

For instance, if the cost of adoption is Rs. 10,000 per hectare, the adoption rate is 50%, the average yield is 1.5 metric tonnes per hectare, and the market price is Rs. 50,000 per metric tonne, the calculation would be:

$$\mathbf{c = (10000 \times 0.5) / (1.5 \times 50000)}$$
$$\mathbf{c = 0.07}$$

This indicates a 7% increase in production costs to achieve an 11% overall production gain. Clearly, this would suggest that the new technology is profitable, though further calculations are needed to precisely determine its economic value.

It is worth noting that researchers may prefer to calculate the yield gain (j) and cost increase (c) solely for adopters of the technology and then apply the adoption rate at the end of the process. This approach avoids using the adoption rate in two separate formulas, although it adds an additional step to the calculation process.

3.3 Economic Parameters on Supply and Demand Response

In the previous example, an 11% increase in production was achieved alongside a 7% rise in input costs. However, this is not the final stage of the impact assessment. The economic benefits of this outcome depend on its comparative value, both relative to alternative ways of increasing production and to consumer preferences.

Supply and demand elasticities are critical in this analysis, but they cannot be directly observed. Instead, they depend on a variety of factors, such as producers' attitudes, production possibilities, purchasing power, and the timeframe allowed for adjustments. Typically, elasticities are low in the short run and higher in the long run, as markets and producers have more time to respond to price changes. While it is possible to statistically estimate historical elasticities, these estimates are highly context-specific. Given the uncertainty surrounding elasticity estimates, sensitivity analyses are often performed. However, such analyses generally reveal that elasticities have minimal influence on the overall profitability of research. Therefore, it is more important for researchers to focus on accurately estimating variables like prices, quantities, production gains, adoption costs, and adoption rates. In fact, elasticity discussions can even be bypassed by assuming supply elasticity (e) equals zero and the proportional reduction in production costs (k) equals one.

To illustrate the use of elasticities, consider the earlier example of a major food crop. Suppose the supply elasticity is estimated at 0.3. To calculate the shift parameter "k," which represents the proportional reduction in production costs due to the new technology, we divide the production increase (j) by the elasticity, using the formula:

$$\boldsymbol{k = [\frac{j}{\varepsilon}] - c}$$

Substituting the values from the example:

$$\boldsymbol{k = \left[\frac{0.11}{0.3}\right] - 0.07}$$

$$\boldsymbol{k = 0.30}$$

This calculation indicates that an 11% increase in production, combined with a 7% rise in input costs, shifts the supply curve by 30%. When the supply elasticity is less than one, increasing production is relatively challenging, which enhances the value of the production gain. Conversely, when the elasticity exceeds one, the value of the production gain is diminished. If the elasticity is exactly one, it has no impact, and the shift parameter becomes ($k = j - c$).

The final step in estimating the economic benefits of technology adoption involves incorporating the demand elasticity parameter to determine the change in equilibrium quantity (ΔQ) caused by adoption. In the case of a major food crop, the demand elasticity might be estimated at a relatively low value, such as 0.4. The change in equilibrium quantity can then be calculated using the formula:

$$\boldsymbol{\Delta Q = Qe\varepsilon k/(e+\varepsilon)}$$

$$\boldsymbol{\Delta Q} = Q * e * \varepsilon * K/ (e+\varepsilon)$$

$$\boldsymbol{\Delta Q} = Q * 0.3 * 0.4 * 0.3/ (0.3+0.4) = 0.05Q$$

This suggests that the equilibrium quantity would increase by approximately 5% of the observed quantity (Q). While this is a modest increase, largely due to the low demand elasticity, it is important to note that consumer prices will decrease, potentially giving the research a significant economic value.

This example highlights the complex interactions between various economic parameters. The supply elasticity (e), which measures the proportional change in quantity produced in response to a 1% change in price, captures the relative difficulty producers face in increasing production. Typically, supply elasticity values range from 0.2 to 1.2, with lower values indicating limited potential for area expansion (as is common with crops that already dominate available resources) and higher values corresponding to crops with significant potential for expansion.

Similarly, demand elasticity (e) reflects consumers' willingness to increase consumption in response to price changes. This elasticity is usually negative, but its absolute value is used in calculations. When demand elasticity is low, consumers show little interest in expanding consumption, leading to smaller increases in quantity produced and greater reductions in market prices. Demand elasticities typically range from 0.4 to 10, with lower values associated with staple food crops in smaller markets, and higher values for export crops or import substitutes that can experience rapid sales growth.

This example illustrates the nuanced role that different types of data play in assessing economic impact, emphasizing the importance of supply and demand elasticities in determining the value of technological change.

3.4 Cost Data for Research and Extension

In assessing the impact of agricultural research, it is essential to consider not only the social gains from farmers adopting new technologies but also the costs associated with conducting the research and promoting its adoption through extension services. To accurately estimate the net social benefits, the costs of research and extension must be deducted from the gross social gains.

One of the most challenging aspects of impact assessment is determining the appropriate cost data. A key step is defining the start date and scope of the research project under evaluation. It is not feasible to evaluate all research efforts collectively; rather, the specific research activity in question must be clearly identified. Costs incurred before the start of that activity, or costs that would have been incurred regardless of the research, are considered "sunk costs." These sunk costs should not be included in the impact assessment because they are unrelated to the particular research project. For instance, any extension costs that would have been incurred even without the research project should be excluded, even if they contributed to the adoption of the new technology.

Research projects can vary significantly in duration and scale, from comprehensive programs spanning decades to smaller, targeted initiatives focused on specific regions or crops. Regardless of the project's size, the social gains should be defined in a manner consistent with the project’s scope. Only the technical changes directly attributable to the specific project should be included in the impact assessment. In some cases, technical changes might have occurred independently of the project, and their effects should be accounted for in a "without-project" scenario. This consideration is particularly relevant when evaluating extension programs, where informal farmer-to-farmer diffusion of technologies might have occurred even in the absence of formal extension efforts.

Even after the project's scope and time frame are established, translating accounting data into relevant economic costs remains difficult. Research and extension expenditures are rarely tied to specific technologies for several reasons:

1. Operating costs are often shared across multiple research projects, such as when plant breeding and agronomy programs share vehicles and other resources.
2. Research projects may rely on various sources of funding, including national budgets and external donors.
3. National agricultural research systems (NARS) often use different accounting methods depending on the funding source, making it difficult to compile comprehensive cost data for a particular project.
4. Research projects frequently draw on the results of previous projects, complicating the attribution of costs and benefits to any one initiative.
5. Research projects may span several years, during which accounting systems can change. For example, fuel expenses may be recorded as an operating cost in one system but classified as an administrative cost in another.

A common approach to estimating research and extension costs involves two steps:

(a) obtaining accounting budgets for the entire research institute (such as a NARS or international agricultural research centre), and

(b) estimating the proportion of resources allocated to the specific project, often based on the number of staff members and the percentage of their time dedicated to it.

As with all financial data, it is important to adjust for inflation. This can be done by dividing the observed costs by a price index, which is set to one in a given base year, allowing costs to be expressed in constant terms relative to that year's prices. This ensures that the costs reflect real values rather than nominal figures that may be distorted by inflation.

3.5 Discounting the Value of Research Over Time

The costs and benefits of research projects are often spread over several years, with costs typically occurring earlier than benefits. To make meaningful comparisons of values that arise in different years, it is necessary to account for the time value of money through a process known as discounting. Modern spreadsheet software usually includes built-in functions to perform discounting, making the calculations straightforward.

One of the key metrics used in comparing discounted costs and benefits is the "internal rate of return" (IRR). The IRR represents the percentage interest rate at which the present value of the research costs equals the present value of its benefits. This rate can be compared to alternative interest rates, such as the cost of borrowing or the return on other investments. If the IRR of a research project exceeds these other rates, the project can be considered a good investment, as it contributes to increase per-capita income relative to other options.

Another common metric is the net present value (NPV), which represents the difference between the total benefits and total costs of a project, discounted at a particular interest rate. The selected interest rate typically reflects the opportunity cost of funds, which could otherwise be invested or borrowed. By definition, when the NPV is calculated using the IRR, it will always equal zero.

The role of discounting in the impact assessment of research projects differs somewhat from other types of project evaluations. Research projects tend to have delayed and uncertain benefits compared to other investments. This delay is illustrated by the progression of the K-parameter (representing the supply shift caused by the adoption of new technology) over time. Initially, adoption rates for new technologies are usually low, which means the supply shift and corresponding economic benefits remain small. However, as adoption increases, economic surplus grows rapidly, since it depends on the extent of the supply shift rather than its initial magnitude. Therefore, in many cases, the most substantial economic benefits from research are realized only after widespread adoption. The supply shift progresses from initial levels (S) to intermediate stages (S') and eventually to a maximum level (Smax), when no further adoption occurs.

Another reason for the delayed benefits of research is that significant costs are often incurred before any gains materialize. Research costs are typically highest during the development phase, before the technology is released. Once released, ongoing research and extension costs may stabilize at lower levels, while the social benefits from adoption begin to accumulate. However, the net social benefits—defined as benefits minus costs—often remain negative for several years, even after adoption begins. As adoption accelerates, the gains increase exponentially. Eventually, the ceiling for adoption is reached, and a new technology may replace the original one, thereby reducing the social benefits. However, this transition usually occurs after the IRR and NPV calculations have been made and has minimal impact on the overall assessment.

4 Estimation of Economic Surplus using AIS: AgrImpactSuite

4.1 AIS: AgrImpactSuite

AIS: AgrImpactSuite is a GUI application developed for performing complex agricultural or economic calculations, related to adoption rates, economic surplus, risk reduction benefits and impact of technology adoption on poverty reduction. This software is built using the Python language. It utilizes libraries like `Tkinter` (for GUI), `NumPy`, `Matplotlib`, `SciPy`, and `Pandas` for mathematical operations, plotting, and data manipulation.

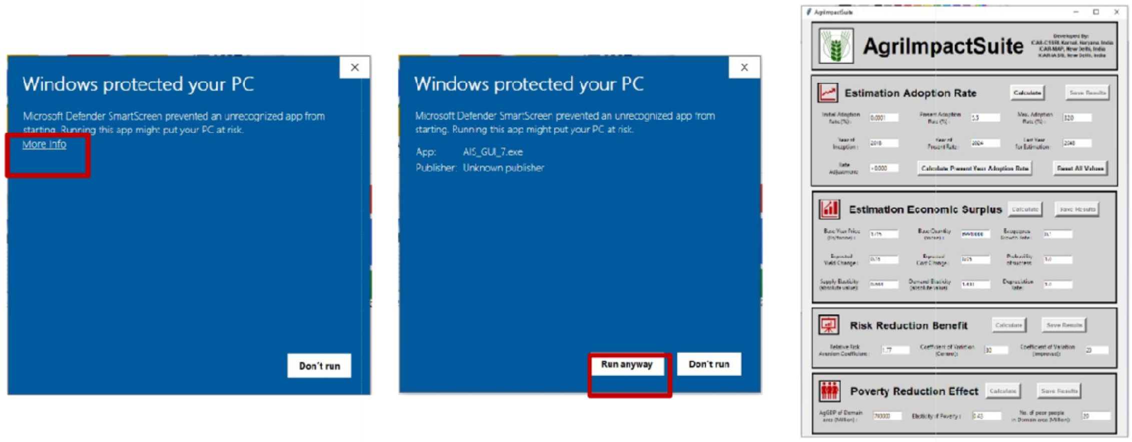
4.1.1 AIS: AgrImpactSuite Modules

- **Estimation of Adoption Rate:** It calculates the adoption rate of a particular agricultural practice or technology over time, based on factors like the initial adoption rate, present adoption rate, maximum adoption rate, and year of inception of technology.
- **Estimation of Economic Surplus:** This section computes economic benefits (surplus) based on factors such as base year price&quantity, yield change, cost change, and elasticity of supply and demand. It provides the option to estimate the consumer surplus, producer surplus and total economic surplus generated from adoption of technology.
- **Risk Reduction Benefit:** This part of the tool assesses how implementing certain agricultural practices could reduce risk, using parameters like the relative risk aversion coefficient and coefficients of variation under control and improved conditions.
- **Poverty Reduction Effect:** This section estimates the impact of agricultural improvements on poverty reduction in a specific area. It factors in parameters such as the agricultural GDP (AgGDP), elasticity of poverty, and the number of poor people in the domain area.

4.1.2PARC: Present-year Adoption Rate Calculator

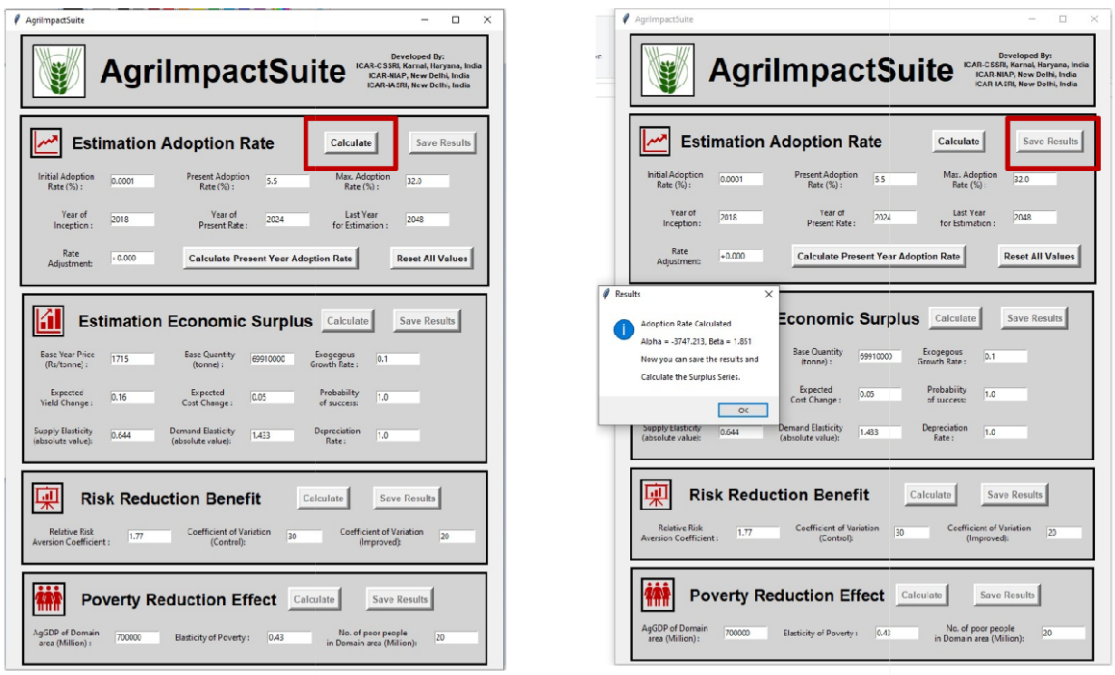
- PARC is a sub-module of the AgrImpactSuite software is designed to calculate the adoption rate of a specific agricultural technology or intervention for the present year. The PARC tool helps in estimating how agricultural technologies (such as improved seed varieties) are adopted in a given region over time. The PARC sub-module calculates the present-year adoption rate of agricultural technology based on various inputs like seed rate, multiplication factor, and crop area. It allows users to input data, calculate the rate, and save results for analysis.

4.2 Steps for Starting the AIP software

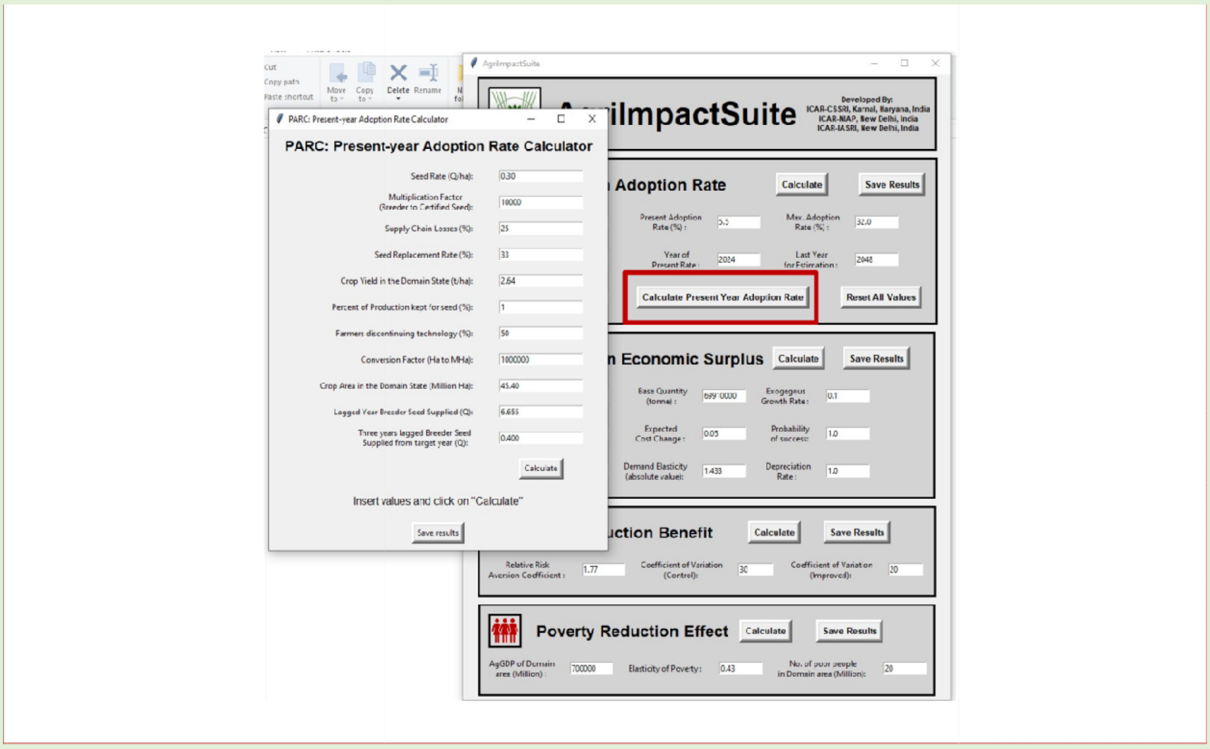


Step 1 – Click on "More info"
Step 2 – Click on "Run Anyway"
Step 3 – AIS software may take 10-20 seconds to show up the first time

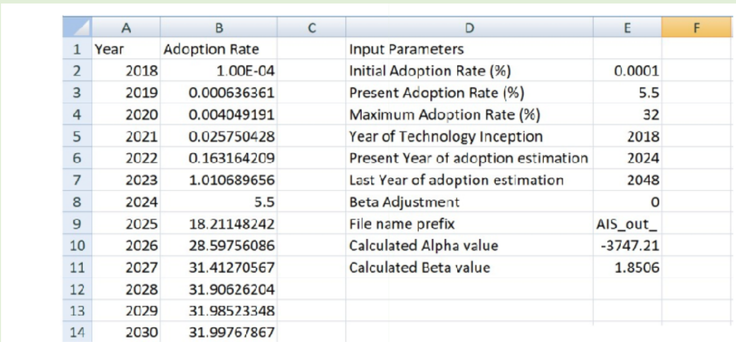
4.2.1 Calculating Technology Adoption Rate



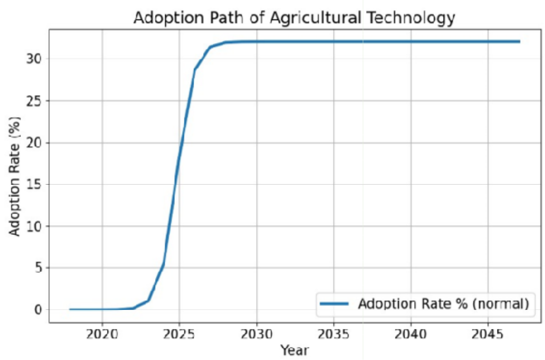
4.2.2 PARC: Present-year Adoption Rate Calculator



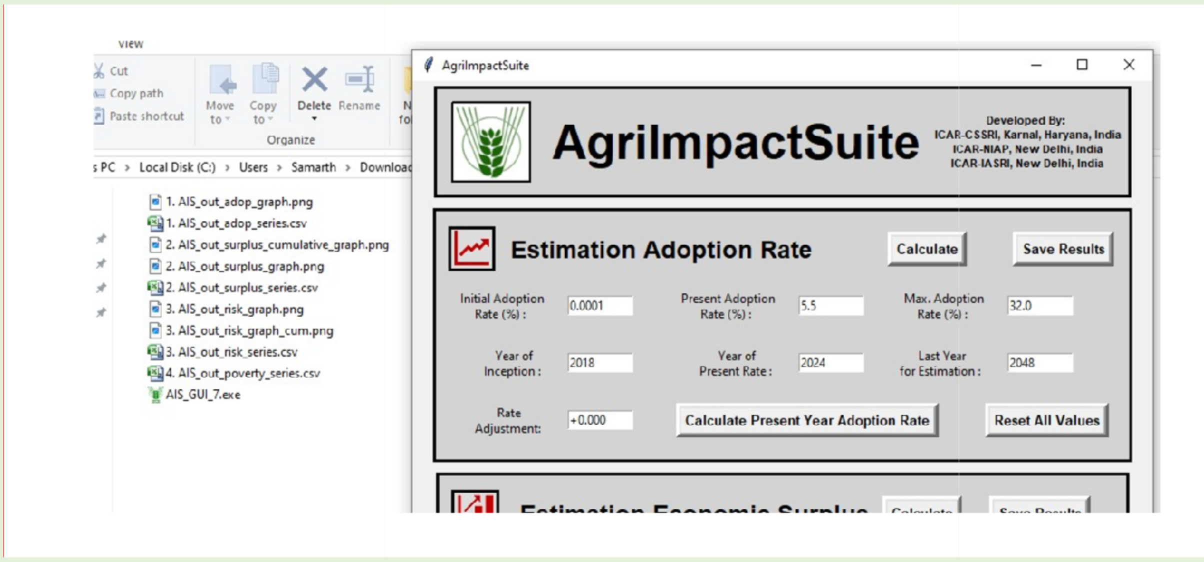
4.2.3Output saved in the same folder with prefix “1. AIS_out_adop”



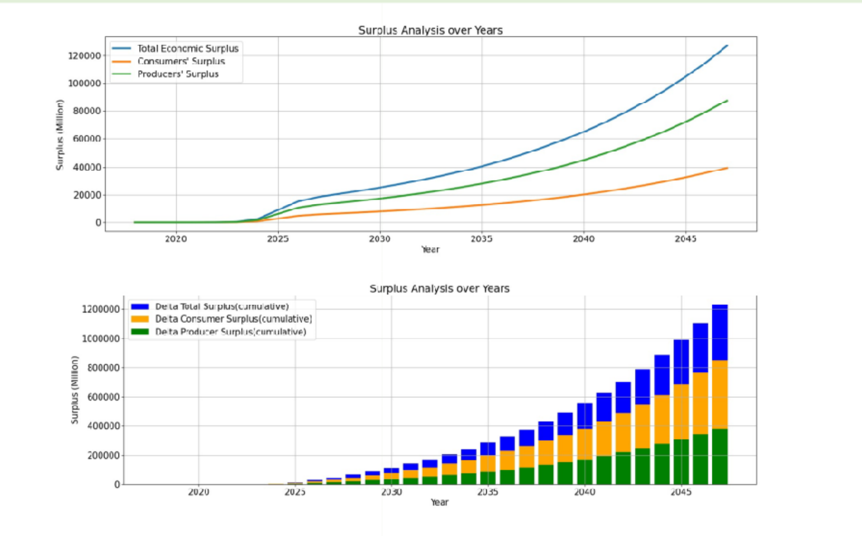
	A	B	C	D	E	F
1	Year	Adoption Rate		Input Parameters		
2	2018	1.00E-04		Initial Adoption Rate (%)	0.0001	
3	2019	0.000636361		Present Adoption Rate (%)	5.5	
4	2020	0.004049191		Maximum Adoption Rate (%)	32	
5	2021	0.025750428		Year of Technology Inception	2018	
6	2022	0.163164209		Present Year of adoption estimation	2024	
7	2023	1.010689656		Last Year of adoption estimation	2048	
8	2024	5.5		Beta Adjustment	0	
9	2025	18.21148242		File name prefix	AIS_out_	
10	2026	28.59756086		Calculated Alpha value	-3747.21	
11	2027	31.41270567		Calculated Beta value	1.8506	
12	2028	31.90626204				
13	2029	31.98523348				
14	2030	31.99767867				



4.2.4All outputs saved in the same folderwith prefix “1. AIS_out_”



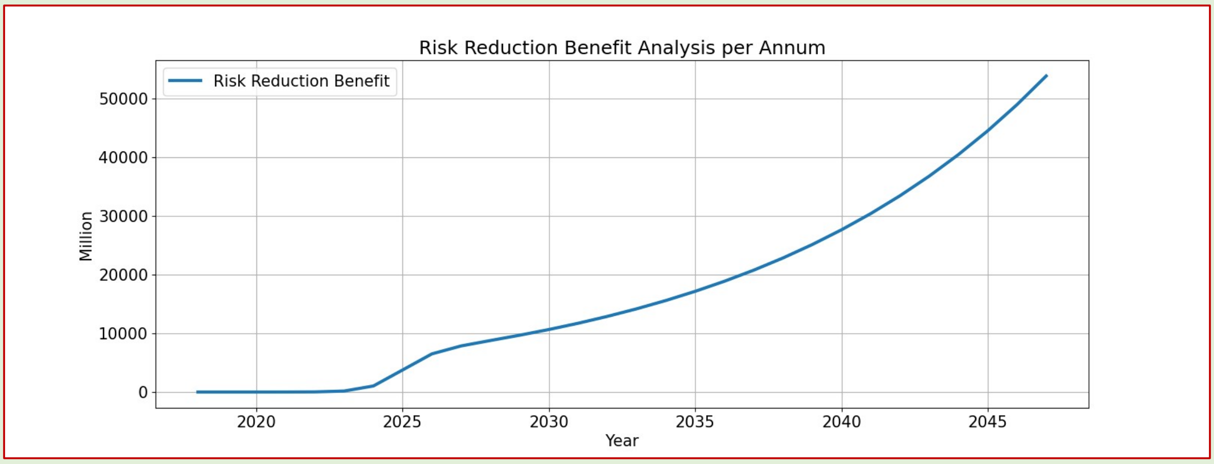
4.2.5. Economic Surplus Estimation Output

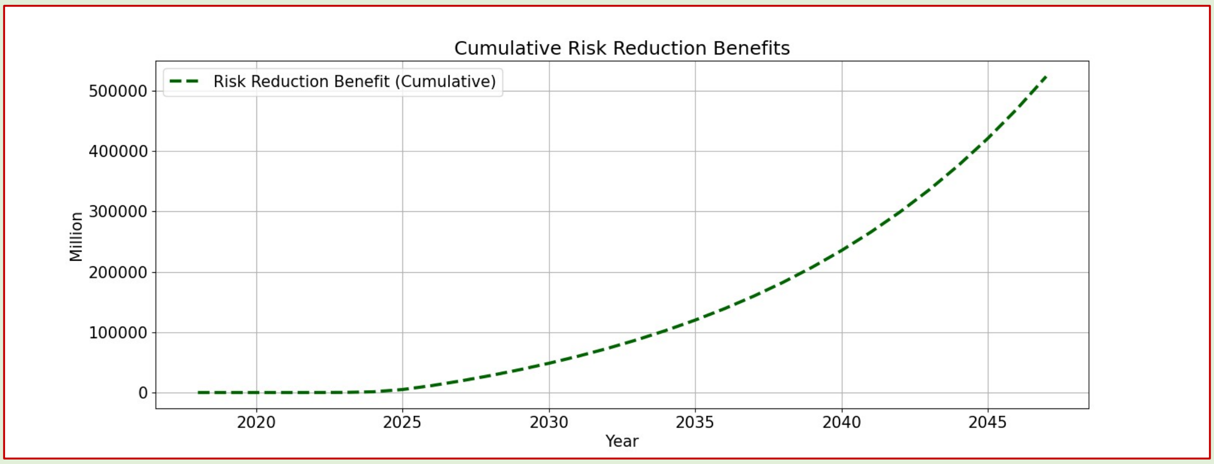


4.2.6. Economic Surplus Estimation Output

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Year	Adoption Rate	K parameter	Z parameter	Q parameter	Delta Consumer Surplus	Delta Producer Surplus	Delta Total Surplus	Cumulative Total Surplus	Cumulative Producer Surplus	Cumulative Consumer Surplus		Input Parameters	
2	2018	1.00E-04	2.05E-07	6.37E-08	69910000	7633.6865	16986.13781	24619.8	24619.82431	16986.138	7633.686496		Base Price (INR)	1715
3	2019	0.000636361	1.31E-06	4.05E-07	76901000	53435.6059	118902.5206	172338	196957.9508	135888.66	61069.29241		Base Qunatity (QNTL)	7E+07
4	2020	0.004049191	8.31E-06	2.58E-06	84591100	374014.711	832240.8087	1206256	1403213.47	968129.47	435084.0033		Exorgeous Growth Rate	0.1
5	2021	0.025750428	5.29E-05	1.64E-05	93050210	2616386.59	5821866.443	8438253	9841466.507	6789995.9	3051470.597		Expexted Yield Change	0.16
6	2022	0.163164209	0.00033505	0.00010389	102355231	18237372.4	40580985.53	5.9E+07	68659824.46	47370981	21288843.02		Expexted Cost Change	0.05
7	2023	1.010689656	0.00207539	0.0006435	112590754.1	124312769	276615214.1	4E+08	469587807.5	323986196	145601611.9		Technology Success Probability	1
8	2024	5.5	0.01129391	0.00350182	123849829.5	745660957	1659211415	2.4E+09	2874460179	1.983E+09	891262568.7		Supply Elasticity	0.644
9	2025	18.21148242	0.03739614	0.01159514	136234812.5	2731628117	6078296726	8.8E+09	11684385022	8.061E+09	3622890686		Demand Elasticity	1.433
10	2026	28.59756086	0.05872331	0.0182079	149858293.7	4740606676	10548585973	1.5E+10	26973577671	1.861E+10	8363497362		Deplition Rate	1
11	2027	31.41270567	0.06450403	0.02000029	164844123.1	5735260784	12761845813	1.8E+10	45470684268	3.137E+10	14098758146			
12	2028	31.90626204	0.06551752	0.02031453	181328535.4	6409332908	14261760958	2.1E+10	66141778133	4.563E+10	20508091053			

4.2.7. Risk Reduction Benefit Analysis Output





4.2.8. Risk Reduction Benefit Analysis Output

J	K	L	M	N	O	P	Q
tive er	Cumulative Consumer Surplus	Risk_reduc_benefit	Risk_reduc_benefit_cum		Input Parameters		
.13781	7633.686496	10610.76502	10610.76502		Relatice Risk Aversion Coefficient	1.77	
8.6584	61069.29241	74275.05962	84885.82464		Coefficient of Variation (Control)	30	
9.4671	435084.0033	519876.6108	604762.4355		Coefficient of Variation	20	
995.91	3051470.597	3636714.519	4241476.954				
981.44	21288843.02	25347920.63	29589397.58				
6195.5	145601611.9	172714159.6	202303557.2				
197610	891262568.7	1033868962	1236172520				
494337	3622890686	3765657286	5001829806				
080310	8363497362	6504548727	11506378533				
[illegible]	14098758146	7859342382	19365720915				

4.2.9Poverty Reduction Effect Calculation

M	N	O	P	Q	R
uc_ cum	Cumulative Risk Reduction benefit		Input Parameters		
.765	10610.76502		AgGDP (Crores)	700000	
246	84885.82464		Elasticity of Poverty	0.43	
.435	604762.4355		No. of poor people (crores)	20	
6.95	4241476.954				
97.6	29589397.58		Change in poverty (crores)	2.1581	
557	202303557.2				
520	1236172520				
806	5001829806				
E+10	11506378533				
E+10	19365720915				
E+10	28146832106				

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