CHAPTER 2:

CONCEPTUAL FRAMEWORK

2.1 Introduction

This chapter consists of a presentation of the model used for the research evaluation. The model uses the economic surplus criterion presented in Alston et al (1995). It measures the change in economic surplus when a new technology is introduced into the economy. In order to achieve the objectives of the study, the basic model is extended to incorporate the characteristics of the market of each main peanut product and the corresponding pricing policy. The analysis employs discounting to evaluate the stream of net benefits over the research and adoption lags of the new technology. A review of the literature on economic surplus analysis helps define the maintained hypotheses of the study.

2.2 Relevant previous studies on economic surplus analysis

2.2.1 Introduction

The Roundtable discussion on Impact Assessment of African Agricultural Technology Development and Transfer held in Washington D.C. on January 9-10, 1997 synthesized knowledge about agricultural research impact assessment in Africa. Most of the studies presented at that meeting consisted of an ex-post evaluation of agricultural research using the concept of costs and benefits and internal rate of return. Though widely used, the rate of return is not the only indicator of investments' profitability.

Three methodological issues arose during the meeting: (i) extending the analysis to environmental costs and benefits; (ii) informing policy makers more clearly about local research benefits and needs; and (iii) identifying the research investments with greatest returns in order to better target the limited funds. The following purposes were attributed to impact assessment studies: (i) generating additional research funds; (ii) identifying technology and development transfer priorities; and (iii) recognizing the benefits of agricultural research (Anandajayasekeram et al, 1997).

2.2.2 Literature review

This section summarizes some studies on economic surplus analysis. The purpose of this literature review is not to provide a complete summary of each of the examined studies, but to focus on the relevant methods used. Some of these methods will be used to build the model in this study.

The first study reviewed presents the simplest case of economic surplus analysis: a cost-benefit and rate of return analysis. In this type of analysis strong assumptions are implicitly made about the elasticities. These assumptions are relaxed in the other reviewed studies. The second study is interesting because it contains several refinements: calculating producer surplus from farm household consumption, a shift in the demand curve and a small open economy model. The third study assesses the impacts of pricing and trade policies on the size and the distribution of research benefits. The fourth study examines the relationship between research expenditures and agricultural output and the appropriate lag length for the evaluation of the net research benefits. The fifth study looks at the distribution of the benefits between the new technology suppliers, producers and consumers.

The remaining studies reviewed look at some other aspects or possible extensions that are not considered in this thesis: i) intellectual property rights in agricultural research; ii) horizontal disaggregation of the net benefits by agro-climatic region of production; iii) quality improvement and subsequent shift in demand curve; iv) probability distributions of research benefits; v) non-parametric analysis of a technical change; vi) level of research expenditures in U.S. agriculture; and vii) level of research expenditures in California agriculture.

1) Sterns, James, and Richard Bernsten. ***Assessing the impact of cowpea and Sorghum Research and Extension in Northern Cameroon*****. Department of Agricultural Economics, Paper 1994-43, Michigan State University, June 1994.**

The Department of Agricultural Economics at the Michigan State University is one important source of cost-benefit analyses of crop research in developing countries. This paper is about the impact assessment of cowpea and sorghum research and extension in northern Cameroon. The objectives of the paper are to: evaluate the returns of past investments to motivate further investments; and explain the variability in the impact of investments. In order to achieve these objectives, the study focuses on the following sub-objectives: (i) the estimation of the benefits from cowpea and sorghum research and extension; (ii) the description of the institutional environment of research and extension; and (iii) the analysis of the results and lessons learned from the study. The main objective of the study is achieved by calculating the cost and benefit streams and the internal rates of return for cowpea and sorghum research. The profitability of the investment is determined through the comparison of the internal rates of return and the opportunity cost of capital, assumed to be 10 percent. To test the validity of the results, sensitivity analyses are conducted on each estimate of the rates of return. Given the lack of availability of data in the region of the study, most of the data used is secondary, hence sensitivity analysis played a crucial role in this study. The internal rates of return of research and extension were estimated at 15 percent for cowpea and 1 percent for sorghum. Accordingly only cowpea research and extension are profitable. This difference of profitability has several explanations. The new cowpea technology completely replaced the traditional system of production whereas the new sorghum technology complemented the traditional system. Furthermore, the new cowpea technology fulfilled a need for an early maturing crop to relieve food shortages.

2) Norton, G., V. Ganoza, and C. Pomareda. *Potential Benefits of agricultural Research and Extension in Peru*. American Journal of Agricultural Economics, 69(1987): 247-257.

The objective of this study is to evaluate the benefits from research and extension for the five most important commodities in Peru (rice, corn, wheat, potatoes and beans) in an ex-ante framework. The conceptual framework consists of an economic surplus model. This model is based on the change in consumer and producer surpluses following a rightward shift of the supply curve due to technical change.

First, the authors describe a basic partial equilibrium model in a closed economy with a fixed demand curve and a pivotal shift of the supply curve. They calculate the change in economic surpluses as follows:

$$\Delta TS = \tfrac{1}{2} kPQ(1 + Zn)$$

$$\Delta CS = ZPQ\,(1 + \tfrac{1}{2} Zn)$$

$$\Delta PS = \Delta TS - \Delta CS$$

where k is the proportionate shift of the supply curve, P and Q are the initial equilibrium price and quantity, e is the supply elasticity, n is the absolute value of demand elasticity and $Z = ke/(e+n)$.

Then, the authors refine the basic model by introducing several extensions. The first extension is the evaluation of the benefits in the context of farm household consumption. This evaluation is achieved on the basis of the assumption that home consumption of own supply is not very price responsive. Accordingly, the demand function is assumed to be perfectly inelastic (vertical line) and supply shift doesn't affect home consumption. Therefore, the price change and the quantity of the supply that is consumed on farm measure research benefits from farm household consumption of the supply. The change in consumer surplus is reduced by the change in the value of the proportion of the supply that is consumed on farm and the change in producer surplus is augmented by the same amount: QPZ(1 – r) where r is the proportion of the supply that is marketed.

The second extension is the demand shift. The authors assume demand shifts due to changes in population and income. They ignore cross-price effects and changes in tastes and preferences. In this case, the authors calculate the equilibrium price and quantity when demand shifts but the supply doesn't: P' = P(1 + V/(n+e)) and Q' = Q(1+V-Vn/(n+e)) where V is the proportionate shift in demand. Then they use the new equilibrium price and quantity in the economic surplus formulae above when the supply shifts.

The third extension is the opening of the economy to the rest of the world. The country imports the commodities that are subject to technical change. In this case, the change in total surplus equals the change in producer surplus: $\Delta TS = \Delta PS = \frac{1}{2} kP_wQ(1+ke)$ where P_w is the world price.

The last extension consists of incorporating an excess domestic supply at the world price. The authors consider the case of commodities whose domestic supply would increase due to technical change, but would not be exported because the commodities do not meet international standards or because the government intervenes in those commodities' markets. Two alternatives to exports are considered. First, supply is domestically cleared at a lower price than world price which means that supply decreases. Second, supply is domestically cleared at a price close to the world price, which means that the government supports the producer price at a cost that equals ZQP_w where $Z = ke/(e+n)$ and Q is the quantity supplied and consumed.

After the evaluation of the consumer, producer and total net benefits, the present value of the net benefits from the adoption of new technologies and the internal rates of return (IRR) are computed for each of the five commodities and for the aggregate. Then, the IRR are compared with rates of return on alternative investments.

Data were collected from researchers and extension agents in seven sites in Peru, from published sources in Peru and from the Instituto Nacional de Investigación y promoción agropecuaria (INIPA). The elasticities are estimated on the basis of economic theory using the Frisch relationship[6]. Results are presented in table 2.1.

Table 2.1: Comparison of the costs and benefits between the main agricultural commodities in Peru

Commodities	Costs	Maximum adoption rates	Income elasticities	IRR
Rice	24%	56%	.76	30%
Corn	21%	50%	.48	20%
Potatoes	36%	15%	.64	22%
Beans	6%	30%	.61	14%
Wheat	12.5%	30%	.78	28%

The distribution of the benefits depends on the relative price elasticities of demand and supply of each commodity. The more elastic the demand, the more benefits

[6] The own-price of demand elasticity is estimated using the following relationship: $e_i = Ei(Ai - (1 - AiEi)/w)$, where Ei is the expenditure elasticity for commodity i, Ai is the proportion of the consumer budget spent on commodity i and w is the flexibility of money.

go to producers. For rice, corn and wheat, producers get most of the benefits. For potatoes and beans, consumers get most of the benefits.

3) Alston, J., G. Edwards, and J. Freebairn. *Market Distortions and Benefits from Research*. American Journal of Agricultural Economics, 70(1988): 281-288.

The objective of this paper is to examine the impacts of government policies on the size and the distribution of research benefits. By affecting research benefits, government policies affect research investments.

The model considers a domestic country and the rest of the world (ROW). The country can be a small country exporter or importer or a large country exporter or importer. Research benefits are determined in a competitive market first and compared to research benefits when the government intervenes.

The assumptions of the model are: i) the downward shift of the supply curve is not affected by government interventions; ii) the downward shift of the supply curve affects economic surplus and the government receipts and outlays; iii) the change in domestic economic surplus is the sum of the changes in consumer and producer surpluses and in government receipts and outlays; iv) the change in the ROW economic surplus depends on the excess supply or demand curve; and v) the aggregate change in economic surplus results from changes in the country's and ROW's economic surpluses.

Four government interventions are considered: i) a quota on the production of a non-traded good; ii) a quota on the production of a traded good; iii) a target price with deficiency payments for a non-traded good; and 4) a production subsidy for an export good.

i/ Production quota for a non-traded good

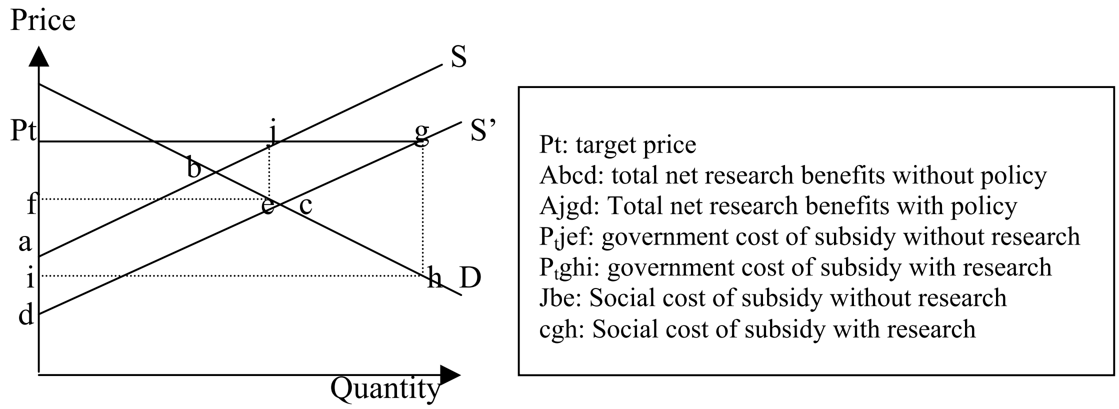
The application of a production quota in a closed economy reduces the consumer and producer surpluses. When supply shifts under the quota the total change in surplus is lower than in a free market, consumer surplus doesn't change, but producer surplus may change. The distribution of research benefits occurs between the producers and the quota owners.

ii/ Production quota for a traded good

The application of a production quota in an open economy (large country exporter) reduces the total change in economic surplus. When supply shifts under the quota, the consumer surplus (domestic and ROW) doesn't change. The entire change in surplus accrues to producers and quota owners.

iii/ Target price with deficiency payments for a non-traded good:

When a target price is applied in a closed economy, a downward supply shift increases the consumer and producer surpluses and the government cost of the subsidy as well. The total change in economic surplus is derived by subtracting the change in the cost of the subsidy from the sum of the changes in consumer and producer surpluses. There is a social cost to the subsidy that increases when supply shifts. Figure 2.1 describes the changes mentioned above.



<u>Figure 2.1</u>: Change in economic surpluses in the context of a target price with deficiency payments for a non-traded good

iv/ Production subsidy for an export good:

Research decreases price and increases quantity equally with and without a subsidy. This is due to the linearity and parallel shift restrictions imposed on the supply curves. Research increases domestic and foreign consumer surplus and domestic producer surplus more with a subsidy than without a subsidy. However, the government cost of the subsidy increases with research. This is due to the fact that with a subsidy equilibrium quantity is higher than without a subsidy. Due to the linearity and parallel shift assumptions, the increase in consumer and producer surpluses equals the increase in government cost of the subsidy. Consequently, the application of a production subsidy offsets the changes in economic surplus due to research. Moreover, the social cost of the subsidy is the same with and without research.

In conclusion, the nature of government intervention and the trading status of the country modify the magnitude and the distribution of research benefits. Table 2.2 summarizes the results of the study.

Table 2.2: Effects of agricultural research in the context of different trade policies

Policy	Country trade status	Domestic Producers	Domestic consumers	Government	Net domestic	ROW	World
Output subsidy	No trade	+*	+	-**	0***	0	0
	Exporter or importer:						
	Small	+	0	-	0	0	0
	Large	+	+	-	-	+	0
Export subsidy	Exporter or importer:						
	Small	+	0	-	0	0	0
	Large	+	-	-	-	+	0
Output quota	No trade	?	-	0	-	0	-
	Small exporter or importer	-	0	0	-	0	-
	Large exporter	?	-	0	?	-	-
	Large importer	?	-	0	-	+	-
Target price	No trade	+	+	+	-	0	-
	Large exporter or importer	+	+	+	-	?	-

*: Research is more profitable under the government intervention than with free trade.
**: Research is less profitable under the government intervention than with free trade.
***: Ambiguous.

By affecting the size and the distribution of research benefits, public policies affect the incentives of governments to invest in research.

4) Pardey, P., and B. Craig. *Causal Relationships between Public Sector Agricultural Research Expenditures and Output*. American Journal of Agricultural Economics, 71(1989): 9-19.

The objective of this article is to analyze the empirical relationship between public expenditures in agricultural research and agricultural output. This study is motivated by two observations. First, contemporary economic literature has shifted from research impact assessment to an explanation of research rate and direction, but public sector agricultural research has been absent from a large part of this literature. Second, literature has estimated the internal rates of return to U.S. agricultural research without paying attention to the relationship between the rates of return and the lag between research spending and research impact on output and productivity.

To define the relationship between agricultural research expenditures and agricultural output and productivity, the empirical analysis uses the Granger test. This test is based on the concept of causality. A random variable x is causal to a random variable y if the past history of x provides the relevant information to predict y. Causality can be tested using time-series data. Observations on agricultural research public expenditures are collected over the period 1890-1983 in current dollars. Three types of expenditures are distinguished: salaries, land and buildings, purchases of goods and services. Then, they are deflated using an index of average university salaries, an index of public construction prices and an implicit price deflator respectively. Similarly, three types of measures of agricultural activity are collected. First, observations on agricultural outputs, inputs and productivity are collected and detrended. The second measure of agricultural activity is the measure of the residuals in a regression of the logged output on logged inputs (labor, real estate, machinery, feed, seed, livestock and chemicals). The share of agricultural income in U.S. gross national product (GNP) gives another measure of agricultural activity for the period 1910-1984.

One relevant issue when testing causality between agricultural research and output is the choice of the lag length, which is often restricted by data limitations. Under strong assumptions, lags of about 15 years from research to output have been considered in past literature. To find out the appropriate lag length under weaker assumptions, two types of predictive tests are used: the Bayesian estimation criterion (BEC) and Akaike's final prediction error (FPE). Because the BEC has strong asymptotic properties, it neither under-estimates nor over-estimates lag lengths in large samples, but it chooses short lag lengths for small samples. The FPE is based on weaker assumptions and indicates longer lags.

The results of the tests reveal causality in some cases such as from research expenditures to productivity. Productivity appears to be the most useful measure of agricultural activity in the context of technological change. However, the tests do not reveal clear causality between research expenditures and agricultural output. These results are less insightful regarding the relationships between research expenditures and output than they are about the methods used.

Regarding lag length, it is shown that long lags of at least thirty years are necessary to come up with better information about the impact of agricultural research expenditures on agricultural output. However, the relationship between lag lengths and the estimated rates of return appear to be difficult to characterize.

5) Falck-Zepeda, J. B., and G. Traxler. *Rent Creation and Distribution from Transgenic Cotton in the U.S.* American Journal of Agricultural Economics, 82(2000): 360-369

This study addresses two questions: the evaluation of economic surplus and the distribution of the surplus from the introduction of highly profitable transgenic cotton varieties in the United States in 1996. The authors consider several conceptual issues in their analysis. The first concept describes the relationship between profitability and the level of adoption of the new technology. Indeed, it captures the relationship between the distribution of profitability between the new technology producers and adopters and the geographic differentiation in adoption rates of the new technology (due to agro-climatic differences). The second concept considers the additional producer surplus from the adoption of a new technology as an incentive to adoption. It focuses on the price determination of the new technology by its providers such that profit is maximized and benefits are shared with producers and consumers in the form of a cost reduction. The third concept provides a link between market power in the input market and the social benefits from research. It evaluates the social welfare impacts of the new technology taking into consideration the monopolistic nature of the cotton market, especially in the context of a drastic innovation. That is an innovation that has no substitute and thus provides a monopolistic position to its developer. In this context, the Marshallian surplus framework has to be adjusted to take into account the monopoly profits.

These three concepts aim to address the following issues. There are two incentives to private investment in agricultural research: well defined intellectual property rights and a large enough market. Profit maximization is not conditional on monopoly rents, but on the difference between the marginal cost of adopting a new technology and the cost reduction that is expected from adoption. A cost reduction exceeding the marginal cost provides a good incentive for adoption.

The changes in economic surplus are evaluated for a large open economy. The economic surplus calculations are made on the basis of changes in the variable profit and in the world price.

Results show that the benefits are equally shared between farmers and the suppliers of the new technology who each received 49 percent of the total additional surplus. The remaining part of the change in surplus goes to the consumers in the United States and in the rest of the world. Producers in the rest of the world lose surplus when the new technology is introduced in their country.

6) Moschini, G., and H. Lapan. ***Intellectual Property Rights and the Welfare Effects of Agricultural R&D.*** **American Journal of Agricultural Economics, 79 (1997): 1229-1242.**

The traditional model for the evaluation of research benefits was developed in the context of public research and competitive markets. However, there is a significant amount of agricultural research and development that is provided by private firms. Intellectual property rights protect and hence confer a monopoly power to these firms. Therefore, the assumptions underlying the traditional model are no longer valid and the model needs to be adjusted for an accurate evaluation of the size and the distribution of the benefits from agricultural research and development.

The authors define two production functions using the old and new technologies. Then, the two functions are aggregated since the pre-innovation and the post-innovation inputs are measured in the same units. From the aggregated production function, a profit function is derived. Then input demand functions are derived from the profit function using Hotelling's Lemma. Finally, a demand function is defined for the output.

Within this framework, the innovation is "drastic" if its monopoly price is unconstrained; this situation happens in the case of a monopoly where the pre-innovation market doesn't affect the innovated input pricing. The innovation is "non-drastic" if its monopoly price is constrained by competition; this situation happens in the case of perfect competition where input suppliers are price takers or in the case of an oligopoly where input suppliers establish the input price above the marginal cost of production.

To measure welfare changes, the authors measure the change in total surplus in the case of a "non-drastic" innovation and in the case of a "drastic" innovation using a traditional model (competitive market). The change in welfare is larger in the context of a monopoly than in the context of competition.

In the traditional model, consumers always benefit from the innovation whereas producers only benefit when the output demand is elastic. In the monopolistic model, there are no welfare changes when the innovation is "non-drastic". When the innovation is "drastic", consumers benefit from the innovation and the change in producer surplus depends on the elasticity of final demand. In addition, the change in total economic surplus is measured not only in the output market, but also in the input market because of the rents accruing to input suppliers. Therefore, a comparison between the competitive model and the monopolistic model shows that the former is not appropriate in the context of innovations protected by property rights because what is measured as part of the increase in consumer surplus and producer surplus is indeed captured by the innovation providers. The magnitude of the changes is smaller in the monopolistic model than in the competitive model, revealing an overestimation of the benefits by the conventional model. This overestimation is higher when the input demand elasticities are higher.

7) Mills F. B. *Ex-ante Research Evaluation and Regional Trade Flows: Maize in Kenya*. Journal of Agricultural Economics, Vol. 49, Nº3 (September 1998): 393-408.

The objective of this study is an ex-ante evaluation of maize research in Kenya. The author uses a spatial equilibrium framework where he specifies different linear supply and demand functions for each of the six identified agro-climatic regions of production and two regions of maize consumption. The initial equilibrium is established using information about initial prices and quantities and elasticity estimates. The supply shift due to the adoption of a new technology is considered to be parallel and is projected for each stage of the adoption profile. The evaluation of the research benefits is based on the following procedure:

- the determination of the supply shift for each production area on the basis of the corresponding adoption profile,
- the incorporation of the trade flows among the different regions by maximizing a net social pay-off function using a quadratic programming spatial equilibrium model,
- the comparison of discounted estimates of the consumer and producer surpluses between the situation with and the situation without research.

The main results of the study are as follows. By augmenting maize supply research reduces domestic price and imports. The magnitude of the change in consumer surplus achieved in each region depends on the size of the production base. However, research is not enough to ensure self-sufficiency in maize. The maize production system should be intensified in order to achieve the needed additional yield increase.

8) Voon, T., and G. Edwards. ***Research Payoff from Quality Improvement: the Case of Protein in Australian Wheat*****. American Journal of Agricultural Economics, 74(1992): 564-572.**

The objective of this paper is an ex-ante evaluation of the magnitude and the distribution of the economic benefits from a research that improved the quality of wheat (through a higher concentration of protein), an exported commodity in Australia (87 percent of domestic production is exported).

The conceptual framework is built upon a trade model where the authors measure the change in welfare within the frontiers of a country following an upward shift of the demand curve and of the supply curve. The supply curve shifts up because quality improvement often requires higher per unit costs of production and in this case causes a yield decrease. The demand curve represents the sum of the domestic demand and the demand in the rest of the world (excess demand). The assumptions of the model are linearity and parallel shifts of the supply and demand curves, uniformity of the quality enhancement in all the country and homogeneity of the commodity.

Data are collected for the period 1977-78 to 1988-89. Demand for wheat for human consumption is price inelastic. Demand for wheat for animal consumption is price elastic. Own-price elasticities of wheat supply are within the range 0.2-1.3.

The analysis brings up a number of issues. One percentage point increase in the concentration of protein in wheat raises the net benefits by $53 million a year. Producers receive 99 percent of these benefits. Consumers' share is very small because most of the wheat is exported. These numbers decrease when the quality improvement occurs at a higher cost ($29 million and 98 percent respectively). A higher export elasticity increases the net total benefits and the producers' share. This latter scenario is very plausible because Australia's wheat supply to the rest-of-world is relatively small. The net total benefits are higher if the wheat quality enhancement is higher valued outside the country than inside. The smaller the supply shift relative to the demand shift, the higher are the total and producers' net benefits.

9) Zhao, X., W. Griffiths, G. Griffith, and J. Mullen. ***Probability Distributions for Economic Surplus Changes: the Case of Technical Change in the Australian Wool Industry*****. Australian Journal of Agricultural and Resource Economics, 44(2000): 83-106.**

The objective of this paper is to examine the stability and the accuracy of the market parameters and the research benefits estimated by economic surplus analysis in the context of Australian woolgrowers. This study goes beyond the simple sensitivity analyses applied in previous studies to test the parameters and beyond the study by Mullen, Alston and Wohlgenant (1989) who developed probability distributions for research benefits in the Australian wool sector. This article proposes a more refined sensitivity analysis approach within a probabilistic framework. Instead of considering a unique value of the benefits that would correspond to the expected value of a probability distribution with variance zero as done in previous studies, the authors suggest developing probability distributions of research benefits. Then they develop a more sophisticated procedure for sensitivity analysis than that proposed by Mullen et al by building these distributions on the basis of a set of probability distributions of market parameters. Truncated normal distributions are assigned to each parameter to restrict the values of the parameters to the ranges imposed by economic theory. A Monte-Carlo simulation is run to obtain the distributions of the economic surplus changes.

The following results are obtained. When the parameters are varied according to their distribution, total research benefits exhibit little variation, which means that there is some certainty about their evaluation. However, there is more uncertainty regarding the evaluation of the net benefits that accrue to producers and consumers.

In order to account for the subjective character of the choice of the distributions, the authors specify hierarchical distributions. Hierarchical distributions are different versions of the original distribution that are obtained when the parameters of the original distribution are allowed to vary. The difference between the traditional results (Mullen et al) and those of hierarchical distributions are greater than the difference between the traditional results and the parent distribution. There is more uncertainty about the expected net benefits.

Finally, the study provides a description of the relationships between the parameters and the total economic surplus. Sensitivity analyses are conducted about individual parameters. It is shown that the change in total research benefits due to a one percent increase in a parameter does not have a significant impact with less than 0.002 percent change in benefits.

10) Chavas J.-P. and T. Cox. "*A Nonparametric Analysis of the Influence of Research on Agricultural Productivity*". American Journal of Agricultural Economics, 74(1988): 583-591.

The objective of the article is to develop a non-parametric procedure to measure the economic impact of a technical change in agriculture in terms of changes in the profit-maximizing or cost-minimizing behavior. The non-parametric approach consists of testing whether the vector of actual input and output decisions coincides with the optimal vector of input and output decisions. The latter vector is the solution of an optimization problem where no specific functional form is attributed to the objective function and the constraints. In the absence of technical change, profits are maximized at time t when time t profits are greater than or equal to profits obtained with any other input-output bundle valued with time t prices. Similarly, costs are minimized at time t when time t costs are less than or equal to costs generated by any other set of inputs valued at time t prices. In the presence of an output-augmenting technical change, the conditions of the maximization or minimization problem are violated and new conditions have to be defined under Hicks-neutral technical change. A Hicks-neutral technical change is a technical change that does not affect the marginal rate of substitution between inputs.

To complement this framework, the authors define the weak separability of a production function in its outputs and inputs. A production function is weakly separable when it can be expressed as a function of a sub-function that aggregates many inputs or outputs. This procedure is applied to the U.S. agricultural technology. Six outputs are considered: small grains, coarse grains, field crops, fruits, vegetables and animal products. Nine inputs are considered: family and hired labor, land, structures, other capital and materials, energy, fertilizers, pesticides and miscellaneous. First, separability tests are conducted to test output and input aggregation. The output separability test fails for the entire period 1948-83 but not for sub-periods of this large period. The inputs capital, labor and materials are tested for separability. They pass the test for the entire period 1948-83. Then, non-parametric tests of technical change are conducted using an aggregate output and multiple outputs. These tests are performed for the entire period 1948-83 and sub-periods, with and without technical change, using profit maximizing and cost minimizing procedures. The hypothesis of no technical change is rejected while the hypothesis of existence of a Hicks-neutral technical change is accepted for the entire period 1948-83.

These results clearly show that technical change occurred in U.S. agriculture in the second half of the past century. This non-parametric approach of testing hypotheses is proposed to complement the traditional methods based on the specification of a functional form of the production function.

11) De Gorter H., D. Nielson, and G. Rausser. *Productive and Predatory Public policies: Research Expenditures and Producer Subsidies in Agriculture*. American Journal of Agricultural Economics, 74(1992): 27-37.

The objective of this paper is to evaluate expenditures on research and production subsidies in agriculture. Public research is considered to be a productive policy because it increases the social welfare; and it is an efficient policy. Production subsidies are considered to be a predatory policy because they generate a welfare cost; and they are distributional policies. Through the examination of the interaction between these two policies the paper provides an explanation for under-investment in U.S. agricultural research and a discussion about the complementarity between the two policies. This complementarity compensates for the losses from research and the under-investment in agricultural research.

The authors use a partial equilibrium model to evaluate the impacts of production subsidies and research expenditures on a given agricultural market. The effect of research expenditures on the market clearing prices and quantities depends on the supply and demand price elasticities and on the derivative of aggregate marginal cost with respect to the total level of research expenditures. The effect of a subsidy on the market clearing prices and quantities depends upon the supply and demand price elasticities. These relationships determine the government's choice about the levels of per unit output subsidies and research expenditures. The level of research expenditures is determined such that the weighted marginal cost of more research expenditures to consumers (taxpayers) equal the weighted marginal benefit of research expenditures to producers. Similarly, the level of subsidies is chosen such that the weighted marginal cost of more subsidies to taxpayers is equal to the weighted marginal benefit of the subsidies to producers.

Using this analysis, the authors compare the actual level of investment in U.S. agriculture with the appropriate level on the basis of the political share of producers and the political share of consumers and of the marginal impact of research expenditures on producer profits. If consumers and producers have equal political shares and when the level of research expenditures is chosen independently from the level of the subsidy, the level of investment in agriculture is appropriate. In developed countries, the political share of producers is higher than the political share of consumers. In this case and if the marginal impact of research expenditures on producer profits is positive (negative), then there is evidence for over-investment (under-investment). When applied to U.S. agriculture, this analysis indicates that there is under-investment. If research expenditures and producer subsidies are complements and chosen jointly, then the level of research expenditures can be raised and the losses incurred by producers can be offset by income-redistributing subsidies. In developing countries, the higher political share of consumers than that of producers and the positive marginal effect of research expenditures on producer profits also provides evidence of under-investment in agriculture.

12) Fox, G. ***Is the United States really Underinvesting in Agricultural research?*** **American Journal of Agricultural Economics, 67(1985): 806-811.**

The objective of this paper is to test the validity of the hypothesis that public investment in the U.S. agricultural research is too low. Literature (Peterson, 1967; Evenson, 1979; Ruttan, 1980, 1982,…) provides a large range of studies in favor of this hypothesis. These studies use two arguments: (i) the comparison of the social rates of return to public investment and the private rates of return to private investments in agricultural research and (ii) the estimation of the costs of public agricultural investments. These studies revealed that the social rates of return to agricultural research are higher for public investments than for private investments.

According to the author, the reasoning that led from the level of the social rates of return to the conclusion that public investments in agricultural research are insufficient is misleading. The author provides two arguments to support his idea: first, the social rates of return from alternative investments were under-valued by not counting for the benefits that do not accrue to the investor; second, the estimates of the social rates of return to public investments may have been overestimated. This upward bias comes from the failure to take into consideration the deadweight losses due to the tax collection system in the calculation of the opportunity cost of public expenditures. On the basis of these remarks, the adjustment of the estimates of the social rates of return leads to the conclusion that the difference between public investments and alternative investments in agricultural research is not significant. Therefore, public investments are neither too low nor too high in agricultural research.

13) Alston, J., P. Pardey, and H. Carter. ***Valuing UC Agricultural Research and Extension*****. Division of Agriculture and Natural Resources. University of California, March 1994.**

The objective of this report is to examine the impact of the University of California's agricultural research and extension on agriculture in California. The amount of public agricultural research investments is calculated and compared to that of other states in the United States and of other countries. The benefits from agricultural research and extension investments and the average annual rate of return are evaluated as well. The percentage of agricultural research expenditures in the agricultural GDP is used for international comparisons. In addition to the general study, case studies are conducted on dairy, grapes, wine, strawberries and a tomato harvester. The purpose of these commodity-studies is to complement evaluations achieved about research and extension programs.

For the estimation of the benefits, two methods are used: the estimation of the producer and consumer surpluses; and the estimation of a productivity growth quadratic function using a regression model to calculate either the additional output or the savings in inputs due to research. The evaluation of research and extension benefits is complicated by the uncertainty of the research and development lag, non-market benefits and costs, spillovers, maintenance research and redistributional effects. It is crucial to know the length of the research and development lag because it directly affects the magnitude of the benefits. A short lag may lead to an underestimation of the benefits. The omission of maintenance research may also cause an underestimation of the research and development benefits. The evaluation of the benefits is also affected by exports to other states and countries allowing for technological spillovers and a decrease in the world price benefiting producers and consumers. Certain types of technological progress such as quality improvement are more appropriately evaluated using a shift in the demand curve in addition to the supply shift. Though it is generally accepted that subsidies reduce and taxes or a free market increase research and development benefits, the most important effects of research and development are distributional rather than a change in the magnitude of the benefits. Environmental regulations pose a problem of accounting for agriculture's response to these regulations. This problem has to be taken into consideration in research evaluations through adapted methods of evaluation incorporating environmental constraints. To take into consideration these different aspects the authors extend the basic model developed by Alston et al (1995) by introducing inter-regional trade, demand-enhancing technological change and market distortions (government interventions and environmental externalities).

Data were collected from the USDA's (U.S. Department of Agriculture) state-level data series for outputs, inputs and related indices and ratios for the period 1949-85. International statistics were collected from the literature.

The average annual internal rate of return is 20 percent, which is a good rate compared to the interest rate in the U.S. money market, but a lower rate than those obtained in other states although the authors think the latter rates were over-estimated. California agriculture realized large gains in productivity by increasing its output relative to the input use. The ratio of output to input has been greater than in the rest of the country. With 83 cents for every 100 dollars gross farm output, California invests less in research and development than the national average, 89 cents. With 45 cents for every dollar invested in public agricultural research, California invests less in extension than the national average, 74 cents. With a percentage of agricultural research expenditures of agricultural GDP of 2.6 in 1985, California spends relatively less on agricultural research than some agricultural exporting countries such as Canada and Australia that spend a little over 5 percent. However, California spends more than many countries in Western Europe (between less than 1 to little over 2 percent). The average annual rate of growth of the ratio agricultural research expenditures to GDP was zero between 1970 and 1985 in California.

At the commodity level, the dairy industry produced 14 percent more output than in the rest of the U.S. in 1991 compared to 6 percent in 1960. California grape commercial yields have doubled since 1930 and grape and wine quality has improved. Four fifths of nation's strawberries were produced in California in 1991.

2.3 Hypotheses

2.3.1 Maintained hypotheses

Alston, Norton and Pardey (1995), Masters (1996) and some of the assumptions of the models described in the above literature review suggest the following maintained hypotheses for the present model. Unlike Alston et al (1994) who measured the benefits from research by the shift of an estimated production function, this study uses the shift of a supply function instead. Generally, when the functional forms of supply and demand curves are not known, they can be approximated by linear functions (Voon and Edwards, 1992; Mills, 1998). Following the model developed by Norton et al (1987), the case of a competitive market in a closed economy is considered first. In this case, economic surpluses are at their maximum levels when the market is in equilibrium. Then the economy is opened to the rest of the world and the case of a small exporter is considered. As described by Norton et al (1987), the adoption of a new technology generates a rightward shift of the supply curve because of increased output and/or decreased cost. The supply shift may be either parallel or pivotal. Both of these cases are considered. The demand curve may be invariant to the adoption of a new technology, but it may shift out over time due to changes in population and income. Cross-price effects and changes in tastes and preferences may be of secondary importance and can be ignored. Although Fox (1985) shows that ignoring the deadweight loss from taxation over-estimates the benefits from research, this assumption is maintained in the present analysis. For the evaluation of the present value of the net benefits, the discount rate is assumed to be constant and as pointed out by Pardey et al (1989), the lags of the new technology are chosen long enough (at least 30 years) for a more accurate evaluation of the net benefits. Another assumption is that there is geographic homogeneity in the country regarding prices, elasticities, the adoption process of the new technology and the fraction of the supply that is consumed on farm.

2.3.2 Working hypotheses

On the basis of the objectives, the following working hypotheses are formulated for subsequent confirmation by the study:

- Research on La Fleur 11 has positive net benefits.
- Consumers benefit from research on La Fleur 11 more than producers in a closed economy, but only producers benefit from research on La Fleur 11 in an open economy.

- The implementation of a producer base price affects the size and the distribution of the benefits between consumers and producers. Producers' share of the benefits from research is greater than consumers'.

2.4 The peanut markets in Senegal

2.4.1 Commodities

The economic surplus is evaluated at different levels of the peanut sector depending upon the importance and the nature of the commodities considered. On the basis of the information provided in chapter 1, table 2.3 depicts the main commodities and their relative importance in the Senegalese peanut sector.

Table 2.3: Relative importance of the main commodities in the Senegalese peanut sector

PEANUT SUPPLY 100%			
OFFICIAL MARKET 65%		**FARM 24%**	**UNOFFICIAL MARKET 11%**
NOVASEN Seeds Peanut meal Cakes	**SONACOS** Seeds 15% Peanut oil 17.5% Cakes 17.5%	Seeds 9% Consumption 3% Gifts … 12%	Unshelled peanuts 10% ~~Shelled peanuts~~ ~~Oil and paste~~

SONACOS sales	NATIONAL CONSUMPTION	EXPORTS
Seeds	100%	
Oil	46%	54%
Cakes	59%	41%

Source: FAO (1999) and Gaye (1997, 1998 a, 2001).

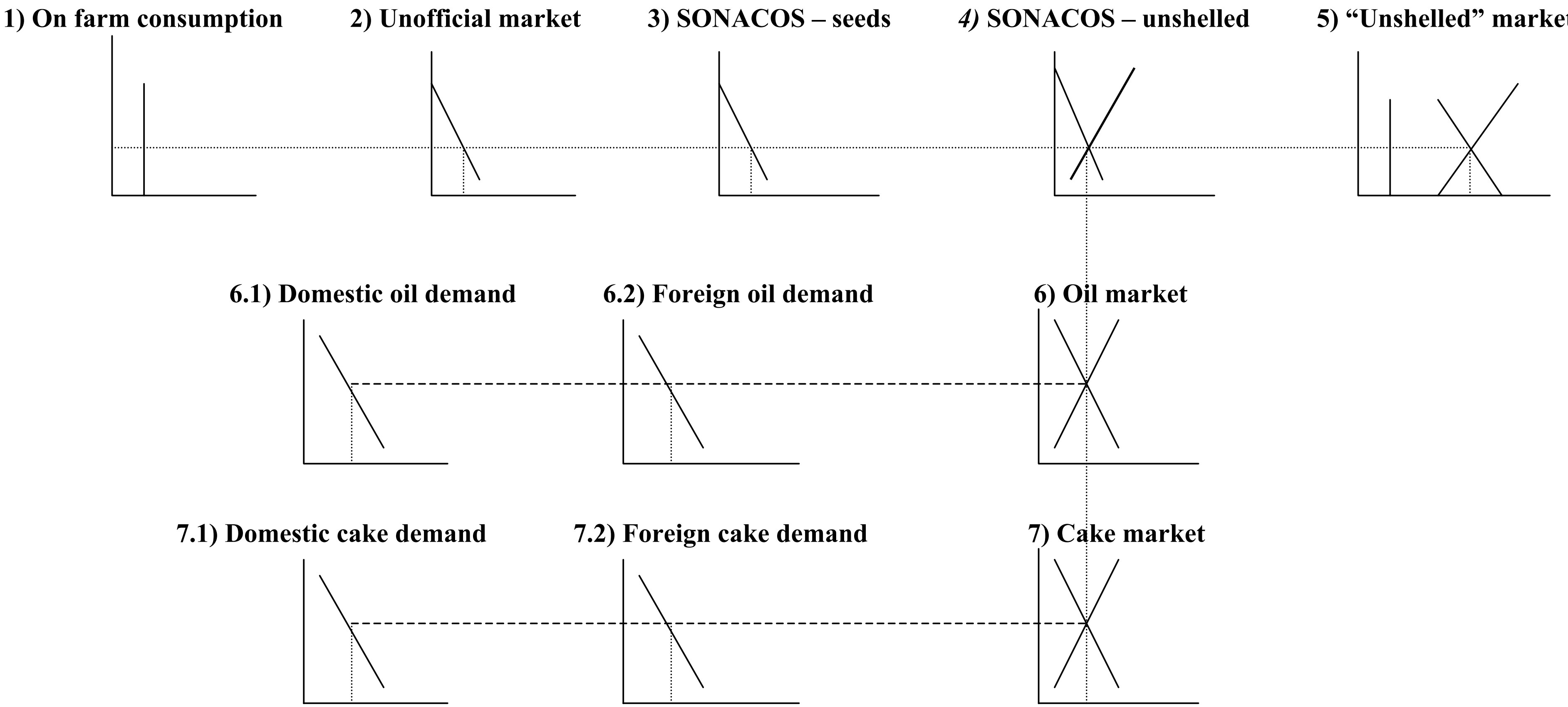
NOVASEN's outputs are not considered in the analysis because La Fleur 11 is an oil seed and hence is not used for the production of confectionery peanuts. Also, shelled peanuts, oil and paste sold on the unofficial market are ignored because their share in the informal market is not significant. Finally, the seed market is reduced to SONACOS purchases. Because La Fleur 11 is still a new variety, there is not an informal market for La Fleur 11 seeds yet. Consequently, it is assumed that farmers sell their supply of peanut seeds on the formal market only.

Therefore, there are five types of commodities to consider: farm household consumption of unshelled peanuts, farm sales of unshelled peanuts on the unofficial market, farm sales of peanut seeds on the official market, SONACOS sales of peanut oil and cakes. At each level (farmers, SONACOS) the producer surplus represents the quasi-rents from the inputs used up to that level and the consumer surplus represents the surplus of the consumers who buy at that level.

2.4.2 Market linkages

Houck et al (1972) provides an example of market linkages based on the U.S. soybean sector. Similar market interrelationships are drawn below in the context of the Senegalese peanut sector. Starting from farm supply of unshelled peanuts, there are four demand curves to be considered: 1) on farm consumption, 2) farm sales on the unofficial market, 3) farm sales of seeds to SONACOS and 4) farms sales of unshelled peanuts to SONACOS for oil and cake production. As shown in figure 2.2, their horizontal summation results in total demand for unshelled peanuts (5). SONACOS purchases of seeds and unshelled peanuts for transformation into oil and cakes are separated because these two types of purchases are subject to different contract agreements between farmers and SONACOS.

As shown in figure 2.2, SONACOS' demand curve for unshelled peanuts is the vertical summation of 6) demand for peanut oil and 7) demand for peanut cakes. Further each of the peanut oil and peanut cake total demands is the horizontal summation of domestic demand and foreign demand. Inventories and handling costs are ignored.



<u>Figure 2.2</u>: Disaggregation of the unshelled peanut markets

The translation of these links into economic surplus models requires the definition of the trade and technical relationships between the different peanut products considered. At the farm level, the total supply of unshelled peanuts is structured as follows: 24 percent is consumed on farm, 10 percent goes to the unofficial market, 15 percent is sold to SONACOS as seeds and 50 percent is sold to SONACOS for transformation into oil and cakes.

Before going forward, special attention is given to the linkage between the oil and cake markets, which are the most closely connected among these peanut markets. There are several relationships that link the annual production and the producer price of unshelled peanuts to the annual production and wholesale prices of oil and cakes. When demand and supply are joined together in the official market for unshelled peanuts (graph 4), market-clearing conditions ensure that the SONACOS demand for unshelled peanuts is satisfied by the yearly farm supply. When disaggregated, this market gives rise to two separate markets, the oil market (graph 6) and the cake market (graph 7). The theoretical link between the official market for unshelled peanuts and the oil and cake markets is represented by the vertical summation of supply and demand in the oil and cake markets. This link is based on several interrelations. As seen earlier, the processing of one ton of unshelled peanuts produces amounts of oil and cakes that are assumed to be in fixed and equal proportions: 0.35 tons of oil and 0.35 tons of cakes. Given that SONACOS purchases of unshelled peanuts for transformation into oil and cakes represent half of the total farm supply of unshelled peanuts, the supply of oil and cakes at the SONACOS level each represent 17.5 percent of the total farm supply of unshelled peanuts. The magnitude of the research-induced supply shift for peanut oil and cakes is assumed to be the same as for unshelled peanuts. When produced, oil and cakes are either sold on the domestic market (respectively 46 percent and 59 percent) or exported. The theoretical link between the total oil demand and total cake demand and demands at the international and domestic levels is represented by the horizontal summation of domestic demand (graphs 6.1 and 7.1) and foreign demand (graphs 6.2 and 7.2) for oil and cakes respectively. Potential substitution or competition with other vegetable oils is reflected in the trade policy in the form of variable levies that are applied on imported vegetable oils, but is not reflected in this analysis.

2.4.3 Pricing policies

As discussed in chapter 1, the Senegalese government sets a producer base price at the farm gate for unshelled peanuts sold on the official market. As shown in figure 2.3 (Just et al, 1982) where S represents the supply curve and D the demand curve, in a closed economy model the producer base price P_b is implemented at a higher level than the competitive equilibrium price P. As a result, producers' and consumers' behaviors change. Producers produce a greater quantity Q_b than the competitive equilibrium quantity Q because of the higher producer price than the competitive equilibrium price. The quantity produced is consumed at a lower consumer price P_c than the competitive equilibrium price. Consequently, producer surplus increases by area $PabP_b$ and consumer surplus increases by area $PacP_c$. The government incurs a cost of subsidy that can be measured by area P_bbcP_c. Society incurs a dead-weight loss that can be measured by area abc.

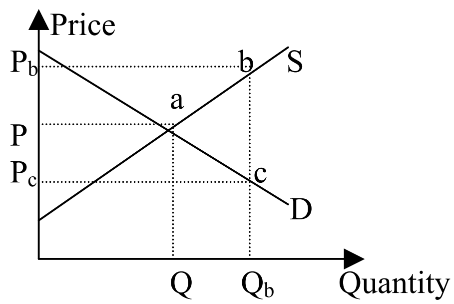


Figure 2.3: Closed economy with a producer base price

Senegalese exports of peanut oil and cakes are subject to the world price. As shown in figure 2.4 where S and D are the supply and demand curves respectively, in a small open economy the world price P_w applies at a higher level than the competitive equilibrium price P. As a result, producers produce a greater quantity Q_{sw} than the equilibrium quantity Q at the world price P_w and consumers consume a smaller quantity Q_{dw} than Q at the world price. The excess supply $Q_{sw} – Q_{dw}$ is exported. Producer surplus increases by area $PcbP_w$ and consumer surplus decreases by area $PcaP_w$.

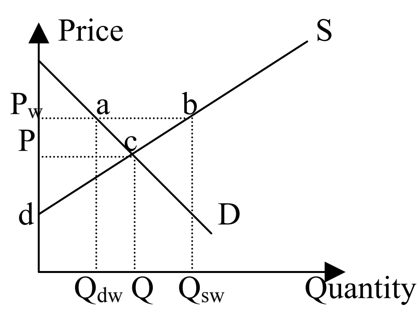


Figure 2.4: Small open economy

2.5 Economic surplus analysis

2.5.1 Introduction

The analysis uses the concepts of supply and demand in partial equilibrium. From economic theory it is known that one way to derive the supply function is from production costs. The supply function is upward sloping, which means that the relationship between quantity and price is positively related. The supply function is not only affected by price or quantity, but also by any factor that could modify the costs of production and shift the supply curve. Such a factor can be the adoption of a new technology.

From economic theory, it is known that a demand function is derived from the constrained utility maximization problem and that it is downward sloping which means that quantity and price move in opposite directions. It is also known that some factors such as changes in population, preferences, tastes or income may shift the demand curve and that demand function measures the consumers' willingness to pay for a good.

Economic theory also provides us with the concept of equilibrium in a perfectly competitive market. At any point in time, there is a single quantity such that supply equals demand and a single corresponding price that consumers pay and suppliers receive.

Another relevant concept is economic surplus, which represents the difference between the monetary value of the units consumed and the monetary value of the units produced up to the equilibrium price and quantity. The economic surpluses for consumers and producers are evaluated and compared between a situation where a new technology is used and a situation where no new technology is used.

When a new technology is adopted, the supply curve shifts to the right because of increased supply and/or decreased costs. This shift creates a new equilibrium point where price is lower and quantity is higher than in initial equilibrium, and new economic surpluses result. A comparison of the economic surpluses between the pre-research and the with-research equilibria shows that the consumer surplus is always higher because of the increase in quantity and decrease in price. The producer surplus may be either higher (because of reduced costs of production or increased supply) or lower (because of lower price) depending on which effect dominates. The impact of research on producers depends on the elasticity of demand. The more elastic the demand, the higher the producer surplus. For the entire economy, the total increase in economic surplus represents the social benefits from the adoption of the new technology. The magnitude of these benefits is determined by the supply shift K, which is the vertical shift of the supply function and a dollar measure of the magnitude of the net cost reduction per unit of output.

2.5.2 The supply shift K

When a new technology starts being adopted, the supply curve starts shifting to the right. This shift reflects either a productivity improvement holding the input mix fixed at the without-research levels or cost savings from the with-research input mix or both. This cost reduction can be measured by the difference in commodity budgets between the without-research and with-research equilibria. Often, this information is hard to obtain when performing an ex-ante evaluation. Alston et al (1995) propose an alternative method based on the research induced increase in experimental or farm-level yield (horizontal shift) that they translate into a per unit of output industry-level gross cost reduction (vertical shift) by dividing the proportionate yield increase by the elasticity of supply[7]. However, the problem with this method is that the increase in productivity is under-estimated when holding the without-research optimal input mix constant because it is not optimal for the with-research situation. Conversely, the increase in productivity is over-estimated when using the with-research optimal input mix because it is not optimal

[7] Alston et al (1995) recommend using a unitary elasticity when no information is available on the supply elasticity.

for the without-research situation. Therefore, this method requires using the optimal input mix corresponding to each situation and adjusting the actual research induced increase in yield by accounting for the differences in input mix between the without-research and the with-research optima. These differences in input use induce differences in variable and fixed costs per unit of output. The per unit of output difference between the cost of the without-research input mix and the cost of the with-research input mix has to be subtracted from the gross cost reduction per unit of output. The resulting net cost reduction per unit of output is multiplied by the probability of success, the adoption rate, the depreciation rate of the new technology for each year of the adoption process and the without-research equilibrium price. The resulting annual supply shift is used to calculate the annual research benefits.

To summarize, the calculation of the supply shift K may be achieved using information about the proportionate yield increase $\Delta Y/Y$, the supply elasticity ε, the proportionate change in variable costs $\Delta C/C$, the proportionate change in fixed costs $\Delta F/F$ and the fraction f of total costs allocated to the commodity in question, the probability of success p, the annual adoption rate A_t, the annual depreciation rate δ_t and the without-research equilibrium price P. The supply shift K is calculated as follows for each year t of the adoption process:

$$K_t = (\Delta Y/Y\varepsilon - \Delta C/C(1+\Delta Y/Y) - f\Delta F/F)\ p\ A_t\ (1-\delta_t)^t\ P$$

2.5.3 Economic surplus models

For the economic surplus analysis several models are considered in order to take into account the characteristics of the different markets that compose the peanut sector in Senegal and to meet the objectives of the study. This section presents verbally, graphically and mathematically the models that will allow the calculation of the social benefits from research. More detail on their mathematical development can be found in appendix A.

a) The closed economy models

The first models developed are closed economy models. These models are used for the commodities that are produced and consumed in Senegal. This is the case of on farm consumption of unshelled peanuts and official and unofficial farm sales of unshelled peanuts.

a.1) On farm consumption of unshelled peanuts

Given that almost one quarter of the peanut supply is consumed on farm, the computation of the change in economic surpluses when a new technology is adopted has to be adjusted accordingly. Assuming that home consumption of own production is perfectly inelastic (Norton et al, 1987)[8], the change in surplus when a new technology is adopted corresponds to the product of the quantity consumed on farm and the change in the producer price. This amount has to be added to the producer surplus.

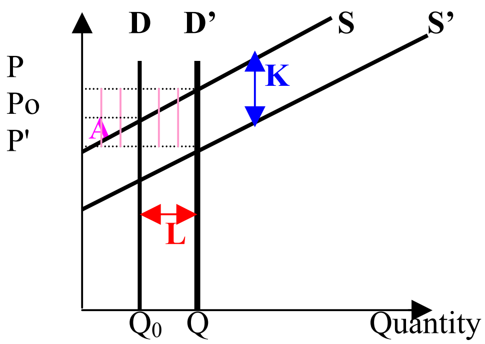
Figures 2.5 and 2.6 represent the change in surplus in the case of a parallel shift and in the case of a pivotal shift respectively from the supply curve S to the supply curve S'. In these graphs, the evaluation is done at the unofficial market price assuming that if the farmers didn't consume part of their supply, they would sell it on the unofficial market at the market price.

Figure 2.7 represents the change in surplus assuming that the evaluation is done at the producer base price. In this graph, it is assumed that if farmers didn't consume part of the supply they would sell it on the official market at the producer base price.

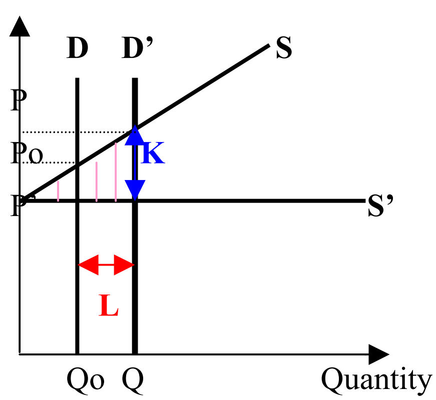
In figures 2.5 through 2.7, the computation of the economic surpluses is based on the equilibrium price P and quantity Q, obtained after the demand curve has shifted from D to D' by L=ΔQ:

$$P = P_o\,(1 + (L/Q_o)/\varepsilon)$$
$$Q = Q_o\,(1 + L/Q_o)$$

where P_o and Q_o are the pre-demand shift equilibrium price and quantity and ε is the supply elasticity.



<u>Figure 2.5:</u> On farm consumption of unshelled peanuts: Change in producers' consumer surplus when a new technology is adopted in a closed economy (parallel shift of the supply curve and parallel shift of the demand curve)

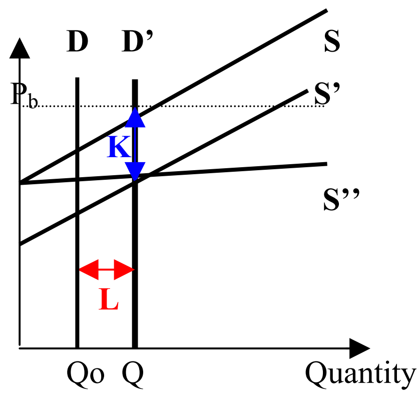


<u>Figure 2.6:</u> On farm consumption of unshelled peanuts: Change in producers' consumer surplus when a new technology is adopted in a closed economy (pivotal shift of the supply curve and parallel shift of the demand curve)

As shown in figure 2.5 (2.6), the measure of the benefits to producers from consuming part of their supply when a new technology is adopted and the supply curve

[8] Other references are in Alston et al (1995).

shifts in a parallel (pivotal) fashion is given by the area A = (P-P')Q (A = ½ (P-P')Q), where P' is the post demand and supply shifts equilibrium. Therefore, the change in consumer surplus is ΔCS = KQ (ΔCS = ½ KQ).



<u>Figure 2.7:</u> On farm consumption of unshelled peanuts: Change in producers' consumer surplus when a new technology is adopted in a closed economy where a producer base price is applied (parallel or pivotal shift of the supply curve and parallel shift of the demand curve)

As shown in figure 2.7, when a producer base price P_b is established, the consumer surplus that goes to producers is P_bQ and this amount is invariant to any shift of the supply curve (parallel or pivotal). Consequently, the adoption of a new technology doesn't affect producers' surplus from consuming part of their supply in the context of a producer base price.

a.2) Farm sales of unshelled peanuts on the unofficial market at the market price

Figures 2.8 and 2.9 represent the change in surplus in the case of a parallel supply shift and a pivotal supply shift respectively. In figure 2.10 the computation of the change in economic surpluses is based on the equilibrium obtained after the demand curve has shifted. In figures 2.8 through 2.10 the evaluation of research benefits is conducted with the unofficial market price.

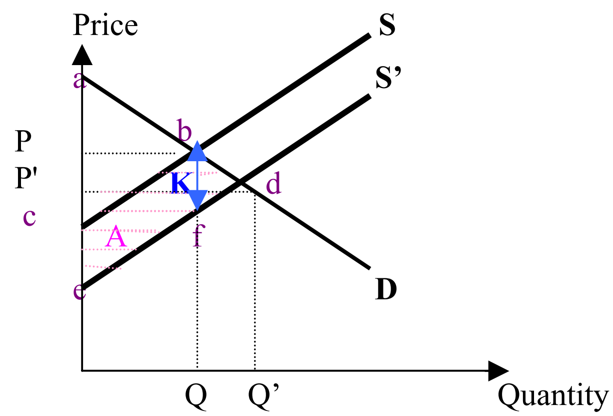


Figure 2.8: **Farm sales of unshelled peanuts on the unofficial market: Change in economic surplus when a new technology is adopted in a closed economy (parallel shift of the supply curve)**

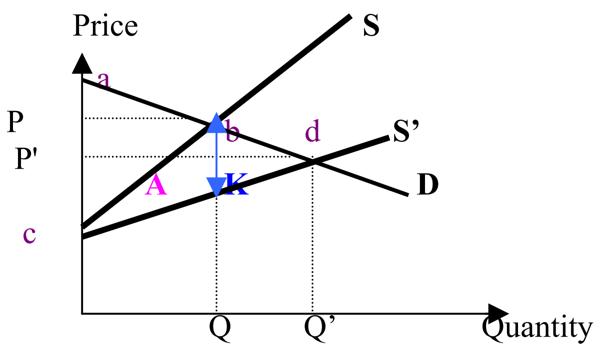
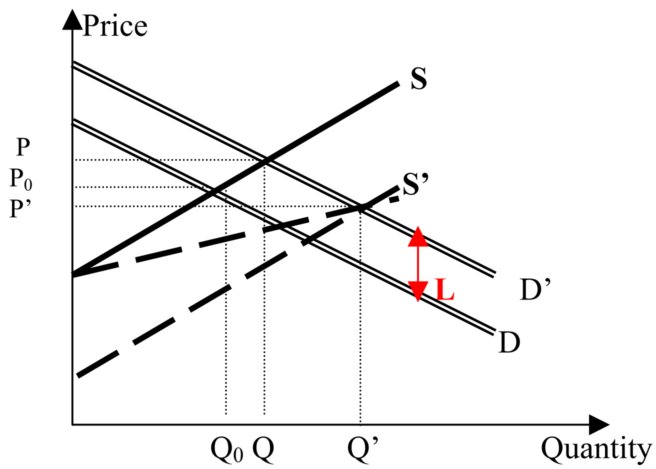


Figure 2.9: **Farm sales of unshelled peanuts on the unofficial market: Change in economic surplus when a new technology is adopted in a closed economy (pivotal shift of the supply curve)**

In figures 2.8 and 2.9, the without research consumer surplus and producer surplus are measured by the areas abP and Pbc respectively. With research, consumer surplus increases by area PbdP' and producer surplus changes by area P'de – Pbc with a parallel supply shift (P'dc – Pbc with a pivotal supply shift). The total change in surplus is measured by PbdP' + P'de – Pbc with a parallel supply shift (PbdP' + P'dc – Pbc with a pivotal supply shift), which corresponds to area A (delimited by curves S, S', and D). Using the elasticity of supply ε, the absolute value of the elasticity of demand *e*, the measure $E = K\varepsilon/(\varepsilon + e)$ and the initial competitive equilibrium price P and quantity Q, the changes in consumer surplus ΔCS, producer surplus ΔPS and total surplus ΔTS are as follows:

$$\Delta CS = EQ\,(1 + \tfrac{1}{2}\,E e/P)$$
$$\Delta PS = (K\text{-}E)Q\,(1 + \tfrac{1}{2}\,E e/P) \text{ (parallel supply shift)}$$
$$\Delta PS = \Delta TS - \Delta CS \text{ (pivotal supply shift)}$$
$$\Delta TS = KQ\,(1 + \tfrac{1}{2}\,E e/P) \text{ (parallel supply shift)}$$
$$\Delta TS = \tfrac{1}{2}\,KQ\,(1 + E e/P) \text{ (pivotal supply shift)}$$



<u>Figure 2.10:</u> Farm sales of unshelled peanuts on the unofficial market: Change in economic surplus when a new technology is adopted in a closed economy (parallel or pivotal shift of the supply curve and parallel shift of the demand curve)

In figure 2.10, the computation of the economic surpluses requires two steps. The first step is the determination of the new equilibrium when only demand has shifted by L=ΔD:

$$P = P_0(1 + (L/Q_0)/(\varepsilon+e))$$
$$Q = Q_0(1 + (L/Q_0) - ((L/Q_0)e/(\varepsilon+e))$$

The second step consists of calculating the change in economic surplus as seen above using the equilibrium price P and quantity Q.

a.3) Farm sales of unshelled peanuts on the official market at the producer base price

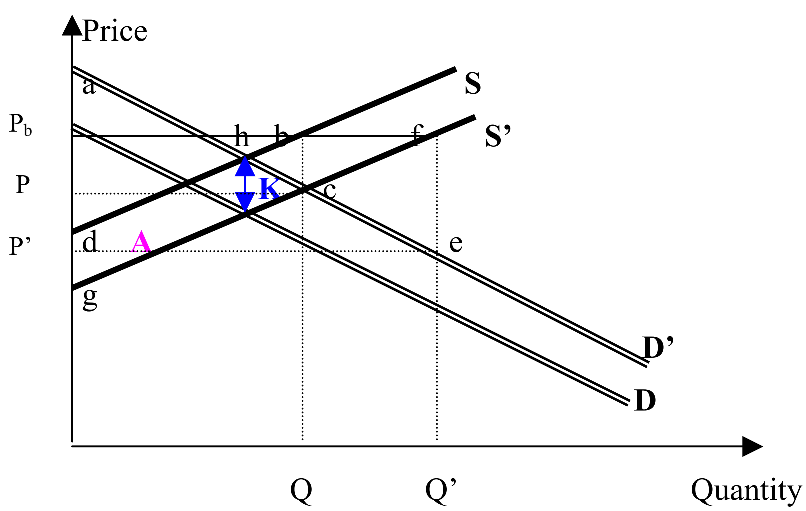
This model is used for the commodities that are sold by farmers to SONACOS. This is the case of the unshelled peanuts used as seeds and unshelled peanuts used in the oil and cake processing.

Figures 2.11 and 2.12 represent the change in surplus in the case of a parallel supply shift and a pivotal supply shift respectively. The evaluation of research benefits is achieved at the producer base price.

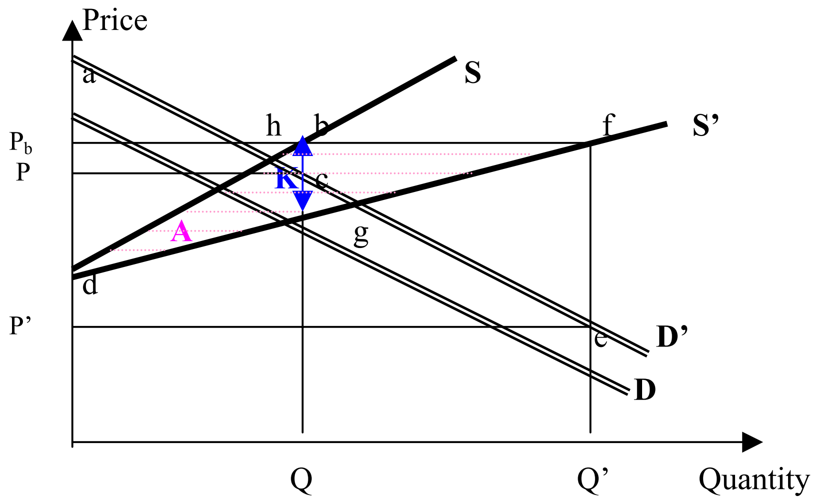
In both figures, the computation of the change in economic surplus is based on the equilibrium price P and quantity Q obtained after the demand curve has shifted by L=ΔD:

$$P = P_o (1+ (L/eQ_o)$$
$$Q = Q_o$$

where P_o and Q_o are the pre-demand shift equilibrium price and quantity and *e* is the absolute value of demand elasticity.



<u>Figure 2.11:</u> Farm sales of unshelled peanuts on the official market: Change in economic surplus when a new technology is adopted in a closed economy where a producer base price is applied (parallel shift of the supply curve and parallel shift of the demand curve)



<u>Figure 2.12:</u> Farm sales of unshelled peanuts on the official market: Change in economic surplus when a new technology is adopted in a closed economy where a producer base price is applied (pivotal shift of the supply curve and parallel shift of the demand curve)

In figures 2.11 and 2.12, without a new technology consumer surplus is measured by area acP and producer surplus is measured by area $P_b$bd. The government cost of the subsidy is measured by the area $P_b$bcP. The dead-weight loss is measured by the area bch. With a new technology, consumer surplus increases by area PceP'. Producer surplus increases by area dbfg with a parallel shift (fbd with a pivotal shift). Government cost of the subsidy increases by area PcbfeP'. The dead-weight loss increases by area cef – bch with a parallel shift (efg – bch with a pivotal shift). The total change in surplus is measured by PceP' + dbfg – PcbfeP' with a parallel shift (PceP' + fbd - bfeP'Pc with a pivotal shift), which corresponds to area A (delimited by curves S, S', and P_b). Using the measure $E = K\varepsilon/e$, and the producer base price P_b, the changes in economic surplus, the change in government cost of the subsidy ΔGC and the change in net social welfare ΔNSW are as follows:

$$\Delta CS = EQ\,(1 + \tfrac{1}{2}\,Ee/P)$$
$$\Delta PS = KQ\,(1 + \tfrac{1}{2}\varepsilon K/P_b) \text{ (parallel shift)}$$
$$\Delta PS = \tfrac{1}{2}\,KQ\,(1 + \varepsilon K/P_b) \text{ (pivotal shift)}$$
$$\Delta GC = EQ\,(1 + ((P_b - P) + E)e/P)$$

$$\Delta NSW = \Delta CS + \Delta PS - \Delta GC$$

b) Small open economy models - SONACOS exports of peanut oil and cakes at the world price

This model is used for the commodities that are produced in Senegal and are exported as well as consumed domestically. This is the case with peanut oil and cakes.

Figures 2.13 and 2.14 represent the change in surplus in the case of a parallel supply shift and a pivotal supply shift respectively. The evaluation of research benefits is done at the world price and at the SONACOS level. Figure 2.15 represents the change in surplus when demand shifts.

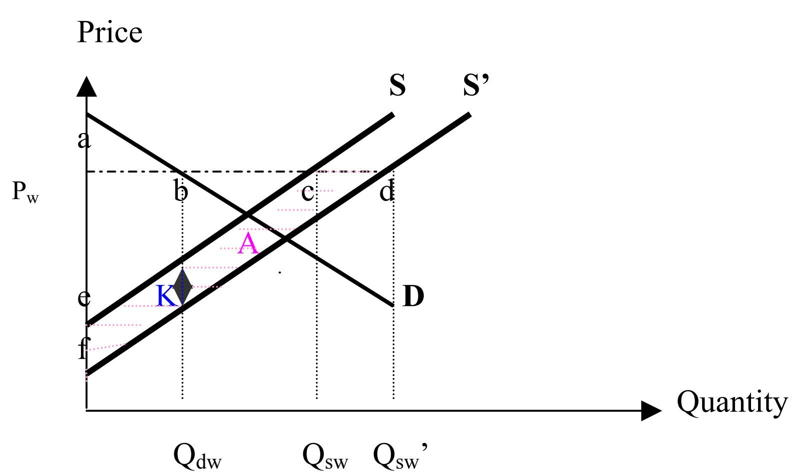
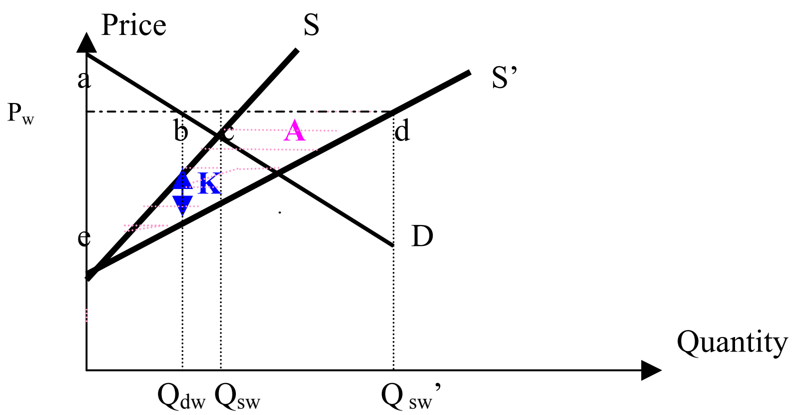


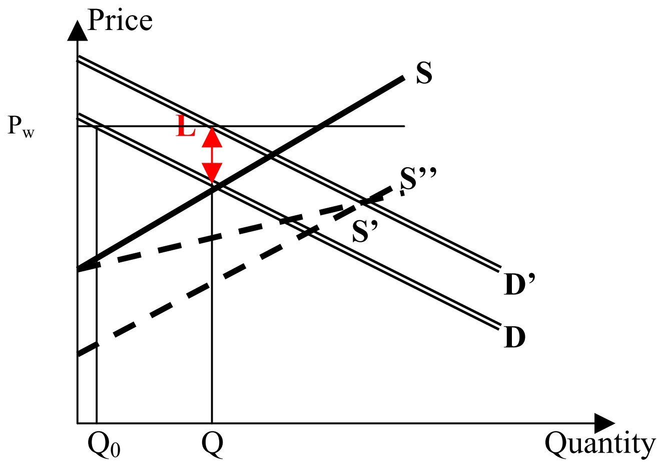
Figure 2.13: **SONACOS exports of peanut oil and cakes: Change in economic surplus when a new technology is adopted in a small open economy (parallel shift of the supply curve)**



<u>Figure 2.14:</u> SONACOS exports of peanut oil and cakes: Change in economic surplus when a new technology is adopted in a small open economy (pivotal shift of the supply curve)

In figures 2.13 and 2.14, without a new technology consumer surplus is measured by area abP_w and producer surplus is measured by area $P_w ce$. With a new technology, producer surplus increases by area ecdf with a parallel shift (ecd with a pivotal shift). Consumer surplus is not affected; consumers continue to face the same price and to consume the same quantity. Therefore, the increase in supply (Q'-Q) is totally exported. The total change in surplus is measured by the change in producer surplus, which corresponds to area A (delimited by curves S, S', and P_w). Using the world price P_w the changes in economic surpluses are as follows:

$$\Delta CS = 0$$
$$\Delta PS = KQ\,(1 + \tfrac{1}{2}\,K\varepsilon/P_w)\ \text{(parallel shift)}$$
$$\Delta PS = \tfrac{1}{2}\,KQ\,(1 + K\varepsilon/P_w)\ \text{(pivotal shift)}$$
$$\Delta TS = \Delta CS + \Delta PS$$



<u>Figure 2.15:</u> SONACOS exports of peanut oil and cakes: Change in economic surplus when a new technology is adopted in a small open economy (parallel or pivotal shift of the supply and parallel shift of the demand curve)

In figure 2.15, the consumer surplus doesn't change when the supply curve shifts. The producer surplus is affected by the supply shift, but is invariant to the demand shift. Therefore, the change in total economic surplus is only affected by the supply shift. Thus, the change in demand is not considered in the small open economy models.

2.6 The discount concept

The models described above correspond to a snapshot of one-year benefits. When producers adopt a new technology, the supply curve shifts progressively as adoption increases. The magnitude of the supply shift is determined by the adoption rate of the new technology.

As illustrated in figure 2.16, the adoption process of a new technology is characterized by four different stages: (I) a research and development lag; (II) an increasing adoption rate, as more farmers are exposed to the new technology; (III) an adoption plateau where the adoption rate is at its maximum level generally below 100%; (IV) a declining adoption rate when the new technology becomes obsolete.

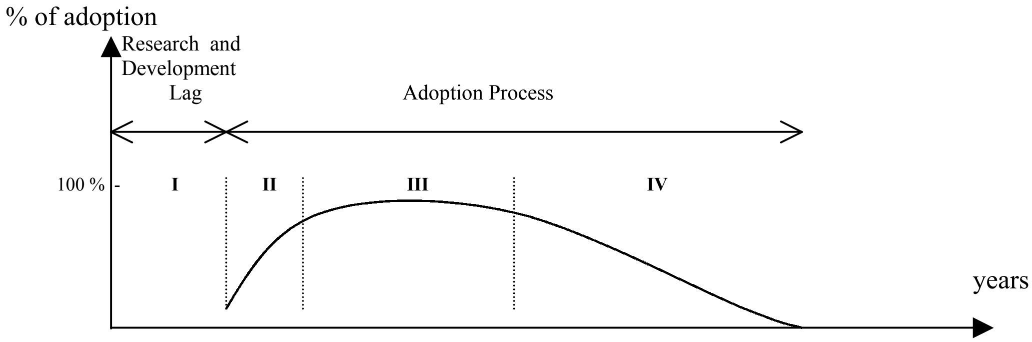


Figure 2.16: Lags in Research and adoption

Costs and benefits are associated with each lag of the development and adoption process of the new technology. Most of the costs are incurred during the research and development lag of the new technology. Some of the costs may be incurred in the beginning of the adoption process in the form of extension costs. Accordingly, in the beginning of the adoption process, the net benefits may remain negative or grow slowly. As adoption proceeds and supply shifts, research benefits grow leading to a stream of future net benefits that continues until the new technology is replaced by other new technologies. Figure 2.17 represents the costs of developing and benefits from adopting a new technology.

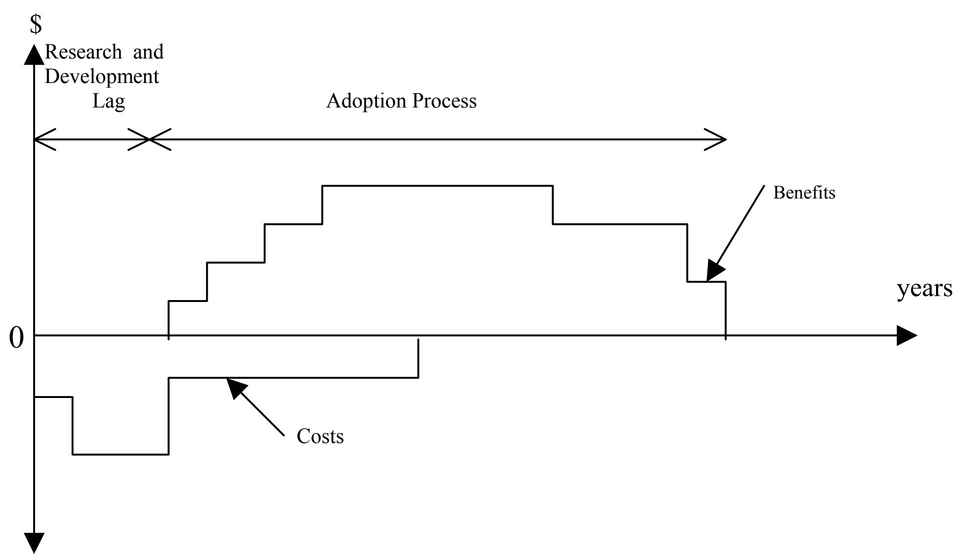


Figure 2.17: Costs and benefits in research and adoption

The evaluation of the net benefits is based on the measurement of two values, the net present value (NPV) and the internal rate of return (IRR) of the benefits of the development and the adoption of a new technology. These two measures are complementary.

The NPV determines the profitability of the new technology. This is shown by a positive value of the NPV over a period of time and for a given discount rate. The net present value of a project is the sum of the stream of future benefits B minus the costs C of the project discounted at a discount rate r during a period of time T:

$$NPV_t = \sum_{t=0}^{T} \frac{B_t - C_t}{(1 + r)^t}$$

The IRR is the discount rate at which the present value of the benefits equals the present value of the costs or the discount rate at which the NPV equals zero. It provides a ranking of alternative situations through the measurement of the net present value per unit of research and adoption investments. The discount rate is the interest rate or the opportunity cost of the funds invested by the Senegalese government. The internal return rate of a project is:

$$0 = \sum_{t=0}^{T} \frac{B_t - C_t}{(1 + IRR)^t}$$

2.7 Summary of economic surplus models

Four types of models are considered in this analysis. The first three models are closed economy models. They evaluate research benefits for the peanut commodities that are produced and consumed in Senegal. The last model is an open economy model. It evaluates research benefits for the Senegalese peanut commodities that are domestically consumed and exported as well.

The first model is used to evaluate research benefits from on farm consumption of unshelled peanuts. This evaluation is achieved at the farm level. Two possible prices can be used to evaluate farm household consumption of unshelled peanuts, the unofficial market price or the producer base price depending on the alternative destination of the unshelled peanuts consumed on farm.

The second model is used to evaluate research benefits at the farm level from farm sales of unshelled peanuts on the unofficial market. The price used is the unofficial market price of unshelled peanuts.

The third model is used to evaluate research benefits at the farm level from farm sales of unshelled peanuts on the official market. The price used is the producer base price.

The fourth model is the small open economy model. It is used to evaluate research benefits at the SONACOS level from SONACOS sales of peanut oil and cakes. The prices used are the world prices of peanut oil and cakes.