AGRICULTURAL RESEARCH IN SENEGAL:

ECONOMIC SURPLUS EVALUATION OF THE ADOPTION OF VARIETY LA FLEUR 11 BY PEANUT FARMERS

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ABSTRACT

Peanut production has been decreasing in Senegal over the past decades for historical, political, economic and environmental reasons. One of the solutions proposed by recent Senegalese administrations is to increase production through agricultural research and the development of peanut varieties that are adapted to the environmental constraints in Senegal. The last variety developed is La Fleur 11, which is very drought tolerant.

The purpose of the study is to assess the economic impact of research on La Fleur 11 on the Senegalese economy through an ex-ante evaluation of the net social benefits from the adoption of this new variety. In order to fulfill this objective, an economic surplus analysis is conducted within the framework of a partial equilibrium model.

Results indicate that the net social benefits from the adoption of La Fleur 11 are positive. Assuming that all peanut supply is sold to SONACOS at a producer base price and that research evaluation is conducted at the farm-level, Consumers (SONACOS) are the main beneficiaries from research. Their benefits are on average 6 times producers' (farmers). The research-induced increase in the government cost of the subsidy represents 84 percent on average of consumers' and producers' benefits; the research-induced increase in net social welfare represents 16 percent on average of consumers' and producers' benefits. The internal rate of return averages around 43 percent.

When peanut markets are disaggregated, research benefits consumers (SONACOS) 3 times more than producers (farmers) at the farm level. Most of producers' benefits come from farm household consumption (47 percent of total farm-level benefits) and most of consumers' benefits come from the official seed market. At the SONACOS-level where peanut oil and cakes are exported, research benefits producers (SONACOS) only; consumers (rest of the world) do not benefit from research at this level. The IRR is more likely to be about 42 percent.

This study suggests that future investments in agricultural research in Senegal can result in a positive economic impact provided that other actions are undertaken regarding extension, credit, and input distribution in order to enhance adoption and take advantage of the yield potential of the new peanut varieties. Also, this study provides a procedure of research evaluation for future use in Senegal and West Africa.

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APPENDIX A:

ALGEBRA

A.1) CLOSED ECONOMY MODEL

ε: Supply elasticity
e: Absolute value of demand elasticity

Supply function: $Q_s = a + b(P+K)$
Demand function: $Q_d = c - dP$
$a<0$, $b>0$, $c>0$ and $d>0$

At equilibrium: $Q_s = Q_d$
$a + b(P+K) = c - dP$
$bP + dP = c - a - Kb$
$P(b + d) = c - a - Kb$
$P = (c - a - Kb)/(b + d)$

Situation without research: $K=0 \rightarrow P = (c - a)/(b + d)$
Situation with research: $K\neq0 \rightarrow P' = (c - a - Kb)/(b + d)$

$P - P' = Kb/(b + d)$
$P - P' = (Kb*P/Q)/[(b + d)*P/Q]$
$P - P' = K\varepsilon/(\varepsilon + e) = E$

$Ee = (P-P')[(Q'-Q)/(P-P')]*(P/Q) = (Q'-Q)*(P/Q) \rightarrow Q'-Q = Ee\ Q/P \rightarrow (Q'-Q)/Q = Ee/P$

$P'-f = (P-f)-(P-P') = K-E$

1) PARALLEL SHIFT OF THE SUPPLY CURVE

K: Vertical shift of the supply function ($)

$\Delta CS = (P-P')\ Q + ½\ (P-P')(Q'-Q) = (P-P')\ Q\ [1 + ½(Q'-Q)/Q] = EQ\ (1 + ½\ Ee/P)$
$\Delta PS = (P'-f)Q + ½\ (P'-f)(Q'-Q) = (P'-f)Q\ (1 + ½\ (Q'-Q)/Q) = (K-E)Q\ (1 + ½\ Ee/P)$
$\Delta TS = \Delta CS + \Delta PS = EQ\ (1 + ½\ Ee/P) + (K-E)Q\ (1 + ½\ Ee/P) = KQ\ (1 + ½\ Ee/P)$

2) PIVOTAL SHIFT OF THE SUPPLY CURVE

k is the proportionate vertical shift (%)$\rightarrow$ K = kP ($)

$\Delta CS = EQ\ (1 + ½\ Ee/P)$
$\Delta PS = \Delta TS - \Delta CS$
$\Delta TS = ½\ KQ + ½\ K(Q'-Q) = ½\ KQ\ [1 + (Q'-Q)/Q] = ½\ KQ\ (1 + Ee/P)$

3) PARALLEL SHIFT OF THE DEMAND CURVE

L: Vertical shift in demand curve ($)
P_0: Initial equilibrium price (before demand shifts)

Q_0: Initial equilibrium quantity (before demand shifts)
P: Final equilibrium price (after demand shifts)
Q: Final equilibrium quantity (after demand shifts)
ε: Supply elasticity
e: Absolute value of demand elasticity

Supply function: $Q_s = a + bP$
Demand function: $Q_{do} = c_o – dP_o$ (before shift)
Demand function: $Q_d = c – dP$ (after shift)
$a<0$, $b>0$, $c>0$, $c_o>0$ and $d>0$ (the slopes of the demand curves are the same because a parallel shift is assumed)

At equilibrium:
$Q_s = Q_{do}$ and $Q_s = Q_d$
$a + bP_o = c_o – dP_o$ and $a + bP = c – dP$
$P_o = (c_o–a)/(b+d)$ and $P = (c–a)/(b+d)$

$P-P_o = (c-c_o)/(b+d)$
$P-P_o = L/b+d$
$P-P_o = (LP_o/Q_o)/[(b+d)(P_o/Q_o)] = (LP_o/Q_o)/(\varepsilon+e)$
$P = P_o + (LP_o/Q_o)/(\varepsilon+e)$
$P = P_o\ (1 + (L/Q_o)/(\varepsilon+e))$

$Q-Q_o = (c – dP) – (c_o – dP_o) = c-c_o – d(P-P_o) = L – d(LP_o/Q_o)/(\varepsilon+e) = L – Le/(\varepsilon+e)$
$Q = Q_o + L – Le/(\varepsilon+e)$
$Q = Q_o\ (1 + L/Q_o – (Le/Q_o)/(\varepsilon+e))$

4) INTRODUCTION OF A PRODUCER BASE PRICE

P_b: Producer base price
P: Consumer price before supply shift
P': Consumer price after supply shift
Q: Quantity supplied and consumed before supply shift
Q': Quantity supplied and consumed after supply shift
ε: Supply elasticity
e: Absolute value of demand elasticity
$\varepsilon = [(Q'-Q)/K]*[P_b/Q] \rightarrow (Q'-Q)/Q = \varepsilon K/P_b$

Supply function: $Q_s = a + b(P+K)$
Demand function: $Q_d = c – dP$
$a<0$, $b>0$, $c>0$ and $d>0$
Situation without research: $K=0 \rightarrow Q_s = a + bP_b$
Situation with research: $K\neq0 \rightarrow Q_s = a + b(P_b+K)$

$Q_d = c – dP \rightarrow dP = c - Q_d \rightarrow P = c/d – Q_d/d$

$P = c/d - 1/d\,(a + bP_b)$
$P' = c/d - 1/d\,(a + bP_b + bK)$
$P\text{-}P' = bK/d = \varepsilon K/e = E$

$Ee = (P\text{-}P')[(Q'\text{-}Q)/(P\text{-}P')]*(P/Q) = (Q'\text{-}Q)*(P/Q) \rightarrow Q'\text{-}Q = Ee\ Q/P \rightarrow (Q'\text{-}Q)/Q = Ee/P$

PARALLEL SHIFT OF THE SUPPLY CURVE

K: Vertical shift of the supply function ($)

$\Delta CS = (P\text{-}P')Q + ½\,(P\text{-}P')(Q'\text{-}Q) = (P\text{-}P')Q\,(1 + ½\,(Q'\text{-}Q)/Q) = EQ\,(1 + ½\,Ee/P)$
$\Delta PS = KQ + ½\,K(Q'\text{-}Q) = KQ\,(1 + ½\,(Q'\text{-}Q)/Q) = KQ\,(1 + ½\,\varepsilon K/P_b)$
$\Delta GC = (P\text{-}P')Q + (P_b\text{-}P')(Q'\text{-}Q) = EQ + (P_b\text{-}P')EeQ/P = EQ\,(1 + (P_b\text{-}P')e/P) = EQ\,(1 + ((P_b\text{-}P) + (P\text{-}P'))e/P) = EQ\,(1 + ((P_b\text{-}P) + E)e/P)$
$\Delta NSW = \Delta CS + \Delta PS - \Delta GC$

PIVOTAL SHIFT OF THE SUPPLY CURVE

k is the proportionate vertical shift (%)$\rightarrow K = kP$

$\Delta CS = (P\text{-}P')Q + ½\,(P\text{-}P')(Q'\text{-}Q) = (P\text{-}P')Q\,(1 + ½\,(Q'\text{-}Q)/Q) = EQ\,(1 + ½\,Ee/P)$
$\Delta PS = ½\,KQ + ½\,K(Q'\text{-}Q) = ½\,KQ\,(1 + (Q'\text{-}Q)/Q) = ½\,KQ\,(1 + \varepsilon K/P_b)$
$\Delta GC = (P\text{-}P')Q + (P_b\text{-}P')(Q'\text{-}Q) = EQ + (P_b\text{-}P')EeQ/P = EQ\,(1 + (P_b\text{-}P')e/P) = EQ\,(1 + ((P_b\text{-}P) + (P\text{-}P'))e/P) = EQ\,(1 + ((P_b\text{-}P) + E)e/P)$
$\Delta NSW = \Delta CS + \Delta PS - \Delta GC$

PARALLEL SHIFT OF THE DEMAND CURVE

L: Vertical shift in demand curve ($)
P_0: Initial consumer price (before demand shifts)
Q_0: Initial quantity consumed (before demand shifts)
P: Final consumer price (after demand shifts)
Q: Final quantity consumed (after demand shifts)
ε: Supply elasticity
e: Absolute value of demand elasticity

Demand function: $Q_{do} = c_o - dP_o$ (before shift)
Demand function: $Q_d = c - dP$ (after shift)
$c>0$, $c_o>0$ and $d>0$ (the slopes of the demand curves are the same because a parallel shift is assumed)
At quantity supplied Q_s at price P_b:
$Q_{do} = Q_d$
$c_o - dP_o = c - dP$
$dP - dP_o = c - c_o$
$P\text{-}P_o = (c\text{-}c_o)/d$
$P\text{-}P_o = L/d$

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

$Q_o = Q$

A.2) FARM HOUSEHOLD CONSUMPTION MODEL

P: Equilibrium price before supply shift
P': Equilibrium price after supply shift
Q_p: Quantity consumed on farm
ε: Supply elasticity
e: Absolute value of demand elasticity
$e = 0 \rightarrow P\text{-}P' = E = K\varepsilon/(\varepsilon + e) = K$

1) PARALLEL SHIFT OF THE SUPPLY CURVE

K: Vertical shift of the supply function ($)

$\Delta CS_p = EQ_p (1 + ½ Ee/P) = EQ_p = KQ_p$

2) PIVOTAL SHIFT OF THE SUPPLY CURVE

k is the proportionate vertical shift (%)$\rightarrow$ K = kP ($)

$\Delta CS_p = ½EQ_p (1 + Ee/P) = ½ EQ_p = ½ KQ_p$

3) PARALLEL SHIFT OF THE DEMAND CURVE

L: Horizontal shift in demand curve ($)
P_0: Initial equilibrium price (before demand shifts)
Q_0: Initial equilibrium quantity (before demand shifts)
P: Final equilibrium price (after demand shifts)
Q: Final equilibrium quantity (after demand shifts)
ε: Supply elasticity
e: Absolute value of demand elasticity

Supply function: $Q_s = a + bP$
Demand function: $Q_{do} = c_o$ (before shift)
Demand function: $Q_d = c$ (after shift)
a<0, b>0, c>0, c_o>0 and d>0 (the slopes of the demand curves are the same because a parallel shift is assumed)

At equilibrium:

$Q_s = Q_{do}$ and $Q_s = Q_d$
$a + bP_o = c_o$ and $a + bP = c$
$P_o = (c_o – a)/b$ and $P = (c – a)/b$

$P\text{-}P_o = (c\text{-}c_o)/b$
$P\text{-}P_o = L/b$
$P\text{-}P_o = (LP_o/Q_o)/b(P_o/Q_o) = (LP_o/Q_o)/\varepsilon$
$P = P_o + (LP_o/Q_o)/\varepsilon$
$P = P_o\,(1 + (L/Q_o)/\varepsilon)$

$Q\text{-}Q_o = c – c_o = L$
$Q = Q_o + L$
$Q = Q_o\,(1 + L/Q_o)$

4) INTRODUCTION OF A PRODUCER BASE PRICE

P_b: Producer base price
P: Consumer price before supply shift
P': Consumer price after supply shift
Q_p: Quantity consumed on farm
e: Absolute value of demand elasticity
$e = 0 \rightarrow E = P\text{-}P' = K\varepsilon/(\varepsilon + e) = K$

$\Delta CS_p = 0$ because $\Delta P_b = 0$ (parallel and pivotal shift of the supply curve)

A.3) SMALL OPEN ECONOMY MODEL

P_w: World price
Q_0: Quantity consumed
Q: Quantity supplied before supply shift
Q': Quantity supplied after supply shift
ε: Supply elasticity
$\varepsilon = [(Q'\text{-}Q)/K]*[P_w/Q] \rightarrow (Q'\text{-}Q)/Q = \varepsilon K/P_w$

1) PARALLEL SHIFT OF THE SUPPLY CURVE

K: Vertical shift of the supply function ($)

$\Delta CS = (P\text{-}P')\,Q + ½\,(P\text{-}P')(Q'\text{-}Q) = 0$ because $\Delta P = \Delta Q = 0$
$\Delta TS = \Delta PS = KQ + ½\,K(Q'\text{-}Q) = KQ\,(1 + ½\,(Q'\text{-}Q)/Q) = KQ\,(1 + ½\,\varepsilon K/P_w)$

2) PIVOTAL SHIFT OF THE SUPPLY CURVE

k is the proportionate vertical shift (%)$\rightarrow K = kP$ ($)
$\Delta CS = (P\text{-}P')\,Q + ½\,(P\text{-}P')(Q'\text{-}Q) = 0$ because $\Delta P = \Delta Q = 0$

$\Delta TS = \Delta PS = ½ KQ + ½ K(Q'-Q) = ½ KQ [1 + (Q'-Q)/Q] = ½ KQ (1 + \varepsilon K/P_w)$

A.4) OTHER FORMULAS

1) SUPPLY SHIFT K

$K = [\Delta Y/\varepsilon Y - \Delta C/C(1+\Delta Y/Y) – f\ \Delta F/F]\ p\ A_t\ (1-\delta)^t\ P$

K: Vertical shift of the supply curve ($)

$\Delta Y/Y$: Expected relative increase in experimental yield per hectare
$\Delta Y/\varepsilon Y$: Conversion of experimental yield increase (horizontal shift) into a gross proportionate reduction in marginal cost per ton of output (vertical shift)

$\Delta C/C$: Proportionate variable input cost change per hectare
$\Delta C/C(1+\Delta Y/Y)$: Proportionate variable input cost change per ton of output

$\Delta F/F$: Proportionate fixed input cost change per ton of output
f: Fraction of pre-research cost per ton of output that accounts for allocatable fixed factors

p: Probability of success

A_t: Adoption rate

$(1-\delta)$: Depreciation factor

P: Pre-research equilibrium price

t: year t

APPENDIX B:

DATA

B.1) LIST OF MODELS

- **Unshelled peanuts – Total (100%)**
  - ➧ Producer base price
    - • Pessimistic adoption profile
      - ★ Parallel shift 1
      - ★ Pivotal shift 2
    - • Optimistic adoption profile
      - ★ Parallel shift 3
      - ★ Pivotal shift 4

- **Unshelled peanuts – On farm consumption (24%)**
  - ➧ Unofficial market price
    - • Pessimistic adoption profile
      - ★ Parallel shift 5
      - ★ Pivotal shift 6
    - • Optimistic adoption profile
      - ★ Parallel shift 7
      - ★ Pivotal shift 8
  - ➧ Producer base price
    - • Pessimistic adoption profile
      - ★ Parallel shift 9
      - ★ Pivotal shift 10
    - • Optimistic adoption profile
      - ★ Parallel shift 11
      - ★ Pivotal shift 12

- **Unshelled peanuts – Informal market (10%)**
  - ➧ Unofficial market price
    - • Pessimistic adoption profile
      - ★ Parallel shift 13
      - ★ Pivotal shift 14
    - • Optimistic adoption profile
      - ★ Parallel shift 15
      - ★ Pivotal shift 16

- **Peanut seeds – Formal market (15%)**
  - ➧ Producer base price
    - • Pessimistic adoption profile
      - ★ Parallel shift 17
      - ★ Pivotal shift 18
    - • Optimistic adoption profile
      - ★ Parallel shift 19
      - ★ Pivotal shift 20

- **Peanut oil – Formal market (17.5%)**
  - ➧ World price
    - • Pessimistic adoption profile
      - ★ Parallel shift 21
      - ★ Pivotal shift 22
    - • Optimistic adoption profile
      - ★ Parallel shift 23
      - ★ Pivotal shift 24

- **Peanut cakes – Formal market (17.5%)**
  - ➧ World price
    - • Pessimistic adoption profile
      - ★ Parallel shift 25
      - ★ Pivotal shift 26
    - • Optimistic adoption profile
      - ★ Parallel shift 27
      - ★ Pivotal shift 28

B.2) SPREADSHEETS

1) UNSHELLED PEANUTS (TOTAL) – PRODUCER BASE PRICE

- Supply elasticity: $\varepsilon = 0.77$ (Akobundu, 1998)
- Demand elasticity: $e = 0.18$ (Sullivan et al, 1992)

- Proportionate yield change per hectare: $\Delta Y/Y = 0.30$ (Ndoye, July 19th, 2000)
- Gross proportionate cost reduction per ton of output: $\Delta Y/\varepsilon Y = 0.30/0.77 = 0.39$
- Proportionate additional cost per hectare: $\Delta C/C = 0.20$ (Table 3.16)
- Proportionate additional cost per ton of output: $\Delta C/C(1+\Delta Y/Y) = 0.20/(1+0.30) = 0.15$
- Net proportionate cost reduction per ton of output: $\Delta Y/\varepsilon Y - \Delta C/C(1+\Delta Y/Y) = 0.39 – 0.15 = 0.24$

- Probability of research success: $p = 1$
- Adoption rate: A_t (Table 3.17)

- Supply shift: $K_t = [\Delta Y/\varepsilon Y - \Delta C/C(1+\Delta Y/Y)]pA_tP_b$
- Proportionate decrease in price: $E_t = K_t\varepsilon/e$

- Proportionate change in population: $u = 0.027$ (Senegal, Republic of, Direction de la Prévision et de la Statistique, 1999)
- Proportionate change in per capita income: $i = 0.0063$ (average of years 1976-86,1987-97 and 1998-02: -0.011-0.004+0.034/3) (IMF, 1998)
- Income elasticity of demand: $e_{ii}+\Sigma e_{ij}+n_i = 0 \rightarrow$ assuming $\Sigma e_{ij}=0$, $n_i = - e_{ii} = 0.18$
- Proportionate change in demand: $u + in = 0.028$ (approximation for L/Q_o)

- Initial consumer price (before demand shift): $P_o = 144$ FCFA/kg (average of years 1996-1999: 183+137.656+114+142/4) (Senegal, Republic of, Ministère de l'Economie, des Finances et du Plan, 2000 a)
- Final consumer price (after demand shift): $P = P_o(1 + (L/Q_o)/e) = 167$ FCFA/kg
- Producer base price: $P_b = 146.5$ FCFA/kg (average of years 1996-1999: 131+150+160+145/4) (Senegal, Republic of, Ministère de l'Economie, des Finances et du Plan, 2000 a)

- Initial quantity (before demand shift): $Q_o = 599{,}731$ 1000kg (average of years 1996-1999 for oil seeds: 588,181+505,894+540,773+764,077/4) (Senegal, Republic of, Ministry of Agriculture, 2000)
- Final quantity (after demand shift): $Q = Q_o = 599{,}731$ 1000kg

- Change in consumer surplus: $\Delta CS = EQ(1+½Ee/P)$ (parallel and pivotal shift)
- Change in producer surplus: $\Delta PS = KQ(1+½\varepsilon K/P_b)$ (parallel shift) or $\Delta PS = ½KQ(1+\varepsilon K/P_b)$ (pivotal shift)
- Change in cost of subsidy: $\Delta GC = EQ\ (1 + ((P_b-P) + E)e/P)$
- Change in net social welfare: $\Delta NSW = \Delta CS + \Delta PS - \Delta GC$

- Cost of salaries: max annual public salary * scientists + minimum annual public salary * assistants for each year between 1985 and 1996 (Table 3.18)
- Research costs: RC = 1.2 * cost of salaries

- Net total benefits: NB = ΔTS – RC
- Discount rate: 0.0625 (1998) (IMF, 2000)
- Net present value in FCFA: (NB, 0.0625)
- Exchange rate: 615.70 FCFA/US$ (1999) (CIA, 2001)
- Net present value in US$: NPV in FCFA/exchange rate

2) UNSHELLED PEANUTS (ON FARM CONSUMPTION) - UNOFFICIAL PRICE

- Supply elasticity: $\varepsilon = 0.77$ (Akobundu, 1998)
- Demand elasticity: $e = 0$

- Proportionate yield change per hectare: $\Delta Y/Y = 0.30$ (Ndoye, July 19th, 2000)
- Gross proportionate cost reduction per ton of output: $\Delta Y/\varepsilon Y = 0.30/0.77 = 0.39$
- Proportionate additional cost per hectare: $\Delta C/C = 0.21$ (Table 3.16)
- Proportionate additional cost per ton of output: $\Delta C/C(1+\Delta Y/Y) = 0.21/(1+0.30) = 0.16$
- Net proportionate cost reduction per ton of output: $\Delta Y/\varepsilon Y - \Delta C/C(1+\Delta Y/Y) = 0.39 - 0.16 = 0.23$

- Probability of research success: p = 1
- Adoption rate: A_t (Table 3.17)

- Supply shift: $K_t = [\Delta Y/\varepsilon Y - \Delta C/C(1+\Delta Y/Y)]pA_tP$
- Proportionate decrease in price: $E_t = K\varepsilon/(\varepsilon + e) = K_t$

- Proportionate change in population: u = 0.027 (Senegal, Republic of, Direction de la Prévision et de la Statistique, 1999)
- Proportionate change in per capita income: i = 0.0063 (average of years 1976-86,1987-97 and 1998-02: -0.011-0.004+0.034/3) (IMF, 1998)
- Income elasticity of demand: $e_{ii}+\Sigma e_{ij}+n_i = 0 \rightarrow$ assuming $\Sigma e_{ij}=0$, $n_i = - e_{ii} = 0.18$
- Proportionate change in demand: $u + in = 0.028$ (approximation for L/Q_o)

- Initial price (before demand shift): $P_o = 135.5$ FCFA/kg (average of years 1995 and 1996: 125.4+128+129.5+130.3+139.7+160.4/6) (Gaye, 1997)
- Final price (after demand shift): $P = P_o(1 + (L/Q_o)/\varepsilon) =$ 141 FCFA/kg

- Initial quantity: $Q_o = 0.24*599{,}731 = 143{,}935$ 1000kg
- Final quantity: $Q = Q_o(1+L/Q_o) = 147{,}985$ 1000kg

- Change in consumer surplus: $\Delta CS = EQ$ (parallel shift) or $\Delta CS = ½\ EQ$ (pivotal shift)

3) Unshelled peanuts (on farm consumption) – Producer base price

- Supply elasticity: $\varepsilon = 0.77$ (Akobundu, 1998)
- Demand elasticity: $e = 0$

- Proportionate yield change per hectare: $\Delta Y/Y = 0.30$ (Ndoye, July 19th, 2000)
- Gross proportionate cost reduction per ton of output: $\Delta Y/\varepsilon Y = 0.30/0.77 = 0.39$
- Proportionate additional cost per hectare: $\Delta C/C = 0.20$ (Table 3.16)
- Proportionate additional cost per ton of output: $\Delta C/C(1+\Delta Y/Y) = 0.20/(1+0.30) = 0.15$
- Net proportionate cost reduction per ton of output: $\Delta Y/\varepsilon Y - \Delta C/C(1+\Delta Y/Y) = 0.39 - 0.15 = 0.24$

- Probability of research success: $p = 1$
- Adoption rate: A_t (Table 3.17)

- Supply shift: $K_t = [\Delta Y/\varepsilon Y - \Delta C/C(1+\Delta Y/Y)]pA_tP_b$
- Proportionate decrease in price: $E_t = K\varepsilon/(\varepsilon + e) = K_t$

- Proportionate change in population: $u = 0.027$ (Senegal, Republic of, Direction de la Prévision et de la Statistique, 1999)
- Proportionate change in per capita income: $i = 0.0063$ (average of years 1976-86,1987-97 and 1998-02: $-0.011-0.004+0.034/3$) (IMF, 1998)
- Income elasticity of demand: $e_{ii}+\Sigma e_{ij}+n_i = 0 \rightarrow$ assuming $\Sigma e_{ij}=0$, $n_i = - e_{ii} = 0.18$
- Proportionate change in demand: $u + in = 0.028$ (approximation for L/Q_o)

- Producer base price: $P_b = 146.5$ FCFA/kg

- Initial quantity: $Q_o = 0.24*599{,}731 = 143{,}935$ 1000kg
- Final quantity: $Q = Q_o (1+L/Q_o) = 147{,}985$ 1000kg

- Change in consumer surplus: $\Delta CS = 0$ (parallel and pivotal shift)

4) UNSHELLED PEANUTS – INFORMAL MARKET – UNOFFICIAL PRICE

- Supply elasticity: $\varepsilon = 0.77$ (Akobundu, 1998)
- Demand elasticity: $e = 0.18$ (Sullivan et al, 1992)

- Proportionate yield change per hectare: $\Delta Y/Y = 0.30$ (Ndoye, July 19th, 2000)
- Gross proportionate cost reduction per ton of output: $\Delta Y/\varepsilon Y = 0.30/0.77 = 0.39$
- Proportionate additional cost per hectare: $\Delta C/C= 0.21$ (Table 3.16)
- Proportionate additional cost per ton of output: $\Delta C/C(1+\Delta Y/Y) = 0.21/(1+0.30) = 0.16$
- Net proportionate cost reduction per ton of output: $\Delta Y/\varepsilon Y - \Delta C/C(1+\Delta Y/Y) = 0.39 – 0.16 = 0.23$

- Probability of research success: $p = 1$
- Adoption rate: A_t (Table 3.17)

- Supply shift: $K_t = [\Delta Y/\varepsilon Y - \Delta C/C(1+\Delta Y/Y)]pA_tP$
- Proportionate decrease in price: $E_t = K_t\varepsilon/(\varepsilon + e)$

- Proportionate change in population: $u = 0.027$ (Senegal, Republic of, Direction de la Prévision et de la Statistique, 1999)
- Proportionate change in per capita income: $i = 0.0063$ (average of years 1976-86,1987-97 and 1998-02: -0.011-0.004+0.034/3) (IMF, 1998)
- Income elasticity of demand: $e_{ii}+\Sigma e_{ij}+n_i = 0 \rightarrow$ assuming $\Sigma e_{ij}=0$, $n_i = - e_{ii} = 0.18$
- Proportionate change in demand: $u +in = 0.028$ (approximation for L/Q_o)

- Initial price (before demand shift): $P_o = 135.5$ FCFA/kg
- Final price (after demand shift): $P = P_o(1 + (L/Q_o)/(\varepsilon + e)) =$ 141 FCFA/kg

- Initial quantity: $Q_o = 0.10*599{,}731 = 59{,}973$ 1000kg
- Final quantity: $Q = Q_o (1 + L/Q_o – (Le/Q_o)/(\varepsilon+e)) = 61{,}341$ 1000kg

- Change in consumer surplus: $\Delta CS = EQ(1+½Ee/P)$ (parallel and pivotal shift)
- Change in producer surplus: $\Delta PS = (K-E)Q(1+½Ee/P)$ (parallel shift) or $\Delta PS = \Delta TS-\Delta CS$ (pivotal shift)
- Change in total surplus: $\Delta TS = KQ (1+ ½ Ee/P)$ (parallel shift) or $\Delta TS = ½KQ (1+ Ee/P)$ (pivotal shift)

- Cost of salaries: max annual public salary * scientists + minimum annual public salary * number of assistants for each year between 1985 and 1996 (Table 3.18)
- Research costs: RC = 0.10*1.2 * cost of salaries

- Net total benefits: NB = ΔTS – RC
- Discount rate: 0.0625 (1998) (IMF, 2000)
- Net present value in FCFA: (NB, 0.0625)
- Exchange rate: 615.70 FCFA/US$ (1999) (CIA, 2001)
- Net present value in US$: NPV in FCFA/exchange rate

5) PEANUT SEEDS – FORMAL MARKET – PRODUCER BASE PRICE

- Supply elasticity: $\varepsilon = 0.77$ (Akobundu, 1998)
- Demand elasticity: $e = 0.18$ (Sullivan et al, 1992)

- Proportionate yield change per hectare: $\Delta Y/Y = 0.30$ (Ndoye, July 19th, 2000)
- Gross proportionate cost reduction per ton of output: $\Delta Y/\varepsilon Y = 0.30/0.77 = 0.39$
- Proportionate additional cost per hectare: $\Delta C/C= 0.20$ (Table 3.16)
- Proportionate additional cost per ton of output: $\Delta C/C(1+\Delta Y/Y) = 0.20/(1+0.30) = 0.15$
- Net proportionate cost reduction per ton of output: $\Delta Y/\varepsilon Y - \Delta C/C(1+\Delta Y/Y) = 0.39 – 0.15 = 0.24$

- Probability of research success: $p = 1$
- Adoption rate: A_t (Table 3.17)

- Supply shift: $K_t = [\Delta Y/\varepsilon Y - \Delta C/C(1+\Delta Y/Y)]pA_tP_b$
- Proportionate decrease in price: $E_t = K_t\varepsilon/e$

- Proportionate change in population: $u = 0.027$ (Senegal, Republic of, Direction de la Prévision et de la Statistique, 1999)
- Proportionate change in per capita income: $i = 0.0063$ (average of years 1976-86,1987-97 and 1998-02: -0.011-0.004+0.034/3) (IMF, 1998)
- Income elasticity of demand: $e_{ii}+\Sigma e_{ij}+n_i = 0 \rightarrow$ assuming $\Sigma e_{ij}=0$, $n_i = - e_{ii} = 0.18$
- Proportionate change in demand: $u + in = 0.028$ (approximation for L/Q_o)

- Initial consumer price (before demand shift): $P_o = 144$ FCFA/kg (average of years 1996-1999: 183+137.656+114+142/4) (Senegal, Republic of, Ministère de l'Economie, des Finances et du Plan, 2000 a)
- Final consumer price (after demand shift): $P = P_o(1 + (L/Q_o)/e) = 167$ FCFA/kg
- Producer base price: $P_b = 146.5$ FCFA/kg (average of years 1996-1999: 131+150+160+145/4) (Senegal, Republic of, Ministère de l'Economie, des Finances et du Plan, 2000 a)

- Initial quantity (before demand shift): $Q_o = 0.15*599,731 = 89,960$ 1000kg
- Final quantity (after demand shift): $Q = Q_o = 89,960$ 1000kg

- Change in consumer surplus: $\Delta CS = EQ(1+½Ee/P)$ (parallel and pivotal shift)
- Change in producer surplus: $\Delta PS = KQ(1+½\varepsilon K/P_b)$ (parallel shift) or $\Delta PS = ½KQ(1+\varepsilon K/P_b)$ (pivotal shift)
- Change in cost of subsidy: $\Delta GC = EQ (1 + ((P_b-P) + E)e/P)$
- Change in net social welfare: $\Delta NSW = \Delta CS + \Delta PS - \Delta GC$

- Cost of salaries: max annual public salary * scientists + minimum annual public salary * number of assistants for each year between 1985 and 1996 (Table 3.18)
- Research costs: $RC = 0.15*1.2$ * cost of salaries

- Net total benefits: NB = ΔTS – RC
- Discount rate: 0.0625 (1998) (IMF, 2000)
- Net present value in FCFA: (NB, 0.0625)
- Exchange rate: 615.70 FCFA/US$ (1999) (CIA, 2001)
- Net present value in US$: NPV in FCFA/exchange rate

6) PEANUT OIL – FORMAL MARKET – WORLD PRICE

- Supply elasticity: $\varepsilon = 0.30$ (Sullivan et al, 1992)
- Demand elasticity: $e = 0.20$ (Sullivan et al, 1992)

- Proportionate yield change per hectare: $\Delta Y/Y = 0.30$ (Ndoye, July 19th, 2000)
- Gross proportionate cost reduction per ton of output: $\Delta Y/\varepsilon Y = 0.30/0.77 = 0.39$
- Proportionate additional cost per hectare: $\Delta C/C = 0.20$ (Table 3.16)
- Proportionate additional cost per ton of output: $\Delta C/C(1+\Delta Y/Y) = 0.20/(1+0.30) = 0.15$
- Net proportionate cost reduction per ton of output: $\Delta Y/\varepsilon Y - \Delta C/C(1+\Delta Y/Y) = 0.39 - 0.15 = 0.24$

- Probability of research success: $p = 1$
- Adoption rate: A_t (Table 3.17)

- Supply shift: $K_t = [\Delta Y/\varepsilon Y - \Delta C/C(1+\Delta Y/Y)]pA_tP_b$

- World price: $P_w = 909$ \$/ton (average of years 1994-2000: 1,023+991+897+1,009+917+788+740/7) (Senegal, Republic of, Ministère de l'Economie, des Finances et du Plan, 2000 a)
  $P_w = 909*560.11/1000 = 509$ FCFA/kg (Table 3.15)

- Quantity supplied: $Q = 0.175*599{,}731 = 104{,}953$ 1000kg

- Change in consumer surplus: $\Delta CS = 0$
- Change in producer surplus: $\Delta PS = KQ\ (1 + ½\ \varepsilon K/P_w)$ (parallel shift) or $\Delta PS = ½KQ\ (1+\varepsilon K/P_w)$ (pivotal shift)
- Change in total surplus: $\Delta TS = \Delta CS + \Delta PS$

- Cost of salaries: max annual public salary * scientists + minimum annual public salary * number of assistants for each year between 1985 and 1996 (Table 3.18)
- Research costs: $RC = 0.175*1.2$ * cost of salaries

- Net total benefits: $NB = \Delta TS - RC$
- Discount rate: 0.0625 (1998) (IMF, 2000)
- Net present value in FCFA: (NB, 0.0625)
- Exchange rate: 615.70 FCFA/US\$ (1999) (CIA, 2001)
- Net present value in US\$: NPV in FCFA/exchange rate

7) PEANUT CAKES – FORMAL MARKET – WORLD PRICE

- Supply elasticity: $\varepsilon = 0.30$ (Sullivan et al, 1992)
- Demand elasticity: $e = 0.20$ (Sullivan et al, 1992)

- Proportionate yield change per hectare: $\Delta Y/Y = 0.30$ (Ndoye, July 19th, 2000)
- Gross proportionate cost reduction per ton of output: $\Delta Y/\varepsilon Y = 0.30/0.77 = 0.39$
- Proportionate additional cost per hectare: $\Delta C/C= 0.20$ (Table 3.16)
- Proportionate additional cost per ton of output: $\Delta C/C(1+\Delta Y/Y) = 0.20/(1+0.30) = 0.15$
- Net proportionate cost reduction per ton of output: $\Delta Y/\varepsilon Y - \Delta C/C(1+\Delta Y/Y) = 0.39 – 0.15 = 0.24$

- Probability of research success: $p = 1$
- Adoption rate: A_t (Table 3.17)

- Supply shift: $K_t = [\Delta Y/\varepsilon Y - \Delta C/C(1+\Delta Y/Y)]pA_tP_b$

- World price: $P_w = 160$ \$/ton (average of years 1994-2000: 168+169+213+221+116+102+130/7) (Senegal, Republic of, Ministère de l'Economie, des Finances et du Plan, 2000 a)
  $P_w = 160*560.11/1000 = 90$ FCFA/kg (Table 3.15)

- Quantity supplied: $Q = 0.175*599,731 = 104,953$ 1000kg

- Change in consumer surplus: $\Delta CS = 0$
- Change in producer surplus: $\Delta PS = KQ (1 + ½ \varepsilon K/P_w)$ (parallel shift) or $\Delta PS = ½KQ (1+\varepsilon K/P_w)$ (pivotal shift)
- Change in total surplus: $\Delta TS = \Delta CS + \Delta PS$

- Cost of salaries: max annual public salary * scientists + minimum annual public salary * number of assistants for each year between 1985 and 1996 (Table 3.18)
- Research costs: RC = 0.175*1.2 * cost of salaries

- Net total benefits: $NB = \Delta TS – RC$
- Discount rate: 0.0625 (1998) (IMF, 2000)
- Net present value in FCFA: (NB, 0.0625)
- Exchange rate: 615.70 FCFA/US\$ (1999) (CIA, 2001)
- Net present value in US\$: NPV in FCFA/exchange rate

APPENDIX C:

PEANUT CRSP

THE PEANUT COLLABORATIVE RESEARCH SUPPORT PROGRAM (CRSP) OF USAID

In 1975, an amendment to the Foreign Assistance Act of 1961 known as Title XII (Famine prevention and freedom from hunger) sought to ”improve the participation of the agriculturally related universities in the United States' governmental efforts internationally to increase world food production and provide support to the application of science to solving developing countries food and nutrition problems.” (Peanut CRSP web page, 2001). In 1979, USAID, which was established under the 1961 Act to expand agricultural research and development programs in developing countries, created the first Collaborative Research Support Programs (CRSPs) in collaboration with the Board for International Food and Agricultural Development (BIFAD).

The CRSPs are communities of Land Grant Universities working with public and private U.S. and international institutions. They pursue the international food and agricultural research mandate of the US Government. There are now nine CRSPs to benefit agriculture in developing countries and in the US as well. USAID, other institutions in the U.S. and collaborating countries fund them.

The University of Georgia, Griffin, manages the peanut CRSP, which was initiated in 1982. The goals of the program are to sustainably develop peanut production and marketing systems, to enhance human resources, to develop research and to facilitate the communication of its results. The objectives underlying these goals are:

- decreasing or eliminating aflatoxin contamination,
- improving production efficiency and sustainability,

- improving the post-harvest and marketing technologies to offer a nutritionally enhanced product,
- encouraging the development and the adoption of profitable technologies using training, information and program support.

The peanut CRSP is implemented in several regions of the world (West Africa, Southern Africa, Eastern Europe, South America, Caribbean and Southeast Asia). It is particularly active in West Africa where peanuts are one of the most important crops for development.

CHAPTER 1:

THE PEANUT SECTOR IN SENEGAL

1.1 Introduction

Peanut production in Senegal has experienced a steady decline over the past decades for historical, political, economic and environmental reasons. In order to reverse this downward trend and ensure future growth in peanut output, the government undertook several initiatives among which was the development of agricultural research in collaboration with international organizations. One recent result of this collaboration was the release by the Senegalese Institute of Agricultural Research (ISRA) of a new peanut variety, La Fleur 11, which is expected to improve peanut productivity. The purpose of this study is to conduct an ex-ante evaluation of research on La Fleur 11. The magnitude of the net social benefits from the adoption of this new peanut variety in Senegal will be determined.

1.2 Peanut sector in Senegal

Peanut production and processing represent an important part of the agricultural and economic activities in Senegal. In 1997-98, 788,120 hectares of peanuts were planted, representing 37 percent of the country's total cultivated area. It was the second largest crop after millet (821,238 hectares) (Senegal, Republic of, Ministry of Agriculture, 1998 a). Peanut exports represented 5 percent of total exports in 1997 (IMF, 1998) and 52 percent of agricultural exports in 1998 (FAO, 2001). Peanuts generate 80 percent of farmers' revenues from sales (Gaye, 1999) and are the most important source of foreign exchange (Bravo-Ureta, 1998). This section provides a description of the peanut sector and its problems regarding production, storage and marketing.

1.2.1 Peanut production

In 1996, the varietal map for peanuts in Senegal was subdivided into five agro-climatic regions: the extreme north, the north, the central, the south and the extreme south. These regions cover the following administrative sub-divisions:

- Saint-Louis (only Dagana, Podor and Richard Toll) in the extreme north,
- Louga in the north,
- Thies (except Dakar) and Djourbel in the central,
- Fatick, Kaolack, north of Tambacounda in the south,
- South of Tambacounda, Kolda and Ziguinchor in the extreme south.

The climate and nature of soil differentiate the five agro-climatic regions identified in Senegal. As one moves from north to south, the amount of rainfall and the clay content of soils increase. Different varieties of peanuts have been adapted to these regions depending on the duration of the growth cycle of the plants and on the amount of rainfall in each area. Table 1.1 is a description of these agro-climatic regions according to their climatic characteristics and the peanut varieties that have been adapted to each region. This table represents the entire country, but most of the peanut area is located in the peanut basin, which covers the north, central and part of the south. The majority of peanut varieties are grown for peanut oil production.

Table 1.1: Characteristics of the regions of peanut production in Senegal

	Extreme North (Vallée du Fleuve Sénégal)	**North**	**Central**	**South**	**Extreme South**
Administrative subdivisions	Saint-Louis (only Dagana, Podor, and Richard Toll)	Louga	Djourbel Thies (except Dakar)	Fatick Kaolack Tambacounda (north) Ziguinchor Kolda	Tambacounda (south) Kolda Ziguinchor
Rainfall (mm/year)	Irrigated	Less than 300	300-500	500-700	700-1100
Duration of peanut plant growth cycle	Middle cycle (90 days)	Short cycle (65-75 days)	Middle cycle (85-95 days)	Long cycle (95-120 days)	Very Long cycle (125 days)
Adapted varieties*	55-437: 90 days La Fleur 11: 90 days	GC8-35: 80 days 55-437: 90 days	55-437: 90 days La Fleur 11: 90 days	73-33: 105 GH119-20:110 days 28-206: 120 days 57-313: 125 days 69-101: 125 days	57-313: 125 days 69-101: 125 days

*: Except GH119-20, which is a confectionery variety, all the other varieties are grown for oil. GH119-20 was imported from the USA. The use of this variety is now declining because it is not well adapted to the climate. It is being replaced by a new variety developed in Senegal, H75-0.
Source: (Ndoye; July 19^{th}, 2000).

The successful development and extension of short-cycle varieties that adapt well to dry conditions reduced the yield difference between the low rainfall and high rainfall zones. Peanuts are produced with an average yield of 900 kg/ha[1] (Senegal, Republic of, Ministry of Agriculture, 1998 a). Peanut supply is inelastic due to the high dependence of farmers' revenues on peanut production and their lack of diversification.

For the period 1982-1996, the average farm size varied between 2.9 hectares and 13.7 hectares and the average land in peanuts varied between 0.4 hectares and 6.5 hectares per farm depending on the regions of production (Bravo-Ureta, Hathie and Thiam, 1998). Thus, Senegalese peanut growers are small farmers.

Production equipment is generally rudimentary and is fully depreciated. It generally consists of non-motorized tools. Labor may be a constraint, especially during the planting, weeding and harvest periods.

The informal market generally provides seeds of old varieties and Sonagraines (Société Nationale d'Approvisionnement en Graines), a public seed distribution company, provides seeds of new or certified varieties. Recently, another institution has been involved in seed distribution, Union Nationale Interprofessionnelle des Semenciers (UNIS), which is an association consisting of private seed providers. Sonagraines and UNIS sell seeds to contracted farmers. The seed supply is insufficient, which limits farmers' peanut income and capacity to purchase productivity enhancing inputs (Crawford et al, 1996). Crawford et al (1996) argue that the seed problem is more a demand problem than a supply problem. They propose several solutions to improve farmers' capacity to purchase seeds: increasing credit availability, enhancing the

[1] According to CIRAD (Centre de Coopération Internationale en Recherche Agronomique pour le Développement) researchers, the national peanut yields provided by the government are overestimated

flexibility of the credit payments, promoting non-cropping sources of cash income, promoting sale and availability of certified seeds year round, encouraging competition in seed production and marketing, increasing distribution points and encouraging sales in smaller units.

Farmers have used less fertilizer in recent decades. As a consequence, soil fertility has declined causing peanut yield to fall. In general, inappropriate production practices caused natural resource degradation (soil erosion, desertification) that has been aggravated by declining rainfall and a shorter growing season. As a consequence, arable land declined and output decreased. In some cases, producers offset the decline in soil productivity by employing a millet-peanut rotation.

Farmers seldom use pesticides and fungicides for crop protection except in irrigated areas and in some cases for new varieties. According to Crawford et al (1996), the extension programs do not sufficiently promote the use of these chemicals. Moreover, farmers have inadequate cash reserves and poor access to credit, preventing them from purchasing adequate amounts of inputs.

In conclusion, there is currently a trend towards a decline in peanut output in Senegal. The next section presents the macroeconomic reasons for this output decline.

1.2.2 Peanut marketing

In 1996-97, 76 percent of Senegalese peanut production was sold. The rest was stored for seeds (9 percent), consumed (3 percent) or used for charity, gifts and payments in kind (12 percent) (Gaye, 1997). Peanuts are sold through two markets, the official

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(Bravo-Ureta et al, 1998).

market (65 percent of the supply) and the unofficial market (11 percent of the supply)[2]. The unofficial market is quickly developing due to some weaknesses in the official market (lower price, weighing problems, long distances to the collection points, limited access to credit and inputs and so forth). The unofficial market works year round. Most of the peanuts sold on the unofficial market are unshelled (91 percent). However, producers may add value to their production by shelling the peanuts or transforming them into paste or oil and selling them on the unofficial market to intermediates or consumers in rural or urban areas. Producers may illegally export part of their production to neighboring countries. Sales of peanut leaves for animal consumption are another component of the unofficial market.

The official market only accepts unshelled peanuts during five months of the year, from December through April. Peanuts are sold to two companies, a public company for the production of peanut oil and a private company for the production of confectionery peanuts.

The public company, SONACOS (Société Nationale de Commercialisation des Oléagineux du Sénégal)[3], buys raw peanuts through contract agreements with farmers. Part of SONACOS purchases is stored, treated with chemicals and sold to farmers as high quality seeds through Sonagraines, which is owned by SONACOS or sold to private seed suppliers when the growing season approaches. The rest of the purchases is processed into peanut oil and cakes for animal feed in mills owned by SONACOS. From each ton[4]

[2] The terminology official/unofficial is no longer valid since the passage of a bill on July 8, 1988, which legalized the unofficial market. However, the existence of this law is not widely known (Gaye, 1998 b). The terms official/formal and unofficial/informal are used interchangeably.

[3] SONACOS has a monopoly on the purchase of peanuts and on the sale of peanut oil. It is afforded a high level of protection on vegetable oil imports while its imports of unrefined vegetable oil are duty free. This public company is being privatized.

[4] Here and in the rest of the thesis the unit used is the metric ton.

of unshelled peanuts, SONACOS produces 350 kilograms of oil and 350 kilograms of cakes (Gaye, 2001).

The private company NOVASEN (Nouvelles Arachides du Sénégal)[5], also buys raw peanuts through contract agreements with farmers. One part of these purchases is returned to the contracted farmers in the form of high quality seeds. The other part is processed to produce edible peanuts (confectionery, paste and butter) and cakes. The by-products are sold to SONACOS to be processed into oil.

Peanut oil and cakes are sold to consumers in Senegal, 46 percent and 59 percent of their production respectively. The rest is mainly exported to Europe (FAO, 1999). Figure 1.2 presents the different actors in the Senegalese peanut sector.

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[5] The private company NOVASEN is the only institution in West Africa, which vertically integrates all the activities in the peanut sector: crop production, harvest, processing and exports of confectionery peanuts.

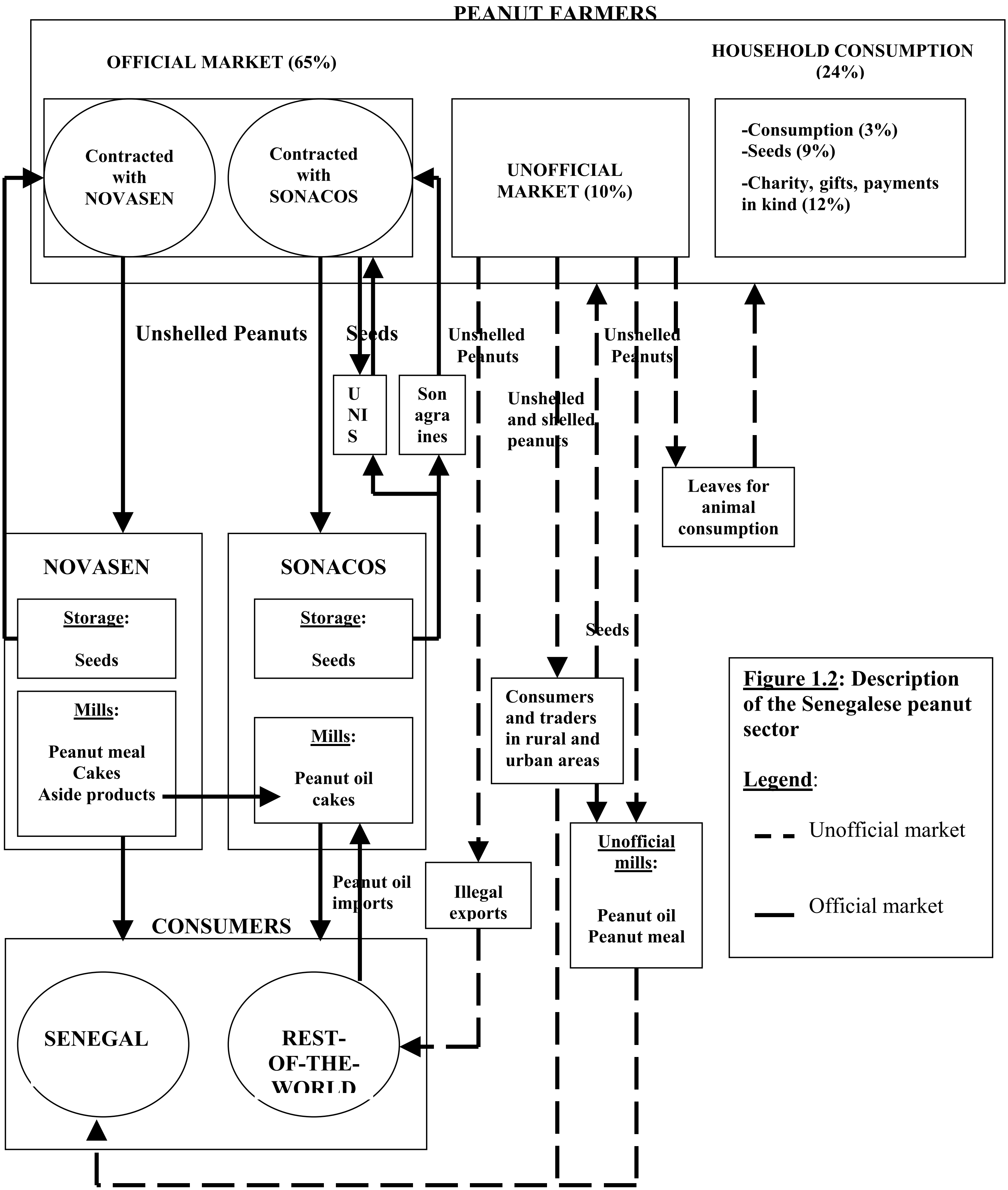


Figure 1.2: Description of the Senegalese peanut sector

An important pre and post-harvest problem is the contamination of peanuts with aflatoxins. Aflatoxins are highly toxic substances produced by fungi Aspergillus flavus and Aspergillus parasisticus. The aflatoxin problem has two major implications: 1) aflatoxins are very harmful to human and animal health causing fatal liver damage; 2) peanut exports to Europe are subject to strict quality standards. This problem is particularly associated with confectionery peanuts and peanut cakes because toxins are eliminated during the transformation of peanuts into oil. The aflatoxin contamination is affected by air temperature and humidity levels. Contamination is more likely to occur when temperature is within the range 25-32ºC and relative humidity is greater than 84%. Contamination risks are increased when peanuts are damaged by drought (before harvest), pest attacks (before or after harvest) or harvested before maturation. According to scientists, an effective solution to this problem requires integrated measures before, during and after harvest. The development of resistant varieties to aflatoxin contamination is a hard task given that contamination may occur at any stage of the peanut production and marketing process. However, some varieties such as 55-437 (the most resistant variety in Senegal and one of the four most resistant varieties in the world), 73-30 and 73-33 exhibit a good resistance level (Ba et al, 1999).

1.3 History of the peanut sector and related governmental policies in Senegal

As discussed below, though the Senegalese peanut sector developed and became one of the most important peanut producers in Africa during the first half of the past century, imperfections in the agricultural institutional system, drought, political events in Europe and Africa and world economic shocks affected it considerably. Peanut production and exports grew rapidly in French West Africa as France attempted to make its colonies support themselves. As shown in table 1.2, between 1875 and 1958, exports were increased by 58 times and grew with an average annual growth rate of 68 percent.

Table 1.2: Early Growth of Peanut Exports from Senegal

YEARS	TONS
1875	13.9
1885	45.1
1895	51.6
1905	96.2
1915	303.1
1925	453.7
1936	487.3
1948	451.0
1958	808.0

Source: Cruise and Donal, 1975.

During the colonial period, two major goals motivated the intervention of the French administration in the peanut sector: (1) ensuring adequate revenues and (2) rewarding political allies. This second objective caused the French administration to control the peanut sector according to political instead of economic interests.

After independence, because the peanut sector represented an economically and politically crucial sector of the economy, the Senegalese government attempted to increase peanut production. A major agricultural program was implemented to provide research, extension, credit, inputs, equipment, marketing and processing. In the first two decades after independence, fertilizer subsidies averaged 56 percent. The government set the price of peanuts and peanut marketing to private traders was prohibited. This government support contributed to the development of the peanut sector. However, the government's large expenditure generated a deficit in the balance of payments and a shortage in foreign exchange for the payment of the external debt (Lopez and Hathie, 1998). Furthermore, after the creation of the European Economic Community, France was pressured to end its preferential trade in favor of Senegalese peanut products, generating a significant decrease in Senegalese peanut exports and in farmers' revenues (Ba, 1998). In order to adapt the peanut sector to changes in the terms of trade, the government restructured the production, processing and marketing of peanuts through the creation of vertically-integrated parastatal organizations. However, because these organizations responded more to political pressures than to economic logic, they became exploitative and subject to abuses of power (Gray, forthcoming; Diagana and Kelly, 1996). The political intervention of the authorities in the peanut sector since the French occupation, and the oligopolistic nature of the peanut market, progressively generated structural problems. "The cumulative effects of over-centralization, inefficiency and corruption in the input distribution and marketing parastatal ONCAD [Office National de Coopération et d'Assistance pour le Développement] and the agricultural extension parastatal SODEVA [Société de Développement et de Vulgarisation Agricole] were having a noticeable impact on the economic performance of the agricultural sector (Crawford et al, 1996, p. 18)." Moreover, "producer prices for peanuts and cotton were systematically kept lower than the level required by true marketing margins. The net result of the pattern of intervention on both the input and output sides was positive to the state and agro-industrialists both, as well as the larger farmers… (Delgado and Jammeh 1991, p.7)."

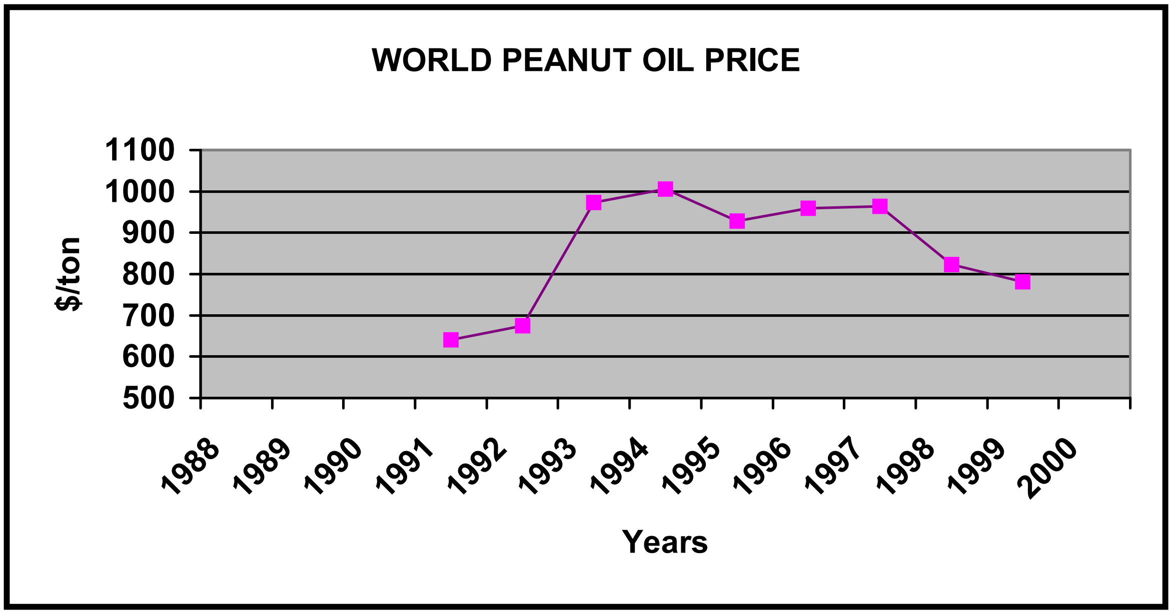
Furthermore, peanut production has been affected by its dependence on rainfall as opposed to irrigation and successive years of increasing drought in the Sahel. As shown in table 1.3, both the average annual peanut production and the average annual rainfall decreased every decade by 11 percent and 8 percent respectively between 1960 and 1999.

<u>Table 1.3</u>: History of Peanut Production in Senegal

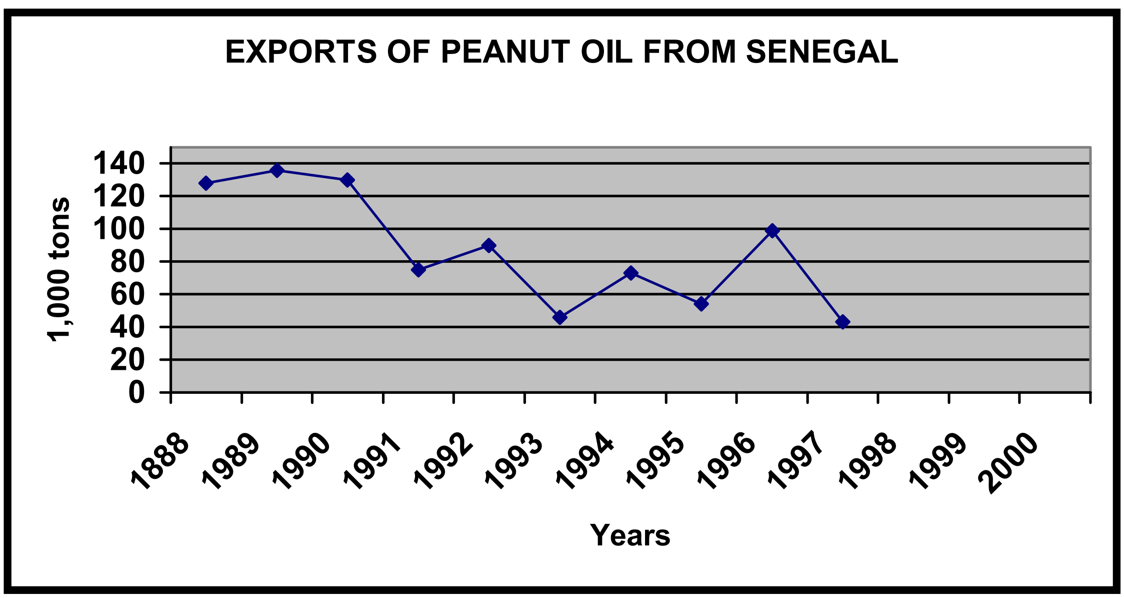
	AVERAGE PRODUCTION (1000 TONS)	**AVERAGE RAIN FOR THE ENTIRE COUNTRY (MM/YEAR)**
1960-69	932	762
1970-79	875	640
1980-89	778	587
1990-99	633	571*

* Peanut basin
<u>Source:</u> *Crawford et al (1996) and IMF (2000).*

In addition, declining world prices adversely impacted the Senegalese economy. Senegalese peanut oil exports suffered from the increasingly competitive world market and the sustained decrease in world peanut oil prices. As shown in figure 1.3, between 1988 and 1997, oil exports fell with an average annual rate of 7 percent and oil world prices (Rotterdam cost insurance fret) tended to decrease between 1994 and 2000.



Source: World Oil Annual, 2000.



Source: FAO, 1999.

Figure 1.3: World peanut oil prices and exports of peanut oil from Senegal

Several other international economic shocks were a great blow to the Senegalese economy (Delgado and Jammeh 1991). In the second half of the 1970's, the price of phosphate, which is another important export product in Senegal, fell. Conversely, the price of petroleum, an import of Senegal, increased when petroleum crises occurred in the 1970's and 1980's. Also, the interest rates and exchange rates for the most important currencies (US Dollar and French Francs) rose and contributed to the problems facing the Senegalese economy. The peanut sector's contribution to Senegalese trade diminished as peanut production and exports decreased. Gross Domestic Product decreased aggravating foreign debt. The payment of foreign debt rose from 4 percent of the value of the exports in 1972 to 15 percent in 1978-79 (Gray, forthcoming). At the microeconomic level, farmers' revenues decreased (see previous section) and their debts increased (Crawford et al, 1996). In this context, the Senegalese Government "approached the multilateral financial institutions in 1979 for assistance with an invitation to policy dialogue, contrary to the image that Structural Adjustment was always initiated from Washington (Delgado and Jammeh 1991, p.9) ".

The purpose of the structural adjustment was to stabilize the economy by reducing government spending, promoting economic growth and reducing trade deficits and foreign debt. Another objective was to provide a framework for the movement of financial aid to Senegal and the implementation of targeted IMF and World Bank programs in the 1980's. The reform of agricultural policies was one of the major components of the Structural Adjustment Loan provided by the World Bank. The specific objectives of this part of the program were to liberalize input supply and establish a basis for agricultural development, decentralize the rural credit system and the costly and inefficient rural development agencies (Gellar, 1982), liberalize trade, and so forth. Another component of the new policies was to encourage the production of food crops (millet, rice, maize, sorghum) and to discourage the production of cash crops (peanuts) via a new food crop pricing and input supply policies in order to improve food self sufficiency.

The impact of structural adjustment on the agricultural sector in Senegal was ambiguous. Some progress in decentralization has been observed, but the program failed to improve input distribution. The pricing decisions were depoliticized. The input market liberalization was followed by an increase in input price. Producers reduced or ended their purchased input use. Consequently, productivity decreased. The output decrease and reduced subsidies caused producers' welfare to decrease. Lopez and Hathie (1998) estimate that before the implementation of structural adjustment, the cost of the subsidies to taxpayers was lower than the benefits from input subsidies to producers. They suggest compensating for the rise in input price by raising productivity through research and extension and by implementing targeted relief programs for producers who are considered the permanent losers of the adjustment programs. Also, the output decrease combined with the development of the unofficial market caused a gap between government peanut purchases (250,000 tons in 1995) and the mills' processing capacity (900,000 tons) (Ba, 1998). Because peanut production is less and less competitive, it is less attractive to producers who are moving towards other crops such as watermelon.

In conclusion, the structural adjustment programs didn't solve the problems of the peanut sector. The reduction of input use, the reduction of soil quality and aging equipment affected peanut productivity. Ba (1998) suggests the lack of institutions to replace the government's intervention after it was suppressed as an explanation for the failure of the structural adjustment programs.

In January 1994, the devaluation of the CFA Franc by 50 percent had another major impact on the peanut sector. Because devaluation increased output prices (40 to 70 percent) more than it increased input prices (20 to 50 percent), it enhanced the profitability of the major crops (millet and peanut) (Diagana and Kelly, 1996). However, inflation reduced the positive effect of devaluation on farmers' incomes (Akobundu, 1998). The relative prices encouraged farmers to increase the share of peanuts in their crop mix by 30 percent in the first planting season after devaluation (Diagana and Kelly, 1996). Because devaluation didn't change the fact that it was more profitable to plant high densities on unfertilized land than recommended densities on fertilized land, farmers didn't adopt soil enhancing technologies. As a consequence, soils were mined and seed quality was reduced. To reverse this trend, studies suggest providing an incentive for more fertilizer use in order to reduce crop density and soil degradation through the supply of more affordable fertilizers (Diagana and Kelly, 1996).

1.4 The peanut pricing policies

The peanut pricing policy remained unchanged under the structural adjustment program. Peanut price was still subsidized by the Caisse de Péréquation et de Stabilisation des Prix, whose funds were mostly provided by Stabex. The European Economic Communities (EEC) established the Stabex scheme in 1975 within the framework of the Lomé Convention between the EEC and the African, Caribbean and Pacific (ACP) countries. The objective of this scheme was to offset fluctuations in export earnings, maintain the oil and confectionery peanut supply in Europe and stabilize the purchasing power and the imports of ACP countries from Europe.

After the implementation of the structural adjustment program, “a sharp drop in the export price for peanuts … led to heavy losses for the Government’s commodity price equalization and stabilization agency (Delgado and Jammeh, 1991, p.48)”. Consequently, the government established a new pricing policy. Its objectives were on the one hand to stabilize peanut prices through ensuring a base price for producers and on the other to reduce the cost of subsidies and to introduce some flexibility in establishing prices relative to world market price fluctuations (Gaye, 1998 b).

This new mechanism of price determination was initiated with the signing of an outline agreement among the Senegalese government, SONACOS and CNIA (Comité National Interprofessionel de l’Arachide) in 1996. Yearly negotiations are held in March and April with all the CNIA members in the peanut sector (farmers, millers, traders and public agencies). A unique base producer price is fixed within the range of the highest and the lowest levels of the peanut oil and cake world prices and on the basis of production costs in recent years. The price determination is based on world prices in the past five years (35 percent) and in the months since the beginning of the current year (65 percent). The cost of the subsidy is born by the government who essentially collects its funds within the Stabex scheme and from taxes on oil imports. Table 1.4 describes the monetary transfers that occurred since the implementation of this new pricing policy.

<u>Table 1.4</u>: Assessment of the implementation of the current pricing policy

	1996-97	1997-98	1998-99	1999-00
Consumer price (CFA Francs/kg)	183	137.656	114	142
Producer base price (CFA Francs/kg)	131	150	160	145
Difference (CFA Francs/kg)	+ 52	-12.344	- 46	- 3
Quantities (tons)	96,000	154,962	242,142	450,000
Cost of subsidy (million CFA Francs)	0	2,128	11,500	1,350

<u>Source:</u> Senegal, Republic of, Ministère de l'Economie, des Finances et du Plan, 2000 (a).

Peanut oil and cake markets were liberalized in 1995, but barriers on imports of non-refined and refined oil (soybean oil, palm oil) still protect the production of peanut oil. This trade policy was implemented in 1991 and updated in 1998. The trade barriers consist of a levy (variable per unit taxes for different ranges of the import price, CAF Dakar) (Senegal, Republic of, Ministère de l'Economie, des Finances et du Plan, 2000 b).

1.5 Agricultural research in Senegal

Bravo-Ureta (1998) commented that growth and development of the peanut sector in Senegal requires increasing peanut production. Output growth is facilitated by two conditions: productivity enhancement and increased input use. There are two possible ways to increase productivity: a technological change and increasing technical efficiency. Technical efficiency is affected by education, training and experience. These three factors combined with agricultural research and development can lead to technological change.

Four broad objectives are attributed to agricultural research (Masters, 1996):

- improvement of overall living standards,
- enhancement of food security and economic stability,
- reduction of poverty,
- sustainability of natural resources.

Agricultural research on peanuts in Senegal is currently conducted by the Institut Sénégalais de Recherche Agricole (ISRA) in collaboration with the Centre International de Recherche Agronomique pour le développement (CIRAD), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the peanut CRSP[6]. The main goal of agricultural research in Senegal is the production of improved varieties adapted to the quality requirements (nutrition, health, tastes and so forth) and to the environmental conditions. Research is also conducted on fertilization, crop and seed protection and post-harvest technologies.

Given the economic importance of the peanut sector in Senegal, agricultural research has been conducted to release new peanut varieties in order to improve peanut productivity and achieve economic and social objectives, particularly in rural areas. ISRA and the peanut CRSP adapted several new peanut varieties to the agro-climatic conditions in Senegal. The last variety developed by ISRA and the Peanut CRSP is La Fleur 11. Research on La Fleur 11 started in 1985. The variety was tested from 1991 to 1993. After the variety was proposed for release in 1992, it was approved in 1993. The variety was then multiplied on selected farms between 1993 and 1996 to spread La Fleur 11 use and to observe how the variety behaved outside experimental conditions. It was broadly marketed in 1997. La Fleur 11 was bred for the central area where rainfall is between 300 and 500 mm a year. Its growth cycle is about 90 days.

La Fleur 11 has several interesting characteristics. It is an oil variety with a high oil content (50-51 percent of the dry seed). It produces shells early that can be sold for consumption in the informal market in order to provide cash to the farmers. Also, La Fleur 11 produces large leaves that are used for animal feed. The shells are bigger than

[6] Appendix C presents the role and activities of the Peanut CRSP.

those of the variety 55-437 that La Fleur 11 is replacing, and its yield has been estimated to be 30 percent higher than that of 55-437 under experimental conditions. Given these characteristics, plantings of La Fleur 11 quickly spread from the central region to the south and to the north where the variety adapts very well to irrigated conditions.

1.6 Problem statement

Surveys conducted in 1996 by the National School of Applied Economics in Senegal (ENEA) and the University of Connecticut reveal that La Fleur 11 has higher yields than the old variety 55-437. Table 1.5 provides a technical comparison between La Fleur 11 and 55-437. At the farm level, land planted with La Fleur 11 represents 23 percent of the land planted with 55-437. However, La Fleur 11's labor productivity and seed productivity exceed those of 55-437 by 25 percent and 12 percent respectively. La Fleur 11's yield exceeds 55-437's by 29.9 percent confirming ISRA's estimation of 30 percent.

Table 1.5: Technical comparison between La Fleur 11 and 55-437

Peanut varieties	Areas Ha/farm	Ratio output/workers-day	Ratio Output/seeds	Yields Kg/ha
La Fleur 11	0.76	14.73	7.33	515.07
55-437	3.3	11.74	6.52	396.26

Source: Surveys in Bravo-Ureta, Hathie and Thiam (1998) and Sow (1998).

An economic comparison shows that variable costs are greater for La Fleur 11 than for 55-437 on average. Farmers use 17% more seeds of La Fleur 11 than of 55-437. The unit-price of La Fleur 11 seeds is higher (465 FCFA/kg on average) than that of 55-437 (224.5 FCFA/kg on average). The unit-price of La Fleur 11 output is higher (250-300 FCFA/kg) than that of 55-437 (250 FCFA/kg on average) (Sow, 1998). According to Bravo-Ureta et al (1998), although the variable costs of La Fleur 11 are higher, its gross returns and profits are greater than those of the variety 55-437 are.

However, La Fleur 11 has some disadvantages. It is a non-dormant variety. Therefore, it germinates in wet conditions, which poses storage problems. Research is currently underway to develop a dormant variety (Ndoye, July 19th 2000). It is subject to leaf diseases such as cercosporiosis and rust and to attacks by Aspergillus flavus. These problems are particularly important when this variety is grown outside the region it was developed for, the center of the peanut basin (Ba et al, 1999).

Moreover, some problems have been reported about the use of La Fleur 11. Farmers do not follow the technical recommendations for La Fleur 11 regarding seed density, irrigation, fertilization, crop cycle duration and so on. Shells are vulnerable to pests and peanuts are harvested before maturation for direct consumption, which exposes La Fleur 11 to contamination by aflatoxins. The genetics of the variety are unstable. The variety behaves as a hybrid, which meant that further research on La Fleur 11 to stabilize its genetics was necessary before its release. All these problems have had a major effect on La Fleur 11 by decreasing its yield comparative advantage and affecting its adoption by farmers (Boye, 2000). Other obstacles to adoption are the production of an adequate seed supply (Peanut CRSP web page, 1999) and the shortage of operating capital to purchase the seeds (Bravo-Ureta, Hathie and Thiam, 1998).

In conclusion, though La Fleur 11 meets the expected yield increase in comparison to 55-437, some problems need to be addressed in order to take full advantage of the potential offered by La Fleur 11: increasing the seed supply, improving the dissemination of La Fleur 11, providing credit and technical assistance and informing farmers about the appropriate practices (Bravo-Ureta et al, 1997 and 1998).

1.7 Objectives

The main objective of the study is to develop an impact assessment evaluation procedure for the peanut sector in Senegal. It will be tested on La Fleur 11 but can be replicated for other interventions.

The sub-objectives of the study are as follows:

- performing an ex-ante evaluation of the adoption of La Fleur 11 in order to evaluate the magnitude of the returns from the intervention of the Senegalese government in the development of this new variety;
- disaggregating the Senegalese peanut sector vertically and computing the benefits from research on La Fleur 11 for the main commodities of the sector: farm household consumption, farm sales of unshelled peanuts on the unofficial market, farm sales of seeds on the official market and SONACOS sales of peanut oil and cakes;
- for each commodity and each market, determining the distribution of the benefits among consumers, producers and the government;
- evaluating the effect of a subsidy on the benefits from research when the producer base price applies to farm sales of unshelled peanuts on the official market.

1.8 Summary of methods

The analysis is based on the assessment of the research-induced change in economic surplus in a partial equilibrium framework. The economic surplus analysis consists of the evaluation of the change in economic surpluses when a new technology is adopted. In order to take into account the change in supply and evaluate the benefits throughout the life of the new technology, discounting is employed in the analysis (see chapter 2).

1.9 Structure of the remainder of the thesis

The study contains three more chapters. The second chapter is a detailed presentation of the conceptual framework. The third chapter is an exposition of the data used for the impact assessment and the results of the surplus analysis. The fourth chapter contains a summary of the research, conclusions of the study, limitations of the study and suggestions for future research.

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: $\Delta TS = \Delta PS = \frac{1}{2} kP_wQ(1+k\textit{e})$ 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.

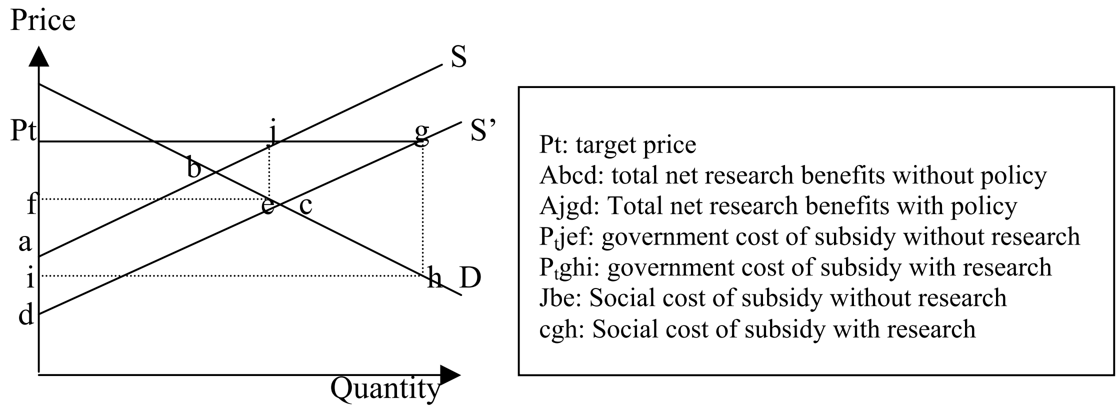


Figure 2.1: Change in economic surpluses in the context of a target price with deficiency payments for a non-traded good

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.

<u>Table 2.3</u>: Relative importance of the main commodities in the Senegalese peanut sector

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

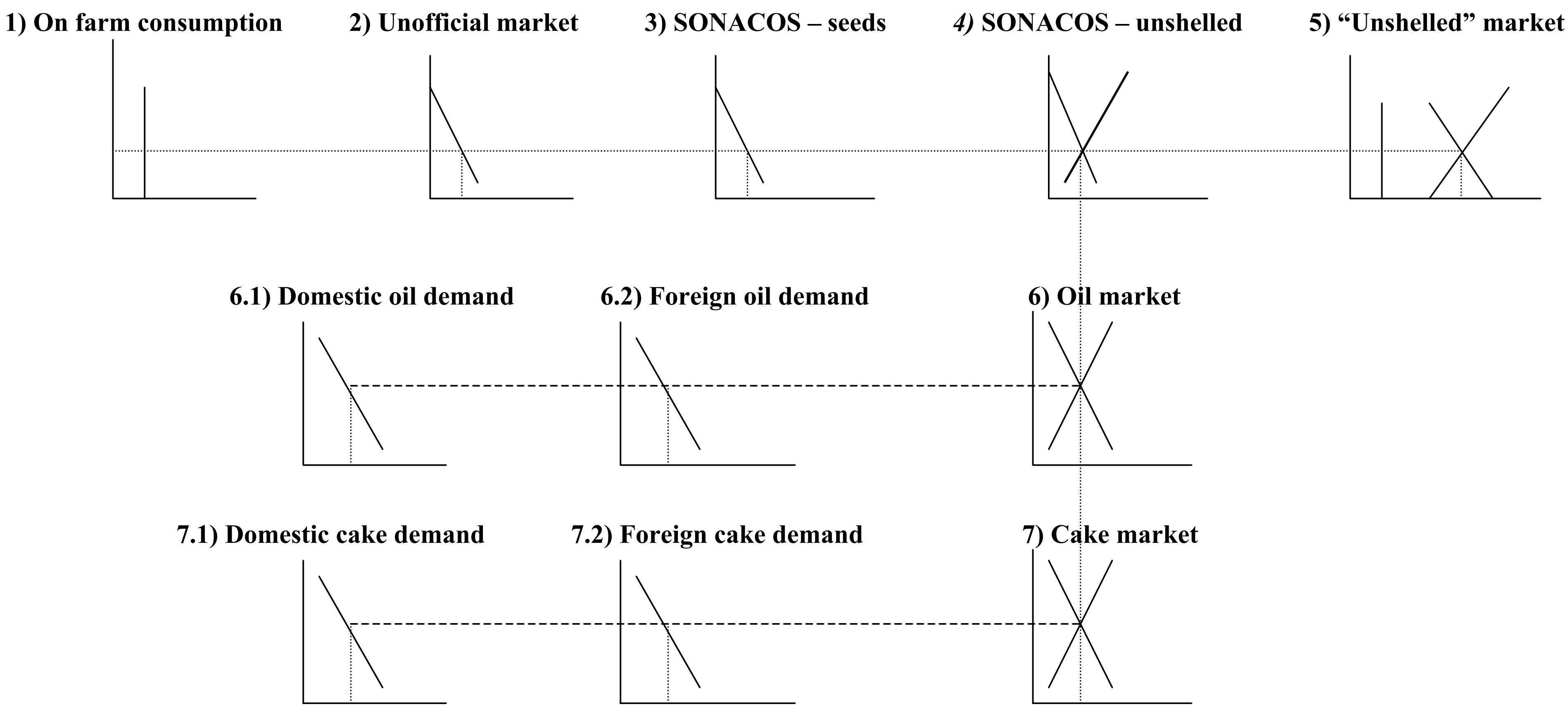


Figure 2.2: Disaggregation of the unshelled peanut markets

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.

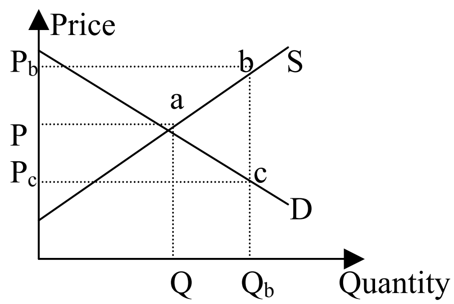


Figure 2.3: Closed economy with a producer base price

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 $PcaP_w$.

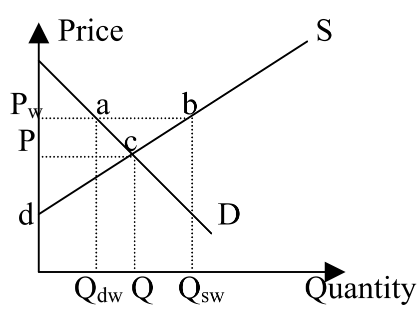


Figure 2.4: Small open economy

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.

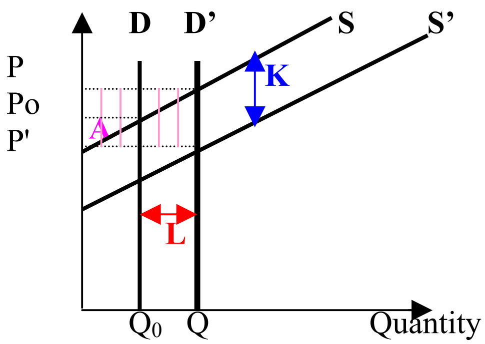
Figures 2.5 and 2.6 represent the change in surplus in the case of a parallel shift and in the case of a pivotal shift respectively from the supply curve S to the supply curve S'. In these graphs, the evaluation is done at the unofficial market price assuming that if the farmers didn't consume part of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

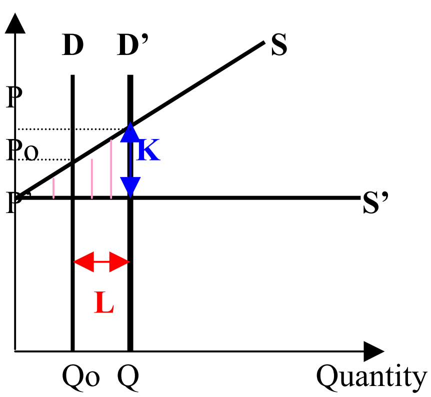
In figures 2.5 through 2.7, the computation of the economic surpluses is based on the equilibrium price P and quantity Q, obtained after the demand curve has shifted from D to D’ by L=ΔQ:

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

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

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[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).

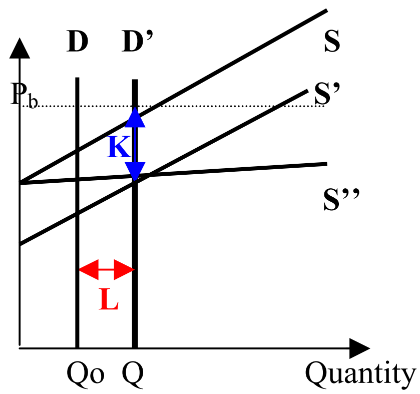


Figure 2.7: On farm consumption of unshelled peanuts: Change in producers' consumer surplus when a new technology is adopted in a closed economy where a producer base price is applied (parallel or pivotal shift of the supply curve and parallel shift of the demand curve)

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.

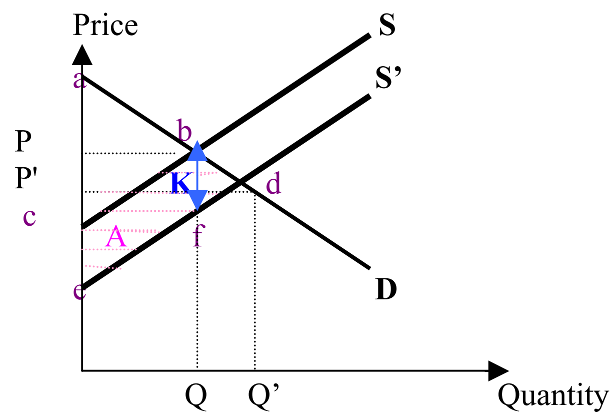


Figure 2.8: Farm sales of unshelled peanuts on the unofficial market: Change in economic surplus when a new technology is adopted in a closed economy (parallel shift of the supply curve)

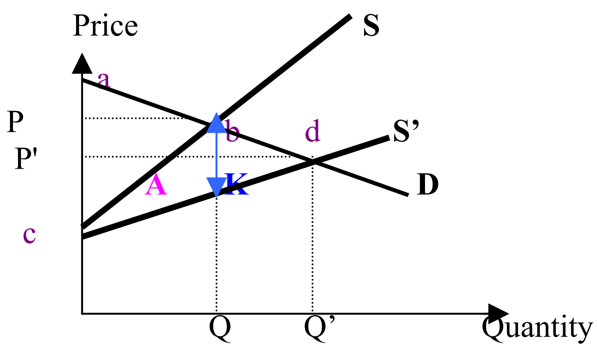
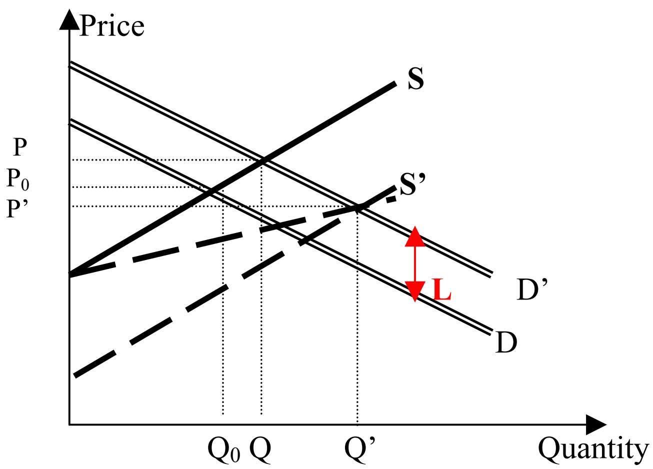


Figure 2.9: Farm sales of unshelled peanuts on the unofficial market: Change in economic surplus when a new technology is adopted in a closed economy (pivotal shift of the supply curve)

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 = Kε/(ε + *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:

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



<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

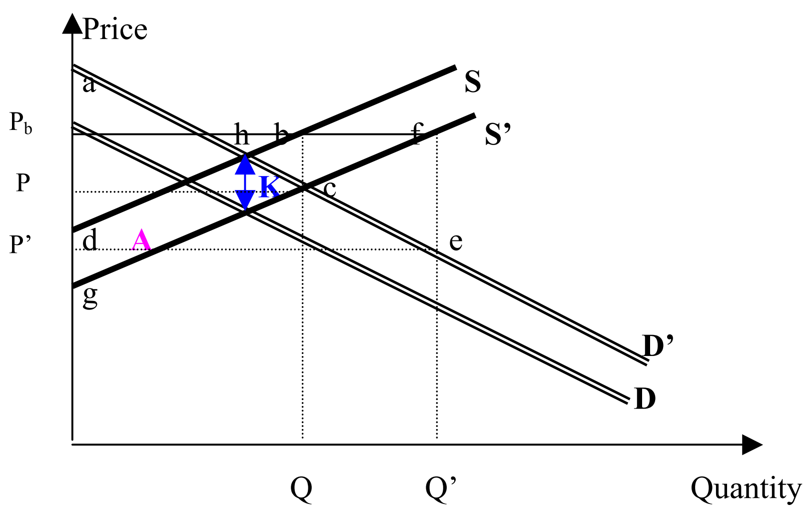
This model is used for the commodities that are sold by farmers to SONACOS. This is the case of the unshelled peanuts used as seeds and unshelled peanuts used in the oil and cake processing.

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.

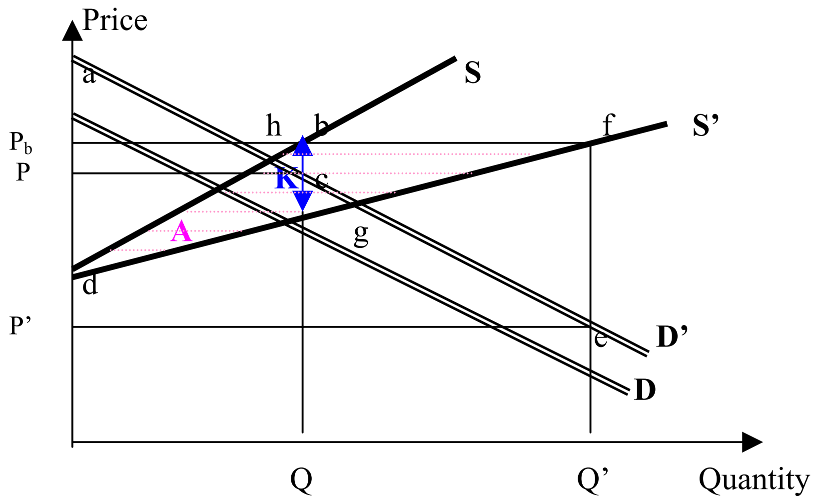
In both figures, the computation of the change in economic surplus is based on the equilibrium price P and quantity Q obtained after the demand curve has shifted by L=ΔD:

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

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:

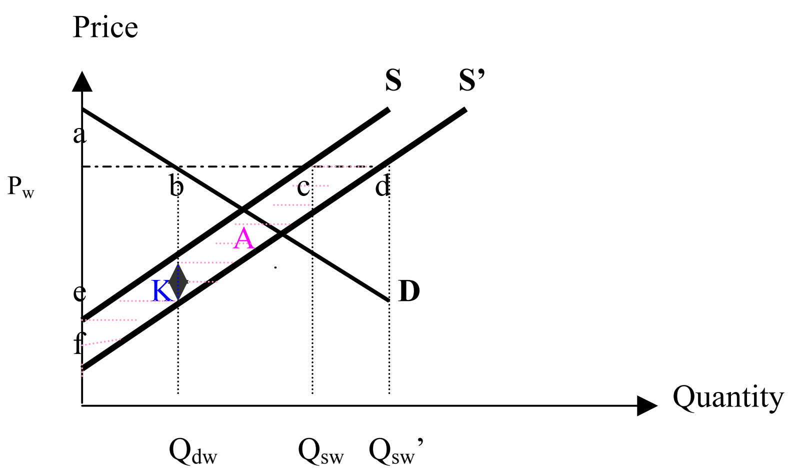
$$\Delta CS = EQ\,(1 + \tfrac{1}{2}\,Ee/P)$$
$$\Delta PS = KQ\,(1 + \tfrac{1}{2}\varepsilon K/P_b) \text{ (parallel shift)}$$
$$\Delta PS = \tfrac{1}{2}\,KQ\,(1 + \varepsilon K/P_b) \text{ (pivotal shift)}$$
$$\Delta GC = EQ\,(1 + ((P_b-P) + E)e/P)$$

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

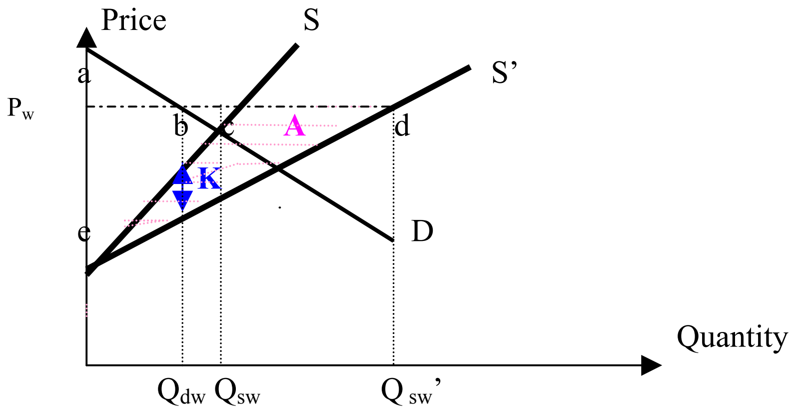
b) Small open economy models - SONACOS exports of peanut oil and cakes at the world price

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.



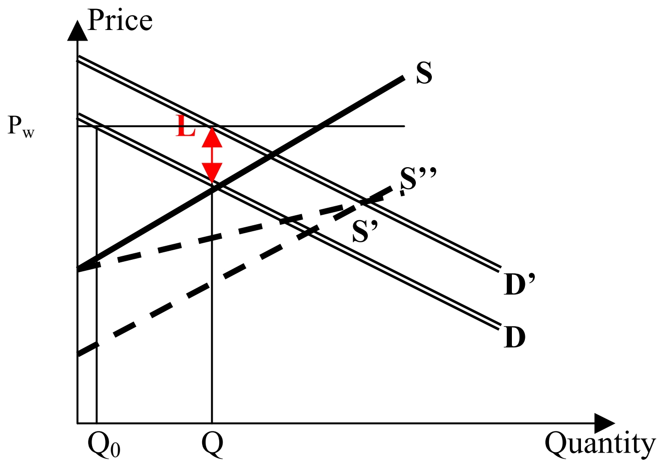
<u>Figure 2.13:</u> SONACOS exports of peanut oil and cakes: Change in economic surplus when a new technology is adopted in a small open economy (parallel shift of the supply curve)



<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.

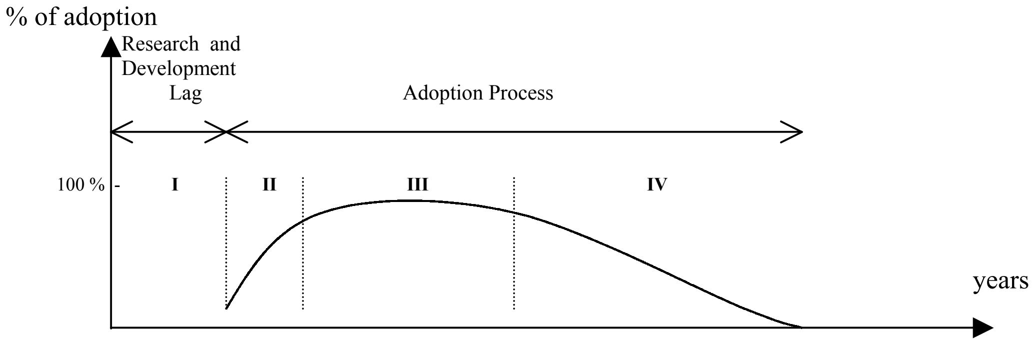


Figure 2.16: **Lags in Research and adoption**

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.

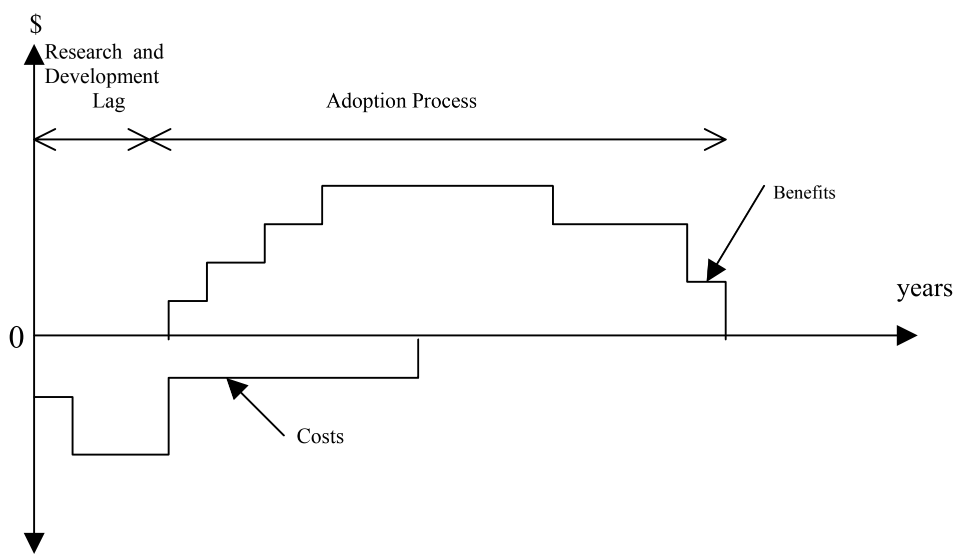


Figure 2.17: **Costs and benefits in research and adoption**

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.

CHAPTER 3:

DATA AND RESULTS

3.1 Introduction

This chapter documents how the data were collected and employed. It presents the results derived from the theoretical framework presented in the previous chapter and provides an analysis of the results.

3.2 Data collection

Two types of data were collected for the study. International organization databases and literature provided general economic information and aggregate economic data. These secondary data are discussed in sub-section 3.2.1. Interviews in Senegal and materials provided in Senegal provided more specific data, particularly on La Fleur 11. These primary data are presented in sub-section 3.2.2. Sub-section 3.2.3 explains how secondary and primary data were used to develop parameters for the analysis. Appendix B contains all the data employed in the analysis.

3.2.1 Data collected from secondary sources

Economic and financial statistics including growth rates of per capita income, interest rates, and exchange rates were obtained from the International Monetary Fund (IMF). Also, the IMF provided information about researchers salaries to estimate La Fleur 11 research costs since information on research costs was difficult to obtain. These statistics are presented in tables 3.1 through 3.4.

Table 3.1 presents the average annual growth of per capita Gross National Product (GNP) for the decades 1976-86, 1987-97 and for the period 1998-2002. The average annual growth of per capita GNP was negative in the two first periods, but positive in the last period.

Table 3.1: Average annual growth of per capita GNP (Gross National Product) in Senegal

	1976-1986	1987-1997	1998-2002
GNP per capita	-0.011	-0.004	0.034

Source: IMF, 1998.

Table 3.2 presents the interest rates applied in the money market in Senegal in the period 1993 through 1998. It decreased during the entire period. In 1993 and in the first half of 1994 it was within the range 0.07-0.09. In 1995-97, it was between 0.05 and 0.06. In 1998, it was between 0.045 and 0.05. The IMF provides another interest rate, 0.0625, which was applied by the Central Bank of Senegal to all loans after August 31st 1998 (IMF, 2000).

Table 3.2: Interest rates applied in the money market in Senegal

Periods	Interest rate
1993	
October	0.0935
November	0.085
December	0.0751
1994	
January	0.0794
March	0.0925
June	0.0885
September	0.0567
December	0.055
1995	
March	0.055
June	0.055
September	0.055
December	0.0578
1996	
January	0.0551
February	0.055
March	0.055
April	0.0548
May	0.0521
June	0.0537
July	0.0541
August	0.0525
September	0.0525
October	0.0525
November	0.052
December	0.0505
1997	
January	0.0504
February	0.0511
March	0.05
April	0.05

May	0.05
June	0.0502
July	0.0502
August	0.0502
September	0.0502
October	0.0502
November	0.0502
December	0.0496
1998	
January	0.0451
February	0.0450
March	0.0453
April	0.0456
May	0.0478
June	0.0495
July	0.0495
August	0.0496
September	0.0496

Source: IMF, 2000.

Table 3.3 presents the exchange rates of CFA Francs for US Dollars. The exchange rate has increased since 1995 with an average annual growth rate of 4.6 percent.

Table 3.3: Exchange rate CFA Franc-US Dollar

Period average	1994	1995	1996	1997	1998*	1999
CFA Franc/U.S. $	555.20	499.15	511.55	583.50	595.56	615.70

*: Jan-Oct

Source: IMF, 2000 and CIA, 2001.

Table 3.4 presents public salaries. Only the maximum and the minimum monthly salaries paid to some employees in Senegal are available. These salaries didn't vary much during the period 1985-1998. The average maximum salary is 237,414 CFA Francs per month. The average minimum salary is 40,863 CFA Francs per month. According to a La Fleur 11 breeder, the maximum salaries represent a good approximation of the salaries paid to the scientists who developed La Fleur 11 (Ndoye, April 24th 2001).

Table 3.4: Maximum and minimum salaries for selected civil servants in Senegal

CFA Francs/month	Jan. 1985	July 1989	Sept. 1993	Jan. 1994	After Apr. 1994
Minimum salary	36,462	40,482	34,409	40,482	52,482
Maximum salary	238,165	242,184	205,855	242,184	258,684

Source: IMF, 2000.

Additional information about researchers salaries was provided by ISRA. Ndoye (April 24th, 2001) provided information about the salaries paid to the assistants who participated to the development of La Fleur 11. Although he mentioned that the assistants received monthly salaries between 70,000 and 110,000 CFA Francs, he suggested that a good average of their monthly salaries is 75,000 CFA Francs.

The Food and Agriculture Organization of the United Nations (FAO) provided data on production quantities and export and import quantities and values of peanut products in Senegal as shown in table 3.5. Production and exports vary greatly from year to year. The production of unshelled peanuts and peanut seeds are correlated. The production and exports of oil and cakes are correlated as well. Besides unshelled peanuts, seeds and cakes are the two most important peanut products because they come from two industries, oil processing and confectionery. For the period considered, there are no imports of unshelled peanuts, peanut seeds, peanut oil and peanut cakes and unshelled peanuts and peanut seeds are not exported.

Table 3.5: Total production, imports and exports of peanut products in Senegal

Tons	1994	1995	1996	1997
Production				
Unshelled peanuts (for oil industry)	678,040	790,617	588,181	505,894
Seeds (oil and confectionery industries)	102,000	120,000	88,000	76,000
Oil	98,191	111,259	167,277	118,243
Cakes (oil and confectionery industries)	122,739	139,074	209,096	147,804
Imports	-	-	-	
Exports				
Unshelled peanuts (for oil industry)	-	-	-	-
Seeds (oil and confectionery industries)	-	-	-	-
Oil				
- Quantity (tons)	73,471	54,518	99,000	43,030
- Value ($1,000)	73,676	53,814	38,622	40,000
Cakes (oil and confectionery industries)				
- Quantity (tons)	83,768	37,163	88,300	45,844
- Value ($1,000)	12,354	5,026	6,322	2,500

Source: FAO, 1999.

Estimates of peanut supply and demand elasticities were found in the literature. Economic studies provided four different estimates of the supply elasticity for unshelled peanuts: 0.77 (Akobundu, 1998), 0.4889 (Lopez and Hathie, 1998), 0.433 (Gaye, 1998 b) and 0.16 (Sullivan et al, 1992). The first estimate is used in the analysis on the basis of the following argument. Alston et al (1995) explain that the choice of a linear supply curve generates an over-estimation of the supply shift and research benefits when supply is inelastic. This over-estimation can be corrected by choosing the highest supply elasticity estimate such that the gross cost reduction per unit of output $\Delta Y/\varepsilon Y$ is adjusted downward and hence the supply shift and research benefits are lowered as well. Only one estimate of demand elasticity for unshelled peanuts was found in the literature: -0.18 (Sullivan et al, 1992). For peanut oil, only one estimate of supply elasticity and one estimate of demand elasticity were found in the literature, 0.3 and –0.2 respectively (Sullivan et al, 1992)[9]. In the absence of estimates of supply and demand elasticities for peanut cakes, it is assumed that the oil elasticities are also valid for cakes.

Previous studies on the peanut sector in Senegal provided information on farm household consumption and the informal and formal peanut markets in Senegal. This information is presented in table 3.6.

Table 3.6: Relative importance of the main commodities of the Senegalese peanut market

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

Source: Gaye (1997, 1998 a).

[9] The elasticities found in Sullivan et al (1992) are for oil seeds other than soy seeds and oils other than soy oil.

Farm household consumption is considered as a whole with 24 percent of the total peanut supply; no differential is made between the different farm household utilizations of supply. In the official market, only SONACOS production is considered in the analysis because La Fleur 11 is an oil seed and hence is not used in the confectionery industry. Therefore, the 65 percent are assumed to include SONACOS purchases only. According to Gaye (February 22nd, 2001), from one ton of unshelled peanuts purchased from farmers SONACOS produces 0.35 tons of oil and 0.35 tons of cakes. In the unofficial market, only unshelled peanuts are considered in the analysis with 10 percent of the total peanut supply because they constitute the greatest part of this market. Prices of unshelled peanuts sold on the unofficial market are presented in table 3.7. They are given for three periods of each year. The second period coincides with the opening of the official market. Prices vary between 125 and 160 CFA Francs/kg.

Table 3.7: Unshelled peanut prices on the unofficial market in Senegal

	1995-96			**1996-97**		
CFA Francs/kg	**First period**	**Second period**	**Third period**	**First period**	**Second period**	**Third period**
Unshelled peanuts	125.40	128.00	129.50	130.30	139.70	160.40

Source: Gaye (1997, 1998 a).

3.2.2 Data collected in Senegal

The rest of the data used in the analysis was collected in Senegal. General information and data about the peanut sector were found at the Ministry of Finance and the Ministry of Agriculture. The Ministry of Finance provided peanut prices and subsidies since the application of the new peanut pricing policy in 1996 as shown in table 3.8. There are two domestic official prices for unshelled peanuts: the producer base price, which is set according to the peanut pricing policy and the consumer price which is the actual price farmers receive from sales to SONACOS. In 1996-97, the consumer price was higher than the producer base price. In the other years, the producer base price was higher causing the government to pay a subsidy to the farmers.

Table 3.8: Unshelled peanut official prices in Senegal

CFA Francs/kg	1996-97	1997-98	1998-99	1999-00
Producer base price	131.00	150.00	160.00	145.00
Consumer price	183.00	137.656	114.00	142.00

Source: Senegal, Republic of, Ministère de l'Economie, des Finances et du Plan, 2000 a.

The world prices for oil and cakes were found in Oil World Annual. As shown in table 3.9, in the period 1994-00 the peanut oil world price was around 900 U.S. Dollars per ton and the peanut cake world price was around 160 U.S. Dollars per ton.

Table 3.9: Peanut world prices

Period average US$/ton	1994	1995	1996	1997	1998	1999	2000
Peanut oil	1,023	991	897	1,009	917	788	740
Peanut cakes	168	169	213	221	116	102	130

Source: Senegal, Republic of, Ministère de l'Economie, des Finances et du Plan, 2000 a.

The Statistical Service of the Ministry of Finance provided statistics on the growth rate of population, 0.027 for the entire country for the period 1988-98 (Senegal, Republic of, Direction de la Prévision et de la Statistique, 1999)[10]. The Ministry of finance also provided regulatory information about peanut policies (Senegal, Republic of, Direction de la Prévision et de la Statistique, 1999). This information was presented in chapter 1.

The Statistical Service of the Ministry of Agriculture provided statistics on peanut production in Senegal for the last fifteen years and for each political district. Table 3.10 reports the quantities produced for the entire country for the period 1996-99. This period is chosen because producer base prices are only available for the years 1996 through

[10] The projection of the population growth rate in Senegal for the period 1997-2015 is 0.025 (UNDP, 1999). It is not very different from the Senegalese population growth rate used in the analysis, 0.027.

2000. Only the portion of the production that is used in the oil processing industry is presented. The output of year 1999-2000 is the highest because of favorable rainfall.

Table 3.10: Production quantities of unshelled peanuts (oil seeds) in Senegal

	1996-97	1997-98	1998-99	1999-00
Tons	588,181	505,894	540,773	764,077

Source: Senegal, Republic of, Ministry of Agriculture, 2000.

ENEA (Ecole Nationale d'Economie Appliquée), ISRA, Sonagraines and UNIS provided specific information and data on La Fleur 11. ENEA provided a study with farm-level yields for the old variety 55-437, 396 kg/ha, and the new variety La Fleur 11, 515 kg/ha (Bravo-Ureta et al, 1998). ISRA provided the yield increase of La Fleur 11, 30 percent in comparison to the variety 55-437's yield (Ndoye; July 19th, 2000), information on the number of researchers who worked on La Fleur 11, and the number of years where they worked on La Fleur 11 as indicated in table 3.11. During the research and development lag, two breeders and two agronomists worked on La Fleur 11. In total five assistants worked with the scientists on La Fleur 11. These assistants had other duties besides the development of la Fleur 11.

Table 3.11: Number of researchers who participated in the development of La Fleur 11

Researchers by category	Years of participation
Breeder 1	7
Breeder 2	5
Agronomist 1	4
Agronomist 2	2
Assistant 1	12
Assistant 2	10
Assistant 3	5
Assistant 4	4
Assistant 5	4

Source: Ndoye; February 22nd, 2001.

Sonagraines provided information about agricultural practices of peanut farmers using La Fleur 11 seeds (Boye, 2000). This information was presented in chapter 1.

UNIS provided some data and information for the evaluation of the change in input costs due to the adoption of La Fleur 11. The change in variable costs mainly corresponds to a change in seed cost. Few farmers use more fertilizer and/or pesticides when adopting La Fleur 11 and information on their use is not available. Table 3.12 presents the quantities and prices of seeds used for the old variety 55-437 and the new variety La Fleur 11.

Table 3.12: Seed quantities and prices for peanut varieties 55-437 and La Fleur 11

		1998-99	1999-00
55-437	Quantity (kg/ha)	120	120
	Price (CFA F/kg)	205	190
La Fleur 11	Quantity (kg/ha)	150	150
	Price (CFA F/kg)	250	225

Source: Ndoye D., 2000.

3.2.3 Use and configuration of data for the analysis

La Fleur 11 started being marketed in 1997, which corresponds to the beginning of the second lag of the adoption profile where the adoption rate started increasing and the supply curve started shifting (see below). Therefore, it would have been appropriate to choose the period 1994-96 for the approximation of the initial equilibrium. However, data on the producer base price are only available for the period 1996-2000. Consequently, all the prices and quantities used in the analysis correspond to this period of time. Data on prices and quantities are averaged. The price is calculated in CFA Francs per kilogram. When prices are only available in U.S. Dollars, the average exchange rate for CFA Francs for the corresponding years is used to convert them. The quantities are in kilograms. From the total supply of unshelled peanuts at the farm level (provided by the Ministry of Agriculture), the supply of each peanut commodity is determined as a fraction of the total supply of unshelled peanuts. From the above information tables 3.13 and 3.14 are derived. Table 3.13 contains the average prices of the different peanut products considered in the analysis and the average exchange rate. Table 3.14 contains the average supply of unshelled peanuts and for each peanut product its proportion in the entire supply of unshelled peanuts. For the evaluation of the farm sales of unshelled peanuts on the official market, the producer base price 146.50 CFA Francs/kg applies to the entire production of unshelled peanuts, 599,731 tons. When other peanut commodities are considered, their corresponding price is used and their supply is calculated as a portion of the entire supply of unshelled peanuts.

Table 3.13: Average peanut product prices and exchange rate

	Average	Reference
Producer base price of unshelled peanuts	146.50 CFA Francs/kg	Table 3.8
Consumer price of unshelled peanuts	144 CFA Francs/kg	Table 3.8
Unofficial price of unshelled peanuts	135.55 CFA Francs/kg	Table 3.7
Price of seeds for variety 55-437	197.50 CFA Francs/kg	Table 3.12
Price of seeds for variety La Fleur 11	237.50 CFA Francs/kg	Table 3.12
World price of peanut oil	909 US$/ton*	Table 3.9
World price of peanut cakes	160 US$/ton*	Table 3.9
Exchange rate	560.11 CFA Francs/US$	Table 3.3

* The prices in US Dollars are converted to CFA Francs using the average exchange rate.

Table 3.14: Average quantity supplied of unshelled peanuts and proportion of each peanut commodity in the total supply of unshelled peanuts in Senegal

	Average	Reference
Production of unshelled peanuts (for oil processing)	599,731 tons	Table 3.10
Ratio of on farm consumption of unshelled peanuts	0.24	Table 3.6
Ratio of farm sales of unshelled peanuts on the unofficial market	0.10	Table 3.6
Ratio of total farm sales of unshelled peanuts to SONACOS	0.65	Table 3.6
Ratio of farm sales of peanut seeds to SONACOS	0.15*	Table 3.5
Ratio of farm sales of unshelled peanuts for oil processing by SONACOS	0.50**	Derived
Ratio of SONACOS production of oil in purchases of unshelled peanuts	0.35	(Gaye, 2001)
Ratio of SONACOS production of cakes in purchases of unshelled peanuts	0.35	(Gaye, 2001)
Ratio of SONACOS sales of peanut oil in total supply of unshelled peanuts	0.175***	derived
Ratio of SONACOS sales of peanut cakes in total supply of unshelled peanuts	0.175***	derived
Proportion of peanut oil exports in peanut oil supply	0.54****	Table 3.5
Proportion of peanut cake exports in peanut cake supply	0.41****	Table 3.5

* Calculated by dividing the average seed production by the average production of unshelled peanuts
** Calculated by subtracting the seed ratio to SONACOS total ratio (0.65-0.15)
*** Calculated by multiplying SONACOS ratio of unshelled peanuts purchased and the ratio of oil and cake production (0.5*0.35)
**** Calculated by dividing the average oil and cake exports respectively by the average production of unshelled peanuts

The growth rate of demand in Senegal is calculated by summing the growth rate of population and the product of income elasticity of demand and the growth rate of per capita income. The growth rate of population is given for the period 1988-1998, 2.7 percent per year. The growth rate of per capita income is an average calculated from table 3.2, 0.63 percent per year[11]. The income elasticity is estimated using the homogeneity condition, which states that the sum of the own-price demand elasticity, the cross-price demand elasticities and the income elasticity equals zero. Alston et al (1995) estimate the income elasticity by assuming that the sum of cross price elasticities is a small number when no information on cross-price elasticities is available. To avoid any arbitrary estimation of that number, the sum of cross price elasticities is assumed to be zero, which is an empirically accepted approximation. Thus the income elasticity equals the negative of the own-price demand elasticity. These results are shown in table 3.15. As a result of a very small income growth, the growth rate of demand, 2.8 percent per year is very close to the growth rate of population.

Table 3.15: Data used for the calculation of the demand growth rate in Senegal

	Ratios	Reference
Growth rate of population per year	0.027	Senegal, Republic of, Direction de la Prévision et de la Statistique, 1999
Growth rate of per capita income per year	0.0063	Table 3.1
Income elasticity per year	0.18	Derived
Growth rate of demand per year	0.028	Derived

For the calculation of the supply shift K, two approximations are made. The first approximation is about fixed costs, which are assumed to remain unchanged between the without-research and with-research situations. The second approximation is about the

[11] Maybe only the period 1987-97 should have been considered for the estimation of the growth rate of per capita income, but a negative value might not reflect the actual growth rate in the next decades. A better estimate of this rate may have been to compute the average growth rate by weighting it by the number of years in each period.

depreciation rate, which is not taken into consideration (see below). The estimation of the research-induced supply shift requires several steps:

- The comparative yield increase between 55-437 and La Fleur 11 is 30 percent. This figure represents the experimental gain in yield and the farm-level yield increase as well (515-396/396).
- The yield increase 0.30, which corresponds to a horizontal shift of the supply curve, is divided by the supply elasticity 0.77 in order to obtain the gross cost reduction per unit of output: 0.39, which corresponds to a vertical shift of the supply curve.
- In order to transform the gross cost reduction per unit of output into a net cost reduction per unit of output, the research-induced change in total cost per unit of output has to be subtracted from the gross cost reduction per unit of output. The estimation of the research-induced additional total cost per unit of output is based on several calculations involving the research-induced change in seed cost.
- The change in seed cost is calculated using La Fleur 11's and 55-437's seed quantities and prices given in table 3.12: (150*237.50)-(120*197.50) = 11,925 CFA Francs per hectare.
- This amount represents an increase in seed cost equal to 0.5 relative to the without-research seed cost (11,925/23,700). The without-research seed cost is calculated on the basis of the seed cost for variety 55-437: 120*197.50 = 23,700 CFA Francs per hectare.

- The without-research seed cost, 23,700 CFA Francs per hectare, represents a fraction of the without-research total cost. The latter is approximated using total revenues[12]. Total revenues are calculated on the basis of the initial equilibrium output price, 146.50 CFA Francs and yield, 396 kg/ha, 146.50*396 = 58,014 CFA Francs per hectare. Therefore, the ratio seed cost over total cost is 23,700/58,014 = 0.41[13].
- Consequently, the proportionate additional total cost per hectare is 0.50*0.41 = 0.20.
- The proportionate change in yield is used in order to transform the proportionate additional cost per hectare into a proportionate additional cost per unit of output, 0.20/(1+0.30) = 0.15.
- The net cost reduction per unit of output, 0.24 is calculated by subtracting the proportionate additional cost per unit of output, 0.15 from the gross cost reduction per unit of output, 0.39.
- The supply shift K is obtained by multiplying the net cost reduction per unit of output by the probability of research success, the annual adoption rate and the initial equilibrium price. Regarding the probability of research success, it is assumed that the yield increase is successfully achieved (100 percent) based on the information given in chapter 1. For the commodities produced on farm, the supply shift is calculated on the basis of the corresponding initial equilibrium price (producer base price for unshelled peanuts sold on the

[12] In economic theory, the supply curve corresponds to marginal costs. Thus, the output price can be used as an approximation of per unit of output production costs.
[13] In this case, only the producer base price is used. Table 3.18 presents the calculation of the supply shift with the unofficial market price also.

official market and unofficial market price for unshelled peanuts consumed on farm or sold on the unofficial market). For the commodities sold by SONACOS (peanut oil and cakes) the supply shift is assumed to be the same as for the unshelled peanuts sold to SONACOS.

These calculations are summarized in table 3.16.

Table 3.16: Data used for the calculation of the peanut supply shift in Senegal

	Data	Reference
Proportionate yield increase per hectare $\Delta Y/Y$	0.30	Ndoye, July 19th 2000 and Bravo-Ureta et al, 1998
Gross proportionate cost reduction per unit of output $\Delta Y/Y\varepsilon$	0.39	0.30/0.77
Additional seed cost per hectare	11,925 CFA Francs/ha	(150*237.50)-(120*197.50)
Proportionate additional seed cost per hectare	0.50	11,925/(120*197.50)
Fraction of seed costs in total costs (revenues): - using producer base price - using unofficial market price	 0.41 0.42	 (120*197.50)/(396*146.50) (120*197.50)/(396*141)
Proportionate additional total cost per hectare $\Delta C/C$: - using producer base price - using unofficial market price	 0.20 0.21	 0.50*0.41 0.50*0.42
Proportionate additional total cost per unit of output $\Delta C/C(1+\Delta Y/Y)$: - using producer base price - using unofficial market price	 0.15 0.16	 0.20/(1+0.30) 0.21/(1+0.30)
Net proportionate cost reduction per unit of output $\Delta Y/Y\varepsilon$ - $\Delta C/C(1+\Delta Y/Y)$: - using producer base price - using unofficial market price	 0.24 0.23	 0.39-0.15 0.39-0.16
Probability of research success p	1	Assumed
Adoption rate	See table 3.18	Ndoye, February 22nd 2001
Initial equilibrium price	146.50 CFA Francs/kg 141 CFA Francs/kg	Table 3.13 Post demand shift equilibrium price

In the absence of information about the adoption lags and rates, the maximum rate of adoption and the length of the second lag are approximated on the basis of the available information. Since research on La Fleur 11 started in 1985 and La Fleur 11 was marketed in 1997, the duration of the research and development lag is 12 years (1985-1996). The second lag is the current lag; the adoption rate is increasing. According to a La Fleur 11 breeder, the second lag will be very long and the adoption will be constrained by exogenous factors such as seed demand and supply (Ndoye, February 22nd 2001).

Accordingly, the analysis will be based on different approximations of the second adoption lag (a short lag and a long lag) and of the maximum adoption rate (a low rate and a medium rate). The lengths considered are 10 and 20 years. A lag longer than 20 years seems to be unlikely because another new variety will probably be developed by then. The maximum adoption rates considered are 15 and 25 percent. A higher adoption rate is not employed for several reasons. La Fleur 11 is currently preferred to 55-437 because it produces larger peanuts and can be sold before the regular harvest period as peanut meal at a high price in the informal market for 300-400 CFA Francs/kg (Boye, 2000). However, because La Fleur 11 is less resistant than 55-437 to aflatoxins, a phyto-sanitary problem may appear and impede the early marketing of peanut meal reducing farmers' demand for La Fleur 11. Adoption of La Fleur 11 may also be limited due to the potential risk of cake contamination by aflatoxins though this problem doesn't exist with oil because aflatoxins are eliminated during the oil refinement process. Also, La Fleur 11 is not suitable for all environments; it was developed for the central area of the peanut basin and to date has been adopted most in that area. In addition, SONACOS currently ensures the supply of high quality seeds. When La Fleur 11 seeds begin to be marketed in the informal market, their quality will probably fall and reduce the farmers' willingness to acquire this seed.

Assuming that the adoption profile is linear, the increasing curve of the adoption profile takes the form: rate = intercept + slope*year. In the first (pessimistic) scenario where the second lag is 20 years and the maximum adoption rate is 0.15, the intercept and the slope can be derived from points (12 years;0 adoption rate) and (32 years;0.15 adoption rate). That is from the resulting system of equations, 0 = intercept + slope*12 and 0.15 = intercept + slope*32, the intercept and the slope can be simultaneously solved for: intercept = -0.09 and slope = 0.0075. Thus, the increasing adoption curve is: rate = -0.09 + 0.0075*year. Similarly, the following function is derived for the second (optimistic) scenario where the second lag is 10 years and the maximum adoption rate is 0.25: rate = -0.3 + 0.025*year.

Assuming that depreciation doesn't affect the net present value of the benefits very much because early years weigh more heavily than later years in the calculation of the NPV (Alston et al, 1995), table 3.17 is derived to describe the adoption profile in both scenarios. The first scenario is likely to be the most probable given the information in hand. It has lower adoption rates than the second scenario.

Table 3.17: Adoption rates in scenarios 1 and 2

Years	Scenario 1 (20 years, 15 percentage adoption)	Scenario 2 (10 years, 25 percentage adoption)
1≤years≤12	0	0
13	0.0075	0.025
14	0.015	0.05
15	0.0225	0.075
16	0.03	0.1
17	0.0375	0.125
18	0.045	0.15
19	0.0525	0.175
20	0.06	0.2
21	0.0675	0.225
22	0.075	0.25
23	0.0825	0.25
24	0.09	0.25
25	0.0975	0.25
26	0.105	0.25
27	0.1125	0.25
28	0.12	0.25
29	0.1275	0.25
30	0.135	0.25
31	0.1425	0.25
Years≥32	0.15	0.25

Research costs are estimated on the basis of the salaries paid to one or two scientists (a breeder and an agronomist) and two to four assistants from 1985 to 1996. In the absence of information about the salaries paid to the scientists, it is assumed that the scientists receive the maximum salary provided by the IMF (table 3.5). Although the assistants receive a higher salary (on average 75,000 CFA Francs per month) than the minimum salary provided by the IMF, the minimum salary is used because the assistants were also involved in other activities than research on La Fleur 11. As shown in table 3.18, the total amount of salaries is calculated for each year in CFA Francs. The annual researcher salaries are between 4 and 7 million CFA Francs during the research and development lag. When augmented by 20 percent to account for other costs than salaries (operating costs), the annual research costs obtained vary between 5 and 9 million CFA Francs.

Table 3.18: Research costs for the development of La Fleur 11
a) Elements for the approximation of the cost of research salaries

Years	Scientists		Assistants	
	number	Monthly salaries (FCFA)	Number	Monthly salaries (FCFA)
1985	1	238,165	3	36,462
1986	1	238,165	3	36,462
1987	1	238,165	3	36,462
1988	1	238,165	3	36,462
Jan-Jun 1989	1	238,165	3	36,462
Jul-Dec 1989	1	242,184	3	40,482
1990	1	242,184	3	40,482
1991	2	242,184	3	40,482
1992	2	242,184	3	40,482
Jan-Aug1993	2	242,184	4	40,482
Sep-Dec 1993	2	205,855	4	34,409
Jan-Mar1994	2	242,184	3	40,482
Apr-Dec 1994	2	258,684	3	52,482
1995	2	258,684	2	52,482
1996	2	258,684	2	52,482

b) Annual research costs

Years	Researcher salaries*	Research costs**
1985	4,170,612	5,004,734
1986	4,170,612	5,004,734
1987	4,170,612	5,004,734
1988	4,170,612	5,004,734
1989	4,267,086	5,120,503
1990	4,363,560	5,236,272
1991	7,269,768	8,723,722
1992	7,269,768	8,723,722
1993	7,367,752	8,841,302
1994	7,890,768	9,468,922
1995	7,467,984	8,961,581
1996	7,467,984	8,961,581

*: Calculated using the information in table a).
**: Calculated by increasing researcher salaries by 20 percent.
Source: Ndoye (2001), IMF (2000)

When benefits net of research costs are calculated for a specific commodity (seeds, oil, cakes,…) in the disaggregated market approach (see next section), research costs are calculated on the basis of a portion of total research costs of la Fleur 11. This portion is determined by the proportion of the supply of that commodity in the total supply of unshelled peanuts (see table 3.14).

The net present values of research benefits are calculated in CFA Francs using a 1998 discount rate, 0.0625. Then, they are converted in U.S. Dollars using the 1999 exchange rate, 615.70 CFA Francs/US$. The internal rates of return are calculated as well.

3.3 Results and analysis

3.3.1 Introduction

There are two main components in the analysis. First, a baseline scenario is calculated, then sensitivity analyses are conducted about some uncertain parameters. The baseline scenario is composed of two scenarios. The assumption underlying the first scenario is that peanut producers sell their production entirely on the official market at the producer base price and the evaluation is conducted at the farm level (aggregated market scenario). The assumption underlying the second scenario is that peanut producers use their supply in different ways but in fixed proportions (on farm consumption, informal sales and formal sales). Consequently, an evaluation is conducted for on farm consumption of unshelled peanuts, for 24 percent of the total supply of unshelled peanuts at the unofficial market price. An evaluation is conducted for farm sales of unshelled peanuts on the unofficial market, for 10 percent of the total supply of unshelled peanuts at the unofficial market price. Another evaluation is conducted for farm sales of peanut seeds on the official market, for 15 percent of the total supply of unshelled peanuts at the producer base price. All these three evaluations are conducted at the farm level. Because the rest of the formal sales involve a transformation into oil and cakes at SONACOS, oil and cakes are evaluated at the SONACOS level, each for 17.5 percent of the total supply of unshelled peanuts at the world price (disaggregated market scenario). These market and price assumptions will have major implications on the size, the sign and the distribution of research benefits among consumers, producers and the government. Every simulation is conducted for both types of adoption profile, the pessimistic adoption profile (20 years, 15 percent maximum adoption), which is likely to occur and the optimistic adoption profile (10 years, 25 percent maximum adoption). Also, each evaluation is conducted for both types of supply shift, parallel and pivotal. Figure 3.1 gives an overall view of the simulations. The analysis is conducted using a spreadsheet program.

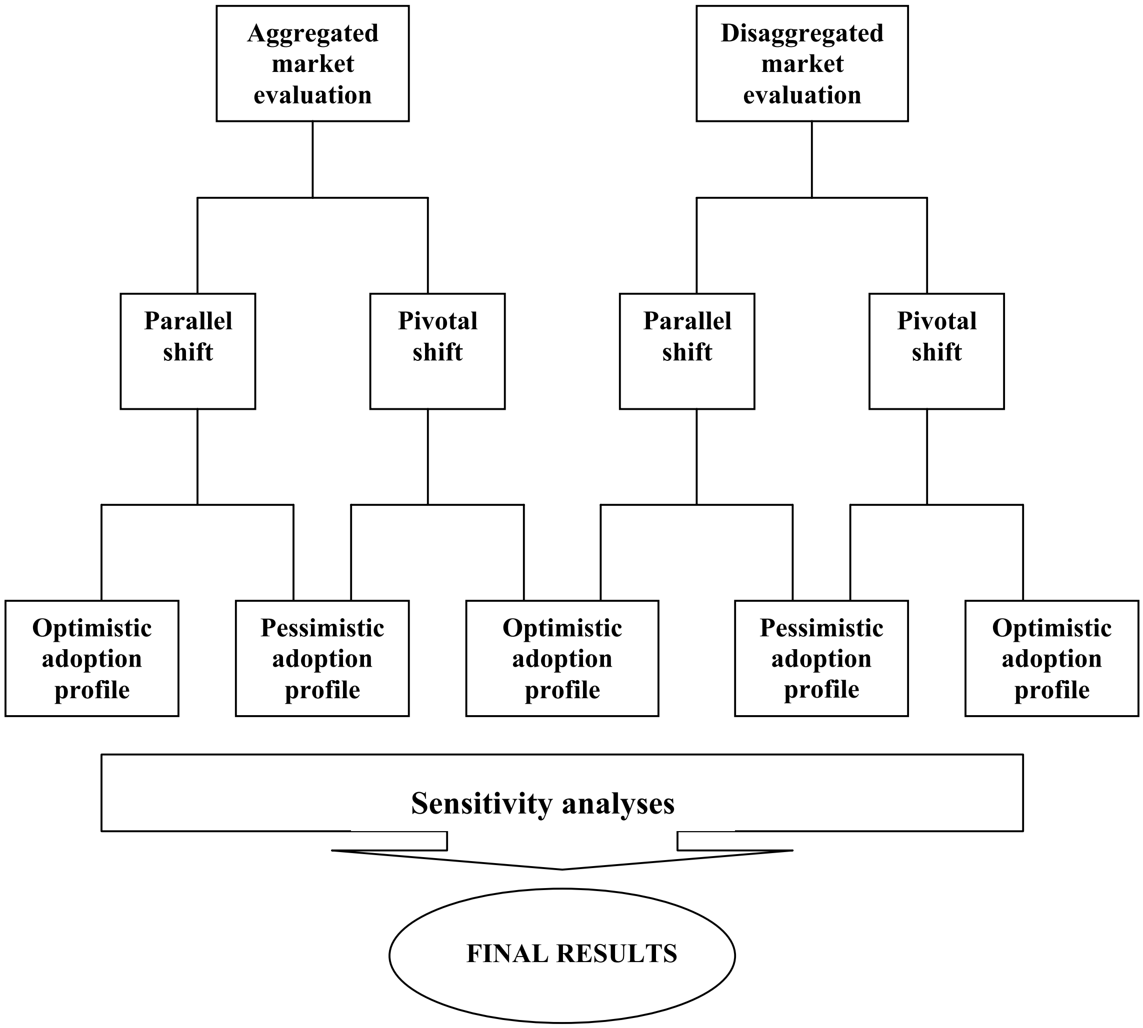


Figure 3.1: Overall view on simulations

3.3.2 Baseline scenario

Results of the baseline scenario are summarized in table 3.19.

Table 3.19: Total research benefits net of research costs for the different evaluations of the baseline scenario

US$	Aggregated market scenario		Disaggregated market scenario	
	Parallel	Pivotal	Parallel	Pivotal
Pessimistic adoption profile	12,416,381.08	6,570,692.68	9,685,676.36	4,873,572.77
Optimistic adoption profile	32,051,841.85	16,598,526.20	25,639,128.99	12,918,136.92

Two results were predictable. First the optimistic adoption profile engenders more benefits than the pessimistic adoption profile because higher adoption rates generate a larger supply shift. Second the parallel supply shift generates almost twice the benefits with a pivotal supply shift.

Research benefits are positive. The aggregated market scenario and the disaggregated market scenario have different results because of different market structures and pricing policies. The aggregated market scenario employs the producer base price. The disaggregated market scenario is composed of two commodities subject to the unofficial market price (farm household consumption and farm sales on the unofficial market), one commodity subject to a producer base price (seeds) and two commodities exported at the world price (oil and cakes). The aggregated market scenario generates more total benefits than the disaggregated market scenario, on average 26 percent more with the parallel supply shift and 31 percent more with the pivotal supply shift. In the aggregated market scenario, the optimistic adoption profile generates about 155 percent more benefits than the pessimistic adoption profile. In the disaggregated market scenario, the optimistic adoption profile generates about 165 percent more benefits than the pessimistic adoption profile. Table 3.20 disaggregates the benefits and provides further insights.

Table 3.20: Distribution of total research benefits among consumers, producers and the government for the different evaluations of the baseline scenario

a) Pessimistic adoption profile:

US$	Aggregated market scenario		Disaggregated market scenario	
	Parallel	Pivotal	Parallel	Pivotal
Consumers	50,377,317.38	50,377,317.38	8,451,166.56	8,451,166.56
Producers	11,788,143.00	5,942,454.60	8,758,463.50	3,946,359.91
Government	49,659,815.81	49,659,815.81	7,448,972.37	7,448,972.37
Net social welfare	12,505,644.57	6,659,956.17	9,760,657.69	4,948,554.10

b) Optimistic adoption profile:

US$	Aggregated market scenario		Disaggregated market scenario	
	Parallel	Pivotal	Parallel	Pivotal
Consumers	134,424,751.52	134,424,751.52	22,533,193.92	22,533,193.92
Producers	31,494,619.47	16,041,303.82	23,247,656.26	10,526,664.19
Government	133,778,265.64	133,778,265.64	20,066,739.85	20,066,739.85
Net social welfare	32,141,105.37	16,687,789.72	25,714,110.33	12,993,118.26

For both scenarios, the type of supply shift does not affect the changes in consumer surplus and in the cost of the subsidy as indicated by the formulas in chapter 2. The changes in producer surplus and net social welfare vary depending not only upon the type of adoption profile, but also upon the type of supply shift. The change in producer surplus is higher with a parallel supply shift than with a pivotal supply shift by 97 percent on average in the aggregated market scenario and 122 percent in the disaggregated market scenario. The change in net social welfare is higher with a parallel supply shift than with a pivotal supply shift by 90 percent on average in the aggregated market scenario and 97 percent in the disaggregated market scenario. The relative difference between a parallel and a pivotal supply shift is greater with the disaggregated market scenario than with the aggregated market scenario.

In the aggregated market scenario, consumers benefit from research more than producers do (4.2 times more when the supply shift is parallel and 8.4 times more when the supply shift is pivotal). This difference is due to the implementation of a producer base price in the context of a closed economy; while consumers benefit from both a price decrease and a supply increase, producers benefit from an increase in supply only. A pivotal shift doubles this difference because with a pivotal shift the change in producer surplus is about half that with a parallel shift. Consumers and producers gain 2.6 times more surplus with the optimistic adoption profile than with the pessimistic adoption profile. The increase in the cost of the subsidy and in the net social welfare is 2.6 times higher with the optimistic adoption profile than with the pessimistic adoption profile. Higher adoption rates generate more surplus for consumers, producers, and society but they induce more losses to the government. With a parallel supply shift, the increase in the cost of the subsidy represents 80 percent of the benefits to consumers and producers; the remaining 20 percent are the increase in net social welfare. With a pivotal supply shift, the increase in the cost of the subsidy and in the net social welfare represent 88 and 12 percent respectively of the total benefits to consumers and producers. Therefore, a pivotal shift increases the relative importance of the change in the government cost of the subsidy and decreases the relative importance of the change in net social welfare.

In the disaggregated market scenario, producers benefit 3 percent more from research than consumers do with the parallel shift. With the pivotal shift, consumers benefit 114 percent more from research than producers do. Again, this difference is due to the fact that producers' benefits with a parallel supply shift are twice those with a pivotal supply shift. As seen with the aggregated market scenario, benefits and costs are 2.6 times higher with the optimistic adoption profile than with the pessimistic adoption profile. With a parallel supply shift, the increase in the cost of the subsidy represents 43 percent of the benefits to consumers and producers; the remaining 57 percent are the increase in net social welfare. With a pivotal supply shift, the increase in the cost of the subsidy and the increase in net social welfare represent 60 and 40 percent respectively of the total benefits to consumers and producers. Therefore, a pivotal supply shift increases the importance of the change in the government cost of the subsidy, but decreases the importance of the change in net social welfare relative to gross social benefits. In addition, in the disaggregated market scenario, the increase in the government cost of the subsidy is lower and the increase in net social welfare is higher relative to gross social benefits in comparison to the aggregated market scenario.

These baseline results show that they are very sensitive to whether a single or a multi market procedure is used in the research evaluation. The rest of the analysis will focus on the disaggregated market procedure given that it better reflects the actual conditions of the peanut sector in Senegal.

The analysis of the vertical disaggregation of the peanut sector examines two different aspects: the distribution of the benefits among markets and the distribution of the benefits among consumers, producers and the government. These results are shown in table 3.21. Also, it would have been interesting to analyze and compare the impacts on the size and the distribution of research benefits between the current pricing policies and alternative prices if the government didn't intervene. To be done, this exercise requires information on alternative prices and the corresponding quantities supplied and consumed. Unfortunately, this information is not available.

Table 3.21: Distribution of the benefits among consumers, producers and the government and among markets in the disaggregated market scenario

US$	Total*	Consumers	Producers	Government
Farm household consumption:				
- Pessimistic adoption profile				
Parallel shift	2,676,501.63		2,676,501.63	
Pivotal shift	1,338,250.82		1,338,250.82	
- Optimistic adoption profile				
Parallel shift	7,075,441.21		7,075,441.21	
Pivotal shift	3,537,720.61		3,537,720.61	
Unofficial farm sales:				
- Pessimistic adoption profile				
Parallel shift	1,103,688.97	894,568.96	209,120.02	
Pivotal shift	552,680.39	894,568.96	-341,888.56	
- Optimistic adoption profile				
Parallel shift	2,923,385.88	2,369,481.19	553,904.69	
Pivotal shift	1,466,772.24	2,369,481.19	-902,708.95	
Farm official sales of seeds:				
- Pessimistic adoption profile				
Parallel shift	1,875,846.69	7,556,597.61	1,768,221.45	7,448,972.37
Pivotal shift	998,993.43	7,556,597.61	891,368.19	7,448,972.37
- Optimistic adoption profile				
Parallel shift	4,821,165.80	20,163,712.73	4,724,192.92	20,066,739.85
Pivotal shift	2,503,168.45	20,163,712.73	2,406,195.57	20,066,739.85
Farm level:				
- Pessimistic adoption profile				
Parallel shift	5,656,037.29	8,451,166.56	4,653,843.10	7,448,972.37
Pivotal shift	2,889,924.64	8,451,166.56	1,887,730.45	7,448,972.37
- Optimistic adoption profile				
Parallel shift	14,819,992.90	22,533,193.92	12,353,538.82	20,066,739.85
Pivotal shift	7,507,661.30	22,533,193.92	5,041,207.23	20,066,739.85
SONACOS sales of oil:				
- Pessimistic adoption profile				
Parallel shift	2,047,889.88		2,047,889.88	
Pivotal shift	1,024,894.41		1,024,894.41	
- Optimistic adoption profile				
Parallel shift	5,420,199.18		5,420,199.18	
Pivotal shift	2,715,868.94		2,715,868.94	
SONACOS sales of cakes:				
- Pessimistic adoption profile				
Parallel shift	2,056,730.52		2,056,730.52	
Pivotal shift	1,033,735.05		1,033,735.05	
- Optimistic adoption profile				
Parallel shift	5,473,918.26		5,473,918.26	
Pivotal shift	2,769,588.02		2,769,588.02	
SONACOS level:				
- Pessimistic adoption profile				
Parallel shift	4,104,620.41		4,104,620.41	
Pivotal shift	2,058,629.47		2,058,629.47	
- Optimistic adoption profile				
Parallel shift	10,894,117.44		10,894,117.44	
Pivotal shift	5,485,456.96		5,485,456.96	

*: Some totals may not correspond to the exact sum of consumer surplus, producer surplus and change in government cost of subsidy due to rounding errors.

A comparison between farm level and SONACOS level evaluations shows that:

- Farm-level research benefits represent 58 percent of the total of farm-level and SONACOS-level benefits;
- consumers benefit from research at the farm-level only;
- producers benefit from research at the farm-level by 13 percent more if the supply shift is parallel and 8 percent less if the supply shift is pivotal than at the SONACOS level;
- the only market involving the government is the seed market where the cost of the subsidy increases because of the implementation of a producer base price.

At the farm level on farm consumption, at 24 percent of production, is the main source of research benefits (47 percent of farm-level total benefits). At the farm level, research benefits consumers more than producers. Consumers benefit from research 1.8 times more than producers with a parallel supply shift and 4.4 times more with a pivotal supply shift. Producers lose surplus when they sell on the unofficial market. One possible reason for producers' loss of surplus when a pivotal shift of the supply curve is considered, is an inelastic demand for unshelled peanuts on the unofficial market. When the demand elasticity of –0.18 is changed for a unitary demand elasticity in the unofficial market, producers' benefits with the pivotal supply shift are no longer negative. With the unitary demand elasticity and the pessimistic adoption profile, they are 610,717.28 US Dollars when the supply shift is parallel and 72,666.38 US Dollars when the supply shift is pivotal. With the optimistic adoption profile, they are 1,623,896.89 US Dollars when the supply shift is parallel and 201,537.42 US Dollars when the supply shift is pivotal. Therefore it is effectively a more inelastic demand relative to supply in the unofficial market that generates the negative results with the pivotal supply shift. The government sets a producer base price in the seed market and incurs a cost of the subsidy, which increases with research. The increase in the cost of the subsidy represents 56 percent of the gross social benefits with a parallel supply shift and 72 percent with a pivotal supply shift.

At the SONACOS level, the cake market generates slightly more benefits than the oil market: 1.004 to 1.019 times more depending on the adoption profile and the type of supply shift, because the cake world price is lower than the oil world price.[14] Producers are the only beneficiaries in these markets.

Regarding the internal rates of return, the aggregated market scenario generates an IRR of 47 percent (parallel shift) or 40 percent (pivotal shift) for the pessimistic adoption profile and 60 percent (parallel shift) or 53 percent (pivotal shift) for the optimistic adoption profile. The lower internal rates of return are the most probable given that the pessimistic adoption profile is more likely to occur than the optimistic adoption profile. According to Alston et al (2000), who provide a critical review of the literature on rates of return to agricultural research, rates of return from research on field crops (including research on peanuts) are expected to be 74 percent on average (p. 58). The average rate of return is 49 percent in Africa and 60 percent in developing countries (p. 62). Nevertheless, rates of return in the present study remain difficult to interpret. First they are not compared with the rates of return of alternative projects. Second there are many parameters that may affect the magnitude and the interpretation of the rates of return: the type and the length of the adoption profile, the type of evaluation (ex-ante or ex-post

[14] In the producer surplus' formula, the initial equilibrium price is in the denominator (see chapter 2).

analysis, parallel or pivotal supply shift, econometric or non-econometric estimation), the type of project (multi-commodity or one commodity), and so forth.

To complete the analysis, table 3.22 provides the internal rates of return for each market. Similarly to the NPV, the IRR is higher when the adoption rate is relatively high and when the supply shift is parallel. The seed market, which exhibits the highest IRR, benefits most from research. On farm consumption and farm sales on the unofficial market have the same IRR. The oil and cake markets have the same IRR. All commodities, particularly those not subject to a price intervention, exhibit approximately the same IRR in each type of evaluation.

Table 3.22: IRR for each market of the disaggregated market approach

	IRR (%)
Farm household consumption:	
- Pessimistic adoption profile	
Parallel shift	45
Pivotal shift	38
- Optimistic adoption profile	
Parallel shift	59
Pivotal shift	51
Unofficial farm sales:	
- Pessimistic adoption profile	
Parallel shift	45
Pivotal shift	38
- Optimistic adoption profile	
Parallel shift	58
Pivotal shift	51
Farm official sales of seeds:	
- Pessimistic adoption profile	
Parallel shift	47
Pivotal shift	40
- Optimistic adoption profile	
Parallel shift	60
Pivotal shift	53
SONACOS sales of oil:	
- Pessimistic adoption profile	
Parallel shift	46
Pivotal shift	39
- Optimistic adoption profile	
Parallel shift	59
Pivotal shift	51
SONACOS sales of cakes:	
- Pessimistic adoption profile	
Parallel shift	46
Pivotal shift	39
- Optimistic adoption profile	
Parallel shift	59
Pivotal shift	51

3.3.3 Sensitivity analyses

In most circumstances, researchers are confronted with some uncertainty regarding the parameters they use in their analyses. In this study, the parameter uncertainty is due to several factors: parameter approximation, parameter estimation and parameter variability from year to year.

Research costs were approximated in the absence of actual data. They were approximated on the basis of salaries, which were augmented by a percentage to account for operating costs. The study has been conducted so far on the basis of a 20 percent increase, but a higher increase could also be considered given that in developing countries the share of salaries in total research expenditures is likely to be relatively low. For sensitivity analysis a 50 percent increase in research costs is considered. Table 3.23 contains the new research costs. The new annual research costs vary between 6 and 11 million CFA Francs.

Table 3.23: Estimated annual research costs on La Fleur 11 with a 50 percent increase of researcher salaries

Years	Researcher salaries	Research costs
1985	4,170,612	6,255,918
1986	4,170,612	6,255,918
1987	4,170,612	6,255,918
1988	4,170,612	6,255,918
1989	4,267,086	6,400,629
1990	4,363,560	6,545,340
1991	7,269,768	10,904,652
1992	7,269,768	10,904,652
1993	7,367,752	11,051,628
1994	7,890,768	11,836,152
1995	7,467,984	11,201,976
1996	7,467,984	11,201,976

Elasticities were estimated in previous studies. All the elasticities found in the literature are short-run elasticities. Given that the present research evaluation is conducted over more than three decades, using long-run elasticities may be more appropriate. Accordingly, another evaluation is conducted using long-run elasticities. The demand elasticity of –1.8 is arbitrarily chosen for the unshelled peanut market to replace the elasticity of –0.18. The supply elasticity of 3 and the demand elasticity of -2 are arbitrarily chosen for the oil and cake markets to replace the elasticities of 0.3 and –0.2 respectively. Concerning the elasticity of supply for unshelled peanuts, a unitary elasticity is used. There are two reasons behind this choice. First, with a unitary elasticity the gross cost reduction per unit of output $\Delta Y/Y\varepsilon$, the supply shift and research benefits are neither under-estimated (as with a very elastic supply) nor over-estimated (as with a very inelastic supply). Second, Gaye (1998 b) showed that the land use is very inelastic with respect to the peanut price: 0.223. Therefore, it is likely that the supply elasticity of unshelled peanuts is not very elastic in the long-run as well. A supply elasticity of 1 versus 0.77 may be enough to capture the effect of a relatively higher elasticity.

Only one number was used for the exchange rate (the average exchange rate for 1999, 615.70 CFA Francs/U.S. Dollar) and for the discount rate (the discount rate applied after August 31st 1998, 0.0625). However, these parameters vary every year. Consequently, instead of considering one-year's information an average is calculated for several years. For the exchange rate the post-devaluation period 1994-1999 is used in order to have comparable exchange rates. For the discount rate, the period October 1993 through September 1998 is used to calculate an average of the interest rate applied in the money market. The choice of this period is based on the availability of the data. The new numbers used are 560.11 CFA Francs/U.S. Dollar for the exchange rate and 0.0559 for the discount rate. The data used for the calculation of these averages were presented earlier in tables 3.2 and 3.3.

Though prices and quantities vary from year to year, no sensitivity analysis is conducted on these variables. The evaluation was conducted on the basis of averages as suggested by Alston et al (1995).

New results are obtained for each parameter changed and compared to the baseline scenario. For each parameter varied, only the most insightful results are presented.

1/ Research costs

Table 3.24: Total research benefits net of research costs for the different evaluations with a 50 percent increase in research salaries

US$	Aggregated market scenario		Disaggregated market scenario	
	Parallel	**Pivotal**	**Parallel**	**Pivotal**
Pessimistic adoption profile	12,394,065.21	6,548,376.81	9,666,931.03	4,854,827.43
Optimistic adoption profile	32,029,525.97	16,576,210.32	25,620,383.66	12,899,391.59

In table 3.24, because research costs are higher compared to the baseline there is a slight decrease in net benefits by $22,315.87 for the aggregated market scenario and by $18,745.33 for the disaggregated market scenario for both types of adoption profiles and supply shifts. These amounts are very low relative to the magnitude of the net benefits. They represent less than 0.4 percent of the benefits: 0.18 percent for the pessimistic adoption profile with the parallel shift; 0.3 percent for the pessimistic adoption profile with the pivotal shift; 0.07 percent for the optimistic adoption profile with the parallel shift; and 0.14 percent for the optimistic adoption profile with the pivotal shift. Therefore, an increase in research costs doesn't change the size of the benefits significantly.

2/ Supply and demand elasticities

<u>Table 3.25</u>: Distribution of total research benefits among consumers, producers, and the government for the different evaluations with long-run elasticities

a) Pessimistic adoption profile:

US$	Aggregated market scenario		Disaggregated market scenario	
	Parallel	Pivotal	Parallel	Pivotal
Consumers	4,053,355.35	4,053,355.35	840,417.97	840,417.97
Producers	7,295,957.31	3,672,125.90	5,709,710.73	2,767,869.84
Government	4,092,584.78	4,092,584.78	613,887.72	613,887.72
Net social welfare	7,256,727.88	3,632,896.47	5,936,240.99	2,994,400.10

b) Optimistic adoption profile:

US$	Aggregated market scenario		Disaggregated market scenario	
	Parallel	Pivotal	Parallel	Pivotal
Consumers	10,807,471.14	10,807,471.14	2,238,743.04	2,238,743.04
Producers	19,452,947.87	9,873,201.77	15,291,255.98	7,514,379.64
Government	11,003,436.74	11,003,436.74	1,650,515.51	1,650,515.51
Net social welfare	19,256,982.28	9,677,236.18	15,879,483.51	8,102,607.17

In table 3.25, long-run elasticities change both the size and the distribution of research benefits in comparison to short-run elasticities. In comparison to the baseline scenario, all benefits and costs are lower. Consumers' benefits decrease by 91 percent on average. In the aggregated market scenario, producers' benefits decrease by 38 percent. In the disaggregated market scenario, producers' benefits decrease by 34 percent with a parallel shift and 29 percent with a pivotal shift. The increase in the cost of the subsidy decreases by 92 percent. The change in net social welfare decreases by 42 percent on average in the aggregated market scenario and 38 percent on average in the disaggregated market scenario.

In comparison to the baseline scenario, producers are now the main beneficiaries. In the aggregated market scenario, producers gain 80 percent more benefits than consumers with the parallel supply shift and 9 percent less with the pivotal supply shift. In the disaggregated market scenario, producers gain 6.8 times more surplus with the parallel supply shift and 3.3 times more surplus with the pivotal supply shift than consumers. Again, while consumers' benefits don't change with the type of supply shift, producers' benefits with a pivotal shift are about half those with a parallel shift. As indicated by theory, producers benefit more from research when demand is relatively elastic. With an elasticity of demand of –0.18 (versus a supply elasticity of 0.77), producers were gaining 77 percent less surplus than consumers with a parallel supply shift and 89 percent less surplus with a pivotal supply shift in the aggregated market scenario. In the disaggregated market scenario, producers were gaining 3 percent more surplus than consumers with the parallel supply shift but 53 percent less surplus with the pivotal supply shift. With an elasticity of demand of –1.8 (versus a supply elasticity of 1), producers' change in surplus is greater than consumers' in most evaluations.

In the aggregated market scenario, with a parallel supply shift the increase in the cost of the subsidy represents 36 percent of the benefits to consumers and producers; the remaining 54 percent are the increase in net social welfare. With a pivotal supply shift, the increase in the cost of the subsidy and the increase in net social welfare represent 53 and 47 percent respectively of the total benefits to consumers and producers. In the disaggregated market scenario, with a parallel supply shift the increase in the cost of the subsidy represents 9 percent of the benefits to consumers and producers; the remaining 91 percent are the increase in net social welfare. With a pivotal supply shift, the increase in the cost of the subsidy and the net social welfare represent 17 and 83 percent respectively of the total benefits to consumers and producers. Therefore, with long-run elasticities the increase in the cost of the subsidy is lower and the increase in net social welfare is higher relative to the gross social benefits. This result is known in economic theory; government interventions generate fewer losses in relatively elastic markets.

For a complete analysis of the impact of long-run elasticities on the distribution and the size of the benefits, it would be insightful to look at the different markets that compose the disaggregated market scenario. Table 3.26 contains the impact of long-run elasticities on the distribution and the size of research benefits for each market.

<u>Table 3.26</u>: Impact of long-run elasticities on the distribution and size of the benefits in the disaggregated market scenario

US$	Total*	Consumers	Producers	Government
<u>Farm household consumption</u>:				
- Pessimistic adoption profile				
Parallel shift	1,611,719.52		1,611,719.52	
Pivotal shift	805,859.76		805,859.76	
- Optimistic adoption profile				
Parallel shift	4,260,646.28		4,260,646.28	
Pivotal shift	2,130,323.14		2,130,323.14	
<u>Unofficial farm sales</u>:				
- Pessimistic adoption profile				
Parallel shift	650,761.08	232,414.67	418,346.41	
Pivotal shift	326,695.66	232,414.67	94,280.99	
- Optimistic adoption profile				
Parallel shift	1,729,342.65	617,622.37	1,111,720.27	
Pivotal shift	872,662.50	617,622.37	255,040.12	
<u>Farm official sales of seeds</u>:				
- Pessimistic adoption profile				
Parallel shift	1,088,509.18	608,003.30	1,094,393.60	613,887.72
Pivotal shift	544,934.47	608,003.30	550,818.89	613,887.72
- Optimistic adoption profile				
Parallel shift	2,888,547.34	1,621,120.67	2,917,942.18	1,650,515.51
Pivotal shift	1,451,585.43	1,621,120.67	1,480,980.27	1,650,515.51
<u>Farm level</u>:				
- Pessimistic adoption profile				
Parallel shift	3,350,989.78	840,417.97	3,124,459.53	613,887.72
Pivotal shift	1,677,489.89	840,417.97	1,450,959.64	613,887.72
- Optimistic adoption profile				
Parallel shift	8,878,536.27	2,238,743.04	8,290,308.73	1,650,515.51
Pivotal shift	4,454,571.06	2,238,743.04	3,866,343.53	1,650,515.51
<u>SONACOS sales of oil</u>:				
- Pessimistic adoption profile				
Parallel shift	1,275,638.54		1,275,638.54	
Pivotal shift	641,468.04		641,468.04	
- Optimistic adoption profile				
Parallel shift	3,397,253.79		3,397,253.79	
Pivotal shift	1,720,798.22		1,720,798.22	
<u>SONACOS sales of cakes</u>:				
- Pessimistic adoption profile				
Parallel shift	1,309,612.66		1,309,612.66	
Pivotal shift	675,442.17		675,442.17	
- Optimistic adoption profile				
Parallel shift	3,603,693.46		3,603,693.46	
Pivotal shift	1,927,237.89		1,927,237.89	
<u>SONACOS level</u>:				
- Pessimistic adoption profile				
Parallel shift	2,585,251.20		2,585,251.20	
Pivotal shift	1,316,910.21		1,316,910.21	
- Optimistic adoption profile				
Parallel shift	7,000,947.25		7,000,947.25	
Pivotal shift	3,648,036.11		3,648,036.11	

*: Some totals may not correspond to the exact sum of consumer surplus, producer surplus and change in the government cost of subsidy due to rounding errors.

In table 3.26, in comparison to the baseline scenario, research benefits decrease by 40 percent at the farm level and 35 percent at the SONACOS level. Benefits from farm household consumption decrease by 39 percent. Benefits from farm sales on the unofficial market decrease by 41 percent. Benefits from the official seed market decrease by 42 percent. At the farm-level, consumers' benefits decrease by 90 percent and producers' benefits decrease by 32 percent with a parallel shift and 23 percent with a pivotal shift. The decrease with the pivotal shift is mostly due to farm household consumption. With the pivotal shift, producer surplus from unofficial farm sales increases with long-run elasticities while it decreases with short-run elasticities. The government cost of the subsidy increases but by 91 percent less than in the baseline scenario.

At the SONACOS level, research benefits decrease by 37 percent in the oil market and about 34 percent in the cake market. Producers' benefits decrease by 35 percent.

In conclusion, in comparison to the baseline scenario long-run elasticities change the magnitude and the distribution of research benefits. They decrease consumers' and producers' research benefits, the government cost of the subsidy, and the net social welfare. Therefore, only the government benefits from long-run elasticities versus short-run elasticities. The distribution of research benefits is more beneficial to producers than consumers in the aggregated market scenario (parallel shift) and at both levels (farmers' and SONACOS') of the disaggregated market scenario than in the baseline scenario.

3/ Exchange rate

<u>Table 3.27</u>: Total research benefits net of research costs for the different evaluations with an average exchange rate

US$	Aggregated market scenario		Disaggregated market scenario	
	Parallel	Pivotal	Parallel	Pivotal
Pessimistic adoption profile	13,648,686.56	7,222,823.17	10,646,963.87	5,357,266.88
Optimistic adoption profile	35,232,934.65	18,245,902.73	28,183,770.55	14,200,240.86

In table 3.27, since the change in the exchange rate applies equally to the different components of each evaluation (change in consumer surplus, change in producer surplus and change in the government cost of the subsidy), it doesn't affect the distribution of the benefits among consumers, producers and the government. However, the size of research benefits is higher because a lower exchange rate is employed. A decrease in exchange rate by 9 percent causes research benefits to increase by 9.9 percent in comparison to the baseline scenario.

4/ Discount rate

<u>Table 3.28</u>: Total research benefits net of research costs for the different evaluations with an average discount rate

US$	Aggregated market scenario		Disaggregated market scenario	
	Parallel	Pivotal	Parallel	Pivotal
Pessimistic adoption profile	14,447,361.94	7,648,579.70	11,273,480.62	5,676,801.12
Optimistic adoption profile	37,003,090.90	19,160,664.20	29,610,031.82	14,922,350.96

In table 3.28, since the change in the discount rate applies equally to the different components of each evaluation (change in consumer surplus, change in producer surplus and change in the government cost of the subsidy), it doesn't affect the distribution of the benefits among consumers, producers and the government. However, the size of research benefits is higher since a lower discount rate is employed. A decrease in the discount rate by 10 percent causes research benefits to increase by 16 percent with the pessimistic adoption profile and 15 percent with the optimistic adoption profile in comparison to the baseline scenario.

3.3.4 Conclusion

Benefits from the adoption of La Fleur 11 are positive. However, no general conclusion can be drawn about the distribution of research benefits among consumers, producers and the government. This depends on the type of procedure considered aggregated market or disaggregated market, on the type of commodity-market, on the level where the evaluation is done, and so forth. The aggregated market scenario (which is also a closed economy scenario) is more favorable to consumers than producers. The disaggregated market scenario is more favorable to producers with the parallel supply shift and more favorable to consumers with the pivotal supply shift. Consumers only benefit from closed economy markets and farm level evaluations. Producers benefit from all markets. Pricing policies change the size and the distribution of research benefits drastically. Consumers are the main beneficiaries from the implementation of a producer base price. Producers benefit mainly from household consumption, which represents a large proportion of the supply, and oil and cake exports at the world price. Research increases the government cost of the subsidy in the markets where a producer base price is implemented (aggregated market and seed market). Most of these results were predicted by theory.

The results of sensitivity analysis show that a change in research costs, the exchange rate and the discount rate don't affect the distribution of research benefits but they do affect the size of research benefits in comparison to the baseline scenario. Research benefits decrease with higher research costs and increase with lower exchange rate and discount rate. When long-run elasticities replace short-run elasticities, both the size and the distribution of research benefits are affected. Consumers and producers benefit less from research in all evaluations with long-run elasticities. With long-run elasticities, the distribution of research benefits is generally more favorable to producers than consumers (because demand is more elastic than supply). The government is the only beneficiary from long-run elasticities as it pays less for the subsidy.

DEDICATION

This thesis is dedicated to my parents and Oncle Abder who have supported me all the way since the beginning of my studies.

Also, this thesis is dedicated to my fiancé who has been a great source of motivation and inspiration.

Finally, this thesis is dedicated to all those who believe in the richness of learning.

LIST OF FIGURES

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LIST OF TABLES

AGRICULTURAL RESEARCH IN SENEGAL:

ECONOMIC SURPLUS EVALUATION OF THE ADOPTION OF VARIETY LA FLEUR 11 BY PEANUT FARMERS

Widad Soufi

Thesis submitted to the Faculty of the Virginia Polytechnic Institute and State

University in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

AGRICULTURAL AND APPLIED ECONOMICS

APPROVED:

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