Ministry of Agriculture and Agrarian Reform

NAPC

National Agricultural Policy Center

TRAINING MATERIALS

Partial Equilibrium Analysis of Policy Impacts (part II)

Compiled by

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Ministry of Agriculture and Agrarian Reform

Foreword

The present volume is part of the series "Training Materials", published by the National Agriculture Policy Center (NAPC) with the support of the FAO Project GCP/SYR/OO6/ITA. The series includes notes and handouts produced as part of the training activities carried out at the NAPC by the international experts recruited by the Project. Even though they cannot be considered as comprehensive textbooks, the NAPC decided to make these materials available for a wider public, considering them as a useful reference for the study and the practice of agricultural economics and policy analysis.

The FAO Project, which is generously funded by the Italian Government and executed in close coordination with the Syrian Ministry of Agriculture and Agrarian Reform (MAAR) has been supporting the establishment of a cadre of professional agricultural policy analysts for the NAPC and other institutions involved in the Syrian agricultural policy making process. This undertaking encompassed an intensive training activity articulated over two programs involving, in a five year period, a total of about 130 officials of the MAAR. Each training program comprised a set of intensive courses to provide theoretical background and familiarize with issues, concepts, methods and tools needed to carry out policy analyses. The set of courses was completed by on-the-job research experiences on issues of relevance for Syrian agricultural development, whose results have been published by the NAPC's Working Papers series. The formal training programs were also accompanied by seminars, shorter intensive courses and participation in research activities, which are still on-going as part of NAPC's staff capacity building process.

Training was part of a wider undertaking in institutions' building for agricultural policy analysis. Indeed, the Project has been providing support to the institutional development of the NAPC, its technical capacity to analyze, formulate and monitor agricultural policies, and its capacity to maintain and develop a comprehensive set of statistical information for the economic analysis of policies (the Syrian Agriculture Database).

The program of study on "Partial Equilibrium Analysis" has been delivered in two modules. In module II, Prof Conforti illustrated the theory of market equilibrium, with reference to the analysis of agricultural policies, within the most common quantitative frameworks, while in module I Prof Perali focused on the analysis of supply and demand, within a partial equilibrium setting.

This volume presents part of the training material of the module II of the program of study on "Partial Equilibrium Analysis". First the partial equilibrium approach is taken into account within the single market static framework. Then hints are provided on multi market analysis and general equilibrium framework.

Special emphasis is placed on the analysis of price policy, since this is among the most commonly implemented policy tools in agriculture. In this analysis special attention is devoted to the welfare effect of policy and technical changes.

This handout is made up of parts of several training materials and papers. These can be considered as additional reading on the topic of the course.

Particularly, section 1 is drawn from

FAO - TCAS, *Agricultural Policy Analysis Exercises*, ID8, Roma 1992

Section 2.1 is drawn from

Rivas L., J. A. García, C. Seré, L. S. Jarvis, L. R. Sanint, and D. Pachico *Economic surplus analysis model (modexc)* website http://www.ciat.cgiar.org/impact/index.htm CIAT, 1999

Section 2.2 is drawn from

Conforti P. "The Common Agricultural Policy in Main Partial Equilibrium Models", *working paper* n 7, Istituto Nazionale di Economia Agraria (INEA), Osservatorio sulle Politiche Agricole dell'UE, website http://www.inea.it/opaue/wp7.pdf, Roma, 2001

Section 2.3 is drawn from

Magnani R. e Perali F. (a cura di) *Laboratorio di Politica Economica*, Dispensa n. 1, Università di Verona, Dipartimento di Scienze Economiche, 2002

De Muro P. e Salvatici L. "The Common Agricultural Policy in Multisectoral Models", *working paper* n 11, Istituto Nazionale di Economia Agraria (INEA), Osservatorio sulle Politiche Agricole dell'UE, website http://www.inea.it/opaue/wp11.pdf, Roma, 2001

The reader should note that exercises pertaining the issues presented in the volume are available at NAPC in electronic format. These exercises are presented as excel workbooks and are solved, with the solutions highlighted in yellow. Accordingly, content of the cells highlighted in yellow should be deleted before doing the exercise. Furthermore, at NAPC, are also available the slides used in class during the lectures and the slides of the seminar on *Partial Equilibrium Analysis of the Agricultural Policies: the case of rice Common Market Organization in the European Union.*

Damascus, December 2003

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Chapter 1 - Market Equilibrium and Analysis[1]

The purpose of this part of the course is to illustrate the use of the partial equilibrium theory to analyze the impact of various policies on consumers, producers government budget and external trade.

To this end three region markets will be considered under different conditions, namely:

- Isolated markets;
- Integration of two regions;
- Full market integration.

Through the various steps, it will be possible to analyze various government interventions such as pan-territorial prices, price stabilization, food self-sufficiency, transportation and infrastructural policies.

The methods of this part of the course are based on demand and supply functions and on the concepts of partial equilibrium analysis.

1.1. Market equilibrium: graphical and computational analysis for fragmented markets

We shall consider three isolated regional markets with no possibilities of trade between them.

We first study Region 1, which has

- one consumption center, called Y, and
- two production areas, called C and D (Figure l).

For the description of the supply and demand curves of these centers we shall use linear functions (y = a + bx) and the following conventional symbols:

Dy	quantity demanded in the consumption center Y
Dy_o	intercept of the linear demand function in Y
Ay	slope of the linear demand function in Y
CPy	consumer price in Y
Sc	quantity supplied in the production center C
Sc_o	intercept of the linear supply function in C
Ac	slope of the linear supply function in C
Tcy	transportation cost from C to Y

[1] From: FAO - TCAS, *Agricultural Policy Analysis Exercises*, ID8, Roma 1992.

Flow chart on the three regions

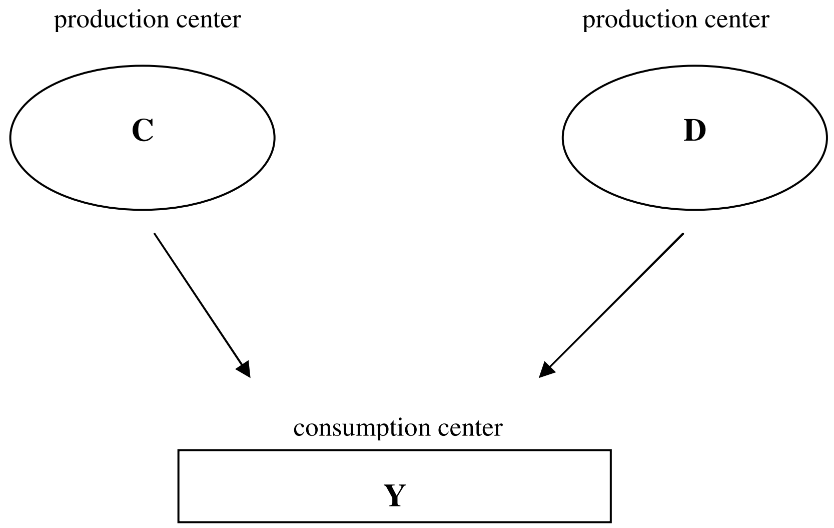


Table l. Region 1

Consumption Center Y	Production Centers C & D
Demand function (1) $Dy = Dy_o + Ay * CPy$ with: $Dy_o = 3000$ $Ay = -4$	Supply functions (2) $Sc = Sc_o + Ac*(CPy - Tcy)$ (3) $Sd = Sd_o + Ad*(CPy - Tdy)$ with: $Sc_o = -500$ $Ac = 6$ $Tcy = 19$ $Sd_o = -500$ $Ad = 4$ $Tdy = 25$

Note: Tcy and Tdy are the transport costs from the production areas to the consuming center; q is the quantity demanded or supplied; p is the price paid by the consumer in Y.

The familiar graphic of demand and supply can now be produced, paying attention to the fact that the above formula has to be inverted in order to have the quantity on X- axis and the price on Y -axis.

1. Demand derived from (1):

1a. $CPy(D) = -Dy_o/Ay + Dy/Ay$

2. Supply of C derived from (2) with and without transport cost.

2a. $CPy = -Sco/Ac + Sc/Ac$ (without transport)

2b $Cpy = (Tcy*Ac - Sco)/Ac + Sc/Ac$ (with transport)

3. Supply of C and D with transport cost obtained by adding the direct functions (2) and (3) and rearranging the terms to get CPy on the left hand side:

3 $CPy = [(Tcy*Ac+Tdy*Ad) -(Sco+Sdo)] / (Ac+Ad) +$

$(Sc+Sd)/(Ac+Ad)$

We want to produce a graph with demand and supply schedules of Region 1. In the following table, using the above formula, we compute few points on each curve. For a number of preselected quantities (x-axis), we compute the corresponding price (y-axis) on the demand curve (la), on the supply curve of C, not including transport cost (2a) and including transport cost (2b) and the combined supply curve of C and D. For example. to a quantity of 1500 tons Corresponds a price of:

375 on the demand curve

333.3 on the supply curve of C

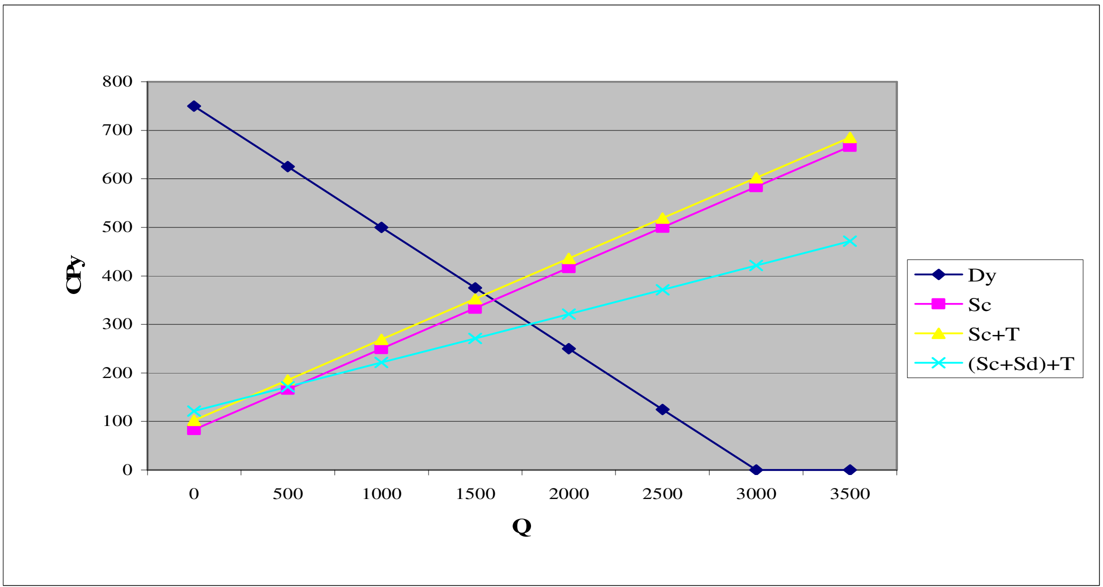
271.4 on the supply curve of C and d

Table 2

Defined Quantity	CPy 1a Dy	CPy 2a Sc	CPy 2b Sc+T	Cpy 3a (Sc+Sd)+T
0	750	83	102	121
500	625	167	186	171
1000	500	250	269	221
1500	375	333	352	271
2000	250	417	436	321
2500	125	500	519	371
3000		583	602	421
3500		667	686	471

We could use the graph to find the equilibrium price of Region 1, that is the quantity to which corresponds the same price on the supply and demand curve. The equilibrium lies on the crossing point of the demand and supply (C and D) curves. In our case, it is in the interval of quantities 1500-2000 and of price 272-322.

Figure 1.1. Supply and Supply C & D



To compute the equilibrium prices in analytical terms it is necessary to write that ìn the consumption center Y, supply is equal to demand.

If only the production center C is considered for supply

Demand = Supply of C

$-Dyo/Ay + Dy/Ay = (Tcy*Ac-Sco)/Ac + Sc/Ac$

since $Dy = Sc = q$

$q = [(Tcy*Ac-Sco)/Ac) + (Dyo/Ay)] / (1/Ay - 1/Ac)$

$q= 1554$

$p = 361$

If both production centers are considered

Demand = Supply of C and D

$Dy = (Sc+Sd) = q$

$-Dyo/Ay + q /Ay = [(Tcy*Ac+Tdy*Ad) - (Sco+Sdo)] / (Ac+Ad) + (Sc+Sd)/(Ac+Ad)$

thus

$q = \{Dyo/Ay + [(Tcy*Ac+Tdy*Ad) - (Sco+Sdo)] / (Ac+Ad)\} / [(1/Ay) - 1/ (Ac+Ad)]$

$q = 1796$

Considering 2a

$p =301$

substituting in the supply schedules we obtain

$qc = 1192$

$qd = 604$

and, by deducting transport costs

$pc = 282$

$pd = 276$

The same result could be obtained (more simply) by equating the direct demand and supplies, and calculating first the equilibrium price.

The equilibrium point in region 1 is obtained when a total of 1796 tons are produced, respectively 1192 in C and 604 in D. 1796 is exactly the amount demanded by the consumers at a price of 301. Since 301 is the price paid by the consumers, we have to subtract the transport cost to get the price paid to the producers of C and D, while we get the price of 282 and 276 respectively.

Some remarks on the results

l) The inclusion of the transportation costs causes an upwards shift of the supply curve.

2) The inclusion of a second center of production causes a shift of the supply curve towards the right.

The same computation can be repeated for Region 2

Table 3. Region 2

Consumption Center Z	Production Centers B and A
Demand function (4) Dz = Dzo + Az*CPz	Supply functions (5) Sb = Sbo + Ab*(CPz- Tbz) (6) Sa = Sao + Aa *(CPz- Taz)

Note: Tbz and Taz arc the transport costs from the producing areas to the consuming center.

Equilibrium price in Z (by equating demand and supply and solving for CPz) we have:

Cpz = (Dzo-Sbo-Sao+Ab*Tbz+Aa*Taz) / (Ab+Aa-Az) = 146

Dz = 1562 Sb = 667 Supply in B

Sa = 895 Supply in A

PPb = 139 Producer prices in B

PPa = 131 Producer prices in A

The same computation can be repeated also for Region 3

Table 4. Region 3

Consumption Center X	Production Center E
Demand function (7) Dx = Dxo + Ax*CPx with: Dxo = 5000 Ax = -5	Supply function (8) Se = Seo + Ae*(CPx-Tex) with: Seo = -1000 Ae = 5 Tex = 7

Equilibrium Price in X (by equating supply and demand and solving for CPx) we have

Cpx = (Dxo-Seo+Ae*Tex)/(Ae-Ax) = 604

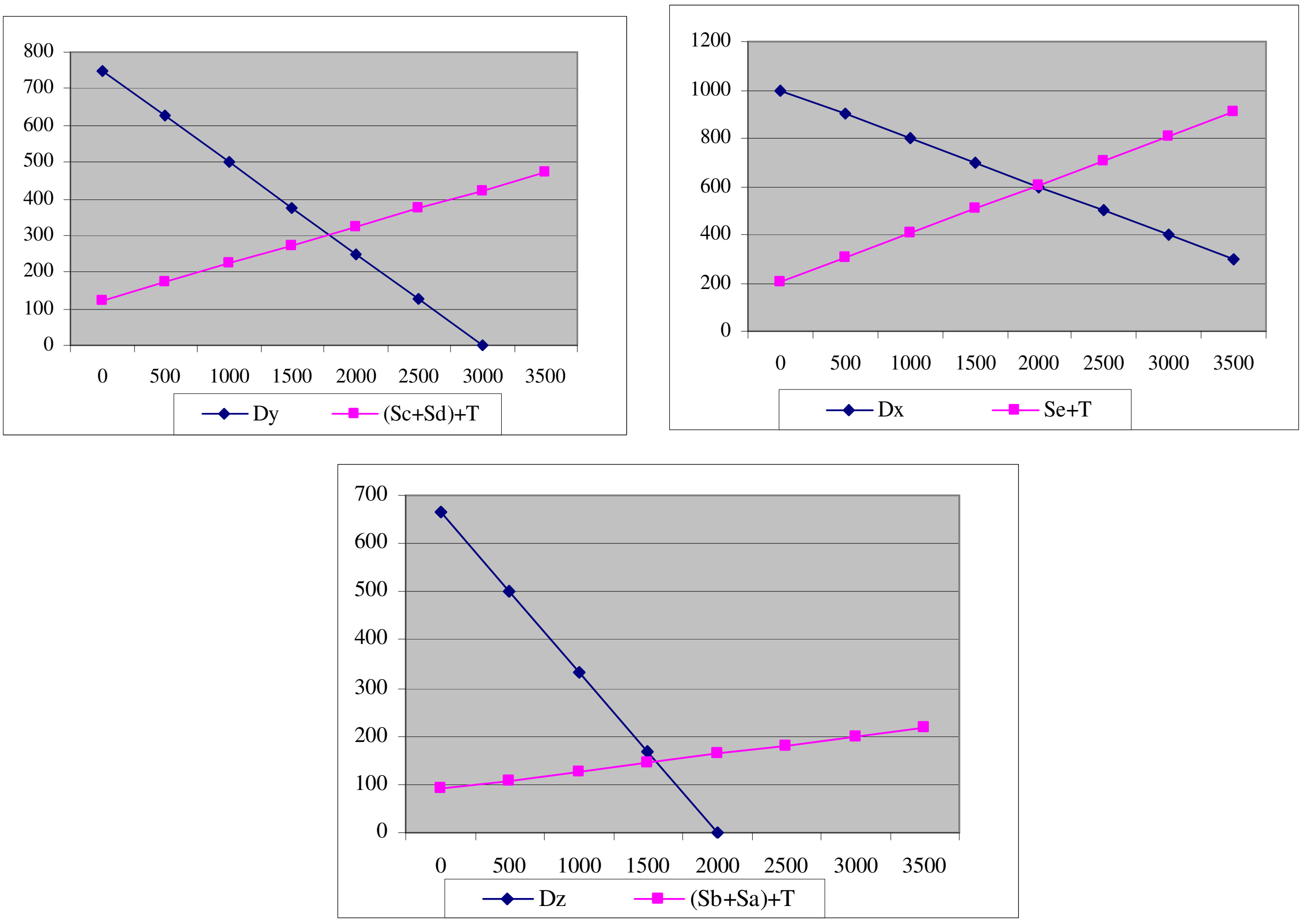
Dx = 1983 Se = 1983 T Supply in E

PPe = 597 Producer price in E

Table 5. Summary Table (Isolated regional markets)

Consumption Centers			Production Areas		
Y Reg 1	Price Quantity	301 1796	C D	Price Quantity Price Quantity	282 1192 276 604
Z Reg 2	Price Quantità	146 1562	B A	Price Quantity Price Quantity	139 667 131 895
X Reg 3	Price Quantity	604 1983	E	Price Quantity	597 1983

Figure 1.2. Demand and Supply in Region 1,2,3



Conclusions: the equilibrium prices in the isolated market of the three regions are quite different: they vary from 146 of Region 2 to 301 of Region 1 and 604 of Region 3. This strong variation reflects the different production and consumption characteristics of the three regions, particularly the strong production capacity of Region 2 and the strong demand of Region 3. Since the markets are isolated, the consumers of Region 3 cannot benefit of the maize produced in Region 1 at very low prices.

The condition of isolation of the three regions can be due to natural or political reasons. Distance and lack of communication facilities can make impossible the trade between the regions. Similarly, custom banners or political reasons can induce policy makers to introduce policy measures that eliminate trade.

1.2. Market integration in a closed economy

We shall now consider that two of the regional markets are actually connected by a road which allows trade to take place between them. The two regions considered here are Region 2, the region with high production potential, and Region 3, where the capital is located.

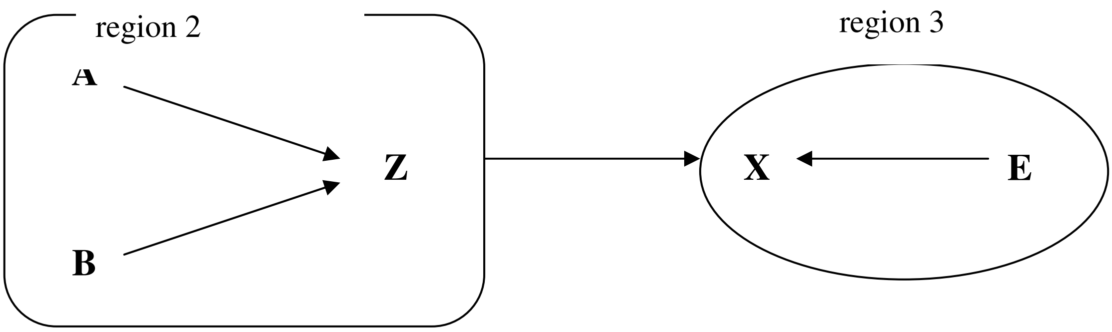
When isolated, these two regions had a high price differential. The consumer prices were respectively of 146 and 604 monetary units (MUs) in Region 2 and Region 3. If the two regions are connected, we can expect to see maize flowing from Region 2 to Region 3. The intensity of flow will depends particularly on the transport cost. Actually, if the transport costs were anywhere close to the price differential (604-146 = 458 MU), trade would become impossible, as the product produced in Region 2 would no more be competitive with the product of Region 3.

In our case, transport cost is actually 65 MU/T. So the road connection should make exchange possible, and the prices should find an equilibrium value where the difference between the consumer price in the two cities would be equal to the transport cost.

Table 6

Region 2		Region 3	
Consumption centre	Production centres	Consumption centres	Production centres
Dz = Dzo + Az*CPz	Sb = Sbo + Ab*(CPz-Tbz) Sa = Sao + Aa *(CPz-Taz)	Dx = Dxo + Ax*CPx	Se = Seo + Ae*(CPx-Tex)
with: Dz_o = 2000 Az = -3	with: Sbo = -1000 Ab = 12 Tbz = 7 Sao = -1200 Aa = 16 Taz = 15	with: Dxo = 5000 Ax = -5	with: Seo = -1000 Ae = 5 Tex = 7
Txz = 65 Transport cost from X to capital Z		Tzx = 65 Transport cost from capital Z to X	

Flow chart on connection be1ween region 2 and region 3



1.2.1. Supply and Demand in the new situation

If we assume to have a unique market in the two regions, we can write the following price relations, where PP stands for Producer Price, CP for consumer Price and T for Transport Cost:

$$CPz = CPx - Tzx$$

$$PPa = CPx - Tzx - Taz$$

$$PPb = CPx - Tzx - Tbz$$

$$PPe = CPx - Tex$$

As in the previous exercise, the equilibrium price CPx is determined by the identity: total demand = total supply, therefore:

$$Dx + Dz = Se + Sa + Sb$$

where:

$$Dx = Dxo + Ax * CPx$$

$$Dz = Dzo + Az * (CPx - Tzx)$$

$$Sa = Sao + Aa * (CPx - Taz - Tzx)$$

Sb = Sbo + Ab * (CPx- Tbz- Tzx)

Se = Seo + Ae * (CPx-Tex)

By substituting and solving far CPx, which is the only unknown, we have the following rather lengthy equation:

$$CPx = \frac{[(Dxo + Dzo - Seo - Sbo - Sao - AzTzx + AeTex + Ab(Tbz + Tzx) + Aa(Taz + Tzx)]}{(Ae + Ab + Aa - Ax - Az)}$$

with

CPx = 307	Se = 498
CPz = 242	Sb = 1816
Dx = 3467	Sa = 2427
Dz = 1275	
	PPe = 300
Total = 4742	PPb = 235
	PPa = 227

The new situation can be summarized in the following table:

Table 7. Summary (Z and X connected, y isolated)

consumption centers			Production areas		
Y reg 1	price	301.0	**C**	price	282.0
	quantity	1796.0		quantity	1192.0
			D	price	276.0
				quantity	604.0
Z reg 2	price	241.7	B	price	234.7
	quantity	1275.0		quantity	1816.2
			A	price	226.7
				quantity	2426.9
X reg 3	price	306.7	E	price	299.7
	quantity	3466.6		quantity	498.4

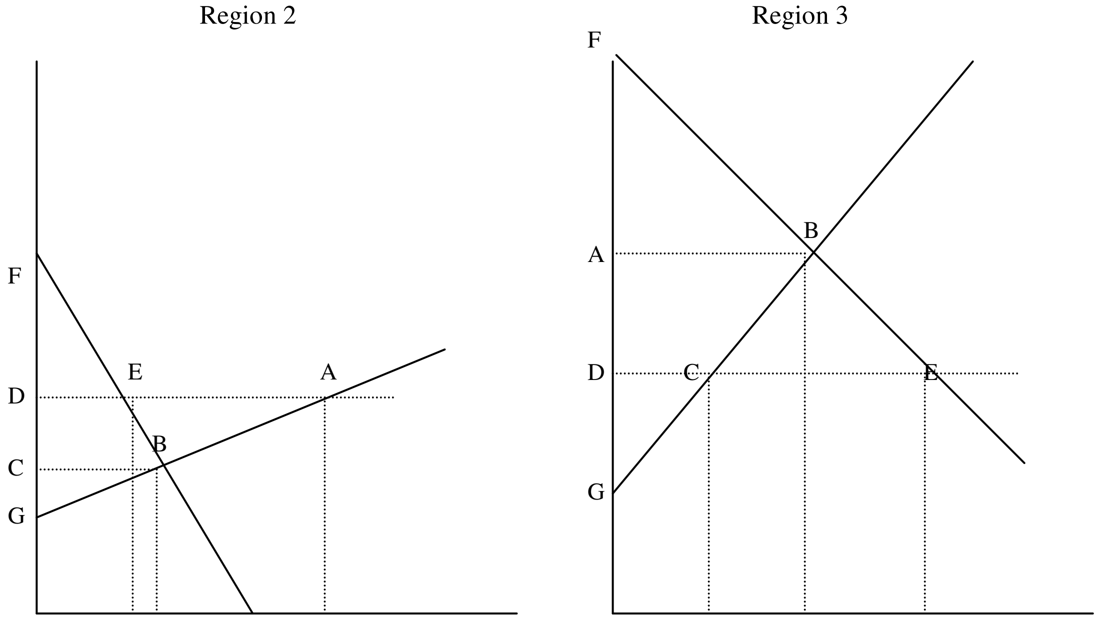
With integration, region 3 consumes 74% more, while region 2 consumes 18% less.

Price decrease by almost 50% in region 3, while it increases by almost 68% in region 2.

Production increases with integration in region 2, by more than 170%, while it decreases by almost 75% in region 3.

Altogether. there is an increase of 22% in total consumption, and an 22% decrease in production.

Impact of the Integration on Producers, Consumers and Traders of the two Regions



We want now to measure the impact of the integration of the markets on producers, on consumers and on traders of the two regions. For this purpose, we will use the concepts of consumer and producer surplus.

The surplus is a money metric welfare measure. Given linear supply and demand schedules, the change in surplus can be measured for consumers and producers respectively as

$(p_o - p_1) * (d_o + d_1) / 2$ (change in consumer surplus)

$(p_o - p_1) * (s_o + s_1) / 2$ (change in producer surplus)

A net surplus change (net welfare gain or loss) can also be calculated as the difference between these two, i.e. as

$(p_o - p_1) * [(d_o + d_1) - (s_o + s_1)] / 2$ (net gain or loss)

<u>Region 2</u>

With reference to the graphs above the consumer surplus is defined as the area FCB and FDE, respectively before and after integration of the two markets. The difference between the two consumer surpluses is the area CBED, which represents the losses of the consumers of Region 2.

The producer surplus is the area GCB and GAD respectively before and after the trade between the two regions. The area GCB is smaller than GAD, and therefore the producers of Region 2 gain the area CBAD with the introduction of trade.

Considering that the area CBAD, gained by the producers, is larger than the area CBDE, lost by the consumers, we conclude that the trade has brought a net benefit to Region 2, equal to BEA area.

In monetary and graphical terms we have:

Table 8. Region 2 Gains and Losses

	Area		Values
Loss of Consumers	CBED	(D-C)*(DE + CB)/2 = (242-140)*(1275 + 1562)/2	136,176
Gain of Producers	CBAD	(D-C)*(DA+CB)/2 = (242-146)*(1816+2427+1502)/2	278,640
Net Gain of Region 2	BAE	(D-C)*(A-E)/2 = (242-146)*(1816 + 2427-1275)/2	142,464

Note: In this calculation, for the sake of simplicity, we use consumer prices rather than producer prices where

D = price after trade integration

C = price before trade integration

DE = quantity consumed after trade integration

CB = quantity consumed before trade integration

DA = quantity produced after trade integration

All values computed are proportionally related to the change in prices and to the variation in quantities, as one can see from the formulae in the table. The loss of consumers (reduction in the consumer's surplus) is computed as the increased expenditure which the consumer has to pay for the price increase. It is obtained by multiplying the price increase by the average quantity consumed before and after the trade. Similarly, the gain of producers is the extra income received by the producers, and it is computed by multiplying the increase of price by the average quantity produced before and after the trade. Finally, the net gain of the region is the difference between the gain in income of the producers and the loss of consumers. In principle this is not fully accurate, since consumer prices are not equal to the producer prices due to transport costs.

To give a better idea of the above values we can compute their percentages with respect to the consumption value of the commodity before the trade.

Table 9. Region 2

	values	%
Consumer Surplus	-135,825	59.6
Producer Surplus	277,922	121.9
Net change of Region 2	142,097	62.3
cons value before trade	227,979	100.0

<u>Region 3.</u>

The opposite will happen in Region 3: through market integration, consumers will gain and producers will loose. Moreover, there will be a transfer of income equal to the amount of purchases made by Region 3 in Region 2, and the transport sector will increase its business by an amount equal to the transport cost.

We can now summarize the results for each one of the two regions and the total of the two regions.

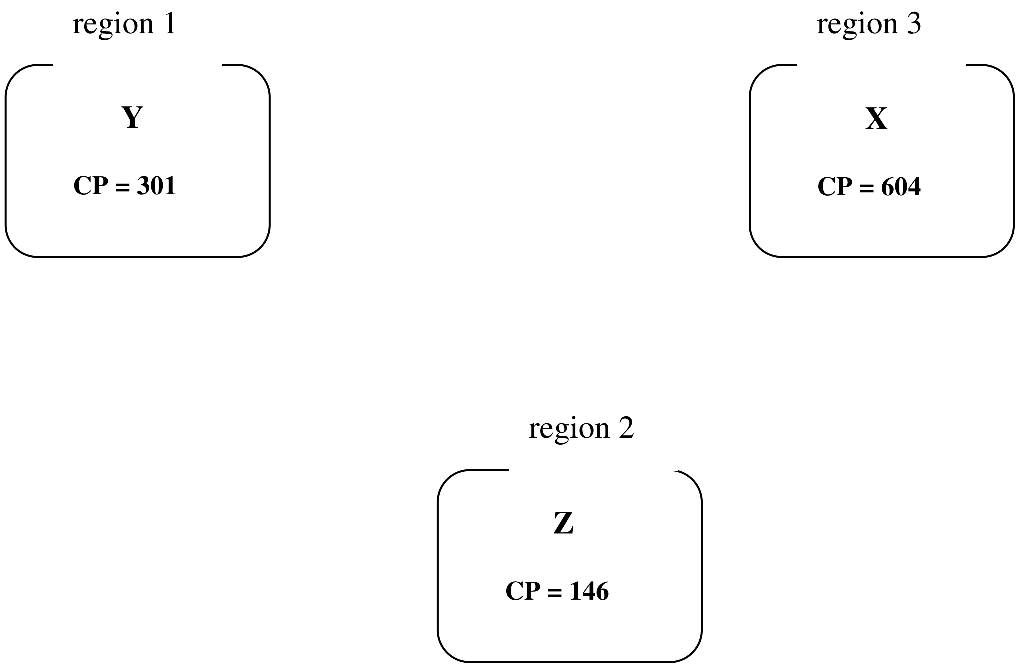
Table 10. Summary results

Region 2		
change in	Values	% of cons
Consumer Surplus	-135,825	59.6
Producer Surplus	277,922	121.9
Net change of Region 2	142,097	62.3
cons value before trade	227,979	100.0
Region 3		
change in	Values	% of cons
Consumer Surplus	808,691	76.1
Producer Surplus	-368,189	34.6
Net change of Region 3	440,502	41.4
cons value before trade	1,063,143	100.0
Total		
change in	Values	% of cons
Consumer Surplus	672,866	47.2
Producer Surplus	-90,267	6.3
Net change of Regions 2 & 3	582,599	40.9
cons value before the trade	1,424,418	100.0

1.2.2 Full Market Integration

In the second exercise we have analyzed the consequence of linking Region 2 and Region 3. Before integration of the two markets, consumers of Region 3 were used to pay a price of 604, while consumers of Region 2 were paying only 146 for a ton of maize. With the possibility of trade, many consumers of Region 3 found convenient to buy the good in Region 2.

Isolated Markets: consumer prices in the three regions



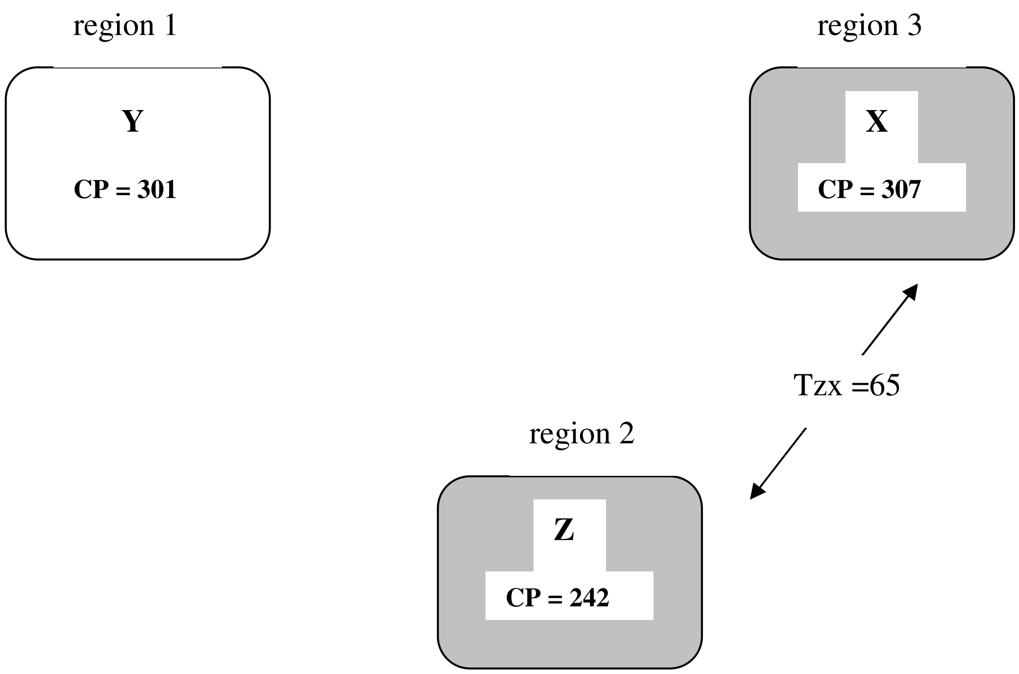
This process increased the quantity demanded in Region 3 (the price falls from 604 to 307) and increased the supply in the production centers A and B in Region 2. Producer prices increased from 139 and 131 to 235 and 227 in B and A respectively, while consumer prices in the consumption center Z rose from 146 to 242.

With a transport cost of 65 between Region 2 and Region 3, the equilibrium prices in the two regions were 307 and 242, respectively, with the difference of the two prices being equal to the transportation cost.

Connection of Region 2 with Region 3;

consumer prices in the three regions;

transport cost per unit



We can now analyze the possibility of trade between Region 2 and Region 1. Before trade prices are respectively 242 and 301. The consumer of Region 1 will buy maize in Region 2 if the transport cost is less than the difference in prices, which is 59. Since the transport cost is only 50, a trade flow from Region 2 to Region 1 will take place until the difference between the two prices is reduced to 50.

The conclusion is that with integration of the markets of the three regions the equilibrium price is reached when the regional price differences are equal to the existing transport costs among the regions.

1.2.3 Calculation of equilibrium price

We are now ready to compute the equilibrium price that will clear the markets in the three regions.

We have the following supply functions.

$$Sc = Sco + Ac\ CPy - Ac\ Tcy$$

$$Sd = Sdo + Ad\ CPy - Ad\ Tdy$$

$$Sb = Sbo + Ab\ CPz - Ab\ Tbz$$

$Sa = Sao + Aa\ CPz - Aa\ Taz$

$Se = Seo + Ae\ CPx - Ae\ Tex$

Using the relations among regional consumer prices, and taking Z as a reference we have :

$Cpy = CPz + Tyz$

$Cpx = CPz + Txz$

Thus we can write

$Sc = Sco + Ac\ CPz + Ac\ Tyz - Ac\ Tcy$

$Sd = Sdo + Ad\ CPz + Ad\ Tyz - Ad\ Tdy$

$Sb = Sbo + Ab\ CPz \qquad - Ab\ Tbz$

$Sa = Sao + Aa\ CPz \qquad - Aa\ Taz$

$Se = Seo + Ae\ CPz + Ae\ Txz - Ae\ Tex$

On the demand side we have

$Dy = Dyo + Ay\ CPy$

$Dz = Dzo + Az\ CPz$

$Dx = Dxo + Ax\ CPx$

Using the above relations among regional prices:

$Dy = Dyo + Ay\ CPz + Ay\ Tyz$

$Dz = Dzo + Az\ CPz$

$Dx = Dxo + Ax\ CPz + Ax\ Txz$

thus

$$CPz = [- (Sco + Sdo + Seo + Sbo + Sao) + (Dyo + Dxo + Dzo) + (Ay\ Tyz + Ax\ Txz) + (Ac\ (Tcy - Tyz) + Ad\ (Tdy - Tyz) + Ae\ (Tex - Txz) + Ab\ Tbz + Aa\ Taz] / (Ac + Ad + Ae + Ab + Aa - Ay - Ax - Az)$$

Table 11. Summary Table of Supply and Demand functions.

Production: Supply functions		Consumption: demand functions	
Region 1		Region 1	
C	Sc = -500 +6(Pz+50-19)	Y	Dy = 3000 - 4(Pz+50)
D	Sd = -500 +4(Pz+50-25)		
Region 2		Region 2	
B	Sb = -1000 +12(Pz-7)	Z	Dz = 2000 - 3 Pz
A	Sa = -1200 +16(Pz-15)		
Region 3		Region 3	
E	Se = -1000 +5(Pz+65-7)	X	Dx = 5000 - 5(Pz+65)

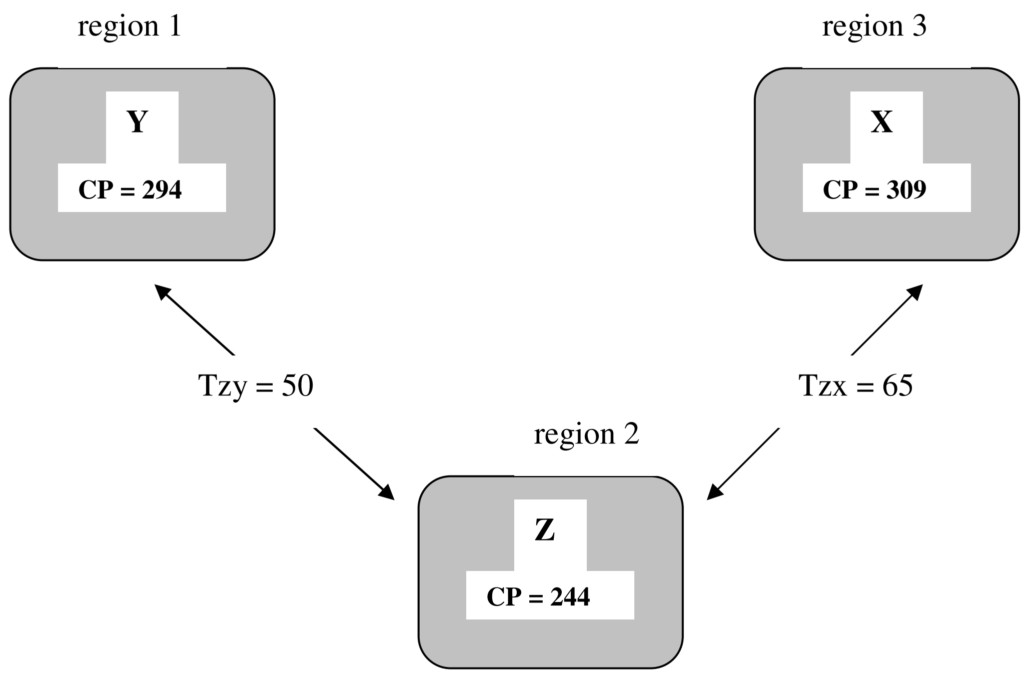
Table 12

Integrated markets					
	prices	demand			
Y	294	1824			
Z	244	1268			
X	309	3455			
	prices	production quantity	local transport cost	production value	
C	275	1,150	21,856	316,403	
D	269	576	14,405	155,034	
B	237	1,845	12,913	437,284	
A	229	2,465	36,973	564,590	
E	302	510	3,572	154,130	
Total		6,546	89,719	1,627,441	
	production quantity	regional trade	regional transport cost	imports	consumption value
Y	1,727	-97	4,862	0	536,291
Z	4,310	3,042	0	0	309,421
X	510	-2,944	191,390	0	1,067,699
Total	6,546	0	196,251		1,913,412

Full Market Integration:

Consumer Prices

transport cost per unit



Full Market Integration

Producers Prices

transport cost per unit

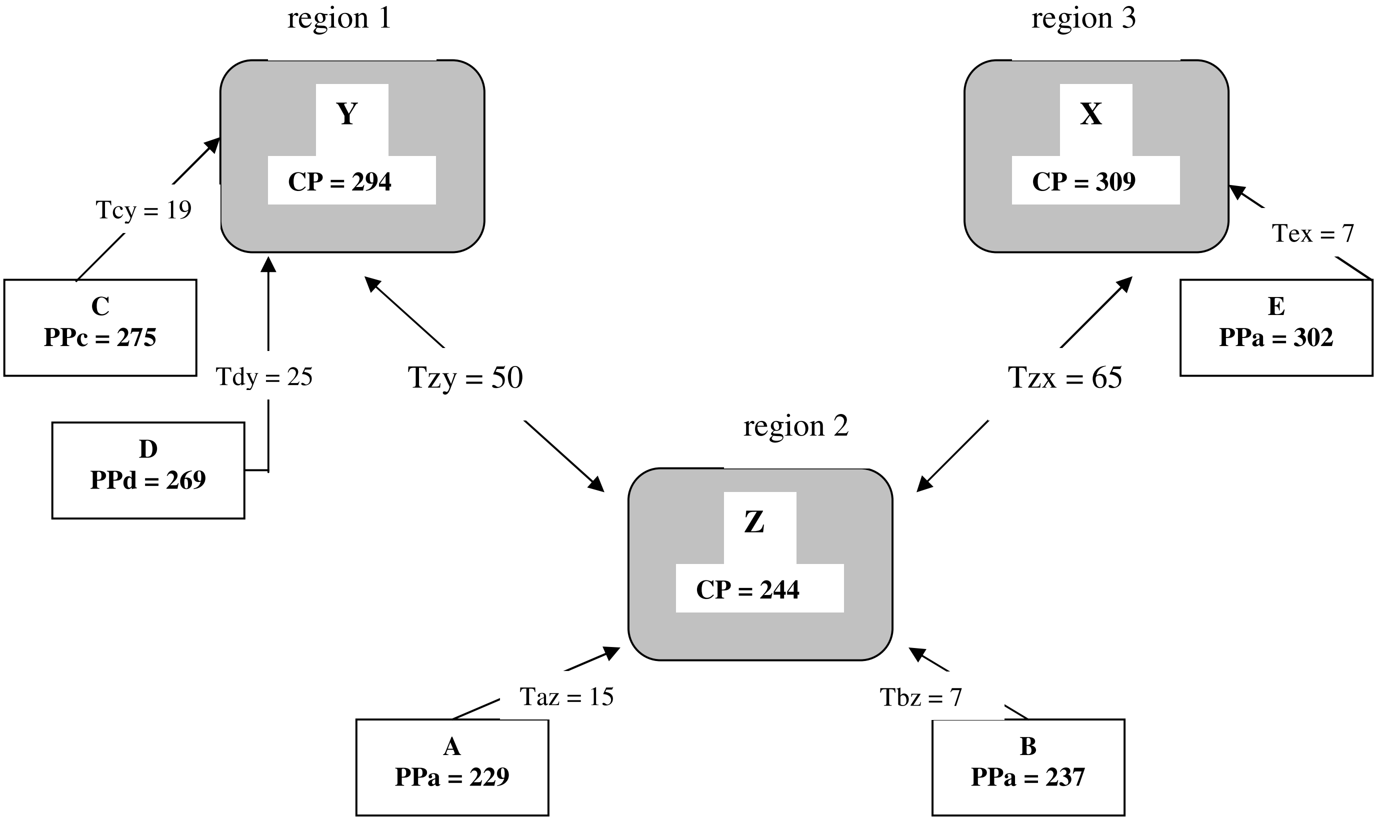


Table 13

Comparison: isolated and integrated markets

	prices		production quantities		Changes in producer surplus	production values	
	closed	open	closed	open		closed	open
C	282	275	1,192	1,150	-8,134	336,144	316,403
D	276	269	604	576	-4,099	166,704	155,034
B	139	237	667	1,845	123,232	92,701	437,284
A	131	229	895	2,465	164,832	117,183	564,590
E	597	302	1,983	510	-366,993	1,182,561	154,130
total			5,341	6,546	-91,162	1,895,294	1,627,441
	prices		consumed quantities		Changes in consumer surplus	consumption values	
	Closed (isolated)	open	Closed (isolated)	open		Closed (isolated)	open
Y	301	294	1,796	1,824	12,571	540,596	536,291
Z	146	244	1,562	1,268	-138,840	227,979	309,421
X	604	309	1,983	3,455	800,483	1,196,439	1,067,699
total			5,341	6,546	674,214	1,965,014	1,913,412

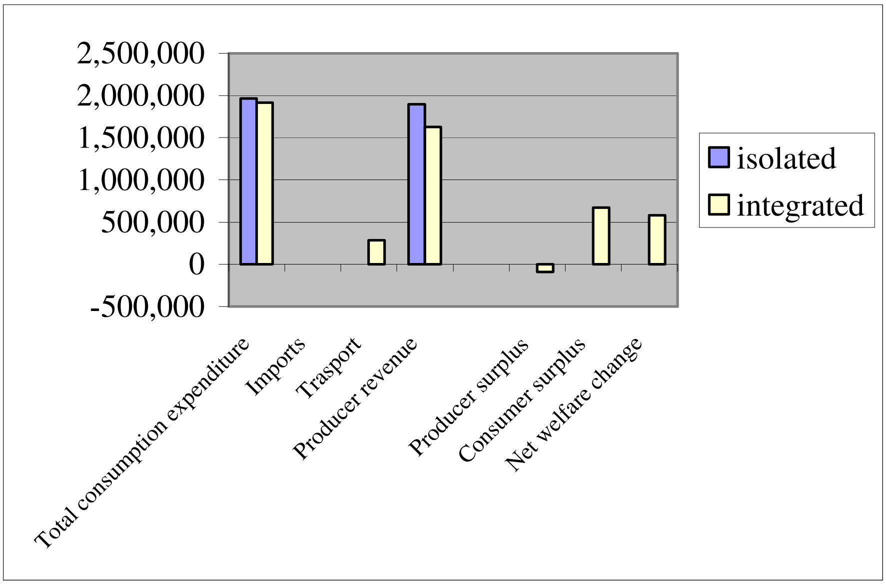
Table 14

Summary: Integrated and isolated markets	closed	open	% change
Total consumption expenditure	1,965,014	1,913,412	-2.6
Imports	0	0	0.0
Transport		285,971	0.0
Producer revenue	1,895,294	1,627,441	-14.1
Producer surplus		-91,162	-5.6
Consumer surplus		674,214	35.2
Net welfare change		583,052	30.5

1.2.4 Welfare calculation

The gains of the consumers are definitively greater than the losses of the producers and the costs of transport. This means that the integration of market is beneficial to the country, although we have to recognize that not everybody will benefit from the new situation.

Figure 1.3. Comparison: Isolated and Integrated Markets



1.3. Production, consumption and trade in an open economy

We can now analyze the impact of opening the country to the international trade.

The integrated market solution in the previous step will be called now “closed economy” and will be compared with the “open economy” situation. We shall suppose that our country has only one port of entry located in Region 3, next to the consumer center X. If the import price is 275, the consumers of X will prefer to consume imported maize, which is cheaper than the local maize presently sold at 309.

The preference will continue to exist until the local maize is sold at the same price of 275. Considering that a lot of maize (almost 3000 tons) sold in X (Region 3) is coming from Z (Region 2) and the transport cost between the two places is 65, the maximum price that can be assigned to the maize in Z is given by the price in X minus the transport cost, that is 210. Otherwise the excess production will not be absorbed by the consumers of Region 3. Similarly, the price in Region 1, which was also importing maize from Region 2, will be also equal to the price of Region 2 (210) plus the transportation cost of 50, that is 260.

Then, the producer prices can be derived by the consumer prices by subtracting the transportation cost within the regions.

Once the consumer and producer prices are known, we can compute demand, production and imports.

Table 15. Calculation of consumption, production and trade in an open economy

	prices		demand		
Y	260		1960		
Z	210		1370		
X	275		3625		
	prices	production quantity	local transport cost	production value	
C	241	946	17,974	227,986	
D	235	440	11,000	103,400	
A	203	1436	10,052	291,508	
B	195	1920	28,800	374,400	
E	268	340	35,574	91,120	
total	214	5082		1,088,414	
	production quantity	regional trade	regional transport cost	imports	consumption value
Y	1,386	-574	28,700	0	509,600
Z	3,356	1,986	0	0	287,700
X	340	-1,412	91,780	1873	996,875
total	5,082	0	120,480	1873	1,794,175

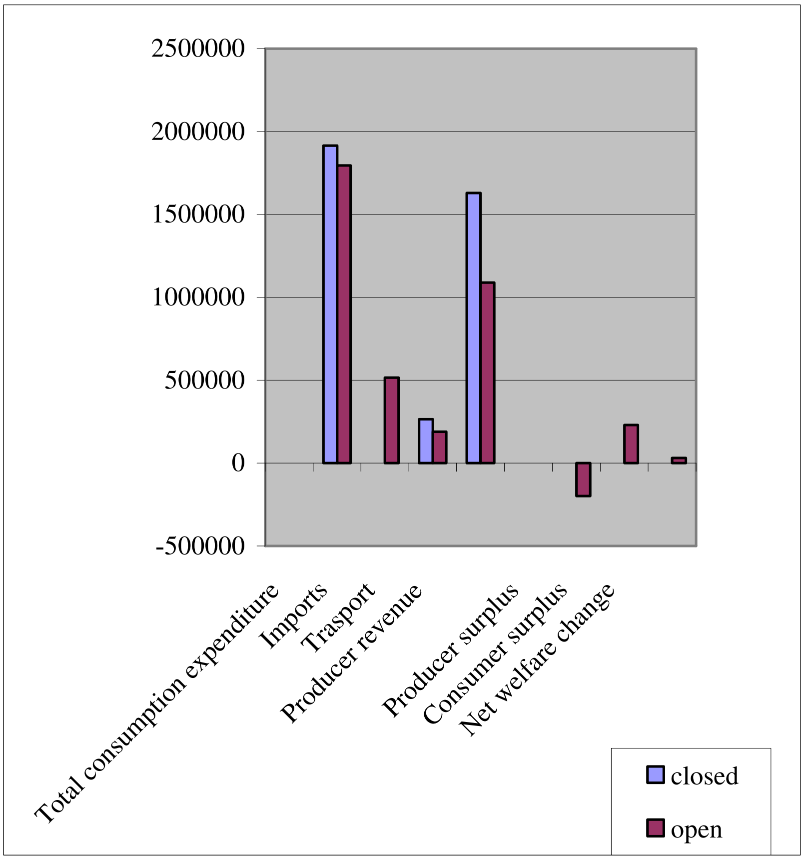
Table 16.

Comparison: closed (isolated) and open economy							
	prices		production quantities		Changes in producer surplus	production values	
	closed	open	closed	open		closed	open
C	275	241	1,150	946	-35,695	316,403	227,986
D	269	235	576	440	-17,303	155,034	103,400
B	237	203	1,845	1,436	-55,861	437,284	291,508
A	229	195	2,465	1,920	-74,662	564,590	374,400
E	302	268	510	340	-14,478	154,130	91,120
Total			6,546	5,082	-197,999	1,627,441	1,088,414
	prices		consumed quantities		Changes in consumer surplus	consumption values	
	closed	open	closed	open		closed	open
Y	294	260	1,824	1,960	64,427	536,291	509,600
Z	244	210	1,268	1,370	44,915	309,421	287,700
X	309	275	3,455	3,625	120,548	1,067,699	996,875
total			6,546	6,955	229,891	1,913,412	1,794,175

Table 17

Summary: closed and open economy			
	closed	open	% change
Total consumption expenditure	1,913,412	1,794,175	-6.2
Imports	0	515,075	0.0
Transport	266,000	190,686	-28.3
Producer revenue	1,627,441	1,088,414	-33.1
Producer surplus		-197,999	-18.2
Consumer surplus		229,891	12.8
Net welfare change		31,892	1.8

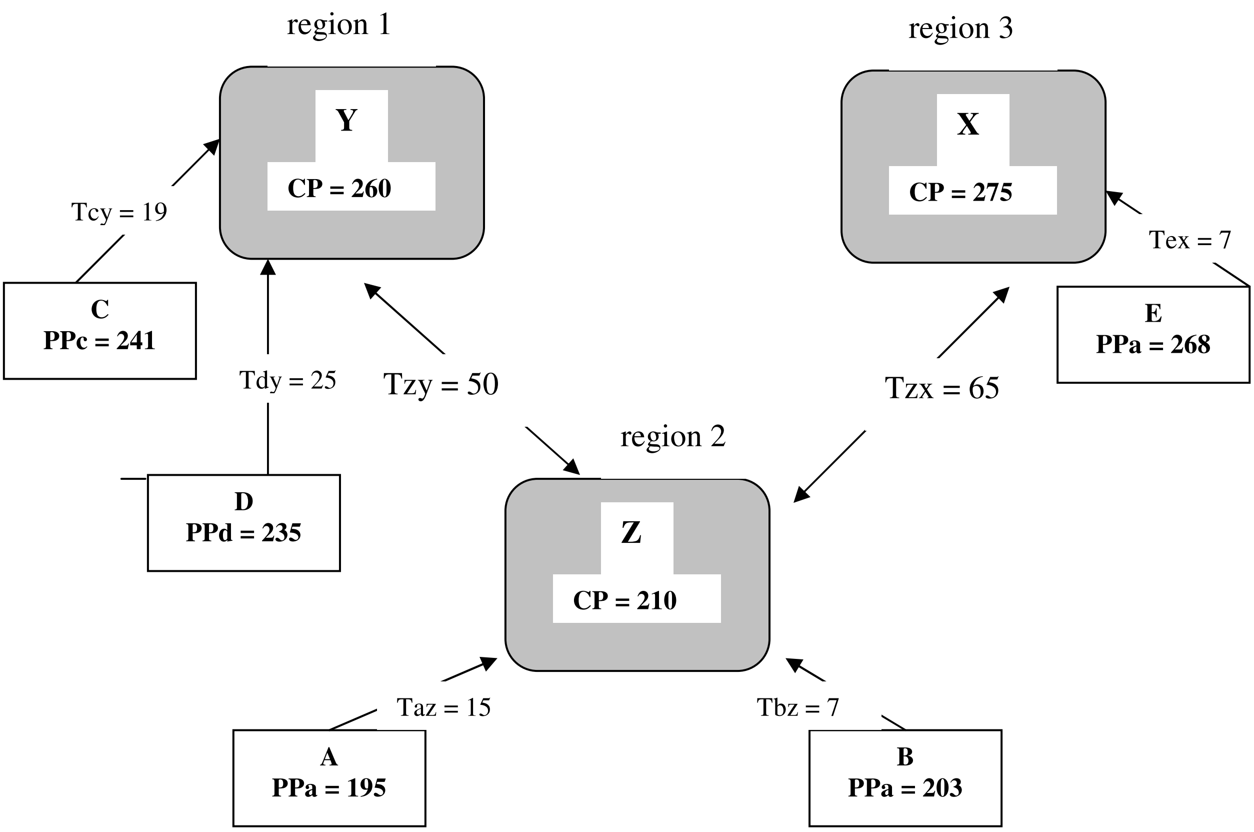
Figure 1.4. Comparison: closed and open economy



Open Economy

Consumer and Producer prices in the three regions

transport cost per unit



1.4. Price policy analysis: the case of pan territorial prices with a marketing board

Using the open economy solution as a basis of reference, we analyze now of some of the price policies more frequently implemented by the Governments.

First of all we shall assume that the Government has a Marketing Board for implementing its policies to pay a given price to producers, to redistribute the goods of the consumers, to import, etc.

Assuming the existence of a single marketing will simplify the analysis also in those cases in which several agents and institutions intervene at different stages with producers, consumers, etc.

The first policy measure analyzed is the "pan-territorial prices", through which the Government guarantees the same price to all producers and to all consumers with the objective of achieving equal treatment for all its citizens, independently of regions and places where they live.

We shall analyze the case in which the Government fixes the price for the consumers and producers equal to the average price obtained in the open market solution. It is also assumed that the price paid by the Marketing Board for the imports is equal to 275.

Table 18

	prices	demand			
Y	258	1968			
Z	258	1226			
X	258	3710			
	prices	production quantity	local transport cost	production value	
C	214	784	14,896	167,776	
D	214	356	8,900	76,184	
B	214	1,568	10,976	335,552	
A	214	2,224	33,360	475,936	
E	214	70	490	14,980	
total		5,002	68,622	1,070,428	
	production quantity	regional trade	regional transport cost	imports	consumption value
Y	1,140	-828	41,400	0	507,744
Z	3,792	2,566	0	0	316,308
X	70	-1,738	112,970	1902	957,180
total	5,002	0	154,370		1,781,232

Table 19.

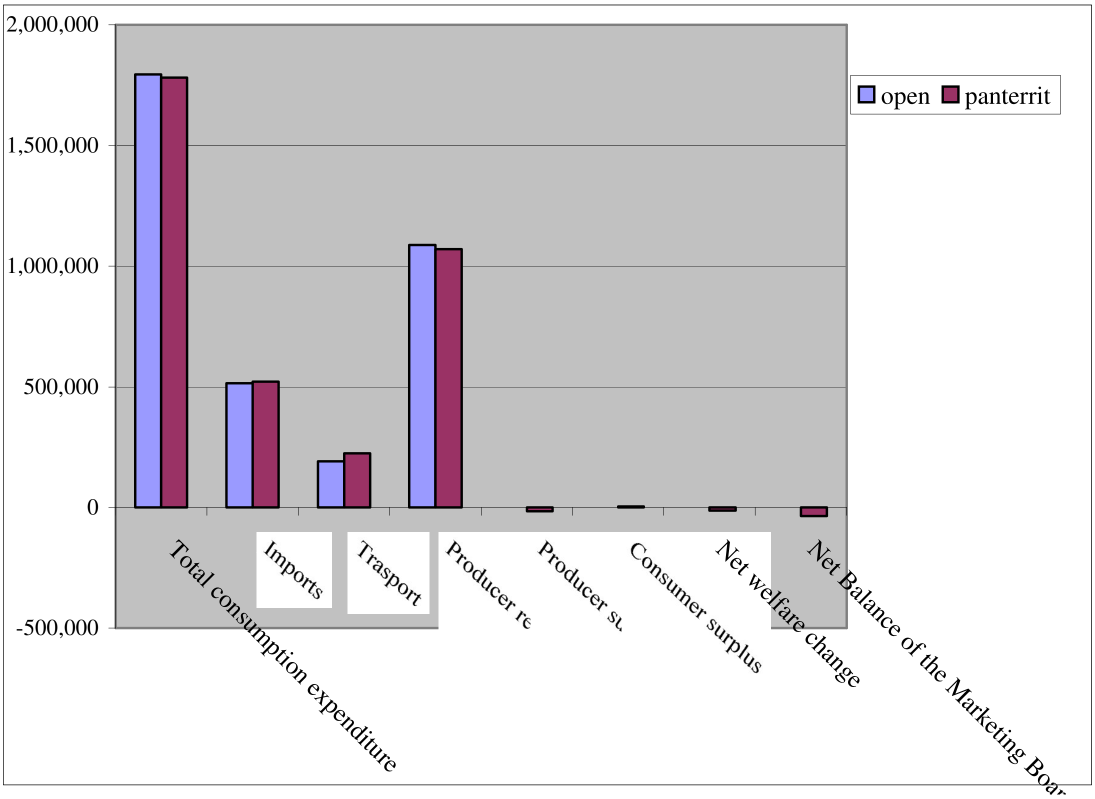
Comparison: open economy and pan territorial prices							
	prices		production quantities		Changes in producer surplus	production values	
	open	panterrit	open	panterrit		open	panterrit
C	241	214	946	784	-52,812	227,986	167,776
D	235	214	440	356	-8,358	103,400	76,184
B	203	214	1,436	1,568	16,522	291,508	335,552
A	195	214	1,920	2,224	39,368	374,400	475,936
E	268	214	340	70	-11,070	91,120	14,980
total			5,082	5,002	-16,350	1,088,414	1,070,428
	prices		consumed quantities		Changes in consumer surplus	consumption values	
	open	panterrit	open	panterrit		open	panterrit
Y	260	258	1,960	1,968	3,928	509,600	507,744
Z	210	258	1,370	1,226	-62,304	287,700	316,308
X	275	258	3,625	3,710	62,348	996,875	957,180
total			6,955	6,904	3,972	1,794,175	1,781,232

Table 20.

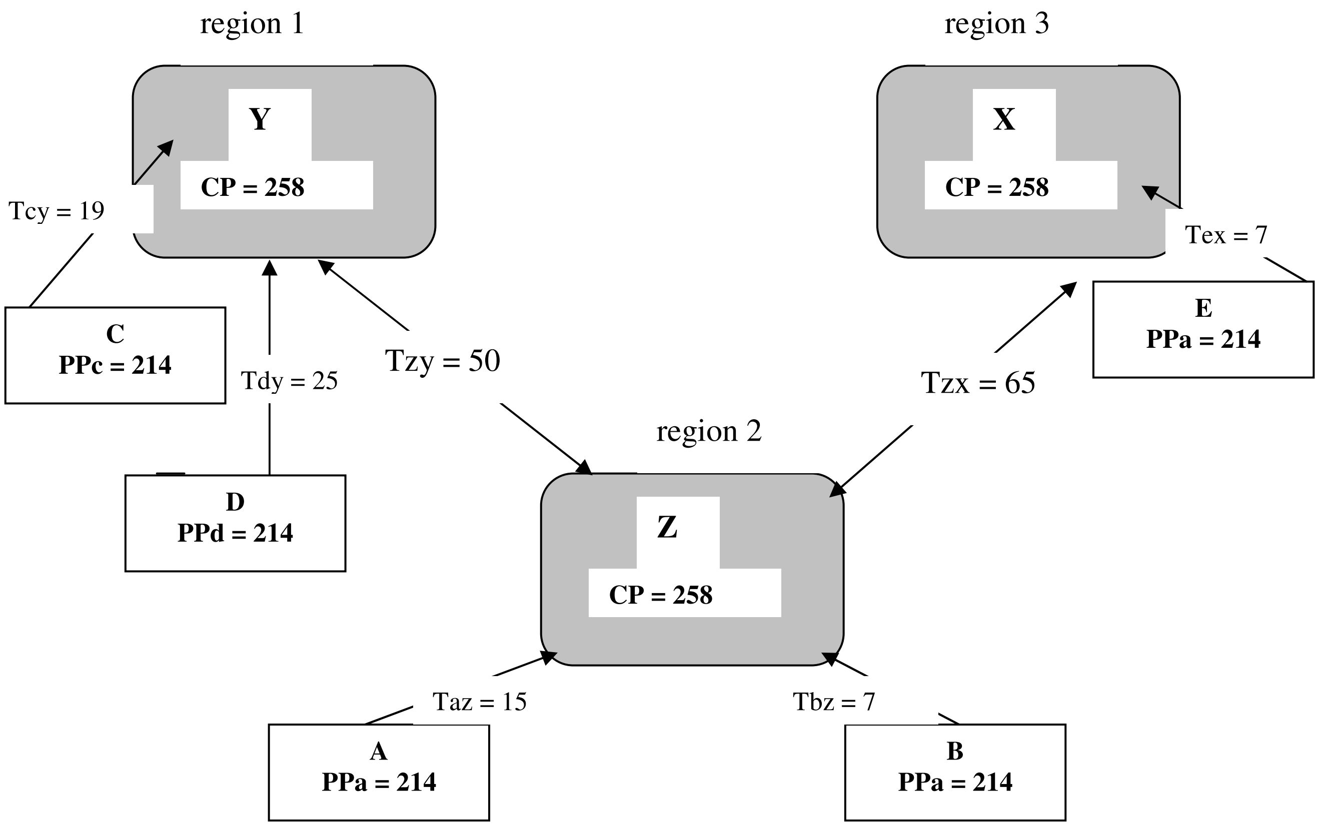
Summary: open economy and pan territorial prices

	open	panterrit	% change
Total consumption expenditure	1,794,175	1,781,232	-0.7
Imports	515,075	523,050	1.5
Trasport	190,686	222,992	16.9
Producer revenue	1,088,414	1,070,428	-1.7
Marketing Board	0	35,238	
Producer surplus		-16,350	-1.5
Consumer surplus		3,972	0.2
Net welfare change		-12,379	-0.7

Figure 1.5. Comparison : Open and Pan-territorial



Pan-Territorial Hypotheses



Net loss of the Marketing Board is 35 thousands monetary units, without considering the administrative cost which could be significant.

The implementation of pan-territorial prices will not be easy. The Marketing Board will find a lot of difficulty in imposing the price of 214 to all producers and the price of 258 to all consumers.

In Region 1 and Region 3 the producers will find more profitable to sell directly their product to the consumers, being the difference of 44 between producer and consumer price well above the local transport cost. Similarly the consumers of Region 2 will find more convenient to buy the product directly from the farmers.

There is effectively the risk that the Marketing Board will remain with the less profitable segment of the market, i.e. purchasing the surplus production from Region 2 and selling in Regions 1 and 3.

Under this assumption one can see that the Marketing Board losses will be much grater than those just now computed.

Using this same calculation scheme, we can analyze the impact of other common policies implemented in the various countries.

1.3. Other policy simulations

Food self-sufficiency

Food self-sufficiency is one of the objectives of most policies. Usually the Governments adopt a package of policies to pursue food security: price incentive to the producers, import tariff and quota (sometimes import ban), consumption rationing, incentive to adoption of new technology, etc.

We can analyze the impact on producers, consumers, balance of payment and on the budget of the marketing board of many of these measures, for example, of a policy consisting in a gradual increase of prices to the producers. At the same time, or separately, we can analyze the impact of maintaining the consumption prices unchanged, or fixed according to certain rules, for example, adding to the producer price a certain margin covering the transport cost. To perform this analysis the user needs only to change the respective consumer and producer prices in the tables above and to look at the results.

In all his experiments the user will notice that the open market solution without Government intervention appears always as the best one.

Import parity price policy

In the attempt to reach self sufficiency, a Government may decide to raise the producer price up to the level of the "import parity price", for example up to 275. The implementation of this measure in the above framework shows that the country not only reaches self sufficiency but becomes an exporter. However, due to high transportation cost of the country, the Marketing Board will suffer from a tremendous increase of its deficit. The explanation of this result is that a correct import parity price depends on the location of production: if the import parity price is 275 for Region 1, which is next to the port, the import parity price for Region 2 is 275 minus the transport cost from Region 2 to Region 1, etc. Therefore a correct border price policy gives different prices to different regions, taking into account transport and marketing costs.

Moreover, as the country becomes an exporter, the border price will not be any more 275, which is the CIF cost of a unit of product, but the FOB price, which is usually well below the CIF price, since the traders must be able to cover transport and insurance to the closer importing country. In this cases, it could be interesting to analyze various options: export the surplus with a loss; store the surplus for next year, which can be a bad year; lower the consumer prices to induce greater consumption; lower the producer price, etc.

Stabilization policy

Another important policy objective that often justifies Government intervention in the market is the stabilization of the prices. As it is known, the weather and other uncertain elements can cause important variations in the level of production and, therefore, in the prices. Good weather can cause bumper crops, that may translate in low output prices, while drought can cause shortages, leading to high prices. Similar effects can affect also world markets and instability can be transmitted to the domestic market. Moreover, changes in the exchange rates also can affect local prices. For these reasons, Governments might want to intervene to stabilize the domestic market, by guaranteeing a floor price to the producers and by maintaining ceiling price to the consumers despite the movement on the import prices.

Also these measures can be analyzed though our simplified calculation scheme. First, by changing the producer and consumer prices according to the measure one wants to analyze, secondly, by simulating the variation of production due to weather conditions through a shift in the supply curves. This can be implemented as a change in the constant term of the supply function. Suppose that unfavorable weather reduces the output by 20%; this can be simulated by multiplying the constant terms by 0.8. Note that weather affects with different intensity different production regions.

Fiscal, technological changes and transport policies

Finally, using the same scheme one can simulate different fiscal policies: tax on producers, tax on consumers, technological change that reduces the cost of production. All of these can be implemented as shifts in the supply function. Similarly, transportation policies (e.g. taxing fuel or transport fees, or improvement in road network) can also be simulated by changing the transport cost at local and at regional level.

These applications of the partial equilibrium analysis are simplified ones, which simulate the market equilibrium mechanism for a single crop. It is worth recalling that the most important limitations are due to the fact that we study the impact of those policies without taking into consideration cross-effects, both at producers and at consumers' level. When the producers increase their production, usually, they use resources previously allocated to other crops and, therefore, they reduce the production of the crops competing for the same resources. Similarly, when the consumers have to pay higher prices for a commodity, they tend to minimize such impact by switching to the consumption of other commodities. All such effects have not been considered here.

Another important limitation is in the fact that we did not take into account the *income effect* on the consumers, producers and of the Government. When there is an increase in the price of an important consumption commodity, the consumers have a reduction in their income, similarly to the producers when there is a reduction in the price of their commodities. The consumers will have less resources to purchase other commodities, the producers to pay for the factors of production. Finally, another limitation of this type of modeling is that they are static in the sense that they don't pay any attention to the time element.

Chapter 2- Beyond the static, single market model

This section of the handout will provide a number of hints on more sophisticated equilibrium modeling frameworks. It will introduce first the MODEXC model; this is a dynamic partial equilibrium model, manly employed in the analysis of technical change. A hint will be provided also on the large multi market multi country frameworks employed in the analysis of agricultural policies. On this topic it will be presented a standard partial equilibrium framework drawn from the large multi-country multi-commodity models. Finally, it will be briefly introduced the functioning and the scope of general equilibrium models.

2.1. The dynamic analysis of the welfare impact of technical change: the MODEX model[2]

The economic surplus model MODEXC is a tool for estimating indicators that will help prioritize technologies (ex-ante analysis) and evaluate them after their adoption and dissemination (ex-post analysis).

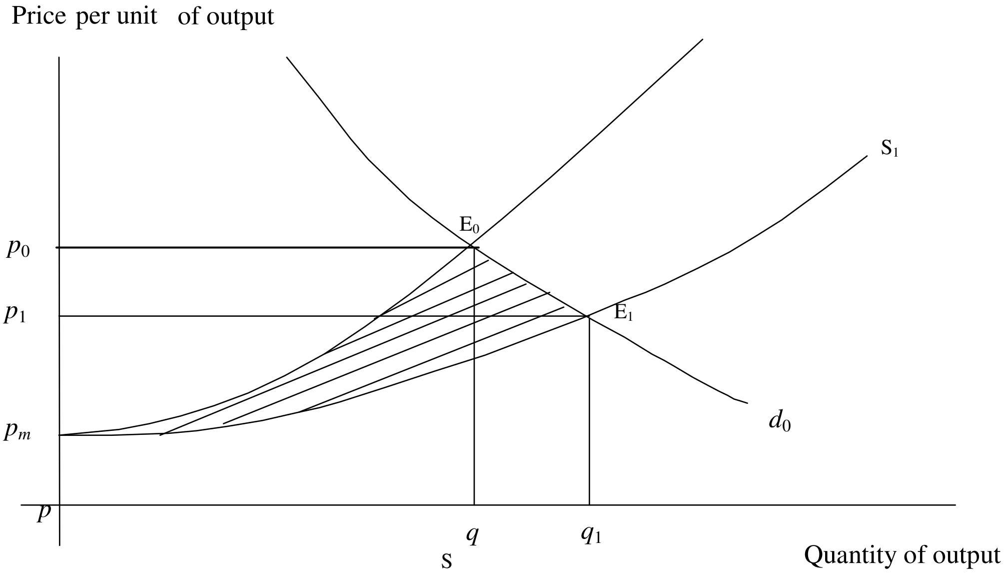
2.1.1 The theoretical model

The MODEXC model helps calculate and analyze the benefits derived from technological change, which are measured as the economic surplus of producers and consumers.

The model is based on the Marshallian theory of economic surplus that stems from shifts over time of the supply and demand curves. In Diagram 1, the rightward shift (s_1) of the original supply curve (s_0) generates economic surplus for producers and consumers. Such a shift can stem from changes in production technology.

[2] From: Rivas L., J. A. García, C. Seré, L. S. Jarvis, L. R. Sanint, and D. Pachico *Economic surplus analysis model (modexc)* website http://www.ciat.cgiar.org/impact/index.htm CIAT, 1999.

Diagram 1



Given that the demand function remains constant, the original market equilibrium

E_0 (p_0, q_0) is transferred by the effect of technological change to E_1 (p_1,q_1).

Consumers gain because they are able to consume a greater amount (q_1) at a lower price (p_1). The area $p_0p_1E_0E_1$ represents this gain. The new technology affects producers in two ways:

1. Lower marginal costs (according to the theory, the supply curve corresponds to the curve of marginal costs as of the minimum value of the curve of average variable costs).
2. Lower market price (p_0 reduced to p_1).

The $p_m FE_1$ area represents producers' gains due to lower costs, and the $p_0E_0Fp_1$ area represents losses caused by price reduction. Therefore, the net producers' surplus (NPS) is defined as $p_mFE_1 - p_0E_0Fp_1$.

The area $p_mE_0E_1$ represents the net social surplus.

The level and distribution of surplus between producers and consumers are mostly determined by the nature of the shift of the supply and demand curves, by price elasticities, and by the minimum bid price (see Alston et al. 1988).

The absolute value of price elasticity of demand is basic in determining whether producers obtain a positive surplus during technological change. If the absolute value of price elasticity of demand faced by producers is very low, the market price will have to be lowered significantly if additional quantities of output derived from technological change are to be placed in the market. This increases the possibility of p_0EFp_1 being greater than p_mFE_1, in other words, the effect of price reductions will be greater than that of cost reductions (increased productivity).

Whether the economy is closed or open (without or with international trade) has a direct effect on the surplus of producers and consumers.

The model assumes free market conditions. In other words, there are no policy distortions such as subsidies, production or trade quotas, or tariffs. Many markets, particularly those of agricultural products, are affected by policy distortions, which in turn affect the level and distribution of benefits derived from technological change (see Alston et al. 1988).

Unlike other models, MODEXC explicitly considers demand shifts caused by different factors such as population growth and income. These demand shifts are introduced through the net annual growth rate of demand. The growth of demand should be explicitly considered in long-term analyses because it clearly influences the level of economic surplus. In open economies, the model works under the assumption of a small market as related to the international market. In other words, surpluses that are marketed abroad do not affect international prices. The local market therefore faces an infinitely elastic external demand ($\eta=\infty$). The partial equilibrium approach assumes that no other adjustments are made in the economy.

The supply expansion factor (k) can be interpreted as a reduction of absolute costs for each production level, or as an increase in production for each price level. The solution algorithm of MODEXC assumes a horizontal supply shift, which means that it works with a k factor expressed as a percentage increase of production. When k is expressed as a percentage change of production costs (k_c), k must be converted to its equivalent in terms of production expansion (k_p) through supply elasticity.

$$k_p = k_c \, \phi_p \tag{3}$$

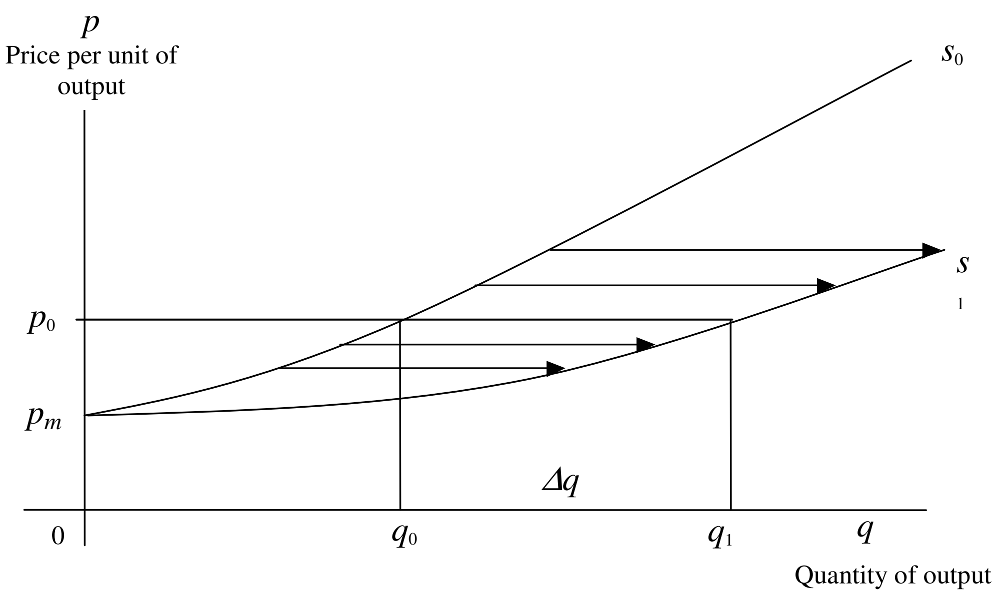
Where Φ_p is the price elasticity of supply.

In other words, it represents an explicit increase in production and an implicit reduction in costs; k is estimated as:

$$k = \frac{q_0 + (q_1 - q_0)}{q_0} = \frac{q_0 + \Delta q}{q_0}$$

Where Δq is the increase in production obtained with improved technology at price p_0.

Diagram 2



2.1.2 The Mathematical Model

The mathematical model used is based on the scheme proposed by Pachico et al. (1987), in which supply and demand functions are nonlinear with constant elasticity.

Supply Functions

When dealing with a single product market, it is assumed that supply curves correspond to the following functional form:

$$s_0 = c(p - p_m)^g \qquad \textbf{(5)}$$

Where: s_0 = Initial supply before technological change,

c, g = Constants,

p = Price of product, and

p_m = Minimum price that producers are willing to offer.

To express the initial supply in mathematical terms, the following information is needed:

1. The market equilibrium before technological change E_0, in terms of quantity and equilibrium price (q_0, p_0).

2. The value of price elasticity of supply ϕ_{p_i}

3. Minimum bid price (p_m).

The minimum bid price (p_{mi}) is the price at which production begins. It can be considered the price that covers variable production costs. Once points 1 to 3 are defined, constants g and c of equation **(5)** are estimated in the following way:

$$g_i = \frac{\phi_{p_i}(p_{0_i} - p_{mi})}{p_{0_i}} \qquad \textbf{(7)}$$

Where: ϕ_{p_i} = Price elasticity of supply of product "i".

$$c_i = \frac{q_{0i}}{(p_{0_i} - p_{mi})^{g_i}} \qquad \textbf{(8)}$$

For more information, see Pachico et al. (1987).

Expected prices are defined according to Nerlove (1958) under a scheme of distributed lags that are set forth mathematically as:

$$p_t^* = \alpha_1 p_{t-1} + \alpha_2 p_{t-2} + \alpha_3 p_{t-3} + \alpha_4 p_{t-4} + \alpha_5 p_{t-5} \qquad \textbf{(10)}$$

Where: P_t^* = Expected price in period "t",

$p_{t-1}...p_{t-n}$ = Lagged prices from period "t-1" to period "t-n", and

$\alpha_1....\alpha_n$ = Weighted factors of lagged prices.

Shift of Supply Functions

It is assumed that, once technological change begins, the supply curve shifts gradually over time. Current literature indicates that the supply shift factor due to technological change is known as *k*. This factor varies in time depending on the dynamics of the adoption and dissemination of new technologies.

There are different types of supply shift: pivotal, divergent, or convergent. Pachico et al. (1987) define three types of supply shift depending on the position *k* takes within the original function.

1. Pivotal shift: $$s_1 = ck(p - p_m)^g \quad \textbf{(11)}$$

2. Divergent shift: $$s_1 = c(kp - p_m)^g \quad \textbf{(12)}$$

3. Convergent shift: $$s_1 = c(p_0 - \frac{p_m}{k})^g \quad \textbf{(13)}$$

The general form of shifted supply is:

$$s_1 = k_1 c(k_2 p - \frac{p_m}{k_3})^g \quad \textbf{(14)}$$

Where: k_1 = When the shift is pivotal,

k_2 = When the shift is divergent, and

k_3 = When the shift is convergent.

If k_1 takes a value higher than 1, k_2 and k_3 will take values equal to 1. Only one *k* at a time can take a changed value.

Logistic Function

Because technological change is gradual and varies in intensity over time, a logistic function is used to simulate adoption, which is slow in its initial stages. As the technology is adopted and its performance and benefits are better known, the rate of adoption increases, then decreases in advanced stages of the process, and finally becomes stabilized.

The model therefore assumes that the supply shift factor, *k*, obeys a logistic-type pattern.

To estimate supply functions under conditions of technological change, the maximum value that *k* will take, once the adoption process has ended, must be known beforehand.

The model also takes into consideration the processes of nonadoption or obsolescence of technologies and the dynamics of both processes.

Demand Functions

The initial demand function of product market "a" is defined as:

$$d_{0a} = b_a p_a^{\eta_a} \quad \textbf{(15)}$$

Where: d_{oa} = The quantity demanded of product "a",

p_a = The price of product "a",

η_a = The price elasticity of demand of product "a", and

b_a = Constant.

To determine the original demand function when working with a single product, the following are needed:

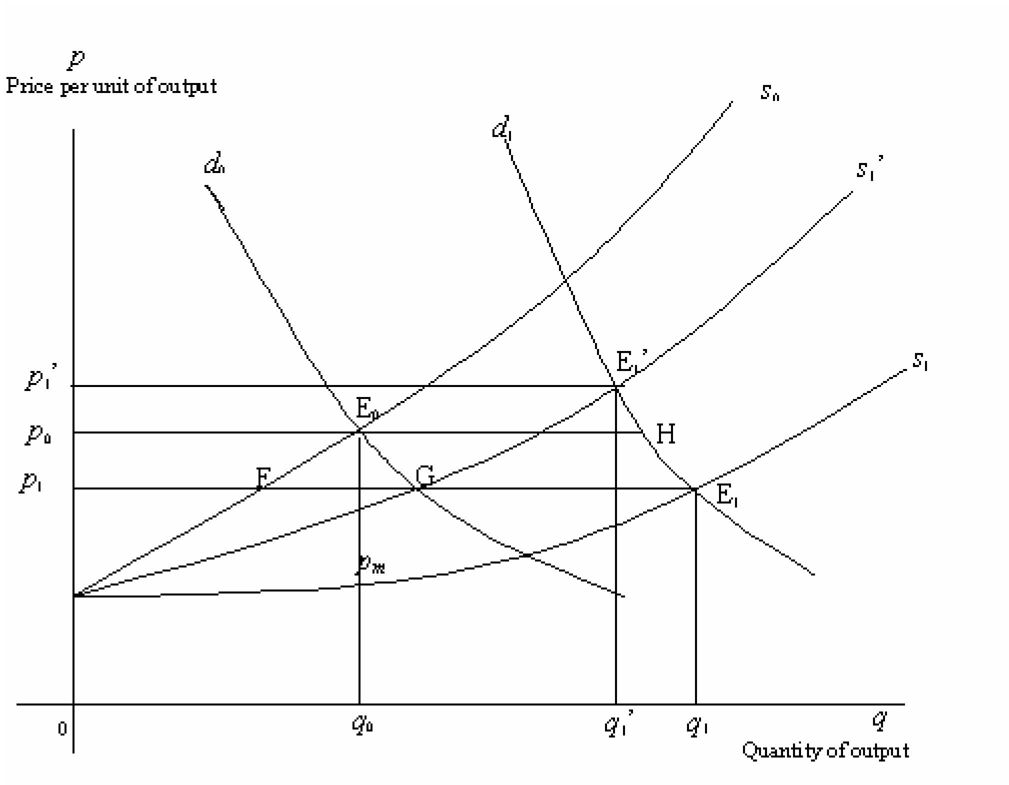
1. The quantity and initial equilibrium price: p_o, $q_{o.}$
2. The own-price elasticity of demand (η).

Factors other than Technological Change that Alter Market Equilibrium

Even though a technological change of the type we are attempting to analyze does not occur, empirical evidence shows that, over time, supply and demand are shifted by factors other than technical change. Supply may increase because of other technological changes of different nature. MODEXC explicitly involves supply shifts independent of those caused by the technological change in question. Diagram 4 illustrates the situation schematically.

Curves s_o and d_o determine the initial equilibrium before technological change. Independent factors, regardless of the technological change in question, shift the initial supply to s_1' and the initial demand to d_1. Subsequently, the technological change shifts the supply from s_1' to s_1 to reach the final equilibrium of period "t" (E_1, Diagram 3).

Diagram 3



Where: s_o = $c(p-p_m)^g$,

s_1' = $c(1+\theta)^t (p-p_m)^g$,

s_1 = $c(1+\theta)^t k(p-p_m)^g$,

d_0 = bp^{Np}, and

d_1 = $b(1+AGRD)^t p^{Np}$.

Demand shift

The model assumes that a demand shift occurs over time, originated by factors such as variations in population, incomes, and prices of substitute or complementary goods. The original demand shift factor is called k_d. It is variable over time and expressed as:

$$k_{d_t} = (1 + AGRD)^t \quad \textbf{(18)}$$

Where $AGRD$ is the net annual growth rate of demand and "t" the time period.

Supply shift

Supply shifts over time, not only because of the technological change in question, but also because of other independent factors, which could be other technological changes. MODEXC incorporates these other factors through a supply expansion factor defined as:

$$k_{0_t} = (1 + \theta)^t \quad \textbf{(19)}$$

Where: θ = Expected annual growth rate of supply because of independent factors, and

k_{ot} = Supply expansion factor because of independent factors during period "t".

Within this scheme, the supply and demand functions are defined as:

$$s_0 = c(p - p_m)^g \quad \textbf{(20)}$$

$$s_1^{'} = c(1 + \theta)^t (p - p_m)^g \quad \textbf{(21)}$$

$$s_1 = c_1(1 + \theta)^t k_1 (k_2 p - \frac{p_m}{k_3})^g \quad \textbf{(22)}$$

$$d_0 = bp^N \quad \textbf{(23)}$$

(24)

$$d_1 = b(1 + AGRD)^t p^N$$

When θ differs from zero, the annual k value is adjusted because θ is applied on a greater base than that used to estimate the final value of k. Annex 1 provides detailed information about this adjustment. When independent supply and demand shifts occur (see Diagram 4), the total economic surplus of society due to technological change and to independent factors is expressed as:

$$p_1 p_0 HE_1 + (p_m E_1 F - p_1 p_0 E_0 F) \qquad \textbf{(25)}$$

The economic surplus due to the technological change under study is:

$$p_1 p_1^{'} E_1^{'} E_1 + (p_m E_1 G - p_1 p_1^{'} E_1^{'} G) \qquad \textbf{(26)}$$

2.2 Relating interdependent markets: hints on the multi market model[3]

In the following section it will be introduced the structure of a *typica*l partial equilibrium model employed in multi market analysis and in the analysis of effects of the agricultural market policies. Reference for this scheme are models such as the AGLINK model of the OECD or the FAPRI model.

A *typical* partial equilibrium model consists of a set of behavioral equations, a set of equilibrium relations between supply and demand, and a set of identities that aggregate variables. Equations can be grouped into a supply component, a demand or utilisation component, and a foreign trade component; this pattern is repeated for each region and product included in the models. In addition, there are price transmission equations, linking world to domestic prices, and world market equilibrium conditions that close the models.

A simplified representation of the standard structure of the models examined in this chapter is reported below.

	Crop products		*livestock product*
	supply		
(1)	$s_{i,n} = s(p_{v,i,n}, p_{v,j,n}, Pols)$	(8)	$c_{i,n} = c(p_{z,i,n}, p_{z,j,n}, Polc)$
(2)	$r_{v,i,n} = r(p_{v,i,n}, PR)$		(9) $AL = al(p_{v,i,n}, p_{v,j,n})$
(3)	$Qo_{v,i,n} = s_{i,n}\ r_{v,i,n}$	(10)	$r_{z,i,n} = r(p_{z,i,n}, AL, PR)$
		(11)	$Qo_{z,i,n} = c_{i,n}\ r_{z,i,n}$
	demand		
(4)	$Cu_{v,i,n} = cu(p_{v,i,n}, Y_n, POP_n)$	(12)	$Qd_{z,i,n} = qd(p_{z,i,n}, Y_n, POP_n)$
(5)	$AA_{v,i,n} = aa(Qo_{z,i,n})$		
(6)	$SE_{v,i,n} = se(s_{v,i,n})$		

[3] From: Conforti P. "The Common Agricultural Policy in Main Partial Equilibrium Models", *working paper* n 7, Istituto Nazionale di Economia Agraria (INEA), Osservatorio sulle Politiche Agricole dell'UE, website http://www.inea.it/opaue/wp7.pdf, Roma, 2001.

(7) $Qd_{v,i,n} = Cu_{v,i,n} + AA_{v,i,n} + SE_{v,i,n}$

price transmission

(13) $p_{i,n} = p(p_{i,w}, tc, Polp)$

trade

(14) $(E_{i,n} - I_{i,n}) = Qo_{i,n} - Qd_{i,n}$

closure

(15) $\Sigma(E_{i,n} - I_{i,n}) = 0$

where:

i, j = products;

v = crops;

z = livestock;

n = country;

and

s = land (hectares);

c = heads (number);

AL = index of feed cost;

r = yield (per hectare or per head);

$Polp$ = policies directly affecting prices;

$Pols$ = policies based on land;

$Polc$ = policies based on livestock heads;

Qo = supply;

p_n = price in country n;

p_w= world price;

Cu = demand for human consumption;

AA = demand for feed;

SE = demand for seeds;

Qd = total demand.

E = exports

I = imports;

tc = exchange rate

PR = yield trend;

Y = GDP;

POP = population;

The supply component consists of equations (1)-(3) for crops and (8)-(11) for livestock; supply is obtained as the product of a yield per hectare of land (2) or per head (10), times the number of hectares employed (1) or the herd size (8). Yields depend on a trend variable - which is used to represent technical change - on output prices, and on feed costs for livestock. These are included in an aggregate feed price index (9). Land and heads allocation depends on relative output prices, and on the policies directly affecting their allocation.

This type of modeling is simplified in several respects. First, production is entirely deterministic: no uncertainty factors are accounted for, such as, climatic variability. No assumptions are made concerning farmers' attitude toward risk, unless they are included in the parameters. Input demand is only included for land, herds, and where primary products are employed as inputs in the production of other (processes) goods included in the model, as is the case with feed crops, oilseed – where seeds are inputs for meals cakes and oils – and in dairy production, where milk is the input of butter, cheese casein etc. The demand for non-agricultural inputs, such as fertilizers, pesticides and machinery is not included. Land use and herd size depends solely on the price obtained for agricultural products, rather than on the prices of land and heads themselves.

The demand component for crops consists of an aggregation, by means of identity (7), of the amount used for human consumption – equations (4) for crops and (12) for livestock - for feed (5), and for seeds (6). For livestock, only the last one is included. Along with the prices of products, the demand for human consumption includes the prices of a few more direct substitutes, together with the GDP level and the population as exogenous shifters. The demand for feed is directly related to the number of livestock heads, through technical coefficients. By the same token, the demand for seed is directly related to the number of cultivated hectares.

The typical partial equilibrium model considered here is comparative static, and does not include stock formation. This choice is usually justified by considering that stocks cannot be increased or depleted after a given point, and thus, their variation must add-up to zero. Nonetheless, the absence of stocks from the model can be a problem, especially in modeling those markets where they may assume a structural character, that may significant affect the behavior of economic agents.

Domestic prices are linked to world prices through the price transmission equations, an example of which is relation (13) in the above box. Along with the exchange rate and trade policies that directly affect prices, transmission equations include price differentials due to transport costs, and those used to approximate differences in the quality of products.

The trade component is made from excess supply equations, relation (14) in the above box. Goods produced in different countries are assumed to be perfectly homogeneous, and world markets are treated as a single arbitrage mechanism of excess supplies. Contrary to the simplified scheme presented in section 2, all markets influence prices throughout the model, that is, price changes occurring in one market are always transmitted to all the other.

The closure rule is defined by relation (15), i.e. excess supply in all markets add up to zero. The solution generates countries' net trade positions, but it does not include information on bilateral trade flows.

Static vs dynamic frameworks

The typical model structure described is comparative static: it compares the solutions of two equilibrium points referred to two different time periods in which the level of the exogenous variables is different. In this case, the results of the model are referred to a period in which the adjustment of endogenous variables is supposed to have taken place completely, and the model does not describe the adjustment path of endogenous variables from one period to another.

However, large size multi country multi commodity models often include some elements of dynamics, i.e. it is taken into account the adjustment path of endogenous variable after a change in an exogenous one. E.g. the model describes the adjustment of supply after a change in the price of a commodity.

In most models, adjustment is modelled simply by including lagged variables in the equations, according to a recursive criterion: in this case the model generates an equilibrium solution based on the forecast of exogenous variables, and on the basis of the value of the endogenous variables obtained in the previous period. This type of dynamics implies that agents' behaviour is optimal with reference to each single period, but not through time.

In more than one model, the dynamic is not homogeneous among the different groups of equations; e.g the supply often includes a partial adjustment mechanism – a naive representation that generates results by assuming that entrepreneurs are unaware of prices and quantities in the previous period - while in the demand equations there are only some lagged price variables.

2.3 Hints on CGE models[4]

Basic structure of a General Equilibrium model

The basic structure of a General Equilibrium (GE) model can be described through blocks of relations dealing with production, consumption and factor use. In this type of models all productive sectors of the economy are represented.

The simplest model of this kind can be represented with 2 good, 2 factors and 2 consumers. We have

production

Goods - sectors	Production function
agriculture	$XS_{agr} = f(L, K)$
textiles	$XS_{tex} = f(L, K)$

consumption

Agents	Utility function
rural	$U_{rur} = f(X_{agr}, X_{tex})$
urban	$U_{urr} = f(X_{agr}, X_{tex})$

Factors of production

	endowments
labour	$L = \mathbf{L}$
capital	$K = \mathbf{K}$

In this very simple example, only the initial factor endowments and the utility function parameter are exogenous, while all the rest can be calculated by the model.

The model includes the following variables:

variables

endogenous		exogenous	
p_i	price of good i	LS_h	Labour endowement of consumer h
w	wage	KS_h	Capital endowement of consumer h
r	Return to capital	a_{hi}	Utility function parameter
XS_i	Supply of sector i		
$_hXD_i$	demand for i of consumer h		
$_DL_i$	Labour demand of sector i		
$_DK_i$	Capital demand of sector i		
Y^h	Income of consumer h		

[4] From: Magnani R. e Perali F. (a cura di) *Laboratorio di Politica Economica*, Dispensa n. 1, Università di Verona, Dipartimento di Scienze Economiche, 2002; and De Muro P. e Salvatici L. "The Common Agricultural Policy in Multisectoral Models", *working paper* n 11, Istituto Nazionale di Economia Agraria (INEA), Osservatorio sulle Politiche Agricole dell'UE, website http://www.inea.it/opaue/wp11.pdf, Roma, 2001

The structure of the model includes a set of relation determining real flows, one determining expenditure, and one that determines income. Equilibrium conditions allow to “close” the model and a set of identities ensure that income does not exceed expenditure, and that it equals that of the factors of production.

Equations of the basic model

real flows		expenditure	
$X^S_i = f(_DL_i, {}_DK_i)$	supply of good i	$_hX^D_i = a_{hi} (Y^h / p_i)$	demand for i
$w = (\partial X^S_i / \partial {}_DL_i)\, p_i$	labour demand		
$r = (\partial X^S_i / \partial {}_DK_i)\, p_i$	capital demand	equilibrium conditions	
		$X^S_i = \sum_h {}_hX^D_i$	demand equal supply
income flows		$\sum_i {}_DL_i = \sum_h L^S_h$	demand for labour equals labour endowement
$Y^h = w\, L^S_h + r\, K^S_h$			
		$\sum_i {}_DK_i = \sum_h K^S_h$	Demand for capital equals capital endowement
identities			
$P_i\, X^S_i = {}_DL_i\, w + {}_DK_i\, r$			supply = factor's income
$Y^h = \sum_i {}_hX^D_i\, p_i$			income = expenditure

In its simplest version, the model can be solved by imposing the equilibrium condition on all markets, i.e. that supply resulting from the production function of the firms equals total demand of the two consumers, resulting from the utility maximisation problem.

In order to be "computable" a general equilibrium model (the common acronym is CGE) requires

- a database describing the flows of resources in the economy at the level of aggregation considered in the model;
- a set of parameters for the behavioural relations of the model.

The database on which a CGE is based is know as Social Accounting Matrix (SAM); this is a consistent set of accounts describing resource flows between consumers producers, the government and foreign economies.

Parameters can be obtained through calibration or estimation.

Calibration and estimation

Calibration is a deterministic procedure that CGE modellers normally use to estimate some or all the parameters required in the model. First it is required the construction of a database consistent for all the variables contained in the model, with respect to a base year.

Once the database which is used as a benchmark equilibrium for the economy has been constructed, a “reverse” solution of the model will be introduced: this will determine the values of the parameters that are compatible with the exogenous variables and the endogenous variables of the base year. In other words, those parameter values which will make it possible, once the model has been made to function “correctly”, to find the initial database, i.e. the equilibrium attained.

Given that the benchmark period is normally represented by one observation (i.e. the reference year), it is worth noting that calibration procedures do not generally make it possible to evaluate the statistical robustness of the results obtained.

The estimation of parameters, that is calculating them with econometric techniques, is theoretically more satisfactory than calibration, but it also raises many questions.

An average size of a CGE model includes a huge number of parameters that need to be estimated, which grow quickly with the number of sectors and households treated. Thus an extremely high number of observations is required in order to estimate all the parameters of the model simultaneously, together with the use of sophisticated econometric techniques.

An alternative can be a separate estimation for each of the model's sub-systems (e.g. a block for production, a block for demand, or a block for each good); but also in this way it may still not be possible to include all the equilibrium conditions considered in the model.

Main advantages and drawbacks in the analysis of agricultural policies

No modelling approach should be considered better than other in absolute terms. Rather, each approach should be used in the analysis of the problem for which is most suited. Thus the effectiveness of a General Equilibrium (GE) approach (or of any other approach) should be assessed with reference to the specific problem to be analysed.

Compared to the Partial Equilibrium (PE) approach, the GE removes the simplifying hypothesis that what happens in one sector does not affect demand and supply in other sectors, including factor markets, because it includes all activities in the economy.

This means that a GE approach can be particularly effective for analysing those issues for which it is important

- to highlight the existence and the effects of a general budget constraint in the economy
- to take into full consideration the feedback from agriculture to the other sectors of the economy, and, in turn the second round effects that can have on agriculture; the importance of these effects are related to the relative size of agriculture compared to the other sectors, on the one hand, and to the degree of integration of the sector analysed in the economy. The more this is high, the more feedback effects tend to be relevant.

At the same time, dealing with these aspects in a GE framework requires

- more data to be assembled and made coherent; more calculations and parameters
- explicit hypotheses on the whole functioning of the economy and on all the markets represented. The scheme presented above is an extremely simplified one; in which the representation of market is standard and homogenous, and the closure rule is the simplest possible. In fact all these aspect are matter for choice of the analysis.

In other words, "it may be difficult to justify devoting otherwise scarce resources to more complex and less transparent models, when they may yield only marginal extensions of the basic insights taken from simpler approaches" (Francois and Hall, 1997, p. 122).

This seems to suggest that specifying a GE model is worthwhile when the additional information that can be obtained with such a model (compared to the treatment of the same problem within a PE framework) is greater than the increase in the "costs" associated with the time spent in data processing and the more complex specification of the model.

In fact, among the models employed in the analysis of agricultural policies GE approaches are more frequent in those cases in which agriculture accounts for a large share of the economy, and inter sectoral relations are more developed.

Recently, given also the development in the power of computers and the easier exchange of information among analysts, the use of GE model has become more frequent. Their level of aggregation, however, is still generally higher compared to PE frameworks.

References

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