THE TRANSLOG COST FUNCTION AND THE COTTON INPUTS MARKET IN THE STATE OF SÃO PAULO: THE CASE FROM CAMPINAS

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ABSTRACT - In this study, the cotton cultivation cost function from the Divisão Regional Agrícola (Regional Agriculture Division --DIRA), Campinas, state of São Paulo, is estimated using the translog model. Cotton input market relationships are analyzed, employing estimates of the input price-elasticity of demand and elasticity of substitution between factors. The production factors considered are labor, machine operations, fertilizers, seeds, and other costs. The results show that labor expenses are the major costs of cotton production in the Campinas DIVR. Labor and machine operations are complementary inputs, but a substitution relationship prevails between the other pairs of production factors. Allen elasticity of substitution estimates also show that labor and machine operations are complementary, and there is substitutability between the other factors. However, using the Morishima elasticity of substitution concept, labor and machine operations are shown to be complements for labor price change and substitutes for machine operations price change.

Key words: Cost, cotton, elasticity if substitution, translog.

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INTRODUCTION

The role of Brazilian cotton in world market has changed significantly over the last twenty-five years. Brazilian trade policies adopted during this period focused on domestic market supply; and Brazil, which has been an net cotton exporter, became a net importer. The crisis in the cotton sector began in the 1970s and became worse in the 1990s, due to opening of the Brazilian economy and agricultural subsidy policies in the United States and the European Community (Barbosa, 1996).

After 1994, the easy availability of international credit at attractive rates and the overvaluation of Brazil's currency facilitated importation of even larger volumes of cotton, further impairing the domestic trade balance (Barbosa, 1996). In 1996, Brazil's cotton imports had more than tripled from 1992 levels, from 103.8 thousand tons in 1992 to 390 thousand tons in 1996. Between 1991 and 1996, Brazilian cotton production fell 42.8%, from 717 thousands tons in 1991 to 410 thousands tons in 1996; and the area under cotton cultivation decreased 50.8%, from 1,939 thousands hectares in 1991 to 925 thousand hectares in 1996.

In the Brazilian state of São Paulo, historically a focus of the country's expanding cotton production, cotton output decreased to 63.4 thousands tons in 1996 from 123.6 thousands tons in 1991, a 48.7% reduction. This indicates that the decrease in cotton production was greater in the state of São Paulo than in the country as a whole (Ferreira Filho, 1998).

The development of cotton as a cash crop in São Paulo took place on small to medium size properties. Production on these types of farms is labor intensive, mainly during harvest, and was well suited to the abundance of available labor in Brazil during the 1970s and 1980s. However, compared to modern farm systems that harvest using machines, this manual harvest eventually led to high production costs.

This study is an analysis of the relationship between inputs used for cotton cultivation in the Regional Agriculture Division, Campinas, São Paulo, using estimates of the price-elasticities of demand for inputs and elasticities of substitution between factors. To accomplish this analysis, the transcendental logarithmic function (translog) will be estimated using data from the period 1975 to 1998.

Biswanger (1974), Ray (1982), Reis & Teixeira (1995), Castro Júnior et al. (1996), Dalton et al. (1997), and Parré & Ferreira Filho (1998) have used the translog cost function to analyze several aspects related to the production economy of agriculture.

METHODOLOGY

Theory

The methodology adopted in this study is based on the dual approach between production and cost functions, from which it is possible to analyze a productive process using its cost function [Silberberg (1993), Lerda (1979), Debertin & Pagoulatos (1985), Beattie & Taylor (1985), Chambers (1988)]. The translog cost function is a functional form that does not set a priori restrictions on its associated production function; the reason it is used in this study.

The cost function expresses production cost as a function of factor prices used in production and quantity produced. It is assumed that for a produced quantity Y, the associated point of the cost function is the minimal; thus, expression (1) represents the cost function associated with a production function:

$$C^* = c(Y, P_1, P_2, P_3, \ldots, P_n) \qquad (1)$$

where C^* is the minimum cost for production level Y, and $P_1, P_2, P_3, \ldots, P_n$ are the prices of factors used in the production process.

Transforming expression (1) in terms of natural logarithm and expanding it through a Taylor series in the neighborhood of the unity vector results in the transcendental logarithmic cost function (translog), represented in expression (2):

$$\ln C^* = \beta_0 + \beta_Y \ln Y + \sum_{i=1}^{n} \beta_i \ln P_i + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \beta_{ij} \ln P_i \ln P_j + \sum_{i=1}^{n} \beta_{iY} \ln P_i \ln Y + \frac{1}{2}\beta_{YY}(\ln Y)^2 \qquad (2)$$

where β represents the parameters and the i e j indexes identify the production factors used to estimate the cost function. The symmetry condition is imposed by the restriction $\beta_{ij} = \beta_{ji}$ for i ≠ j, and linear homogeneity is guaranteed by the conditions $\sum_{i=1}^{n} \beta_i = 1$ and $\sum_{i=1}^{n} \beta_{iY} = \sum_{i=1}^{n} \beta_{ij} = \sum_{j=1}^{n} \beta_{ij} = 0$. The monotonicity and concavity conditions for a translog function are locally checked. The monotonicity of the function is attended if the cost shares show nonnegative signs, and concavity is satisfied if the determinant of the Hessian results is negative semi-defined.

Taking the partial derivative of expression (2) with respect to all factor prices and using Shephard's Lema, a n system equation is obtained, which represents the derived-demands of the production factors as a function of prices. As presented in expression (3), the derived demand is expressed in terms of cost shares:

$$\frac{\partial \ln C^*}{\partial \ln P_i} = S_i = \beta_i + \sum_{j=1}^{n} \beta_{ij} \ln P_j + \beta_{iY} \ln Y \qquad (3)$$

where Si is the cost share related to factor i. Thus, the parameters of the translog cost function can be estimated through estimation of the n cost shares which compose the equation system represented in (3).

According to Biswanger (1974), the factor own demand and the factor cross price-elasticity of demand, represented respectively by η_{ii} e η_{ij} ,can be obtained by expressions (4) and (5):

$$\eta_{ii} = \frac{\beta_{ii}}{S_i} + S_i - 1 \qquad (4)$$

$$\eta_{ij} = \frac{\beta_{ij}}{S_i} + S_j \qquad (5)$$

The Allen elasticity of substitution can be calculated through expressions (6) and (7), following Biswanger (1974):

$$\sigma_{ii} = \frac{1}{S_i^2}(\beta_{ii} + S_i^2 - S_i) \tag{6}$$

$$\sigma_{ij} = \frac{1}{S_i S_j}\beta_{ij} + 1 \tag{7}$$

The Morishima elasticity of substitution (σ_{ij}^M) can be obtained from Allen elasticity of substitution or from the factors price-elasticity of demand (Chambers, 1988):

$$\sigma_{ij}^M = S_j(\sigma_{ij} - \sigma_{jj}) = \eta_{ij} - \eta_{jj} \tag{8}$$

Two points must be observed with respect to the Morishima elasticity of substitution: first, it is not a symmetric concept, i.e., $\sigma_{ij}^M \neq \sigma_{ji}^M$, and the second a pair of inputs can be complementary in terms of the Allen elasticity of substitution $(\sigma_{ij} < 0)$ while its correspondent Morishima measure could class it as substitute ($\sigma_{ij}^M > 0$). Note that if $|\sigma_{ij}| < |\sigma_{jj}|$ (remember that $\sigma_{jj} \leq 0$), then σ_{ij}^M will have always positive sign, even if $\sigma_{ij} < 0$.

The standard deviation of the elasticity values can be calculated through expression (9) and the t value through expression (10) to proceed the Student test and verify the significance level of the obtained values:

$$se_{\eta_{ij}} = \frac{se_{\beta_{ij}}}{S_i} \tag{9}$$

$$t = \frac{\eta_{ij}}{se_{\eta_{ij}}} \tag{10}$$

where i=j in expressions (9) and (10) refer to the factor's own price-elasticity of demand and $i \neq j$ refers to cross price-elasticity of demand.

Estimation of the translog cost function for cotton

Data

Data used in this study were the annual series of Total Operational Cost (TOC) of production surveyed by the Instituto de Economia Agrícola do Estado de São Paulo (IEA) and published in Informações Econômicas. The values and prices from 1975 to 1998 were deflated to April 1998 values using the Índice Geral de Preços (IGP) calculated by the Fundação Getúlio Vargas (FGV). It should be noted that until 1987, the TOC used in this study refers to the crop's actual economic results, i.e., the observed values (ex post). From 1988 onwards, the TOC has been calculated through estimated productivity (ex ante).

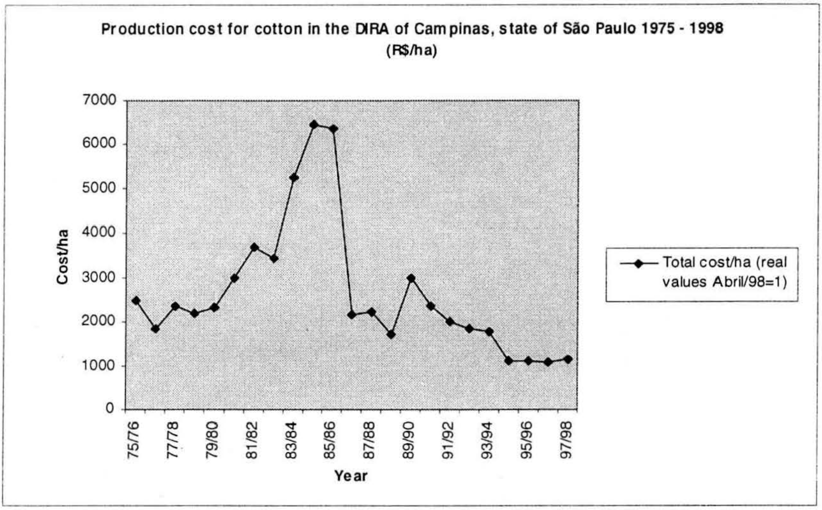
The IEA adopted this procedure because TOC estimates up to 1985 included an expectation of the inflation for several inputs that make up the cost; after 1985 that methodology was abandoned. Therefore, it was difficult to deflate the series before 1985 (included).

The IEA defines TOC of production/hectare as the Effective Operational Cost (EOC) plus depreciation and interest rate. The Effective Operational Cost is composed of operational expenses plus material used. The operational expenses include common labor, harvesting labor, machines, implements, seeds, chemical products, fertilizers, carts, and harvesting machines.

In this study, the TOC for cotton production in the Divisão Regional Agrícola (DIRA), Campinas, state of São Paulo, for the period 1975 to 1998[3] is used to estimate the translog cost function. The cotton production system adopted is Tração Motomecanizada [Mechanized Traction Machinery] (TM). This DIRA and production system was chosen based on data availability.

[3]The cotton production cost in 95/96 are not avaliabre, therefore an average of the values in 94/95 and 96/97 is used.

Figure 1 - Total Operational Cost for cotton production in the DIRA of Campinas, state of São Paulo (1975 - 1998)



Source: IEA

The production factors considered are labor (MO), machine operations (OPM), fertilizers (FERT), seeds (SE), and other costs (OC)[4]. The cost shares of the production factors are represented by the total expense of each factor. Labor expenses include common labor and labor used for harvesting, due to the great importance of manual harvesting for cotton production in the state of São Paulo. The factors prices are obtained directly or through a ratio of factor expenses and the amount of the factor used.

Proceedings

The factors i and j are defined as labor (MO), machine operations (OPM), fertilizers (FERT), seeds (SE), and other costs (OC). To estimate the cost share equation system represented in (3), the linear

[4]The factors were selected according to the availability of data to estimate the cost function.

homogeneity in factor prices is imposed by normalization of the equation system by the OC cost share. (11), (12), (13), and (14) represent the estimated equation system:

$$S_{MO} = \beta_{MO} + \beta_{MO,MO} \ln P_{MO} + \beta_{MO,OPM} \ln P_{OPM} + \beta_{MO,FERT} \ln P_{FERT} + \beta_{MO,SE} \ln P_{SE} + \beta_{MO,Q} \ln Q \quad (11)$$

$$S_{OPM} = \beta_{OPM} + \beta_{OPM,OPM} \ln P_{OPM} + \beta_{OPM,FERT} \ln P_{FERT} + \beta_{OPM,SE} \ln P_{SE} + \beta_{OPM,Q} \ln Q \quad (12)$$

$$S_{FERT} = \beta_{FERT} + \beta_{FERT,FERT} \ln P_{FERT} + \beta_{FERT,SE} \ln P_{SE} + \beta_{FERT,Q} \ln Q \quad (13)$$

$$S_{SE} = \beta_{SE} + \beta_{SE,SE} \ln P_{SE} + \beta_{SE,Q} \ln Q \quad (14)$$

where S refers to each factor's cost share, β represents the estimated parameters in each equation, lnP is the natural logarithm of the factors price, and Q is the cotton quantity produced.

The sum of the cost shares is equal to one; therefore, it is necessary to omit one of the equations to avoid singularity in the variance/covariance matrix. Moreover, because the cost share equation errors can be contemporarily correlated, the Seemingly Unrelated Regression (SUR) method is used. The equations are estimated using the Zellner method, which is invariant with respect to the omitted equation (Kmenta, 1990).

RESULTS AND DISCUSSION

Table 1 shows the results of the cost shares estimates using the SUR method, imposing the linear homogeneity and symmetry restrictions. The linear homogeneity is guaranteed through the sum of the intercept column equal to one ($\sum_{i=1}^{n} \beta_i = 1$) and through the zero sum of the other columns and rows in Table 1 $\left(\sum_{i=1}^{n} \beta_{iY} = \sum_{i=1}^{n} \beta_{ij} = \sum_{j=1}^{n} \beta_{ij} = 0 \right)$. The symmetry condition is attended to by imposing the restriction $\beta_{ij} = \beta_{ji}$, for i $\neq$ j.

The positive signs of the cost shares guarantee the monotonicity of the cost function. The cost shares were calculated through the sample average, and the values are: SMO=0.2877, SOPM=0.1455, SFERT=0.1850, SSE=0.02837, SOC=0.3533. The OC share is obtained by subtracting the sum of the other shares from one.

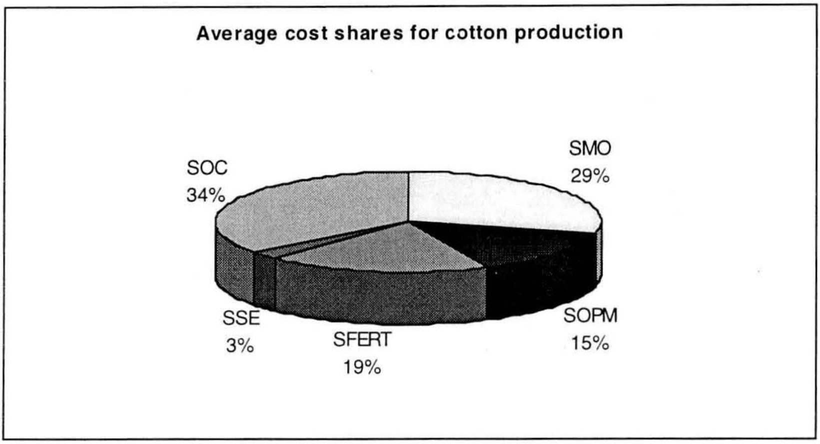
Table 1 - Results of cost share equation estimates for cotton in the DIRA of Campinas, state of São Paulo.

				Dependent variables				
Share	Intercept	LQ	LMO	LOPM	LFERT	LSE	LOC	**Sum**
SMO	3,135859*	-0,457461*	0,047479****	-0,12821*	-0,021556	0,00119	0,101097	0
	(8,453)	(-6,795)	(-1,469)	(-5,273)	(-0,0951)	(-0,062)		
SOPM	-1,193214*	0,236757*	-0,12821	0,04509**	-0,004802	-0,003568	0,09149	0
	(-3,488)	(3,772)		(2,18)	(-0,275)	(-0,194)		
SFERT	-1,284006	0,154251	-0,021556	-0,004802	0,104505**	-0,001305	-0,076842	0
	(-1,309)	(0,869)			(2,422)	(-0,025)		
SSE	-0,180687***	0,041056**	0,00119	-0,003568	-0,001305	0,016972	-0,013289	0
	(-1,803)	(2,005)				(2,881)		
SOC	0,522048	0,025397	0,101097	0,09149	-0,076842	-0,013289	-0,102456	0
Sum	1	0	0	0	0	0	0	

Note: the t rate is presented in parentheses; * significantly different from zero with a P-value of 1%, ** significantly different from zero with a P-value of 5%, *** significantly different from zero with a P-value of 10%, **** significantly different from zero with a P-value of 20%.
SMO=labor cost share; SOPM=machine operations cost share; SFERT=fertilizers costs share; SSE=seeds cost share; SOC=other costs cost share; LQ=natural logarithm of cotton quantity produced; LMO=natural logarithm of labor price; LOPM=natural logarithm of machine operations price; LFERT=natural logarithm of fertilizers price; LSE=natural logarithm of seeds price; LOC=calculated
through the homogeneity restriction.

Figure 2 shows that labor expenses have the second greatest share of costs, after other costs (OC). The labor costs as a share cotton production's TOC is notable, probably because manual labor is the harvesting technology used in the DIRA of Campinas, and prevails throughout the state of São Paulo. The state's cotton crop has been developed using manual labor to harvest cotton on small to medium size properties; this has become very expensive when compared with mechanized harvesting costs. However, mechanized harvesting is economically feasible only over large areas, and cotton is not cultivated on large agricultural properties in the state of São Paulo.

Figure 2 - Average cost shares for cotton production factors in the DIRA of Campinas, state of São Paulo (1975 - 1998)



Note: SMO=labor cost share, SOPM=machine operations cost share, SFERT=fertilizers cots share, SSE=seeds cost share, SOC=other costs cost share.

Table 2 presents price-elasticities of demand. The negative signs of the factor's own price-elasticities of demand show that the concavity of the cost function is attended. All values are statistically significant except those for the value of fertilizer. All the values obtained for the factor's own price-elasticity of demand are less than unity, indicating that the demand for the considered factors is inelastic, i.e., the demand change is less than proportional to the change in respective prices. The zero sums found in each row of Table 2 for the factor's own demand and factor cross price-elasticities of demand confirm the linear homogeneity restriction of the cost function.

In Table 2, except for OC, labor and machine operations show the highest values for their own price-elasticity of demand; a result consistent with the cost share estimates. For a 1% increase (decrease) in the cost of labor, labor demand decreases (increases) 0.547%. A 1% increase (decrease) in the cost of machine operations, causes a 0.545% decrease (increase) in machine operations demand.

Table 2 - Estimates of the factor demand and the factor cross price-elasticity of demand for cotton production factors in the DIRA of Campinas, state of São Paulo (1975 - 1998)

	Factor price					
Quantity	Labor (MO)	Machine Op. (OPM)	Fertilizers (FERT)	Seeds (SE)	Other costs (OC)	**Sum**
Labor	-0,547258*	-0,300065*	0,110113****	0,032510	0,704700	0
(MO)	(-4,8712)	(-3,5508)	(1,3971)	(0,4838)		
Machine Op.	-0,59328*	-0,544633*	0,152033****	0,003856	0,982024	0
(OPM)	(-3,5508)	(-3,8326)	(1,2649)	(0,03052)		
Fertilizers	0,17123****	0,119574	-0,250170	0,021321	-0,061955	0
(FERT)	(1,3971)	(1,2649)	(-1,07262)	(0,01179)		
Seeds	0,329670	0,019777	0,139037	-0,373471***	-0,115013	0
(SE)	(0,4838)	(0,03050)	(0,07687)	(-1,7988)		
Other costs	0,573849	0,404455	-0,032444	-0,009236	-0,936625	0
(OC)						

Note: the t rate is presented in parentheses; * significantly different from zero with a P-value of 1%, *** significantly different from zero with a P-value of 10%, **** significantly different from zero with a P-value of 20%.

Seed price-elasticity of demand presents a smaller value than that of labor and machine operations. The more inelastic demand for that factor is probably related to the purchase of seeds in the state of São Paulo. Until 1997, the state's cotton growers were only allowed to plant varieties which came from seed developed and produced by the Instituto Agronômico de Campinas (IAC), São Paulo. Fertilizer price-elasticity of demand is more inelastic when compared with that of the other inputs, probably due to the need for soil fertilization and correction to produce cotton in the DIVR, Campinas, São Paulo.

Considering the cross price-elasticities of demand shown in Table 2, positive signs indicate that the factors are substitutes and negative signs indicate that they are complementary. Less than half of the obtained values are statistically significant; and except for the cross price-elasticity of demand between labor and machine operations, the significance levels for the other values are low. Therefore, the analysis of cross price-elasticity of demand is limited.

Labor and machine operations are complementary, i.e., when the price of one factor increases, the demand for the factor itself and for the complementary factor decreases. Other costs and fertilizers and other costs and seeds are also complements. All other factor pairs are substitutes. A substitution relationship indicates that as a factor price increases the substitute factor is more intensively used.

Table 3 presents the results for Allen elasticity of substitution between factors. This concept is used to indicate the relative demand change in one factor when its price changes relative to another factor price. For the most part the Allen elasticity of substitution values are significant at a 1% level.

The major diagonal found in Table 3 is composed of each of the five factor's own elasticity of substitution. The values outside the main diagonal are symmetric; positive signs indicate substitution and negative signs indicate complementarity. As expected by the theory, all of the values in the main diagonal are negative. This result has little economic meaning, but does indicate that each production factor is self-complementary and confirms the concavity of the cost function.

According to the Allen elasticity of substitution concept, labor and machine operations factors are complementary in cotton production. For a 1% relative increase (decrease) in labor price, the relative demand for machine operations decreases (increases) 2.06%. Considering machine operations and labor factors, the same rationale applies because Table 3 is symmetric. This result shows a strong complementary relationship, since the relative demand change of one factor is more than proportional to its relative price change.

Table 3 - Estimates of Allen elasticity of substitution between factors for cotton production in the DIRA of Campinas, state of São Paulo

	Factor price				
Allen Elasticity of Substitution	Labor (MO)	Machine Op. (OPM)	Fertilizers (FERT)	Seeds (SE)	Other costs (OC)
Labor	-1,902*	-2,0619*	0,5951*	1,1458*	1,9944
(MO)	(-16,9299)	(-2,4403)	(7,5505)	(17,0522)	
Machine Op.		-3,7425*	0,8217*	0,1359	2,7793
(OPM)		(-26,3362)	(6,8363)	(1,0755)	
Fertilizers			-1,3521*	0,7514	-0,1753
(FERT)			(-5,7970)	(0,4154)	
Seeds				-13,1625*	-0,3255
(SE)				(-63,3968)	
Other costs					-2,6508
(OC)					

Note: the t rate is presented in parentheses; * significantly different from zero with a P-value of 1%.

Most of the other elasticities presented in Table 3 show a positive sign, indicating substitution between these cotton production factors. There is a substitution relationship between fertilizers and labor, fertilizers and machine operations, and fertilizers and seeds. Among these pairs of factors, fertilizers and machine operations have the larger elasticity of substitution (0.8217), indicating that the relative demand for that pair of factors is inelastic.

Seeds and labor and seeds and machine operations are substitutes in the productive process. The value of the Allen elasticity of substitution between seeds and labor is larger than one. In this case, as the relative price of one factor increases (decreases) 1%, the relative demand for the substitute factor increases (decreases) 1.15%, i.e., there is an increase (reduction) in the relative demand for the substitute factor that is more than proportional.

Considering the Allen elasticity of substitution between other costs and labor and other costs and machine operations, in both cases there is a substitution relationship. While the elasticity of substitution between other costs and machine operations is the larger of the two substitution values (2.7793), both values indicate more than a proportional substitution relationship between factors. There is a complementary relationship between other costs and seeds and other costs and fertilizers, but the elasticities of substitution are less than one.

The concept of the Allen elasticity of substitution is OOES (One Factor One Price Elasticity of Substitution), i. e., it is a concept which relates the price change in one factor and the respective quantity change in another factor. The large obtained value for machine operations' own Allen elasticity of substitution (the value correspondent to machine operations in the main diagonal of Table 3) suggests that it would be convenient to consider a less restrictive concept of elasticity of substitutions: the Morishima concept. This concept is TOES (Two Factors One Price Elasticity of Substitution), i. e., the Morishima concept relates the change in relative quantities of factors i and j, when both are optimally adjusted for factor j price changes.

The values represent the Morishima elasticities of substitution for the factor in line with respect to the column, for changes in price of the factor in column

Table 4 shows the Morishima elasticities of substitution figures. The numbers found in each cell represent the Morishima elasticity of substitution values of the factor heading the row for price changes of the factor found in the column. For example, the value found in cell--row 1, column 2, is the elasticity of substitution of labor with respect to machine operations for a machine operations price change. In the same way, the value in cell--row 2, column 1, is the elasticity of substitution for machine operations with respect to labor for a labor price change. The Morishima concept is not symmetric while the Allen concept is.

Table 4 - Estimates of Morishima elasticity of substitution between factors for cotton production in the DIRA of Campinas, state of São Paulo

	Labor	Machine Op.	Fertilizers	Seeds	Other costs
Labor		0,2445	0,3602	0,4059	1,6412
Machine Op.	-0,0460		0,4022	0,3772	1,9185
Fertilizers	0,7184	0,6641		0,3947	0,8746
Seeds	0,8769	0,5643	0,3891		0,8215
Other costs	1,1210	0,9489	0,2177	0,3642	

Besides showing result magnitudes different from the Allen result magnitudes, the Morishima results also show an important change in the classification of the substitution relationship between the factors labor and machine operations. According to the Allen concept, those production factors are complementary; but by employing the Morishima concept they are classified as substitutes for price changes in machine operations (σ_{ij}^{M} =0,2445) and as complements for labor price changes (σ_{ij}^{M} =-0,046).

Thus, as the price of machine operations increases, labor use decreases, indicating complementary behavior. However, the decrease in labor use then causes a decrease in machine operations, due to the cost function concavity in factors prices, but at a rate that makes the relationship between labor and machine operations increase, clearly demonstrating the substitution relationship. This chain of cause and effect is not captured by the Allen concept, which considers the change of only one factor quantity due to the change in one other factor quantity.

CONCLUSIONS

The present study estimated cotton cost functions for the Divisão Regional Agrícola (Regional Agriculture Division--DIRA), Campinas, state of São Paulo, using the translog model. The results show that labor expenses are the major cotton production factor cost in the region. Moreover, individual factor's own price-elasticities of demand indicate that factor demand is inelastic and that labor is the factor most sensitive to price changes, possibly because the production technology adopted in the DIRA, Campinas, is based on manual harvesting.

The cross price-elasticities of demand show that labor and machine operations are complementary factors, and a substitution relationship prevails between the other pairs of production factors. Labor and machine operations were affirmed as complements because of the high significance level of the value obtained. However, as the most of the other factor's cross price-elasticities of demand are not statistically significant, any analysis these results is limited.

The Allen elasticity of substitution results indicate a strong complementary relationship between labor and machine operations. However, a substitution relationship prevails between the other pairs of factors. The extent and statistically significant level of the Allen elasticity of substitution results for labor and machine operations allow one to conclude that a change of these factors' prices will have a great affect on the composition of cotton production costs

The Morishima elasticity of substitution results show that labor and machine operations are substitutes for machine operations price change but they are complements for labor price change. The Morishima concept is less restrictive because it relates the change in the relative factor quantity when both adjust optimally for one factor's price change. Therefore, when the price of machine operations increases, labor is less intensively used, causing machine operations to decrease. However, this decrease occurs at a rate which makes the labor/machine operations ratio increase, indicating substitution.

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