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THE ABSORPTION OF LABOR IN INDONESIAN AGRICULTURE

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I. INTRODUCTION

THE Indonesian agricultural sector has demonstrated a remarkable ability to absorb labor in the face of sustained, rapid population growth. In 1961, the agricultural sector employed 24 million persons; by 1986 the figure had increased to 38 million persons, accounting for just over 55 per cent of total employment [16]. While other developing nations have been faced with excessive, and in some instances premature urbanization, continued growth in agricultural employment has enabled Indonesia to remain a rural-based society. Nearly 70 per cent of the total population continues to reside in rural areas.

This seemingly unending capacity of rural Indonesia to generate productive employment has attracted the attention of social scientists. Clifford Geertz's classic study of "agricultural involution" argued that the combination of the environmental nature of wet rice cultivation with the social proclivity of Javanese communities to share resources explains the growth in labor absorption [11]. More recent commentators have focused their attention on the effects of the green revolution on rice production, with its associated increase in cropping intensities and agrochemical inputs, to stimulate increased labor demand.[1]

This paper evaluates the Indonesian agricultural sector's capacity to absorb further increases in labor supply. Second, the paper examines the degree of substitutability and behavior of relative income shares between household and hired labor in Indonesian agriculture. While many studies have examined Indonesian rural labor markets, there has yet to be a formal model of agricultural commodity markets by which to assess labor absorption capacity, labor substitutability, and likely changes in relative income shares of hired as opposed to family labor under further growth. The third issue addressed in this paper is the degree to which

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1 Important contributions include Abey, Booth, and Sundrum [1], Booth [5], Collier [6], Collier et al. [7], Hart [13], Hayami and Kikuchi [14], Hüsken [15], Manning [20], Stoler [28], and White [30] [31]. While off-farm employment and urban migration are also important for absorbing labor increases [13] [20] [30] [31], these topics are beyond the scope of this paper.

family and hired agricultural labor can be aggregated and treated separately from production decisions regarding other factors of production. Although much of the anthropological and sociological literature assumes that agricultural labor may be treated separately from other factor markets, formal testing is required to make such important assumptions, particularly in the light of the rapid commercialization of agriculture and the improved communications and transport accompanying growth.

The paper is organized as follows. The next section provides additional background material. Section III describes the data and methodology. Section IV discusses the empirical results and Section V offers concluding remarks.

II. BACKGROUND

Geertz's influential treatise, *Agricultural Involution,* provides a natural starting point for discussion of the dynamics of Indonesian agricultural labor markets [11]. Geertz argued that Dutch colonialism reinforced a highly egalitarian Javanese social structure. This, in conjunction with the technical capacity of flooded rice cultivation to provide increasing returns to increasing applications of labor, allowed Javanese rural society to absorb ever-increasing amounts of labor. Geertz's argument consists of two parts: the capacity of agricultural production to absorb more labor per unit of cultivated land, and shared poverty in distribution and consumption of the product and employment [29].

Geertz's thesis assumes that wetland rice-based agriculture, due perhaps to a virtuous cycle of technological transformations, will have the technical capacity to absorb additional labor ad infinitum. But, with near continuous rice cultivation in many areas, the likelihood that there is a surplus capacity for labor absorption in agriculture is called into question.

A voluminous literature developed in response to Geertz's thesis has been summarized by Hayami and Kikuchi [14] and White [31]. Those who argued in favor or against Geertz's thesis tended to argue on the basis of either anthropological observation or small-scale sociological studies. There have been limited formal attempts to develop an economic model, or assess econometrically, the capacity of the agricultural sector to absorb increasing supplies of labor. Hayami and Kikuchi used formal economic models based on production functions as a theoretical framework [14].

A second concern is that agricultural commercialization, brought about by the green revolution, may have shifted the behavioral underpinnings of rural labor markets from a moral-economy type of employment spreading or "shared poverty" to a more atomistic form of profit maximization based on household economy. Observers of the process of rural change have commented on the loss of village welfare institutions, and other changes in labor market arrangements, associated with the introduction of the modern rice technologies [7] [13] [14] [15] [30].

Again, very little formal economic analysis has been conducted of alternative behavioral relationships in rural labor markets. An exception was the study by Ravallion and Dearden which found strong evidence of preferences for less inequality among rural households in the Province of Yogyakarta [22]. For wet rice farmers off Java, Squires observed that the shadow price of labor was statistically insignificant from zero and that farmers employed more labor than warranted by profit maximization [27].

The agricultural labor market is more highly differentiated today than when Geertz conducted his pioneering fieldwork in the 1950s. According to the 1983 agricultural census, 57 per cent of all agricultural households in Java operate holdings estimated to be too small to support a family (at 0.5 hectares), the vast majortiy supplementing their income through work as hired labor [6]. The increase in the use of hired, as opposed to family supplied, labor in Indonesian agriculture raises questions regarding the degree to which traditional village employment-sharing, or equity-reinforcing mechanism, if such mechanisms still exist, apply to all types of agricultural labor [6] [7] [13] [14] [15] [20]. The empirical issue, in part, hinges on the degree to which family and hired labor is formally substitutable and separable from other factors of production.[2] A related issue is the behavior of relative factor shares between hired and household labor under further economic growth.

III. METHODOLOGY

This section discusses the procedures used to develop a model of agricultural production, to test the functional separability of hired and family labor, and to compute the degree of substitution and behavior of relative factor shares between labor types, and the data.

A. *Translog Production Function*

The agricultural production technologies are modeled by the translog production function [2]:

$$\ln Y=\alpha_0+\sum_k \tau_k D_k+\sum_i \alpha_i \ln X_i+0.5\sum_i \sum_j \alpha_{ij} \ln X_i \ln X_j, \tag{1}$$

where Y = kilograms of farm output, X_1 = days of family labor, X_2 = days of hired labor, X_3 = intermediate inputs, a Divisia index of kilograms of seeds and four fertilizers, X_4 = meters of land, and D_k is a dummy variable for area k. Each labor variable is a Divisia index of seven labor categories.[3] The translog function is interpreted as a second-order Taylor's series approximation to a general, unknown function. Because each variable is scaled by its geometric mean, the point of approximation is the geometric mean. The restriction of symmetry ($\partial^2 Y/\partial X_i \partial X_j = \partial^2 Y/\partial X_j \partial X_i$) was imposed by the econometric restriction: $\alpha_{ij}=\alpha_{ji}$.

The production function was individually estimated for: (1) wet rice in West Java; (2) wet rice in Yogyakarta and Central and East Java; (3) wet rice in

2 The differentiation within labor groups is only touched upon by the approach of this paper. This differentiation includes the exclusion of some hired labor groups. Instead, we consider family and hired labor with access to employment opportunities.

3 The seven labor categories for both family and hired labor are: land preparation, planting, fertilizer application, weeding, irrigation, harvest, and postharvest operations.

Sulawesi; (4) wet rice in Sumatra, Kalimantan (Borneo), and other islands, including Bali, Nusa Tenggara Barat or NTB (Lesser Sundas), and Maluku (Moluccas); (5) cassava throughout Indonesia; (6) peanuts throughout Indonesia; (7) mung beans throughout Indonesia; (8) maize throughout Indonesia; (9) dry rice in Java; (10) dry rice off Java; and (11) soybeans in Java. For the all-Java models, regional dummy variables were specified for the provinces of Yogyakarta and Central and East Java, with West Java as the intercept. For the all-Indonesia models, regional dummy variables were specified for Kalimantan, Sulawesi, and a residual, "other islands" (including Bali, Maluku, Irian Jaya, and NTB); Sumatra is the intercept.

B. *Labor Separability*

In this section, nested hypothesis-testing procedures are developed to test for the separability of labor from the other inputs. Aggregation of family and hired farm labor into a composite index (total farm labor) requires the assumption of either weak or strong separability of labor from the other inputs. An assumption of weak labor separability implies that the marginal rate of substitution (MRS) between family and hired labor is invariant to changes in other inputs, while an assumption of strong separability implies that the MRS between labor and another input is invariant to changes in still another input. In addition, Berndt and Christensen showed that estimates of marginal products may be biased if unacceptable restrictions are placed on separability, unlike estimates of output [2].

Production can be viewed as a two-stage process if labor is separable from the other inputs. In the first stage, the mix of hired and family farm labor is optimized independently of the mix and level of other inputs. In the second stage, the levels and mix of all other inputs are optimized holding labor intensities fixed [2].

The separability of labor from other inputs can be tested by a series of restrictions on the production function (equation 1). These tests follow a nested sequential procedure, starting with tests for weak separability and proceeding to tests for strong separability. Each succeeding hypothesis is tested given that the previous hypothesis is maintained. The testing sequence ends whenever a hypothesis is rejected. A test for the Cobb-Douglas form is included. While not strictly part of the separability-testing scheme, the hypothesis is tested because it is often maintained in studies of Indonesian agriculture and because of its implications for composite labor indices and elasticities of factor substitution. Following Denny and Fuss [9], the overall significance of the nested hypothesis tests is approximately equivalent to the sum of the individual test's significance; we assign a significance of 0.02 for each test, giving an overall significance of 0.06.[4] Because the translog function is interpreted as a second-order approximation to an underlying production technology, the separability tests hold only at

[4] When there is a high degree of dependence between the individual significance tests, each with significance level α, the overall significance level may be somewhat smaller than its upper bound of $s\alpha$, where s is the number of tests, whereas if the tests are independent it is given by $1-(1-\alpha)^s$ [12].

the point of approximation (the geometric mean in this case) and approximately in the neighborhood of the point of expansion [9].

To assume weak separability of labor from the other intermediate inputs and land requires the following econometric restrictions on the translog production function (equation 1):

$$\alpha_1/\alpha_2 = \alpha_{13}/\alpha_{23} \text{ and } \alpha_1/\alpha_2 = \alpha_{14}/\alpha_{24}, \tag{2}$$

where family labor = 1, hired labor = 2, intermediate inputs = 3, and land = 4. Approximate strong labor separability requires:

$$\alpha_{13} = \alpha_{23} = \alpha_{14} = \alpha_{24} = 0. \tag{3}$$

The restriction for the Cobb-Douglas functional form is:

$$\alpha_{ij} = 0, \qquad i = 1, 2, 3, \text{ and } 4. \tag{4}$$

If the null hypothesis (equation 4) is not rejected, homogeneity, strong separability, and unitary price elasticities of substitution amongst all inputs are globally maintained hypotheses.

C. *Elasticities of Substitution*

From the translog production function, we compute the elasticity of substitution amongst labor types and between labor and other factors of production. The greater the degree of complementarity between labor and other productive factors, the greater the capacity of the agricultural sector to absorb more labor with increased capital investment. In contrast, when labor is a substitute for land or intermediate inputs, investment in these other factors reduces labor demand.

Substitution elasticities between labor and other factors are measured using the Hicks elasticity of complementarity (HEC) rather than the widely applied Allen elasticity of substitution (AES) due to the introduction of biases in the latter when derived from a translog production function [10].[5] We also choose the HEC because it more appropriately addresses two questions of interest to this paper: (1) what happens to output and the marginal production of one factor (and hence value of marginal product or labor demand) when there is an exogenous increase in the quantity of another factor and (2) what happens to the price or marginal product and quantity of one factor when a price incentive is given to encourage the supply of another factor [26]. Both of these questions relate to the effects on the derived demand for labor of changes in quantities for two common key elements in agricultural development: capital formation and the additional quantities used of variable inputs such as pesticides and fertilizers. Given the price incentives through input subsidies for the policy of rice self-sufficiency [5] [8] [13] [14], the impact on labor demand and hence rural

[5] Field notes that AESs estimated from the (primal) translog production function may not be desirable because the matrix of estimated coefficients must be inverted to derive an AES [10]. If one coefficient has a large standard error, all AESs are affected.

employment is an important issue. The Appendix reviews these and other elasticities and their relative contributions.

The HEC registers the effect on the price or marginal product of one factor of a change in the quantity of another factor, where the partial derivative holds marginal cost and quantities of other factors constant but not the level of output. The HEC measures the degree to which two factors jointly contribute to an output change, since the expression involves the cross partial derivative of the production function with respect to the two-factor inputs concerned. Thus two factors which are q-complements by this measure work together to increase output level, and reversing the argument, are q-substitutes [23]. Increasing the marginal product also increases the value of marginal product and thus labor demand.

The HEC measures are derived by logarithmically differentiating the translog production function with respect to the relevant quantities of inputs. The cross HEC is written as:

$$h_{ij}=(\alpha_{ij}+M_iM_j)/M_iM_j, \tag{5}$$

where M_i is the logarithmic marginal product of factor i: $\partial \ln Y/\partial \ln X_i=\alpha_i+\sum_j\alpha_{ij}\ln X_j$. A positive (negative) value of h_{ij} indicates that inputs i and j are q-complements (q-substitutes), so that increased usage of one increases (decreases) the marginal product and demand for the other. With the Cobb-Douglas form, $\alpha_{ij}=0$ and $h_{ij}=1$, indicating global q-complementarity between X_i and X_j.[6]

The own HEC may be written as:

$$h_{ii}=(\alpha_{ii}+M_i^2-M_i)/M_i^2. \tag{6}$$

Own HECs should be negative, indicating diminishing returns or marginal product. All own and cross HECs for the translog form were calculated at the geometric mean of the data.[7] Unlike the AES, any maintained separability restrictions are directly imposed on equation (5) or (6).

The HECs or AESs do not provide direct information on the behavior of relative factor shares and isoquant curvature, unlike the direct elasticity of substitution (DES) and Morishima elasticity of substitution (MES) [3] [18] [24]. Because computation of the MES from the translog production function faces the same computational bias as the AES, we concentrate our attention on the DES. We also choose the DES, because as noted in the Appendix, the DES is a two factor–two price elasticity, and as such, comes closest to the concept of the original definition proposed by Robinson and Hicks.

The DES measures the substitution between two inputs along an isoquant with all other inputs and output held constant. The DES between X_i and X_j is defined as [19]:

6 Conversely, with a Cobb-Douglas functional form, X_i and X_j are global p-substitutes.

7 At the geometric mean of the data set when variables are scaled by the geometric mean, $\ln(\hat{X}_i/\hat{X}_i)=\ln(1)=0$, so that $M_i=\alpha_i$, where ^ indicates the geometric mean. Moreover, economies of scale for the translog evaluated at the geometric means become $\sum_i\partial\ln Y/\partial\ln X_i=\sum_i\alpha_i$, the same formula as the Cobb-Douglas.

$$d_{ij}=\frac{d(X_i/X_j)}{d(f_i/f_j)}\frac{f_i/f_j}{X_i/X_j}, \tag{7}$$

where $f_i=\partial f(X)/\partial X_i$ and i is not equal to j. The DES is a generalization of the two-factor elasticity of substitution formula applied to each pair of inputs and is symmetric. The DES has the following range: $0<d_{ij}\leq\infty$, and grows larger as the substitution becomes easier between two inputs. The DES is a two factor–two price elasticity of substitution. The DES is a short-run elasticity since it holds all other inputs constant, but under weak (or strong) separability, the DES, a short-run measure, equals the long-run two-factor, two-price elasticity of substitution for the separable inputs [21].[8]

The DES for the translog production function approximated at the geometric mean may be written as [4]:

$$d_{ij}=\frac{-(\alpha_i+\alpha_j)}{-(\alpha_i+\alpha_j)+\dfrac{\alpha_i^2\alpha_{jj}-2\alpha_i\alpha_j\alpha_{ij}+\alpha_j^2\alpha_{ii}}{\alpha_i\alpha_j}}. \tag{8}$$

Any separability restrictions that are not rejected can be directly imposed in equation (8). For the Cobb-Douglas form $d_{ij}=1$ globally.

D. *Data*

The data include primary farm management survey records collected routinely by extension agents from the Ministry of Agriculture. It is part of the raw data used by that ministry for compiling annual cost of production estimates, which in summary form, are published in a report entitled *Struktur Ongkos Produksi Bahan Pertanian* [17].[9]

Each farm management survey includes information on farm size, cost of cultivation, production, sales price, and marketing arrangements. Each month, field level extension agents complete between five to ten surveys of farm enterprises in randomly selected farm households. Since the distribution of extension agents is approximately proportional to the distribution of agricultural households (far more in Java, very few in Irian Jaya), the sampling frame is approximately proportional to the distribution of farm households. On average, nearly five thousand questionnaires are collected each year and tabulated at the Directorate of Foodcrops Development, Ministry of Agriculture. The year 1983 was

[8] Hence, the results for the separable inputs hold for both partial and full static equilibrium and any output level. In addition, the (symmetric) DES provides information on the relative shares of inputs i and j, S_i and S_j, where $sgn\, \partial(S_i/S_j)/\partial(X_i/X_j)>or=or<0$ according as $d_{ij}>$or$=$or<1 [24]. Thus, if hired labor i is substituted for family labor j, so that the ratio of hired to family labor increases, the share of hired labor increases or remains constant or decreases relative to the share of family labor as $d_{ij}>$or$=$or<1.

[9] Neither author participated in one of the data-collecting surveys although both have had considerable experience in Malaysia and Indonesia, either by participating in or organizing and heading direct field surveys of smallholder and estate agriculture and peasant fishermen. Moreover, the raw data are not directly available from the government although arrangements for access to computerized data might be possible.

selected because the diffusion of green revolution technologies was largely completed, a special government effort to improve data collection procedures was made in that year, and there were no production disturbances.

IV. EMPIRICAL RESULTS

All translog production functions (equation 1) were directly estimated by ordinary least squares, under the assumption of expected profit maximization [33], correcting for heteroscedasticity, when appropriate, by White's general procedure [32].[10] The initial regression results, prior to hypothesis testing, are not presented here for brevity, but are available from the authors upon request. The production function parameter estimates with the final hypothesis test results imposed are presented in Table II. (Parameter estimates of flexible functional forms have little meaning in themselves; instead, elasticities are required.)

A. *Hypothesis Tests*

The likelihood ratio test results for the nested hypothesis tests at the geometric mean are presented in Table I. The results indicate that approximate weak separability of family and hired labor from intermediate inputs and land cannot be rejected for any commodity except peanuts. The results further indicate that approximate strong separability of family and hired labor from intermediate inputs and land cannot be rejected for any of the remaining commodities except soybeans in Java. Finally, given approximate strong separability of labor, the Cobb-Douglas form is not rejected for: (1) wet rice in Yogyakarta and Central and East Java; (2) cassava; and (3) mung beans. The Cobb-Douglas form is rejected for: (1) wet rice in West Java; (2) wet rice in Sulawesi; (3) wet rice in Sumatra, Kalimantan, and other islands; (4) dry rice on Java; (5) dry rice off Java; and (6) maize.

To sum up, the tests for approximate separability of family and hired labor from intermediate inputs and land indicate that, for all commodities except peanuts, labor is a separable and hence aggregate input. Furthermore, the results indicate that the farm production process does involve a two-stage allocation, with decisions on labor allocation made separately from decisions on allocations of other factors.[11] This fact adds empirical support to those studies which have analyzed rural labor markets separately from the markets of other productive

[10] Direct estimation of the production function, equation (1), was chosen over iterative Zellner estimation of the input cost shares (less one), because the latter approach required constant returns to scale for the share equations to add up. Multicolinearity from direct estimation of equation (1) poses less of a problem with cross-sectional than time-series data and when structure is imposed upon the technology after hypothesis testing.

[11] The informational content of labor is separated from intermediate inputs and land, and optimal and efficient within-labor allocations can be made without requiring information on the other inputs. Thus, a farm family can decide how to optimally allocate its own labor to farm and to off-farm employment and the proportion of hired to family labor, independent of the family's decisions on fertilizer, seed, and land use. The optimal levels and mix of the composite labor and intermediate inputs and land are decided separately.

TABLE I

TESTS FOR SEPARABILITY OF FAMILY AND HIRED FARM LABOR AND COBB-DOUGLAS FUNCTIONAL FORM

A. Weak Separability

Crop and Region	Likelihood Ratio	Reject (Yes/No)
Wet rice West Java	3.189	No
Wet rice Yogyakarta and Central and East Java	4.278	No
Wet rice Sulawesi	5.809	No
Wet rice Sumatra, Kalimantan, and other islands	0.108	No
Dry rice Java	0.574	No
Dry rice off Java	0.788	No
Maize all Indonesia	0.911	No
Cassava all Indonesia	0.094	No
Peanuts all Indonesia	8.366	Yes
Mung beans all Indonesia	5.215	No
Soybeans Java	2.046	No

Note: Number of independent restrictions=2.

B. Strong Separability

Crop and Region	Likelihood Ratio	Reject (Yes/No)
Wet rice West Java	2.737	No
Wet rice Yogyakarta and Central and East Java	2.132	No
Wet rice Sulawesi	2.298	No
Wet rice Sumatra, Kalimantan, and other islands	3.786	No
Dry rice Java	1.004	No
Dry rice off Java	4.368	No
Maize all Indonesia	4.682	No
Cassava all Indonesia	1.256	No
Mung beans all Indonesia	3.002	No
Soybeans Java	16.778	Yes

Note: Number of independent restrictions=4.

C. Cobb-Douglas Functional Form

Crop and Region	Likelihood Ratio	Reject (Yes/No)
Wet rice West Java	18.150	Yes
Wet rice Yogyakarta and Central and East Java	1.474	No
Wet rice Sulawesi	321.918	Yes
Wet rice Sumatra, Kalimantan, and other islands	114.576	Yes
Dry rice Java	86.210	Yes
Dry rice off Java	32.206	Yes
Maize all Indonesia	68.010	Yes
Cassava all Indonesia	4.004	No
Mung beans all Indonesia	10.777	No

Note: Number of independent restrictions=6. All hypothesis tests with translog production function at point of approximation, the sample geometric mean. Significance level of 0.02 for each hypothesis test.

TABLE II-A
PRODUCTION FUNCTION PARAMETER ESTIMATES

Variable	Wet Rice			
	West Java	Other Java[a]	Sulawesi	Other Indonesia[b]
Intercept	0.039	2.814*	0.132	−0.017
	(0.087)	(0.815)	(0.107)	(0.090)
Family labor	0.130	0.068*	0.106	0.462*
	(0.081)	(0.038)	(0.082)	(0.135)
Hired labor	0.208*	0.105	0.077	0.130
	(0.062)	(0.041)	(0.153)	(0.108)
Other inputs	0.018	0.303*	−0.127	0.309*
	(0.086)	(0.096)	(0.241)	(0.102)
Land	0.148*	0.416*	0.262	−0.336*
	(0.072)	(0.132)	(0.143)	(0.141)
Family labor × hired labor	−0.012		−0.054	0.009
	(0.063)		(0.083)	(0.083)
Other inputs × land	0.169		0.281*	−0.119*
	(0.119)		(0.170)	(0.036)
Family labor squared	0.033		0.037	−0.010
	(0.039)		(0.030)	(0.037)
Hired labor squared	0.097*		−0.140	−0.002
	(0.032)		(0.080)	(0.041)
Other inputs squared	−0.039		−0.073	0.137*
	(0.061)		(0.071)	(0.041)
Land squared	−0.054		−0.156	−0.079*
	(0.062)		(0.108)	(0.032)
Yogyakarta dummy		−0.495*		
		(0.180)		
East Java dummy		−0.133*		
		(0.067)		
Kalimantan dummy				−0.084
				(0.090)
Other islands dummy				−0.101
				(0.083)
Returns to scale	0.504	0.892	0.318	0.564
R^2	0.61	0.52	0.20	0.29
No. of observations	182	230	119	127

Note: Translog production function approximated at geometric mean for 1983. Heteroscedastic-consistent estimates. Standard errors in parentheses. Hypothesis test results imposed.
[a] Other Java includes Yogyakarta and Central and East Java.
[b] Other Indonesia includes Sumatra, Kalimantan, and other islands (Bali, Nusa Tenggara Barat, Irian Jaya, and Maluku).
* Statistically significant at 5 per cent.

TABLE II-B
PRODUCTION FUNCTION PARAMETER ESTIMATES

Variable	Cassava	Mung Beans	Peanuts	Soybeans
Intercept	3.261* (0.960)	3.896* (0.970)	0.023 (0.049)	0.101 (0.106)
Family labor	−0.127 (0.098)	−0.125 (0.122)	0.089 (0.078)	0.049 (0.073)
Hired labor	0.364* (0.096)	0.537* (0.130)	0.349* (0.084)	0.019 (0.027)
Other inputs	0.031 (0.036)	0.073 (0.061)	0.085 (0.090)	−0.029 (0.092)
Land	0.515* (0.122)	0.065 (0.131)	0.101 (0.113)	1.059* (0.144)
Family labor × hired labor			0.084 (0.101)	−0.201* (0.078)
Family labor × other inputs			−0.363* (0.106)	
Family labor × land			0.016 (0.135)	
Hired labor × other inputs			−0.272* (0.122)	0.142 (0.113)
Hired labor × land			−0.497* (0.123)	0.073 (0.089)
Other inputs × land			0.216* (0.111)	0.259 (0.139)
Family labor squared			0.049 (0.047)	0.250* (0.087)
Hired labor squared			0.074 (0.085)	−0.278* (0.041)
Other inputs squared			−0.051 (0.093)	0.001 (0.051)
Land squared			0.139 (0.085)	−0.483* (0.201)
Yogyakarta dummy				−0.013 (0.044)
Central Java dummy				0.135 (0.098)
East Java dummy				−0.149* (0.056)
Sumatra dummy	0.418* (0.189)	0.279 (0.205)	0.081 (0.117)	
Kalimantan dummy	0.124 (0.239)	0.825 (0.277)	0.016 (0.106)	
Sulawesi dummy	0.020 (0.514)		−0.074 (0.111)	
Other islands dummy[a]	0.154 (0.179)		0.064 (0.078)	

TABLE II-B (Continued)

Variable	Cassava	Mung Beans	Peanuts	Soybeans
Returns to scale	0.783	0.550	0.624	1.098
R^2	0.35	0.55	0.35	0.47
No. of observations	110	39	133	140

Note: The same as in Table II-A.
[a] Other islands include Bali, Nusa Tenggara Barat, Irian Jaya, and Maluku.

TABLE II-C
PRODUCTION FUNCTION PARAMETER ESTIMATES

Variable	Dry Rice Java	Dry Rice off Java	Maize
Intercept	−0.136	−0.187	0.095
	(0.095)	(0.104)	(0.167)
Family labor	0.095	−0.105	0.155
	(0.104)	(0.094)	(0.134)
Hired labor	0.084	0.199*	0.133
	(0.120)	(0.097)	(0.154)
Other inputs	0.215*	0.183*	−0.081
	(0.076)	(0.078)	(0.135)
Land	0.282*	0.457*	0.085
	(0.153)	(0.118)	(0.171)
Family labor × hired labor	0.318	−0.173	0.063
	(0.137)	(0.092)	(0.258)
Other inputs × land	−0.035	−0.209	0.751*
	(0.173)	(0.174)	(0.269)
Family labor squared	0.149*	0.143*	0.074
	(0.076)	(0.069)	(0.070)
Hired labor squared	−0.068	0.078	0.013
	(0.075)	(0.041)	(0.056)
Other inputs squared	−0.017	0.055	−0.050
	(0.069)	(0.070)	(0.059)
Land squared	0.093	−0.183	0.033
	(0.096)	(0.147)	(0.156)
Yogyakarta dummy	−0.144		
	(0.094)		
Central Java dummy	0.114		
	(0.218)		
East Java dummy	−0.166		
	(0.093)		
Sumatra dummy			−0.009
			(0.142)
Kalimantan dummy		−0.200*	−0.095
		(0.065)	(0.126)
Sulawesi dummy		0.075	
		(0.166)	

TABLE II-C (Continued)

Variable	Dry Rice Java	Dry Rice off Java	Maize
Other islands dummy[a]		0.130* (0.068)	
Returns to scale	0.676	0.734	0.292
R^2	0.21	0.25	0.20
No. of observations	138	102	69

Note: The same as in Table II-A.
[a] Other islands include Bali, Nusa Tenggara Barat, Irian Jaya, and Maluku.

factors. In addition, employment and other policies can target labor separately from other economic inputs.

B. *Agriculture's Capacity to Absorb Labor*

Agricultural demand for total labor will expand with increases in area cultivated and cropping intensities if labor is a complementary input to the other inputs.[12] The Hicks elasticities of complementarity (HEC) indicate whether or not increased capital investment in agriculture (of the pattern undertaken to date) will q-complement (HEC $>$ 0) or will q-substitute (HEC $<$ 0) for agricultural labor. The calculated HECs (Tables III and IV), together with the results of the nested hypothesis tests (Table I), suggest that in certain regions, labor does q-substitute for other inputs, but that labor demand is generally q-complementary to demand for intermediate inputs and land.

In Yogyakarta and Central and East Java the tests of restrictions on the translog production function for wet rice failed to reject the Cobb-Douglas functional form (Table I). Non-rejection of a Cobb-Douglas technology implies that labor is a q-complement to the intermediate inputs of fertilizer and agrochemicals in production. Hence, in these regions, there is reason to suspect that further capital deepening may expand the process of overall agricultural labor absorption in wet rice production, since capital deepening will increase the marginal product and derived demand for labor. Raising labor's marginal product and labor demand also introduces the potential for increased earnings [14].

For wet rice outside of Java, and in the Province of West Java, rejection of the Cobb-Douglas form and the positive values of the derived HECs (Table III) imply that labor is again a q-complement to the intermediate inputs. Hence, in these regions, increased investment in fertilizers and other agrochemicals will also promote an expansion in marginal product and overall labor demand in wet rice production since increased use of these intermediate inputs increases the derived demand for labor.

12 The marginal products of family and hired labor are positive at the geometric mean for all crops and regions except for family labor with cassava and mung beans, although the latter are not statistically significant. At the geometric mean the marginal product of X_i for the translog is written as $\partial Y/\partial X_i = \alpha_i Y/X_i$, the same formula as the Cobb-Douglas.

TABLE III

HICKS ELASTICITIES OF COMPLEMENTARITY FOR WET RICE

Input and Region	Family Labor	Hired Labor	Intermediate Inputs	Land
Family labor:				
West Java	−4.784	0.546	1.000	1.000
Sulawesi	−5.092	−5.740	1.000	1.000
Sumatra, Kalimantan, and other islands	−1.214	1.157	1.000	1.000
Hired labor:				
West Java		−1.559	1.000	1.000
Sulawesi		−35.748	1.000	1.000
Sumatra, Kalimantan, and other islands		−6.813	1.000	1.000
Intermediate inputs:				
West Java			−190.621	63.100
Sulawesi			4.368	−7.419
Sumatra, Kalimantan, and other islands			−0.806	2.150
Land:				
West Java				−8.228
Sulawesi				−5.512
Sumatra, Kalimantan, and other islands				3.280

Notes: 1. Calculated at sample geometric mean for 1983.
2. Strong separability of family and hired labor from other inputs and land.
3. Other islands include Bali, Nusa Tenggara Barat, Irian Jaya, and Maluku.

The empirical results for the main *palawija* or secondary food crops also indicate that there is a significant scope for enhancing labor absorption through further capital investment for dryland rice on and off Java and maize. These results were obtained for these crops because of the strong separability of labor from the other inputs (Table I), giving a cross HEC of one between labor and the other inputs (Table IV), which indicates q-complementarity. The empirical results show that capital investment will increase the marginal product of labor and expand employment demand in the primary *palawija* crops, maize, and dryland rice, throughout the country. These results have important equity effects as well, for such crops are typically grown under dryland conditions by the poorest farming families.

The Cobb-Douglas functional form was not rejected for cassava and mung beans (Table I), indicating HECs of one and q-complementarity of labor with other inputs. Hence, capital investment may expand labor demand. In peanut production, family and hired labor (which do not form an aggregate labor given rejection of weak separability reported in Table I) are q-complementary to one another, both are q-substitutes to intermediate inputs, and family labor is a q-complement to land but hired labor is a q-substitute for land (Table IV).

Although capital investment in wet rice, in selected areas of Indonesia, and in the main secondary crops, will tend to increase the marginal product of labor and expand labor demand, this does not necessarily imply that all types of

TABLE IV

HICKS ELASTICITIES OF COMPLEMENTARITY FOR PALAWIJA CROPS

Input and Region	Family Labor	Hired Labor	Intermediate Inputs	Land
Family labor:				
Dry rice Java	6.962	40.745	1.000	1.000
Dry rice off Java	23.481	9.295	1.000	1.000
Maize	−2.385	4.052	1.000	1.000
Peanuts	−4.050	3.704	−46.984	2.780
Hired labor:				
Dry rice Java		−20.418	1.000	1.000
Dry rice off Java		−2.044	1.000	1.000
Maize		−5.801	1.000	1.000
Peanuts		−1.258	−8.169	−13.100
Intermediate inputs:				
Dry rice Java			−4.028	0.426
Dry rice off Java			−2.830	−1.497
Maize			5.730	−109.531
Peanuts			−17.824	26.160
Land:				
Dry rice Java				−1.376
Dry rice off Java				−2.063
Maize				6.171
Peanuts				4.725

Note: Calculated at sample geometric mean for 1983.

agricultural labor will benefit from growth. Technological change in production induces changes in social relations in agriculture which affect the pattern of labor demand. For example, under traditional technology, all villagers who wished to participate in harvesting of rice were allowed to work in exchange for a share of the proceeds. This pattern of open-access harvesting has been superseded by the use of contract harvest teams and hired laborers in the areas where modern rice technology has been adopted.[13] Due to these changes in labor market institutions, the increase in labor market demand will likely be differentially distributed [7] [13] [14] [15] [30].

Given the high incidence of landlessness in the more densely populated areas of the inner islands (principally Java and Bali), of particular concern is the extent to which expansion in overall agricultural labor market demand and changes in off-farm employment opportunities will increase the demand and relative factor share for hired, as opposed to family labor. This topic will be considered in the following section.

13 Exclusionary labor relationships include *tebasan* or contract harvesting, *kedokan* or the offer of unpaid work in preharvest activities for the right to participate in the harvest, and employment contracts tied to credit and land transactions. Hayami and Kikuchi [14] concluded that labor is paid its marginal product but that wage rates adjust not through a Walrasian market mechanism but through modification of institutions.

TABLE V

DIRECT ELASTICITIES OF SUBSTITUTION BETWEEN HIRED AND FAMILY LABOR FOR WET RICE

West Java	Yogyakarta, Central & East Java	Sulawesi	Sumatra, Kalimantan & Other Islands
1.682	1.000	0.761	0.749

Notes: 1. Calculated at sample geometric mean for 1983.
2. Strong separability of family and hired labor from other inputs and land.
3. Other islands include Bali, Nusa Tenggara Barat, Irian Jaya, and Maluku.

C. *The Relative Share of Family and Hired Labor*

The degree to which family and hired labor are substitutes (in the sense of isoquant curvature), and the degree to which the relative income shares of different labor types are invariant to changes in labor mix, can be measured by the direct elasticities of substitution (DES).[14] The DESs between family and hired labor for wet rice are presented in Table V. These wet rice elasticities are calculated at the geometric mean of the data set incorporating the final forms of the production technology given by the hypothesis testing: strong labor separability in all regions on and off Java, and in addition, a Cobb-Douglas technology for Yogyakarta and Central and East Java.

The DESs between family and hired labor for wet rice in Java are relatively high, indicating that the two types of labor—household and hired—have close economic substitution possibilities in production. The DESs between family and hired labor are higher for wet rice on Java (i.e., 1.68 in West Java and 1.00 in other Java) than off Java (i.e., 0.75 for Sumatra and 0.76 for Sulawesi). Hence, there is a greater degree of substitution possibilities between hired and family labor in wet rice production on Java than off Java. This result is consistent with the greater commercialization of agricultural relations, higher population densities, and wider labor markets on Java and the greater reliance on family labor off Java.

The DES in excess of one for wetland rice in West Java implies that substitution of hired for family labor would continue with increased investment in rice production capacity or increased off-farm employment for family labor. The relative income share of hired labor would also increase, mitigating some of the concerns that hired labor in West Java might suffer under further growth. Relative factor shares between hired and family labor in the other regions of Java would remain constant as indicated by unitary DESs. Conversely, off Java, demand for hired labor and its income share relative to family labor would both fall (DESs < 1). This condition off Java can best be explained by lower population densities, a greater preponderance of family labor to begin with and,

[14] Returns to landownership for owner-operators can form an important source of their family earnings [14]. We focus our discussion solely on relative labor shares.

TABLE VI

DIRECT ELASTICITIES OF SUBSTITUTION BETWEEN HIRED AND FAMILY LABOR FOR PALAWIJA CROPS

Dry Rice Java	Dry Rice off Java	Maiz	Peanuts	Soybeans Java	Cassava	Mung Beans
0.084	1.584	3.432	0.218	0.260	1.000	1.000

Notes: 1. Calculated at sample geometric mean for 1983.
2. Weak or strong separability for all commodities except peanuts.
3. Cobb-Douglas functional form for cassava and mung beans.

due to limited nonagricultural labor markets, less scope for the use of casual agricultural labor.

The substitution possibilities and behavior of proportions between hired and family labor for the *palawija* crops are indicated by the DESs presented in Table VI. Again, DESs for the translog form are calculated at the geometric mean of the sample and DESs for the Cobb-Douglas are globally equal to one. The DES ≥ 1 between hired and family labor, for four of the seven crops (importantly, for dryland rice off Java and for maize), indicates that the share of hired labor will tend to rise or remain constant with increased investment in these commodities. This assumes, of course, a continued slow pace of mechanization in these small-scale, dryland and/or upland crops.[15]

V. CONCLUDING REMARKS

The Indonesian agricultural sector will come under increasing pressure to absorb new entrants to the labor market in the decades to come. In 1990, it is estimated that approximately 2 million new jobs will need to be created per year to meet growth in the labor supply [16]. Agriculture would need to absorb just over a million workers per year to maintain its share of the labor force.

While labor absorption on this scale is unlikely to occur, this analysis suggests that the capacity of agriculture to absorb additional labor is not yet exhausted. In certain regions, there will surely be problems of an excess supply of agricultural labor. Nonetheless, the empirical results suggest that the capacity for agricultural labor absorption remains widespread and in terms of the mix between hired and family labor. On and off Java, labor absorption is likely to continue with increasing investment in wetland rice production. Throughout Indonesia, expansion of investment in secondary food crops will tend to increase employment and the relative income shares of hired, as opposed to family labor,

[15] Mechanization in agriculture has not been rapid and generally not labor displacing. In Java, most mechanization in rice production has involved postharvest operations, particularly the shift from hand pounding of rice to small rice mills. The sickle has also replaced the finger knife (*ani-ani*) in harvesting operations, reducing labor demand. By the early 1980s, tractor use, mechanized threshing, and mechanized harvesting were relatively rare [7] [13] [15] [20] [23].

will tend to rise or remain constant.[16] Under existing technology and labor supply conditions, employment expansion and growth in relative income shares will favor hired labor on Java and family labor off Java.

Higher labor productivity, and thus incomes, in agriculture can be enhanced by a faster pace of mechanization. This hinges very much on the degree to which nonagricultural sectors can absorb the large rural labor force. As of mid-1993, Indonesia had approximately one (two-wheel) tractor for each 1,000 hectares of arable land, one of the lowest rates of mechanization in Asia. Nonetheless, even with rural wages of less than 1.5 U.S. dollars per worker per day, small-scale tractors are a highly profitable investment.

During the 1970s, the government tried to introduce tractors to farmers in labor-scarce regions. These schemes have tended to fail because of a lack of spare parts and the local capacity to maintain the machines. During the early 1970s, experiments with large-scale, mechanized, food production plantations were undertaken. These also failed, primarily because of problems in pest and disease management.

As Indonesia rapidly industrializes, and as rural education standards improve, the capacity to maintain and operate farm machinery is higher than two decades ago. With the development of small-scale tractors and threshers, there is no need to link agricultural mechanization to the cultivation of large-scale holdings. As a means of raising labor productivity, and facilitating higher incomes in agriculture, selective mechanization will likely emerge as an important priority. Provision of adequate sources of investment finance to the agricultural sector will be needed to finance investments in this area.

Finally, in this paper, we have presented formal techniques for the analysis of labor markets in Indonesian agriculture. An application of these techniques to microeconomic data from a cross-sectional survey of agricultural households confirms the validity of past approaches of analyzing agricultural labor markets in isolation from other factor markets. The variation in patterns of labor demand and factor substitution observed, across commodity markets and regions, raises questions regarding the ability to generalize about labor market characteristics from limited-scope anthropological and sociological inquiry. Given the importance of a sound understanding of labor market operations to government planners and policymakers, more formal analysis of labor market performance and operation is warranted.

[16] Intermediate inputs and land generally form elastic q-substitutes for both wet rice and *palawija* crops. This result suggests that increased usage of fertilizers and agrochemicals substitutes for land. Given the widespread q-complementarity of intermediate inputs and land with labor, and the high expense of expanding the extensive margin of land, a growth employment strategy might focus on intermediate inputs. The input subsidy on fertilizer follows this strategy. Conversely, relaxation of this subsidy could reduce employment.

REFERENCES

1. Abey, A.; Booth, A.; and Sundrum, R. M. "Labour Absorption in Indonesian Agriculture," *Bulletin of Indonesian Economic Studies,* Vol. 17, No. 1 (March 1981).

2. BERNDT, E., and CHRISTENSEN, L. "The Translog Function and the Substitution of Equipment, Structures and Labor in U.S. Manufacturing 1929–68," *Journal of Econometrics,* Vol. 1, No. 1 (March 1973).
3. BLACKORBY, C., and RUSSELL, R. "Will the Real Elasticity of Substitution Please Stand Up?" *American Economic Review,* Vol. 79, No. 4 (September 1989).
4. BOISVERT, R. "The Translog Production Function: Its Properties, Its Several Interpretations and Estimation Problems," Agricultural Economics Research 82–28 (Cornell University, 1982).
5. BOOTH, A. *Agricultural Development in Indonesia* (Sydney: Allen & Unwin, 1988).
6. COLLIER, W. "Agricultural Evolution in Java," in *Agricultural and Rural Development in Indonesia,* ed. G. Hansen (Boulder, Colo.: Westview Press, 1981).
7. COLLIER, W., et al. "Acceleration of Rural Development in Java," *Bulletin of Indonesian Economic Studies,* Vol. 18, No. 3 (November 1982).
8. DAMARADJATA, D.; TABOR, S.; OKA, I.; and DAVID, C. "Emerging Problems Arising from the Indonesian Success in Rice Production," *Indonesian Agricultural Research Journal,* Vol. 10, No. 1 (1988).
9. DENNY, M., and FUSS, M. "The Use of Approximation Analysis to Test for Separability and the Existence of Consistent Aggregates," *American Economic Review,* Vol. 67, No. 3 (June 1977).
10. FIELD, E. "Free and Slave Labor in the Antebellum South: Perfect Substitutes or Different Inputs?" *Review of Economics and Statistics,* Vol. 70, No. 4 (November 1988).
11. GEERTZ, C. *Agricultural Involution* (Berkeley, Calif.: University of California Press, 1971).
12. GODFREY, L. G. *Misspecification Tests in Econometrics: The Lagrange Multiplier Principle and Other Approaches,* Econometric Society Monograph No. 16 (Cambridge: Cambridge University Press, 1988).
13. HART, G. *Power, Labor, and Livelihood: Processes of Change in Rural Java* (Berkeley, Calif.: University of California Press, 1986).
14. HAYAMI, Y., and KIKUCHI, M. *Asian Village Economies at the Crossroads* (Tokyo: University of Tokyo Press, 1981).
15. HÜSKEN, F. "Landlords, Sharecroppers and Agricultural Labourers: Changing Labour Relations in Rural Java," *Journal of Contemporary Asia,* Vol. 9, No. 2 (1979).
16. Indonesia, Central Bureau of Statistics. *Statistical Yearbook* (Jakarta, various years).
17. Indonesia, Ministry of Agriculture. *Struktur Ongkos Produksi Bahan Pertanian* [Cost structure of agricultural production] (Jakarta, various issues).
18. KANG, H., and BROWN, G. "Partial and Full Elasticities of Substitution and the Energy-Capital Complementarity Controversy," in *Modeling and Measuring Natural Resource Substitution,* ed. B. Field and E. Berndt (Cambridge, Mass.: MIT Press, 1981).
19. MCFADDEN, D. "Constant Elasticity of Substitution Production Functions," *Review of Economic Studies,* Vol. 30, No. 2 (June 1963).
20. MANNING, C. "Rural Employment Creation in Java: Lessons from the Green Revolution and Oil Boom," *Population and Development Review,* Vol. 14, No. 1 (March 1988).
21. MUNDLAK, Y. "Elasticities of Substitution and the Theory of Derived Demand," *Review of Economic Studies,* Vol. 35, No. 2 (April 1968).
22. RAVALLION, M., and DEARDEN, L. "Social Security in a 'Moral Economy': An Empirical Analysis for Java," *Review of Economics and Statistics,* Vol. 70, No. 1 (February 1988).
23. SATO, R., and KOIZUMI, T. "On the Elasticities of Substitution and Complementarity," *Oxford Economic Papers,* Vol. 25, No. 1 (March 1973).
24. ————. "The Production Function and the Theory of Distributive Shares," *American Economic Review,* Vol. 63, No. 3 (June 1973).
25. SEGERSON, K., and RAY, S. "On the Equivalence of Alternative Measures of the Elasticity of Substitution," *Bulletin of Economic Research,* Vol. 41, No. 3 (July 1989).
26. SEIDMAN, L. "Complements and Substitutes: The Importance of Minding p's and q's," *Southern Economic Journal,* Vol. 56, No. 1 (July 1989).

27. SQUIRES, D. "Firm Behavior under Input Rationing," *Journal of Econometrics*, forthcoming.
28. STOLER, A. "Rice Harvesting in Kali Loro," *American Ethnologist*, Vol. 4, No. 4 (November 1977).
29. VAN DEN MUIZENBERG, O. "Involution or Evolution in Central Luzon?" in *Cultural Anthropology in the Netherlands*, ed. P. Kloos and H. Claessen (Rotterdam: Anthropological Branch of the Netherlands Sociological and Anthropological Society, 1975).
30. WHITE, B. "Political Aspects of Poverty, Income Distribution and Their Management: Some Examples from Rural Java," *Development and Change*, Vol. 10, No. 1 (January 1979).
31. ————. "'Agricultural Involution' and Its Critics: Twenty Years After," *Bulletin of Concerned Asian Scholars*, Vol. 15, No. 2 (April–June 1983).
32. WHITE, H. "A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity," *Econometrica*, Vol. 48, No. 4 (May 1980).
33. ZELLNER, A.; KMENTA, J.; and DREZE, J. "Specification and Estimation of Cobb-Douglas Production Function Models," *Econometrica*, Vol. 34, No. 4 (October 1966).

APPENDIX

ELASTICITIES OF SUBSTITUTION AND COMPLEMENTARITY

The elasticity of substitution was originally introduced to represent a proportionate change in the ratio of two factors corresponding to a proportionate change in their marginal rate of substitution or in their price ratio [21]. In practice, the measures have evolved to represent at least three basic types of information by different elasticities of substitution or complementarity: (1) the response of derived factor demands (marginal products) to price (quantity) changes; (2) the ease of substituting one input for another, i.e., isoquant curvature; and (3) the effects of price and quantity changes on relative factor income shares (and hence the distribution of income). The latter two are fundamentally the same information.

There are five major elasticities of substitution or complementarity: Allen elasticity of substitution (AES); Hicks elasticity of complementarity (HEC); Morishima elasticity of substitution (MES); shadow elasticity of substitution (SES); and direct elasticity of substitution (DES). Their differences are based on different combinations of the elements of the underlying Hessian matrix [21]. All five measures coincide when there are two factors but generally differ when there are more than two, unless the Cobb-Douglas or CES functional form is used [25]. The various definitions differ in two major aspects: the variables which are held constant (output, cost, marginal cost) and the number of variables involved [21].

The AES and HEC are one factor–one price elasticities and hence indicate whether inputs are substitutes or complements in terms of direct or inverse derived demand for factors. They differ from the two-factor definitions in that the latter measure elasticities of ratios of variables rather than of variables themselves [21]. The AES addresses the first elasticity issue. The AES registers the effect on the quantity demanded of one factor of a change in the price of another factor where output and other factors are held constant [3]. This leads to the terms *p*-substitutes and *p*-complements, where *p* denotes price. The HEC is dual to the AES. The HEC registers the impact on marginal product or price of one factor with a change in the quantity demanded of another [23]. This leads to the terms *q*-substitutes and *q*-complements, where *q* denotes quantity. Neither the AES or HEC measures isoquant curvature nor indicates the behavior of factor shares. Both are symmetric, in that they are independent of the directions in which the relevant prices or quantities change, and independent of the magnitude of price (AES) or quantity (HEC).

The MES is a two factor–one price elasticity, i.e., two factors and one price change [21]. The MES does measure isoquant curvature (the ease of factor substitutability) and is a sufficient statistic for assessing the effects of changes in price or quantity ratios on relative factor shares. The MES is not symmetric, so that the measure is not independent of the directions in which the relevant prices change [3] [18].

The two factor–two price elasticities, in which two factors and two prices change, most closely resemble the original definition proposed by Robinson and Hicks: the percentage change in relative input quantities divided by the percentage change in relative input prices (or equivalently, the marginal rate of substitution). As such they address the issues of isoquant curvature and relative factor shares. Their magnitude in general depends upon the magnitude of the specific changes in factor prices or quantities considered [18] [19] [21] [23] [24] [25] [26].

The DES and SES are two factor–two price elasticities. The DES and SES examine isoquant curvature and income distribution for each pair of factors. The DES fixes the remaining factor input levels. The SES fixes the imputed prices of the remaining factors and the imputed total cost, i.e., factor prices can only change to keep average cost constant [19] [21] [25]. Both are short-run elasticities because the other factors or their prices are held constant. However, the DES or SES under weak or strong separability equals the long-run two factor–two price elasticities of substitution for the separable inputs [21]. Finally, the inverse of the DES (SES) is a weighted average of all the proper partial elasticities of complementarity (substitution) related to two factors [23].