Eastern Economic Journal, Vol. X, No. 1, January–March 1984

Substitution Between Imports and Primary Inputs in the Netherlands, 1953–1977

BOBBY E. APOSTOLAKIS*

1. Prologue

Recent renewed emphasis in the analysis of input substitutability/complementarity in the production process has been undertaken by new flexible econometric techniques which have rendered conventional single-output two-input functions obsolete. In general equilibrium models, firms choose a bundle of available inputs to minimize the cost of producing a certain output level; derived demand for these inputs is determined by their relative prices, the output level, and any substitution possibilities permitted by the existing technology and factor endowment. Using this analytical framework this paper examines the contribution made by imports to the Dutch production process. The traditional assumptions of perfect competition in commodity and factor markets and constant returns to scale (CRTS) are, in fact, uniquely relevant to this economy because of the structure of Dutch technology. The Dutch economy is "open" by virtue of its association with various organizations such as Beneloux, ECSC, OEEC (OECD), EAEC, and EEC. Balassa (1976) justifies the assumption of perfect competition as follows: "In most industries there has been no conflict between the exploitation of economies of scale and increased competition as the integration of national markets has permitted both to occur simultaneously in the EEC. Thus, the predictions of those who feared the strengthening of monopolies have not been realized." Furthermore, "the larger the market, the fewer will be the industries where monopoly positions may emerge."

The CRTS assumption a) enables the acquisition of linear equation shares, b) implies consistent prices (value of output is equal to value of inputs), and c) allows simplification. According to R. G. D. Allen (1965) "the choice between the two (production) formulations or any variations of them, is not a question of choosing between right and wrong, nor can it be made solely by reference to the facts of life. Technical conditions in the real world are so complex that any formulation of them for analysis involves *simplification*. Which simplified "production function" is to be adopted is a matter of economic convenience and of mathematical approximation." The estimating procedure employed in this paper is thus a joint translogarithmic cost function using aggregate annual Dutch time-series data, 1953–77. Departing from traditional practice we partition final output into consumption goods (C) and investment goods (I) produced by capital (K), labor (L) and im-

*Assistant Professor of Economics, Texas Southern University, Houston, Texas 77004. This paper was in progress when the author was at the University of Detroit, Economics Department. The assistance of Mr. P. Vitisvorakarn is acknowledged, while comments by Professors M. Williams and A. Dalal (Northern Illinois University) have been extremely constructive. Any errors, of course, are the author's responsibility.

ports (M) which are treated as a factor input akin to primary factors.[1] The rationale for output disaggregation is to determine whether or not the composition of output has any effect on the cost minimization bundle of input mix.

The findings of this study may have significant policy implications for the Dutch balance of payments, factor utilization, and income distribution. This paper thus supplements and extends the work undertaken by Magnus (1979). The paper is organized as follows: in section 2 we briefly describe the translog production and cost functions along with the related concepts of duality, aggregation, and separability. In section 3 we report the empirical results, in section 4 we state the conclusions, while in the Appendix we indicate the sources of the data and explain the arithmetic manipulations and data-normalizations.

2. The Translog Specification

Shephard (1953), Uzawa (1964), and McFadden (1973) have shown that a well-behaved cost-minimizing technology may be described sufficiently by a joint cost function in lieu of a production function. A systematic analysis of the properties of price derivatives of the cost function was first performed by Hotelling (1932), and Samuelson (1947) identified the properties of cost functions.

Ease of implementation dictates use of the cost approach thereby bypassing the multicollinearity problems inherent in production functions. We focus on the following two relationships: a) the partial derivatives of the joint cost function with respect to input prices and output yields the input demand functions and marginal costs respectively; b) logarithmic differentiation with respect to factor prices and output quantities yields the cost and revenue shares respectively (Shephard's Lemma).

The joint cost function is represented as

$$TC = \mu(Y_C, Y_I; W_K, W_L, W_M) \quad (1)$$

where TC = total cost, $Y_i(i = C, I)$ and $W_j(j = K, L, M)$ are vectors of output and input prices respectively. For our estimation procedure, we use the following translog function:

$$\ln (TC) = \alpha_0 + \sum_i \alpha_i \ln Y_i + \sum_j \beta_j \ln W_j + 1/2 \sum_i \sum_r \delta_{ir} \ln Y_i \ln Y_r + 1/2 \sum_j \sum_s \gamma_{js} \ln W_j \ln W_s + \sum_i \sum_j \rho_{ij} \ln Y_i \ln W_j \quad (2)$$

where $i, r = C, I; j, s = K, L, M$.

The parameters of (2) are estimated from the cost and revenue shares obtained by Shephard's Lemma:

$$S_L \equiv \frac{\partial \ln (TC)}{\partial \ln W_L} = \beta_L + \gamma_{LL} \ln \frac{W_L}{W_K} + \gamma_{LM} \ln \frac{W_M}{W_K} + \rho_{CL} \ln \frac{Y_C}{Y_I}$$

$$S_M \equiv \frac{\partial \ln (TC)}{\partial \ln W_M} = \beta_M + \gamma_{MM} \ln \frac{W_M}{W_K} + \gamma_{LM} \ln \frac{W_L}{W_K} + \rho_{CM} \ln \frac{Y_C}{Y_I}$$

$$S_K \equiv \frac{\partial \ln (TC)}{\partial \ln W_K} = 1 - S_L - S_M, \quad (3)$$

and

$$R_C \equiv \frac{\partial \ln (TC)}{\partial \ln Y_C} = \alpha_C + \delta_{CC} \ln \frac{Y_C}{Y_I} + \rho_{CC} \ln \frac{W_L}{W_K} + \rho_{CM} \ln \frac{W_M}{W_K}$$

$$R_I \equiv \frac{\partial \ln (TC)}{\partial \ln Y_I} = 1 - R_C \quad (4)$$

where S_i and R_j are the cost and revenue shares. It should be noted that due to the adding-up criterion ($\Sigma S_i = \Sigma R_j = 1$), S_K and R_I are treated as residuals. An error term is included in each cost share equation due to random errors; these errors sum to zero at each observation since all cost shares sum to unity. Thus, the covariance structure is singular and one equation is omitted for the joint estimation.

The technology is represented by the cost function, which is "well-behaved" according to neoclassical postulates:

a) linear homogeneity in factor prices:

$$\sum_j \beta_j = 1; \quad \sum_j \gamma_{js} = \sum_s \gamma_{js} = \sum_j \sum_s \gamma_{js} = 0; \quad \sum_j \rho_{ij} = 0. \quad (5)$$

b) Monotonicity with respect to input prices (first-order condition):

$$\frac{\partial \ln (TC)}{\partial \ln W_i} > 0. \quad (6)$$

c) Concavity in input prices (second-order condition): the Hessian matrix of second partial derivatives with respect to factor prices is imposed to be negative semi-definite.

We impose the following additional restrictions to maintain the hypothesis of constant returns to scale (CRTS):

$$\sum_i \alpha_i = 1; \quad \sum_i \rho_{ij} = 0; \quad \sum_i \delta_{ij} = 0. \quad (7)$$

Since concern is with the Dutch economy as a whole, all data are aggregates which are homothetic in their components. Aggregation is linked to separability; i.e. whether a function can validly be separated into subfunctions which reflect the structure of the economy.

Input-output separability requires (1) the marginal rate of transformation between the output pair is independent of the factors composition and (2) the marginal rate of substitution between pairs of factors is independent of the composition of output. These require the interaction terms between output and input pairs to be zero:

$$\rho_{CL} = \rho_{CM} = 0 \quad (8)$$

The superiority of the translog function over the traditional Cobb-Douglas and CES forms is that separability is tested rather than assumed. Moreover, the translog does not dictate that the partial Allen-Uzawa elasticities of substitution (AUES) be unitary or constant, but permits them to vary from period to period.

Linear separability exists if $\sigma_{ik} = \sigma_{jk} = 1$ implying a partial Cobb-Douglas structure; complete global separability requires $\sigma_{ik} = \sigma_{jk} = \sigma_{ij} = 1$ in which the translog reduces to a complete Cobb-Douglas function. Moreover, non-linear separability exists if $\sigma_{ik} = \sigma_{jk} \neq 1$. Rejection of linear and non-linear hypotheses indicates that no consistent aggregate indices of (K, L), (K, M), or (L, M) exists for the aggregate Dutch data. This is equivalent to assuming that the conventional multi-factor Cobb-Douglas and CES functions are rejected.

3. Results

Alternative tests on separability are laid-out below. All tests and estimations are based on the χ^2 distribution calculated by $\lambda = \hat{L}_\omega/\hat{L}_\Omega$, where $\hat{L}_\omega$ and $\hat{L}_\Omega$ respectively show the values of the constrained and unconstrained likelihood functions. Thus, $\ln \lambda = \ln \hat{L}_\omega - \ln \hat{L}_\Omega$ and $\chi^2 = -2 \ln \lambda = 2(\ln \hat{L}_\Omega - \ln \hat{L}_\omega)$ with degrees of freedom (df) determined by the

[1]The bulk of imports consists of intermediate goods requiring further processing. For a complete analysis and justification see Chenery and Strout (1966) and Burgess (1974).

TABLE 1
UNRESTRICTED ESTIMATES OF TRANSLOG COST FUNCTIONS:
THE NETHERLANDS 1953–77

$\hat{\alpha}_C$ = .71783 (255.23)*	$\hat{\rho}_{CM}$ = .00560 (2.74)	$\hat{\gamma}_{LL}$ = .06146 (10.84)
$\hat{\delta}_{CC}$ = .16790 (17.41)	$\hat{\beta}_L$ = .31139 (80.83)	$\hat{\gamma}_{LM}$ = −.06012 (−22.03)
$\hat{\rho}_{CL}$ = −.00680 (−1.96)	$\hat{\beta}_M$ = .37470 (47.27)	$\hat{\gamma}_{MM}$ = .01584 (2.35)
Log Likelihood Function = 248.103		

*t-statistics in parentheses.

TABLE 2
PARAMETER ESTIMATES WITH INPUT-OUTPUT SEPARABILITY IMPOSED

$\hat{\alpha}_C$ = .71897 (238.18)*	$\hat{\rho}_{CM}$ = 0	$\hat{\gamma}_{LL}$ = .06068 (10.89)
$\hat{\delta}_{CC}$ = .18627 (26.67)	$\hat{\beta}_L$ = .31453 (86.67)	$\hat{\gamma}_{LM}$ = −.05994 (−22.81)
$\hat{\rho}_{CL}$ = 0	$\hat{\beta}_M$ = .37270 (48.50)	$\hat{\gamma}_{MM}$ = .01626 (2.46)
Log Likelihood Function = 245.158.		

*t-statistics in parentheses.

number of imposed restrictions.

Table 1 presents estimates of the nine free parameters with imposed restrictions required by symmetry, CRTS, and a well-behaved cost function.

First, we test the hypothesis that the Dutch technology is separable between inputs and outputs. The parameter estimates are shown in Table 2.

The calculated χ^2-statistic with $2df$ ($\rho_{CL} = \rho_{CM} = 0$) is 5.89 being below the 5% critical level of 5.991 so that the null hypothesis that the Dutch technology is separable between inputs and outputs cannot be rejected. Henceforth, changes in the composition of output do not have any effect on the cost minimizing input mix at given factor prices.[2] The present results are in disagreement with Burgess' (1974) who concluded that input-output separability for the U.S. economy is rejected.

In the next step we test whether the Cobb-Douglas or CES functions are appropriate in representing the Dutch technology. To this end, we test linear and non-linear separabilities. With three inputs the possibilities for separability are:

$$[(K, L), M] \;:\; \sigma_{KM} = \sigma_{LM}$$

$$[(K, M), L] \;:\; \sigma_{KL} = \sigma_{ML}$$

$$[(L, M), K] \;:\; \sigma_{KL} = \sigma_{KM}$$

Only two of the above are independent since any two of these restrictions imply the third.[3] If linear and non-linear functional separabilities are rejected, it is concluded that the traditional Cobb-Douglas and CES functions are inappropriate. The successive tests are summarized in Table 3.

All null hypotheses of functional separability are rejected even at the 1% (9.21) critical level of statistical significance.[4] Hence,

[2]Since input-output separability is adopted, for all subsequent estimations the restrictions $\rho_{CL} = \rho_{CM} = 0$ will be imposed.

[3]By definition, $\sigma_{ij} = CC_{ij}/C_iC_j$ where $C_i = \partial(TC)/\partial W_i$, $C_{ij} = \partial^2(TC)/\partial W_i \partial W_j$. More specifically: $\sigma_{LM} = 1 + \gamma_{LM}/S_LS_M$, $\sigma_{KM} = 1 - (\gamma_{MM} + \gamma_{LM})/S_KS_M$, and $\sigma_{KL} = 1 - (\gamma_{LL} + \gamma_{LM})/S_KS_L$. For all pair-wise input separabilities, the required restrictions on the parameters are explicitly shown in the text, Table 3.

[4]Apparently, complete global separability ($\sigma_{KL} = \sigma_{KM} = \sigma_{LM} = 1$) is also rejected.

TABLE 3
PARAMETER ESTIMATES WITH LINEAR AND NON-LINEAR SEPARABILITY IMPOSED

Parameters	Linear			Non-Linear		
	$[(K, L), M]$	$[(K, M), L]$	$[(L, M), K]$	$[(K, L), M]$	$[(K, M), L]$**	$[(L, M), K]$
$\hat{\alpha}_C$	.71411 (258.91)*	.71385 (260.60)	.71315 (259.04)	.71379 (259.08)		.71262 (263.07)
$\hat{\delta}_{CC}$	.17446 (27.68)	.17383 (27.80)	.17213 (27.47)	.17375 (27.55)		.17084 (27.81)
$\hat{\rho}_{CL}$	0	0	0	0	0	0
$\hat{\rho}_{CM}$	0	0	0	0	0	0
$\hat{\beta}_L$	.38776 (44.19)	.38048 (49.45)	.3465 (67.71)	.36584 (63.81)	$1 + \frac{\beta_M\gamma_{LL}}{\gamma_{LM}}$	$\frac{\beta_M\gamma_{LM}}{\gamma_{MM}}$
$\hat{\gamma}_{LL}$	−.03042 (−1.57)	0	$-\gamma_{LM}$	.00868 (8.58)	$\frac{\gamma_{LM}^2}{\gamma_{MM}}$	$\frac{\gamma_{LM}^2}{\gamma_{MM}}$
$\hat{\gamma}_{LM}$	0	0	−.03096 (−11.09)	−.01495 (−8.96)		.00262 (1.19)
$\hat{\beta}_M$	.34441 (155.34)	.34859 (106.82)	.37838 (68.94)	$1 + \frac{\beta_L\gamma_{LM}}{\gamma_{LL}}$		.34582 (142.99)
$\hat{\gamma}_{MM}$	0	.00488 (1.73)	$-\gamma_{LM}$	$\frac{\gamma_{LM}^2}{\gamma_{LL}}$		.00237 (1.18)
Log Likelihood Function	226.60	226.91	231.21	229.667		226.334
Calculated χ^2	37.12	36.50	27.90	30.98		37.66

*t-statistics in parentheses.
**After 51 iterations convergence was not achieved.

we conclude that Cobb-Douglas and CES specifications cannot appropriately explain the Dutch technology. Of special importance is the rejection of the specification $Y(C, I) = \Phi[\phi(K, L), M]$ which implies that the Dutch value-added (VA) is not produced exclusively by the primary factors. This conclusion supports the incorporation of imports as a factor input in the production process; thus $VA = \xi(K, L)$ is a misspecification.

Next, we evaluate the AUES (σ_{ij}) among the three factor inputs and their own-price elasticity of demand (η_i) and report selected estimates in Table 4.[5,6]

Characteristically, the elasticity of substitution between capital and imports is above unity throughout the sample period, while the remaining two pair-elasticities remain below unity with σ_{KL} approaching unity. Based on the Stolper-Samuelson theorem, imposition of import tariffs will improve both primary factors of production, but as long as $\sigma_{LM} < \sigma_{KM}$ income is redistributed from capitalists to laborers. Production techniques which encourage the substitution of machinery and equipment for relatively expensive imports may improve the BOP status.

In Table 4 we also observe that the own-price elasticities of demand are negative and

[5]AUES expressions have been shown in ft. 2. Estimates of η_i are derived by

$$\eta_i = \frac{\gamma_{ii} + S_i^2 - S_i}{S_i}$$

where $i = L, M$ and $\eta_K = -(S_L\sigma_{KL} + S_M\sigma_{KM})$.

[6]Complete tables are available on request.

TABLE 4
SELECTED ESTIMATES OF σ_{ij} AND η_i: THE NETHERLANDS 1953–77

Year	σ_{LM}	σ_{KM}	σ_{KL}	η_M	η_L	η_K
1953	.488677	1.37471	.992478	−.5837	−.4925	−.8245
1960	.527039	1.42173	.992707	−.5951	−.4754	−.8611
1965	.544027	1.46528	.992948	−.6096	−.4584	−.8831
1970	.538578	1.50948	.993423	−.6337	−.4402	−.8851
1975	.560242	1.53437	.993146	−.6281	−.4327	−.9143
1977	.579610	1.55324	.992786	−.6196	−.4286	−.9419

TABLE 5
σ_{ii} AND η_{ij}: SELECTED OBSERVATIONS

Year	σ_{LL}	σ_{MM}	σ_{KK}	η_{KL}	η_{LK}	η_{KM}	η_{MK}	η_{LM}	η_{ML}
1953	−1.56598	−1.56606	−2.63618	.312	.310	.512	.430	.182	.154
1960	−1.34925	−1.65466	−2.99039	.350	.286	.511	.409	.190	.186
1965	−1.19585	−1.77766	−3.22610	.381	.272	.503	.401	.187	.209
1970	−1.06607	−2.01410	−3.24808	.410	.271	.475	.411	.169	.222
1975	−1.01976	−1.95539	−3.59309	.421	.253	.493	.390	.180	.238
1977	− .99588	−1.87041	−3.95198	.427	.237	.515	.370	.192	.249

inelastic indicating that the demand curve for each factor is downward sloping. Since the demand for labor appears to be inelastic with a declining trend, labor unions may have a strong bargaining position in wage negotiations.

Throughout the 25-year period, the revenue share of investment has increased substantially against the consumption share. On the other hand, the cost share of labor has increased from 31% in 1953 to 43% in 1977 generating decreases in both import and capital cost shares. Comparisons of the actual and fitted cost and revenue shares indicate that divergences are minor which suggests the model represents the data adequately.[7]

For added information Table 5 reports the own-elasticities of substitution (σ_{ii}) and cross-price elasticities of input demand (η_{ij}) for selected years.[8] The positive signs of η_{ij} verify the aforementioned results with respect to input substitutability.

In accordance with microeconomic foundations, the sum of the own-price elasticities of input demand in absolute terms is equal to the sum of the cross-price elasticities:

$$-\sum_{i,j=1} \eta_{ij} = \sum_{j=1} \eta_{i}; \quad i, j = K, L, M.$$

The present results are comparable to those of Burgess (1974) for the US, Denny and Pinto (1978) for Canada, and Magnus (1979) for The Netherlands.

4. Conclusions

We have hypothesized that imports are akin to primary factors in the Dutch aggregate economy. The two-output, three-input translog cost model has generated a number of important conclusions about the total product. Since input-output separability was not rejected, it is concluded that changes in the composition of output do not affect the cost minimizing input-mix. Moreover, the rejection of the specification $Y(C, I) = \Phi[\phi(K, L), M]$ implies rejection of the Dutch value-added concept. Hence, imports cannot be deleted from the production function. The rejection of linear and non-linear separability hypotheses means that the Cobb-Douglas and CES specifications cannot adequately represent the Dutch technology.

All elasticity estimates satisfy theoretical expectations. Labor capital and imports are substitute inputs for each other, and display fair stability throughout the sample period. The observed substitution possibilities are especially important for BOP improvements and for avoiding such economic rigidities as aggressive labor unions. Provided $\sigma_{KM} > \sigma_{LM}$ a gradual further reduction in tariffs, as suggested by EEC, will benefit labor. Intensive investment in human capital, especially in the blue-collar production sector, is suggested to diminish certain costly imports. Inputs demand curves are all downward sloping and inelastic. Finally, the divergences observed between actual and fitted cost and revenue shares are small which attests to the goodness of fit of the model and its specification.

[7]Actual and fitted cost and revenue shares are available on request.

[8]σ_{ij} may be used for the calculation of η_i. The estimates of σ_{ii} may be used for the calculation of η_i; the positive signs of η_{ij} ($\partial \ln X_i / \partial \ln P_j > 0$) verify input substitutability.

Appendix

Data

Assuming function (2) is linear homogeneous, the sum of the value shares is unity so that the value of output is equal to the value of inputs:

$$P_C Y_C + P_I Y_I = W_K K + W_L L + W_M M. \quad \text{(A-1)}$$

Since output is expressed as final sales, imports of consumption and investment goods must be added to gross domestic product (GDP) and non-factor costs must be excluded:

$$TC \equiv P_C Y_C + P_I Y_I = \text{GDP} + \text{mM} - \text{T}_{\text{ind}} + S \quad \text{(A-2)}$$

where T_{ind} = indirect taxes, S = subsidies, and mM = value of imports.

All information needed for the right-hand side of (A-2) is provided by the *OECD, National Accounts* (NA), for the entire period.[9] The total value of consumption goods is the sum of the expenses on non-durables and services undertaken by households (H), government (G), and exports (X):

$$P_C Y_C = P_C^H Y_C^H + P_C^G Y_C^G + P_C^X Y_C^X \quad \text{(A-3)}$$

where P_C^i, Y_C^i ($i = H, G, X$) are the unit value and quantities respectively. The value of non-durable exports were calculated from the *UN, Yearbook of International Trade Statistics*. Exports of services were calculated as the difference between the value of exports of goods and services (OECD, NA) minus the value of merchandise exports (*UN, Yearbook of International Trade Statistics*).

Investment figures were treated as a residual:

$$P_I Y_I = TC - P_C Y_C. \quad \text{(A-4)}$$

Thus, $R_C = P_C Y_C / TC$ and $R_I = P_I Y_I / TC = 1 - R_C$ are the consumption and investment revenue shares respectively. For estimation purposes the ratio $P_C Y_C / P_I Y_I$ was calculated and scaled to 1.00 in 1953, the base year.

The data for the factors of production were obtained as follows. The wage bill was provided by *The Netherlands, National Accounts*. The labor force was readily available by *OECD, Labor Force Statistics*. Thus, the wage index W_L was calculated by the average wage level W/L and scaled to 1.00 in 1953. With respect to imports, the unit value index W_M was obtained from the *UN, Yearbook of International Trade Statistics*. Both labor and imports cost shares were obtained by dividing the respective bills by TC. Also, the unit value index for the services of capital W_K

[9]All data are in current prices. Detailed information accompanied by tables with data are available upon request.

(scaled to 1.00 in 1953) was obtained from Magnus (1979, Table 2).

Finally, we calculated the unit price ratios W_M/W_K, W_L/W_K and since each of the individual prices are scaled to 1.00 in 1953, the ratios will also be scaled to 1.00 in the base year. These ratios are required for the estimations of the parameters in the cost share equations.