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Chapter Author: Sung Y. Kwack

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SUNG Y. KWACK
Board of Governors of the Federal Reserve System

Price Linkage in an Interdependent World Economy: Price Responses to Exchange Rate and Activity Changes

The rate of inflation in major industrial countries has increased steadily from the late 1960s and spread dramatically throughout the world in the last several years. Given the persistence of inflation on a worldwide basis, it is natural to seek for explanations of it from an international point of view. Consequently, the transmission of inflation from one country to another has received increasing attention.[1] In this paper I analyze the behavior of inflation in an individual country in a world of direct price linkages. Such an analysis is useful because it sheds some light on the question of how much the

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prices of other countries respond to a change in one country's exchange rate and unemployment rate.

In section I, I specify a model of the direct price linkages in a world economy. The model contains three sectoral equations for individual countries to explain the behavior of domestic prices, import prices, and changes in output levels. In section II, I discuss the estimated equations for twelve industrial countries: Australia, Austria, Belgium, Canada, Finland, Italy, Japan, Netherlands, Sweden, the United Kingdom, the United States, and West Germany. Then the model is tested by examining the results of dynamic simulations within the sample period. Section III contains some estimates of the multipliers on the own- and cross-country inflation rates due to a change in an individual exchange rate and unemployment rate. In addition, the model is used for assessing the contribution of actual changes in the exchange and unemployment rates to the rates of inflation during 1971–1973. The paper is concluded in section IV with a summary of the main results.

I. A MODEL OF INTERNATIONAL PRICE LINKAGES

Price behavior in most industrial countries reflects a variety of factors peculiar to each particular country. None of these countries, however, is isolated completely from the activity of the rest of the world. Thus, it is quite likely that some inflationary pressures originate abroad. In this broad sense, countries can be said to trade not only goods and services with each other but also inflations. Of course, countries differ significantly in their openness, and, thus, the propensity to import or export inflation can be expected to differ markedly among countries.

In seeking explanations for international transmissions of inflation, three types of mechanism can be distinguished: (a) direct, via prices of goods imported and wage rates; (b) indirect, via the changes in the aggregate demand working through the external account; and (c) indirect, via the change in the money supply induced by changes in international reserves. Although the latter two channels are considered to be important, too, I deal with only the first—the direct mechanism of inflation transmission—in this paper.[2]

The model of direct price linkages presented here is basically an extension of the Phillips model of price determination to a world containing many countries trading with each other. It consists of

equations determining both domestic and import prices for each country. As shown below, the domestic price of each country is influenced not only by the unemployment rate and output at home, but also by import prices. Import prices of a given country are export prices of other countries to that country, adjusted for the variations in exchange rates. Through this direct relationship, domestic prices in the world are interdependent and therefore determined jointly. Thus, for example, an autonomous increase in the aggregate demand in anv one country increases prices in the rest of the world.

In the model estimated below the world consists of n countries. For each country i, the domestic price of consumer goods is denoted by P_i; the wage rate, by W_i; the domestic output level, by Q_i; the import price, by P_i^m; the unemployment rate, by U_i; the exchange rate, defined as the number of U.S. dollars per unit of home currency i, by E_i; and the expected price, by P_i^e. A flex ($\hat{}$) indicates a proportional change in the variable.

Formally, the two structural equations are specified to explain the domestic price and the money wage rate. It is hypothesized that the domestic price is determined by unit labor costs and the import price, and the money wage rate is influenced by the unemployment rate and the expected domestic price.[3] Due to lack of adequate quantitative information, the rate of change in man-hours employed is assumed to be constant. Hence, they are written in a rate-of-change form:

$$\hat{P}_i = m_{0i} + m_{1i}\hat{W}_i - m_{2i}\hat{Q}_i + m_{3i}\hat{P}_i^m \tag{1}$$

$$\hat{W}_i = n_{0i} + n_{1i}U_i^{-1} + n_{2i}\hat{P}_i^e \tag{2}$$

To show that the domestic price is determined by the unemployment rate, output, and the import price, after allowing for simultaneous interactions between prices and the wage rate, equations 1 and 2 are solved for $\hat{P}_i$ and $\hat{W}_i$. If the rate of change in actual domestic prices is not equal to the rate of change in expected prices, expected inflation is adjusted for the unanticipated inflation. Such an adjustment continues until actual and expected inflation are equal ($\hat{P}_i = \hat{P}_i^e$). Imposing that equality in the solved reduced-form price equation, we obtain the equation for explaining price behavior in equilibrium, P_i^*:

$$\hat{P}_i^* = k_{0i} + k_{1i}U_i^{-1} - k_{2i}\hat{Q}_i + k_{3i}\hat{P}_i^m \tag{3}$$

where $k_{0i} = (m_{0i} - m_{1i}n_{0i})/(1 - m_{1i}n_{2i})$, $k_{1i} = m_{1i}n_{1i}/(1 - m_{1i}n_{2i})$, and $k_{si} = m_{si}/(1 - m_{1i}n_{2i})$ for $s = 2, 3$. It is expected that k_{si} for $s = 1, 2, 3$

are positive, since m_{si} and n_{si} are positive, and $0 < m_{1i}n_{2i} < 1$, based on the available empirical evidence listed in Kwack (1973, p. 5).

The equality of actual and equilibrium prices may not hold at every point in time and adjustment toward such an equality takes some time because there are pecuniary and nonpecuniary adjustment costs associated with institutional rigidities and lack of accurate information. Therefore, it is assumed that the change in actual price is initiated by the changes in equilibrium prices in the current and previous periods. A Koyck-type form is selected as the partial adjustment mechanism, a choice that seems to provide a convenient starting point for empirical implementation. When the partial adadjustment mechanism is incorporated into (3), the following price equation is obtained:[4]

$$\hat{P}_i = \alpha_{0i} + \alpha_{1i}U_i^{-1} - \alpha_{2i}\hat{Q}_i + \alpha_{3i}\hat{P}_i^m + \alpha_{4i}\hat{P}_{i-1} \tag{4}$$

where θ_i is the coefficient of adjustment and $\alpha_{1i} = k_{1i}\theta_i > 0$, $\alpha_{2i} = k_{2i}\theta_i > 0$, $\alpha_{3i} = k_{3i}\theta_i > 0$, and $\alpha_{4i} = 1 - \theta_i > 0$.

Generally speaking, the import price of a country is influenced by the demand and supply of the imports. Thus, other things being equal, the domestic prices and levels of activity of both exporting and importing countries determine the import price. However, shifts in the supply schedule caused by changes in output levels may be taken as small, especially in the short run, perhaps because of the limited mobility of productive factors between the traded and nontraded goods sectors. Also, the substitutability in consumption between imports and domestic goods is assumed to be small in the short run. In this case, the import price can be hypothesized as being determined largely by the prices of tradables in exporting countries adjusted for changes in exchange rates and by the income of the importing country.[5] The prices of tradable and nontradable goods are linked within each country through competition in production and consumption. This link ensures that the price of nontradable goods will vary with the price of tradable goods over a longer period of time, and, perhaps, at the same rate of change. On the basis of this relation, the domestic prices of tradables in exporting countries, which are a determinant of the import price, are assumed to be represented by their consumer prices.[6] Hence, we have the following equation for the import price:

$$\hat{P}_i^m = \beta_{0i} + \beta_{1i}\left[\sum_j a_{ij}(\hat{P}_j + \hat{E}_j) - \frac{\hat{E}_i}{1 + \hat{E}_i}\right] + \beta_{2i}\hat{Q}_i \tag{5}$$

where $a_{ii} = 0$, $1 \geq a_{ij} \geq 0$ for $i \neq j$ and $\sum_j a_{ij} = 1$.

It is implicit in equation 5 that the aggregate foreign domestic

price and the exchange rate are defined as, respectively, averages of the domestic prices and exchange rates of exporting countries, weighted geometrically by their export value shares in the importing country. It will be recalled that the exchange rate of currency j, E_j, is measured by the number of U.S. dollars per unit of currency j. Therefore, the term $\sum_j (a_{ij} - \delta_{ij})\hat{E}_j/(1 + \delta_{ij}\hat{E}_j)$ is a rate of change of the exchange rate of currency i in home currency units, and δ_{ij} is a Kronecker delta having the property $\delta_{ij} = 1$ for $i = j$ and $\delta_{ij} = 0$ for $i \neq j$. Thus, the term serves as a measure of the proportional change in the effective exchange rate. By hypothesis, the signs of both β_{1i} and β_{2i} are positive. The value of β_{1i} is expected to be close to unity if the price elasticity of supply is very large relative to the price elasticity of import demand.[7] Also, the value of β_{2i} is likely to be high when the economic size of the importing country is large, thereby strongly affecting the latter's import price.

Both the unemployment rate and the rate of change in the level of output enter the domestic price equation (equation 4) as exogenous variables. In order to isolate the transmission of inflation due to a change in the activity of a particular country, an equation is introduced in the model for the well-known mapping between unemployment and output, as shown by Okun (1962). Assuming that potential output grows at a constant rate, the specification of Okun's relationship is approximated by:

$$\log Q_i = c_{0i}t - c_{1i}(U_i - U_i^0) \tag{6}$$

where t is a linear time trend and U_i^0 is the unemployment rate existing at the potential output level. The change in the unemployment rate is derived by differentiating (6) with respect to time:

$$\hat{Q}_i = C_{0i} - C_{1i}\Delta U_i \tag{7}$$

Equations 4, 5, and 7 are the basis for describing price behavior of an individual country in an interdependent world. Combining the three equations yields:

$$\hat{P}_i = \phi_i + \alpha_{1i}U_i^{-1} + \lambda_i \Delta U_i + \sum_j \mu_{ij}\hat{P}_j + \sum_j (\mu_{ij} - \sigma_{ij})\hat{E}_j/(1 + \delta_{ij}\hat{E}_j) + \omega_i P_{i-1} \tag{8}$$

where $\phi_i = \alpha_{0i} - \alpha_{2i}c_{0i} + \beta_{0i}\alpha_{3i}$, $\lambda_i = \alpha_{2i}c_{1i}$, $\mu_{ij} = \alpha_{3i}\beta_{1i}a_{ij}$, $\sigma_{ij} = \alpha_{3i}\beta_{1i}\delta_{ij}$, and $\omega_i = \alpha_{4i}$. In equation 8, it can be easily seen that the rate of inflation in country i depends not only on its own unemployment rate and exchange rate but also on the exchange rates and prices of all other countries. To simplify our model for quantitatively analyzing the effect of changes in foreign prices and exchange rates, the constant term (ϕ_i) and ΔU_i are ignored. $\hat{E}_j$ is assumed to be small

enough for $1 + \delta_{ij}\hat{E}_j$ to be approximated by 1, and U_i^{-1} is linearized by $1 - U_i$. Thus, equation 8 is simplified to:

$$\hat{P}_i = \rho_i U_i + \sum_j \mu_{ij}\hat{P}_j + \sum_j (\mu_{ij} - \sigma_{ij})\hat{E}_j + \omega_i \hat{P}_{i-1} \tag{9}$$

where $\pi_i = -(\alpha_{1i} - \lambda_i)$. The signs of the parameters are $\rho_i < 0$, $\mu_{ij} > 0$, $\sigma_{ij} > 0$, and $\omega_i > 0$. The system of equation 8 for n countries can be written as follows:

$$\hat{P} = SU + R\hat{P} + [R - T]\hat{E} + L\hat{P}_{-1} \tag{10}$$

where $\hat{P}$, U, and $\hat{E}$ are n-dimensional vectors with respective elements $\hat{P}_i$, U_i, and $\hat{E}_i$, for $i = 1,2, \ldots, n$; and S, T, and L are diagonal matrices, with respective elements ρ_i, σ_{ii}, and ω_i. The matrix R has the off-diagonal elements μ_{ij} and diagonal elements 0.

For the countries in the system, the effects on inflation of a change in a predetermined variable can be described by the values of the multipliers implied in (10). Since $[I - R]$ possesses an inverse, the system can be solved for the vector of domestic price inflations, $\hat{P}$:

$$\hat{P} = [I - R]^{-1}SU + [I - R]^{-1}[R - T]\hat{E} + [I - R]^{-1}L\hat{P}_{-1} \tag{11}$$

where $[I - R]^{-1}S$ and $[I - R]^{-1}[R - T]$ are the impact or short-run multiplier matrices containing the elements of own- and cross-country effects induced by a change in the unemployment rate or exchange rate of a country. Since R is a non-negative matrix, all elements of $[I - R]^{-1}$ are non-negative. Moreover, all elements of $[I - R]^{-1}$ and $[I - R]^{-1}[R - T]$ will not be decreased or will be increased when one element of R increases. This means that the larger the own (diagonal) and cross-country (off-diagonal) effects, the greater is the interdependence of the prices among countries. Also, the own multiplier is generally larger than the cross-multipliers because the μ_{ij} are smaller than unity. So far, the vector of lagged inflation, $\hat{P}_{-1}$, has been treated as exogenous. In the longer run, the $\hat{P}_{-1}$ are considered as endogenous. The system is stable in the long run because each characteristic root of $[I - R]^{-1}L$ is less than 1.0 in absolute value.[8] Thus, the long-run-equilibrium multiplier values of a change in U and $\hat{E}$ are $[I - R - L]^{-1}S$ and $[I - R - L]^{-1}[R - T]$, respectively. L is a diagonal matrix with positive elements, $0 \leq \omega_i < 1$. Thus, $[I - R - L]^{-1} \geq [I - R]^{-1}$ because $R + L$ is a non-negative matrix that is greater than R. This proves that the long-run multipliers are not less than the corresponding short-run ones.

It has been shown that a change in the unemployment rate and

exchange rate of a given country will result in changes in the inflation rates of all countries. Now consider a special case where the initiating country i is small in the sense $a_{ji} = 0$ for country j. By definition, $a_{ji} = 0$ implies $\mu_{ji} = 0$ for all j, leading to the matrix $R = 0$. Therefore, there are no feedback effects through the induced changes in foreign domestic prices. Consequently, the effect of the initiating country on inflation depends exclusively on the magnitudes of its own parameters, ρ_i, σ_{ii}, and ω_i. Moreover, by introducing the condition $R = 0$ into equation 11, it can be proved that the multiplier values of a change in U_i and $\hat{E}_i$ in this special case are smaller than the values obtained in the case of induced cross-country effects, $R \neq 0$. This is so because $[I - R - L]^{-1} > [I - L]^{-1}$ for the long-run multipliers and $[I - R]^{-1} > I$ for the impact multipliers.

Table 1 is a summary of the direction of the effects of a unit change in the unemployment rate and exchange rate of a particular country. Two points merit special attention. First, a reduction in the unemployment rate of a given country leads to a rise in the rate of inflation of all countries. The resulting increases in the inflation rates become stronger in the presence of cross-country effects ($\mu_{ij} \neq 0$) than the rates expected when the country is small. The reason is that the induced increases in foreign prices result in induced increases in import prices of all countries. Second, an appreciation of a currency against the U.S. dollar lowers that country's domestic price and raises the prices of the other countries, including the United States. However, the reduction in own inflation is smaller when foreign prices also rise, as is the case if $\mu_{ij} \neq 0$, because import prices of the appreciating country then rise.

II. ESTIMATION OF PARAMETERS

Equations 4, 5, and 7 were estimated with annual data for 1957–1973 for each of twelve countries: Australia, Austria, Belgium, Canada, Finland, Italy, Japan, the Netherlands, Sweden, the United Kingdom, the United States, and West Germany. [The data are from *International Financial Statistics* (International Monetary Fund) and the United Nations *Monthly Bulletin of Statistics*.] Except where necessary to obtain reasonable estimates, modifications of the equation specifications were not made. Also, ordinary least squares was employed, ignoring possible simultaneous equation bias. These two simplifications were adopted to avoid a flood of

TABLE 1 Direction of Multipliers

		No Cross-Feedback Effect ($\mu_{ji} = 0$)		Cross-Feedback Effect ($\mu_{ji} \neq 0$)	
		Impact	Long Run	Impact	Long Run
$\frac{\partial \hat{P}}{\partial U}$		S	$[I - L]^{-1}S = s_i$	$[I - R]^{-1}S = s_i^*$	$[I - R - L]^{-1} = s_i^{**}$
	$\frac{\partial \hat{P}_i}{\partial U_i}$	ρ_i	$s_i > \rho_i(1 + w_i)$	$s_i^* > \rho_i$	$s_i^{**} > s_i^*(1 + w_i)$
	$\frac{\partial \hat{P}_j}{\partial U_i}$	0	0	$s_j^* > \mu_{ji}\rho_i$	$s_j^{**} > s_j^*(1 + w_j)$
$\frac{\partial P}{\partial \hat{E}}$		$[R - T]$	$[I - L]^{-1}[R - T] = r_i$	$[I - R]^{-1}[R - T] = r_i^*$	$[I - R - L]^{-1}[R - T] = r_i^{**}$
	$\frac{\partial \hat{P}_i}{\partial \hat{E}_i}$	$-\sigma_{ii}$	$r_i < -\sigma_{ii}(1 + w_i)$	$r_i^* > -(\sigma_{ii} - \sum_{k \neq 1} \mu_{ik}\mu_{ki})$	$r_i^{**} < r_i^* - w_i\sigma_{ii}$
	$\frac{\partial \hat{P}_j}{\partial \hat{E}_i}$	0	0	$r_j^* < \mu_{ji}(1 - \sigma_{ii}) + \sum_{k \neq i,j} \mu_{ik}\mu_{ki}$	$r_j^{**} > r_j^* + \mu_{ji}w_j$

NOTE: The information on individual elements, s_i, r_i, s_i^*, r_i^*, s_i^{**}, and r_i^{**} is compared with the direction and magnitude obtained by the first-order Taylor approximations, i.e., $[I - L]^{-1}$, $[I - R]^{-1}$, and $[I - R - L]^{-1}$ are compared with the values of $[I + L]$, $[W + R]$, and $[I + R + L]$, respectively.

permutations and alternative specifications. Nevertheless, the estimates presented below are subject to the qualifications that result from the use of ordinary least squares and the existence of some missing variables. In the tables that follow, the numbers in parentheses below the coefficient estimates are t statistics. $\bar{R}^2$ is the coefficient of determination adjusted for degrees of freedom; *SEE*, the standard error of estimate; and *DW*, the Durbin-Watson statistic.

Table 2 contains estimates of the price equations for each of the twelve countries. At first glance, most of the estimated equations are reasonable. In particular, both the unemployment rate and import price have significant coefficients with the expected sign in all equations. This seems to confirm that in addition to the unemployment rate, the import price of a country is an important determinant of domestic prices.[9] This finding is consistent with past studies (see Ball and Duffey 1972) in which the import prices are shown to be significant in structural price equations in most industrial countries. The coefficient on the U.S. unemployment rate is larger than that on most of the unemployment rates of other countries. This confirms the finding of previous studies (such as Kwack 1973) that the U.S. trade-off between inflation and unemployment is worse than that abroad. The dummy variables in the equation for the Netherlands and the United Kingdom are designed to capture the income restraint policies, and the dummy variable in the Australia equation is introduced to eliminate the observation for 1973.[10] Note, however, that incomes policies are either perverse, or are introduced in response to strong exogenous price pressures.

When the equation results are closely inspected, however, there are some disturbing elements. The price equation for Canada is not satisfactory, in that the long-run coefficient on the import price, 2.42, is substantially higher than a priori expected maximum value of 1.0 and the estimate of 0.55 in TRACE reported in Bodkin (1972). But, the impact effect, 0.35, is close to TRACE's estimate of 0.45, indicating that the estimated equation can be used for short-term analysis. In addition, the coefficient of the U.K. import price, 0.18, seems to be low. Excluding Canada, the long-run coefficients of import prices range between 0.10 and 0.96. For six of the countries—Australia, Belgium, Canada, Finland, the United States, and West Germany—the coefficients on the one-year lagged price variable are found to be significant. The implied coefficients of adjustment are between 0.15 and 0.65. The estimates seem to be plausible, in view of the existence of institutional rigidities such as escalator clauses and imperfect information.

TABLE 2 Consumer Price Equations,[a] 1957–1973

Country i	α_{0i}	α_{1i}	α_{2i}	α_{3i}	α_{4i}	α_{5i}	$\bar{R}^2$ [*SEE*] {*DW*}
Australia[b]	−0.016	0.041		0.409	0.576	0.130	0.877
	(1.89)	(3.42)		(3.52)	(4.07)	(5.88)	[0.007]
							{2.488}
Austria	0.004	0.108	−0.131	0.095			0.611
	(0.32)	(4.05)	(1.25)	(1.20)			[0.010]
							{2.218}
Belgium	−0.010	0.063		0.098	0.754		0.878
	(1.84)	(3.38)		(3.72)	(6.44)		[0.005]
							{2.338}
Canada	−0.021	0.111		0.347	0.857		0.806
	(2.31)	(2.53)		(4.47)	(5.73)		[0.007]
							{1.659}
Finland	−0.014	0.057		0.420	0.342		0.614
	(0.52)	(1.58)		(4.51)	(1.98)		[0.019]
							{1.797}
Italy	−0.004	0.146		0.194			0.592
	(0.27)	(2.40)		(3.32)			[0.016]
							{2.009}

Japan	0.050	0.023	−0.169	0.383			0.794
	(3.28)	(1.57)	(3.44)	(7.60)			[0.011]
							{2.196}
Netherlands[c]	0.015	0.025		0.361		0.025	0.462
	(0.93)	(1.48)		(2.54)		(1.75)	[0.017]
							{2.512}
Sweden	0.034	0.038	−0.452	0.389			0.381
	(1.92)	(1.08)	(2.15)	(3.42)			[0.016]
							{2.796}
United Kingdom[d]	0.007	0.062	−0.357	0.174		0.049	0.848
	(0.52)	(2.34)	(3.01)	(3.07)		(5.04)	[0.009]
							{2.136}
United States	−0.014	0.161	−0.125	0.195	0.399		0.898
	(2.02)	(4.92)	(3.63)	(5.91)	(3.53)		[0.005]
							{2.202}
West Germany	0.003	0.008		0.137	0.682		0.696
	(0.32)	(1.70)		(2.75)	(3.29)		[0.008]
							{1.501}

[a] The equation is

$$\log [P/P(-1)]_i = \alpha_{0i} + \alpha_{1i}(1/U_i) + \alpha_{2i} \log [Q/Q(-1)]_i + \alpha_{3i} \log [P^m/P^m(-1)]_i + \alpha_{4i}\{\log [P/P(-1)]_i\}_{-1} + \alpha_{5i}D_i$$

[b] The sample period is 1959–1973, and $D_i = 0.5$ in 1973.
[c] The unemployment rate enters with a lag of two years, and $D_i = 0.5$ in 1970 and 1971 and 1.0 in 1972 and 1973.
[d] $D_i = 0.5$ in 1969 and 1970, and 1.0 in 1971–1973.

Table 3 contains the equations for explaining import prices as represented by unit value indexes in home-currency units. P_i^F and F_i, are weighted averages of the domestic prices of countries that export to country i and the effective rate for currency i, and are defined in Table 4. The coefficients of the domestic prices abroad adjusted for the exchange rate variations, $P_i^F + F_i$, are between 0.4 and 1.2 for all countries except Austria, Italy, and the Netherlands. The coefficients for these three are close to 1.5, and are not statistically different from 1.0. On the whole, nevertheless, the coefficient estimates seem to overstate the extent to which foreign domestic prices are reflected in import prices. The dummy variable D in the import price equations (except for Austria, Italy, Sweden, and the United States) accounts for the influence of the extraordinary upward surge of raw materials and oil prices that took place in the early 1970s. The output variables are found to be significant or almost so for six countries: Austria, Belgium, Japan, Sweden, the United Kingdom, and West Germany. The results further indicate that import prices are not related to the income of the six remaining countries: Australia, Canada, Finland, Italy, the Netherlands, and the United States. This seems particularly puzzling because the United States, for example, is considered to be a large country, and Sweden, a small one. The results are only tentative because no explicit differentiation is made between tradable and nontradable prices. Nevertheless, the empirical results may very moderately overstate the impact of a change in output levels.

Table 5 presents the results obtained for the unemployment rate equations. First-order Almon-distributed lags on real output are introduced to allow for the possible effects of past changes in real output. The coefficients of current and previous real output levels are negative for all twelve countries, indicating that Okun's relationship holds. The long-run change in the unemployment rate with respect to real output is indicated by the sum of the distributed lag coefficients of current and lagged real output. As expected, the sum of the coefficients varies substantially among countries, ranging from -2.5 for Japan to -47.0 for Canada. However, the estimate for Japan appears to be unrealistic, suggesting that the Okun specification needs to be modified for that country. For the United States, the sum of the coefficients, -31, is in agreement with the estimate of Friedman and Wachter (1974), -29, based on quarterly data for 1954I–1970IV. The constant terms are significant and positive for all countries. Consequently, the explanation of potential output by a time trend is a reasonable first-order approximation.

Even though each individual equation is acceptable, there is no a

TABLE 3 Import Price Equations,[a] 1957–1973

Country i	β_{0i}	β_{1i}	β_{2i}	β_{3i}	$\bar{R}^2$ [SEE] {DW}
Australia	−0.014	0.831		0.012	0.708
	(2.74)	(6.30)		(1.43)	[0.012]
					{2.213}
Austria	−0.071	1.331	0.408		0.504
	(3.80)	(3.46)	(1.53)		[0.029]
					{2.460}
Belgium	−0.071	1.164	0.740	0.071	0.572
	(2.89)	(1.83)	(2.66)	(2.24)	[0.040]
					{1.562}
Canada	−0.006	0.681		0.021	0.670
	(0.96)	(4.44)		(1.98)	[0.014]
					{1.871}
Finland	−0.003	0.465		0.060	0.506
	(0.19)	(3.83)		(1.86)	[0.045]
					{1.945}
Italy	−0.054	1.539			0.696
	(3.61)	(6.13)			[0.041]
					{2.039}
Japan	−0.103	1.129	0.495	0.127	0.558
	(3.99)	(2.31)	(3.02)	(3.87)	[0.041]
					{1.365}
Netherlands	−0.032	1.481			0.498
	(2.75)	(4.11)			[0.025]
					{1.946}
Sweden	−0.033	0.816	0.368	0.034	0.613
	(2.28)	(2.51)	(1.64)	(1.49)	[0.024]
					{2.460}
United Kingdom	−0.048	0.833	0.778	0.057	0.853
	(4.42)	(4.86)	(2.97)	(2.46)	[0.027]
					{2.331}
United States	−0.031	1.231			0.833
	(3.95)	(8.98)			[0.020]
					{2.168}
West Germany[b]	−0.038	0.853	0.219	0.386	0.824
	(3.15)	(2.98)	(1.66)	(8.62)	[0.019]
					{0.941}

[a]The equation is

$$\log [P^m/P^m(-1)]_i = \beta_{0i} + \beta_{1i}\{\log [P^x/P^x(-1) + \log [F/F(-1)]\}_i + \beta_{2i} \log [Q/Q(-1)]_i + \beta_{3i}D_{-2}$$

where D is a dummy variable reflecting structural shifts during 1970–1973, and has 0.5 for 1970 and 1971 and 1.0 for 1972 and 1973.

[b]The dummy variable is 0.5 for 1973 only.

TABLE 4 Foreign Export Prices and Effective Exchange Rates in Each Domestic Currency Unit[a]

Country i	Average Import Value Shares (a_{ij}), 1971											
	AS	AU	BL	CA	FI	IT	JA	NE	SW	UK	US	WG
Australia (AS)	0.0	0.004	0.008	0.053	0.006	0.026	0.222	0.018	0.025	0.261	0.292	0.085
Austria (AU)	0.000	0.0	0.026	0.003	0.008	0.098	0.014	0.043	0.047	0.090	0.034	0.637
Belgium (BL)	0.005	0.005	0.0	0.021	0.005	0.068	0.027	0.234	0.027	0.096	0.123	0.389
Canada (CA)	0.010	0.003	0.005	0.0	0.001	0.013	0.068	0.007	0.009	0.066	0.785	0.033
Finland (FI)	0.004	0.025	0.026	0.007	0.0	0.033	0.030	0.057	0.284	0.211	0.055	0.267
Italy (IT)	0.011	0.039	0.072	0.028	0.007	0.0	0.026	0.098	0.029	0.080	0.174	0.437
Japan (JA)	0.193	0.002	0.010	0.104	0.001	0.016	0.0	0.010	0.010	0.041	0.534	0.070
Netherlands (NE)	0.006	0.008	0.212	0.021	0.009	0.063	0.032	0.0	0.029	0.089	0.158	0.373
Sweden (SW)	0.003	0.030	0.051	0.011	0.091	0.045	0.032	0.073	0.0	0.227	0.114	0.325
United Kingdom (UK)	0.054	0.022	0.045	0.134	0.045	0.059	0.057	0.102	0.100	0.0	0.229	0.156
United States (US)	0.021	0.004	0.028	0.397	0.004	0.049	0.250	0.019	0.016	0.087	0.0	0.124
West Germany (WG)	0.008	0.039	0.170	0.017	0.013	0.189	0.036	0.260	0.045	0.071	0.152	0.0

[a]The estimating equation for foreign export prices (P^x) is

$$\log [P^x/P^x(-1)]_i = \sum_j a_{ij} \log [P/P(-1)]_i$$

The estimating equation for effective exchange rates (F_i) is

$$\log [F/F(-1)]_i = \sum_j a_{ij} \log [E/E(-1)]_j / \{1 + \log [E/E(-1)]\}_i$$

The diagonal element in the matrix becomes -1.0 when effective exchange rates are calculated.

priori assurance that performance of the system of equations as a whole is satisfactory. If the system does not track price behavior reasonably well, it may not be adequate for policy simulations. A test of this is based on summary statistics derived from the within-sample dynamic simulation for 1957–1973. The mean bias and root-mean-square error for individual equations are given in Table 6. The statistics of mean bias show that the errors generated in the simulation are not severely cumulative and tend to offset each other over time. The values for the root-mean-square error indicate that the import price and output equations for Italy and Japan seem to perform poorly relative to other equations, perhaps because the cyclical behavior of import and consumer prices generated by the low coefficients of real output in the unemployment rate equations differs substantially from the actual movements. Thus, the analysis of the simulation exercises in the following section must be interpreted with caution. Given this caveat, however, the test statistics seem to indicate that the model is able to trace the actual behavior of the rates of change in consumer and import prices and in output.

III. SIMULATION RESULTS: EFFECTS OF EXCHANGE RATE AND UNEMPLOYMENT RATE CHANGES

Different types of dynamic simulation can be carried out to observe the behavior of inflation in all countries in response to a shock to a particular exogenous variable. In each simulation, all other exogenous variables are kept at their actual values. Thus, the differences between the shocked and the control solutions are the estimates of the own- and cross-country multipliers discussed in the previous section. In the following, the model will be simulated over the period 1968–1973 to derive the multipliers of a unit change in the exchange rate and unemployment rate of each country in the system. After these simulations are carried out, two more are performed to ascertain how much of actual inflation rates during 1971–1973 has been associated with actual changes in the exchange and unemployment rates. The model is nonlinear and simultaneous. Consequently, the estimates derived from the simulations depend on initial conditions and the size of shocks.

The model is simulated with a sustained increase of 1 percent in the exchange rate of each country, one country at a time. The multiplier values for domestic and import prices of all countries are

TABLE 5 Unemployment (Okun's Law) Equations,[a] 1957–1973

Country i	γ_{0i}	γ_{1i}	γ_{2i}	γ_{3i}	γ_{4i}	γ_{5i}	$\bar{R}^2$ [*SEE*] {*DW*}
Australia[b]	0.496	−10.269					0.607
	(3.32)	(4.76)					[0.397]
							{2.100}
Austria	0.511	−6.288	−4.192	−2.096			0.325
	(2.01)	(2.95)	(2.95)	(2.95)			[0.311]
							{1.084}
Belgium	1.386	−13.96	−10.47	−6.980	−3.490		0.622
	(4.66)	(5.23)	(5.23)	(5.23)	(5.23)		[0.487]
							{0.835}
Canada	2.308	−20.04	−13.36	−6.679			0.428
	(3.66)	(3.60)	(3.60)	(3.60)			[0.745]
							{1.793}
Finland[b]	1.046	−15.09					0.572
	(3.81)	(4.44)					[0.457]
							{2.009}
Italy	0.646	−5.726	−4.295	−2.863	−1.432		0.195
	(1.36)	(2.21)	(2.21)	(2.21)	(2.21)		[0.609]
							{0.683}

Japan	0.296	−1.298	−0.865	−0.433			0.194
	(1.97)	(2.20)	(2.20)	(2.20)			[0.163]
							{2.118}
Netherlands	1.120	−7.387	−4.925	−2.462			0.236
	(2.61)	(2.44)	(2.44)	(2.44)			[0.472]
							{1.187}
Sweden	0.550	−10.113					0.672
	(5.32)	(5.81)					[0.191]
							{1.839}
United Kingdom	1.417	−15.31	−12.24	−9.183	−6.122	−3.061	0.484
	(4.11)	(4.00)	(4.00)	(4.00)	(4.00)	(4.00)	[0.383]
							{1.380}
United States	1.311	−12.36	−9.273	−6.182	−3.091		0.496
	(3.68)	(4.09)	(4.09)	(4.09)	(4.09)		[0.712]
							{2.374}
West Germany	0.962	−9.876	−6.584	−3.292			0.545
	(3.57)	(4.49)	(4.49)	(4.49)			[0.403]
							{1.866}

[a] The equation is

$$\Delta U_i = \gamma_{0i} + \sum_{K=0}^{4} \gamma_{1+k,i} \log [Q(-k)/Q(-k-1)]_i$$

[b] The sample period is 1959–1973.

TABLE 6 Prediction Error Statistics of the Dynamic Simulations, 1957–1973 (fractions)

Country	Mean Bias			Root-Mean-Square Error		
	Consumer Price	Import Price	Output	Consumer Price	Import Price	Output
Australia	.0053	.0007	.0097	.0105	.0093	.0365
Austria	.0002	.0047	.0024	.0110	.0280	.0471
Belgium	.0022	.0028	.0009	.0066	0400	.0353
Canada	.0012	.0007	.0010	.0101	0157	.0429
Finland	.0013	.0006	.0115	.0266	.0417	.0383
Italy	−.0004	.0001	.0021	.0144	.0418	.0854
Japan	.0016	.0030	.0027	.0167	.0754	.1600
Netherlands	.0001	.0033	.0021	.0201	.0299	.0581
Sweden	.0006	.0014	.0000	.0130	.0262	.0170
United Kingdom	−.0009	.0046	.0041	.0094	.0303	.0246
United States	.0010	.0019	.0025	.0090	.0214	.0700
West Germany	.0043	.0007	.0007	.0113	.0228	.0504

computed by comparing the solution with the control solution. The own- and cross-country multipliers for domestic prices are summarized in matrix form in Table 7.

Although the table contains a wealth of information, only a few general conclusions can be drawn because of limited space. The reductions in the domestic prices of countries whose currencies appreciate vary from one country to another, as shown by the diagonal elements of the matrix. On the average, a 1 percent appreciation reduces prices by about 0.26 percent in the first year after the policy change and by about 0.36 percent after six years. Thus, the effect on own domestic inflation is substantial. As revealed in the off-diagonal elements, a currency appreciation is accompanied by induced increases in the prices of other countries, although not by an appreciable amount initially. But, the cross-country effects tend to become gradually greater as time passes, because of the lagged adjustments. Since all the cross effects are not found to be zero, the inflationary pressure from a change in currency value can be transmitted abroad.

The sum of the off-diagonal row elements represents the extent to which the prices of receiving countries are influenced. According to the figures shown, changes in the value of the U.S. dollar and West German deutsche mark (DM) are expected to have an appreciable impact on prices in other countries. On the other hand, the sum of the off-diagonal column elements is a measure of the vulnerability of a country's domestic prices to changes in external currency values. Canada, Australia and the Netherlands, for example, are very vulnerable.

As noted earlier, domestic prices are also affected by changes in unemployment rates abroad, not only through inverse changes in unemployment rates but also through changes in the rate of growth of output levels. The multipliers to reveal these influences are also computed by simulations. Table 8 contains the own and cross effects on the domestic prices of all countries of a 1 percent increase in the unemployment rate of each country. As expected, domestic prices in a country tend to fall appreciably in the long run as a result of the simulated increase in its own unemployment rate. As shown by the diagonal elements, in the long run, domestic prices decline by approximately 0.24 percent, on the average. The responses in the first year are mixed, however, depending on whether the positive effect attributable to the induced decrease in the output level (possibly a proxy for lower productivity growth) as described by the Okun equation outweighs the negative effect of the increased unemployment itself.

TABLE 7 Effects of a 1 Percent Appreciation in the Dollar Price of an Initiating Country's Currency on Foreign Consumer Price Inflation[a] (percent)

Initiating Country	Receiving Country												Off-Diagonal Row Sum
	AS	AU	BL	CA	FI	IT	JA	NE	SW	UK	US	WG	
Australia (AS)													
Impact	−0.32	0.0	0.0	0.0	0.0	0.0	0.06	0.0	0.0	0.01	0.01	0.0	0.09
Long run	−0.67	0.0	0.0	0.01	0.0	0.0	0.02	0.0	0.0	0.0	0.01	0.0	0.04
Austria (AU)													
Impact	0.0	−0.12	0.0	0.0	0.01	0.01	0.0	0.01	0.01	0.0	0.0	0.0	0.04
Long run	0.01	−0.10	0.0	0.01	0.01	0.01	0.0	0.01	0.01	0.0	0.0	0.01	0.07
Belgium (BL)													
Impact	0.01	0.01	−0.11	0.0	0.01	0.03	0.01	0.11	0.02	0.01	0.01	0.02	0.24
Long run	0.02	0.01	−0.34	0.02	0.01	0.02	0.01	0.07	0.02	0.01	0.01	0.04	0.24
Canada (CA)													
Impact	0.03	0.0	0.0	−0.21	0.0	0.01	0.06	0.02	0.01	0.02	0.08	0.0	0.23
Long run	0.02	0.0	0.01	−0.92	0.0	0.0	0.01	0.01	0.0	0.0	0.03	0.01	0.09
Finland (FI)													
Impact	0.0	0.0	0.0	0.0	−0.30	0.0	0.0	0.0	0.02	0.01	0.0	0.0	0.03
Long run	0.01	0.0	0.0	0.0	−0.28	0.0	0.0	0.0	0.02	0.01	0.0	0.0	0.04
Italy (IT)													
Impact	0.01	0.01	0.01	0.0	0.01	−0.29	0.01	0.03	0.01	0.01	0.01	0.02	0.13
Long run	0.03	0.01	0.03	0.03	0.01	−0.31	0.01	0.03	0.02	0.01	0.02	0.04	0.24

Japan (JA)													
Impact	0.05	0.0	0.0	0.02	0.01	0.0	−0.40	0.02	0.01	0.01	0.04	0.01	0.16
Long run	0.13	0.0	0.01	0.11	0.01	0.01	−0.33	0.02	0.01	0.01	0.09	0.01	0.41
Netherlands (NE)													
Impact	0.01	0.01	0.01	0.0	0.01	−0.01	0.01	−0.52	0.02	0.01	0.0	0.02	0.09
Long run	0 02	0.01	0.05	0.01	0.01	0.0	0.01	−0.43	0.02	0.01	0.01	0.04	0.19
Sweden (SW)													
Impact	0.01	0.01	0.0	0.0	0.06	0.01	0.01	0.01	−0.29	0.01	0.0	0.0	0.12
Long run	0.02	0.0	0.01	0.01	0.06	0.01	0.01	0.02	−0.28	0.01	0.01	0.01	0.17
United Kingdom (UK)													
Impact	0.08	0.01	0.01	0.02	0.05	0.02	0.03	0.05	0.06	−0.19	0.02	0.01	0.36
Long run	0.18	0.01	0.04	0.09	0.06	0.03	0.05	0.05	0.07	−0.15	0.05	0.03	0.66
United States[b] (US)													
Impact	0.09	0.01	0.01	0.14	0.08	0.08	0.18	0.08	0.02	0.06	−0.21	0.02	0.77
Long run	0.17	0.0	0.05	0.55	0.03	0.12	0.16	0.06	0.04	0.06	−0.29	0.04	1.28
West Germany (WG)													
Impact	0.04	0.08	0.05	0.01	0.07	0.13	0.04	0.19	0.10	0.03	0.03	−0.10	0.77
Long run	0.08	0.05	0.13	0.07	0.07	0.11	0.05	0.15	0.08	0.03	0.06	−0.25	0.88
Off-diagonal column sum													
Impact	0.33	0.14	0.09	0.19	0.31	0.28	0.41	0.52	0.28	0.18	0.20	0.10	
Long run	0.69	0.09	0.33	0.91	0.27	0.31	0.33	0.42	0.29	0.15	0.29	0.23	

[a]The off-diagonal row sum is the effect of the initiating country's rate on foreign consumer prices; the off-diagonal column sum is the effect of foreign countries' rates on the consumer price of the receiving country; the diagonal is the effect of the initiating country's rate on its own consumer price. The impact figure shows the effect of a change in the initiating country's rate at the end of the first year following the change; and the long run, the effect after the sixth year.

[b]In the case of the United States, the dollar is appreciated by 1 percent against the currencies of *all* the other countries.

TABLE 8 Effects of a 1 Percent Increase in the Unemployment Rate of an Initiating Country on Foreign Consumer Price Inflation[a] (percent)

Initiating Country	Receiving Country												Off-Diagonal Row Sum
	AS	AU	BL	CA	FI	IT	JA	NE	SW	UK	US	WG	
Australia (AS)													
Impact	−1.10	0.0	0.0	0.01	0.0	0.01	−0.09	−0.01	0.0	−0.01	−0.01	0.0	−0.14
Long run	−1.85	0.0	−0.01	−0.06	−0.01	−0.01	−0.17	−0.02	−0.01	−0.02	−0.04	−0.01	−0.36
Austria (AU)													
Impact	0.0	0.51	0.0	0.0	0.0	0.01	0.0	0.0	0.01	0.0	0.0	0.0	0.02
Long run	−0.01	−2.54	−0.01	−0.01	−0.02	−0.04	−0.01	−0.02	−0.03	−0.01	−0.01	−0.03	−0.20
Belgium (BL)													
Impact	−0.02	−0.01	−0.78	−0.01	−0.01	−0.03	−0.02	−0.10	−0.03	−0.01	−0.01	−0.02	−0.27
Long run	−0.03	−0.01	−1.44	−0.03	−0.03	−0.05	−0.02	−0.19	−0.04	−0.02	−0.03	−0.09	−0.54
Canada (CA)													
Impact	−0.01	0.0	0.0	−0.41	0.0	−0.01	−0.03	−0.01	0.0	−0.01	−0.04	0.0	−0.11
Long run	−0.12	0.0	−0.02	−1.38	−0.01	−0.03	−0.12	−0.05	−0.02	−0.04	−0.22	−0.02	−0.65
Finland (FI)													
Impact	0.0	0.0	0.0	0.0	−0.29	0.0	0.0	0.0	−0.01	0.0	0.0	0.0	−0.01
Long run	−0.01	0.0	0.0	0.0	−1.12	0.0	0.0	−0.01	−0.03	−0.01	0.0	−0.01	−0.07

Italy (IT)													
Impact	−0.01	−0.01	−0.01	−0.01	−0.01	−0.93	−0.01	−0.04	−0.02	−0.01	−0.01	−0.02	−0.16
Long run	−0.04	−0.02	−0.04	−0.04	−0.02	−0.94	−0.02	−0.05	−0.03	−0.01	−0.03	−0.07	−0.37
Japan (JA)													
Impact	−0.22	−0.01	−0.02	−0.08	−0.02	−0.04	−2.52	−0.07	−0.04	−0.03	−0.17	−0.02	−0.72
Long run	−0.18	0.0	−0.02	−0.16	−0.01	−0.02	−0.88	−0.03	−0.02	−0.02	−0.11	−0.02	−0.59
Netherlands (NE)													
Impact	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long run	−0.02	−0.01	−0.06	−0.01	−0.02	−0.03	−0.01	−0.62	−0.02	−0.01	−0.01	−0.06	−0.26
Sweden (SW)													
Impact	0.02	0.02	0.01	0.0	0.13	0.02	0.0	0.04	2.43	0.03	0.01	0.01	0.29
Long run	−0.02	−0.01	−0.01	−0.01	−0.06	−0.01	−0.01	−0.02	−0.69	−0.01	−0.01	−0.01	−0.18
United Kingdom (UK)													
Impact	0.06	0.01	0.01	0.01	0.03	0.02	0.01	0.04	0.05	0.74	0.02	0.01	0.27
Long run	−0.11	−0.01	−0.03	−0.06	−0.03	−0.02	−0.03	−0.04	−0.04	−0.49	−0.03	−0.02	−0.42
United States (US)													
Impact	0.0	0.0	0.0	0.01	0.0	0.0	0.01	0.0	0.0	0.0	0.04	0.0	0.02
Long run	−0.32	−0.01	−0.08	−0.80	−0.04	−0.09	−0.32	−0.14	−0.07	−0.06	−1.12	−0.08	−2.01
West Germany (WG)													
Impact	−0.03	−0.05	−0.03	−0.02	−0.04	−0.08	−0.04	−0.12	−0.07	−0.02	−0.03	−0.53	−0.53
Long run	−0.14	−0.11	−0.21	−0.11	−0.13	−0.18	−0.08	−0.29	−0.15	−0.04	−0.10	−1.23	−1.54
Off-diagonal column sum													
Impact	−0.21	−0.05	−0.04	−0.11	0.08	−0.12	−0.17	−0.27	−0.11	−0.06	−0.24	−0.04	
Long run	−1.00	−0.18	−0.49	−1.29	−0.38	−0.48	−0.79	−0.86	−0.46	−0.25	−0.59	−0.42	

[a]See Table 7, note a.

The cross effects, particularly in the long run, appear to be large and negative, as given by the off-diagonal elements. This suggests that the inflationary pressure generated by the increased activity in one country produces inflationary pressures in other countries. While the cross effects of a change in unemployment rates could be exaggerated, as indicated in the previous section, they are definitely sharper and larger than those resulting from currency appreciations. The sums of the off-diagonal row and column elements are also given in Table 8. As expected, the changes in U.S. and German activity strongly affect the inflation in other countries, whereas the inflation in Australia, Canada, Japan and the Netherlands seems to be highly influenced by foreign activity.

One of the interesting conclusions emerging from the discussion on economic policy in an interdependent world is that the achievement of the policy targets of a country is less costly if policy decisions take into account the interactions with other countries.[11] Table 9 contains calculations of the effects of changes in the exchange and unemployment rates of a country upon its own inflation through their impact abroad, in order to see how important the repercussions of interdependence can be. As discussed in the pre-

TABLE 9 Size of Feedback Effects[a] on Domestic Inflation (percent)

	1% Exchange Rate Appreciation		1% Rise in Rate of Unemployment	
	Impact	Long Run	Impact	Long Run
Australia	.01	.0	−.01	−.04
Austria	.0	.0	.0	.0
Belgium	.0	.1	−.01	−.03
Canada	.02	.05	−.01	−.12
Finland	.01	.0	−.01	.0
Italy	.0	.01	.0	−.01
Japan	.02	.03	−.06	−.05
Netherlands	.01	.02	.0	−.02
Sweden	.01	.01	.0	.0
United Kingdom	.0	.01	.0	−.01
United States	.03	.11	.0	−.15
West Germany	.01	.03	−.01	−.05

[a] Feedback effects are defined as the effects estimated with no changes in the consumer price and output rates of all other countries minus the effects with the changes reported in tables 7 and 8. A negative sign indicates addition to the negative effect; a plus sign, offsetting of the negative effect.

vious section, the feedback effect of a currency appreciation tends to offset the initial dampening effect on the inflation of the appreciating country, whereas the feedback effect of a rise in the unemployment rate reinforces the price-dampening effect of the higher unemployment rate in the initiating country. In addition, the estimates reveal that the feedback effect is greater, the larger the country's share in world trade. Although the feedback effects on the whole are smaller than expected, the presence of such repercussion effects suggests that in order to achieve policy targets, it is necessary to take into account the interdependence of countries' rates of inflation.

Finally, simulation experiments are made for 1971–1973 under the assumption that either exchange rates or unemployment rates during the three years are identical to those prevailing in 1970. The results are presented in Table 10.[12] In countries whose currencies have effectively appreciated, domestic prices decreased. For instance, average annual inflation rates in Japan and West Germany were lower by about 2.3 and 0.7 percent than they would have been predicted to be in the absence of currency appreciations. These reductions are substantial; they amount, respectively, to one-third and one-fifth of the predicted inflation rates. Symmetrically, those countries whose currencies have effectively depreciated have experienced increased inflation. For example, the U.S. dollar was effectively depreciated by about 5 percent per year. Accordingly, an annual increase in the U.S. price of about 1.4 percent can be attributed to the devaluation. As shown in the table, the devaluation-induced rise is one-third of the predicted inflation rate, a proportion that is about the same size as that implied in Kwack (1973). On this ground, the U.S. devaluation can be regarded as an important factor in generating inflationary pressure in the U.S. economy.

As shown in the table, annual average unemployment rates in all countries except Austria have increased anywhere from 0.3 to 1.2 percent during the three years. As expected from our finding that a rise in the unemployment rate of a country leads to decreases in the prices of all countries, the increases in unemployment rates would have produced a decline in domestic prices of between about 0.4 and 1.3 percent annually.

Although very informative, my analysis based on the simulations certainly does not deal with all the events that may be regarded as causes of sharply accelerated worldwide inflation during those three years. For example, increases in petroleum and materials prices and upward shifts of natural unemployment rates due to changes in demographic and related factors could have been con-

TABLE 10 Response of Consumer Price Inflation to Changes in the Exchange Rate and Unemployment Rate during 1971–1973 (percent)

Country	Exchange Rate Effect			Unemployment Rate Effect		
	Effective Exchange Rate Change (1)	Consumer Price Change (2)	Relative Magnitude (3)	Unemployment Rate Change (4)	Consumer Price Change (5)	Relative Magnitude (6)
Australia	−3.697	−1.289	0.215	0.533	−1.370	0.233
Austria	−1.293	−0.207	0.038	−0.533	1.037	0.198
Belgium	−1.077	−0.210	0.045	0.467	−0.603	0.133
Canada	−0.047	−0.020	0.005	0.200	−0.397	0.097
Finland	2.753	0.703	0.110	0.433	−0.817	0.129
Italy	3.490	0.973	0.185	0.233	−0.473	0.091
Japan	−5.830	−2.330	0.341	0.100	−0.483	0.071
Netherlands	−1.960	−1.073	0.182	1.267	−0.573	0.098
Sweden	−0.080	−0.027	0.005	0.567	−0.480	0.083
United Kingdom	4.437	0.637	0.078	0.733	−0.933	0.121
United States	5.113	1.363	0.282	0.567	−0.777	0.175
West Germany	−4.670	−0.720	0.173	0.333	−0.623	0.152

NOTE: Column 1—average effective exchange rate change in a country's currency from 1971 through 1973 (negative sign indicates appreciation). The effective appreciation of the U.S. dollar is equivalent to the depreciation of all other currencies.

Columns 2 and 5—average change in consumer price inflation due to the change in the exchange rate (column 2) or unemployment rate (column 5).

Columns 3 and 6—change in consumer price inflation due to the exchange rate (unemployment rate) change as a fraction of the actual inflation.

Column 4—average change in the unemployment rate from 1971 through 1973.

tributing factors.[13] The monetary expansions in the world, either passively or actively, can be said to be associated with the inflation in a sense that persistent inflation over a long period of time is incompatible with the absence of excessive monetary expansions.

IV. CONCLUSIONS

In this paper I attempted to provide a framework for the analysis of price behavior and inflation in an interdependent world. It must be repeated that the model is limited in scope and much remains to be done; sectoral specifications can be improved for individual countries, and real demand and monetary sectors could be incorporated to get more comprehensive conclusions. Nevertheless, the simulation results of the model are useful in increasing our understanding of a phenomenon that has not previously been examined in great detail—the international transmission of inflation.

The major conclusion emerging from this study is that a rise in the exchange rate of a country not only shifts the trade-off relation between inflation and unemployment but also has an inverse effect on such relations in other countries. Consequently, changes in external currency values and activities are transmitted to the rest of the world independent of the effects of changes in aggregate demand and monetary stocks. For a given change in the domestic prices of a country, the more open the initiating country is and the wider its trade relations with other countries, the greater will be the responsiveness of foreign prices. My results seem to suggest that the capability of a country to manage its own inflation may be strengthened if national policymakers take into account the degree of interdependence of prices among countries.

The foregoing results also indicate that a currency depreciation contributes to domestic inflation. That is what is expected when a currency value is depreciated without being accompanied by an appropriate reduction in domestic absorption. If there is worldwide downward rigidity in prices, it seems highly likely that a currency depreciation of an important trading country will give rise to pressures toward a worldwide inflation.

The analysis was carried out in a preliminary way by the use of an aggregative model. Consequently, little attention was paid to differences in rates of inflation between tradable and nontradable goods. A promising avenue for further investigation would be to make an

explicit distinction between the two types of goods within a model covering worldwide activity and financial transactions, such as the Project LINK model. For the present, I hope I have shed some light on the interdependence of the economies of industrial nations.

NOTES

1. While a fuller discussion and reconciliation of some works in the area of international transmission of inflation can be found in Sweeney and Willett (1974), an example of the works in this area is found in Haberler (1974). Johnson and Klein (1973, 1974), and Hickman (1974) attempted to examine quantitatively the interdependence of activities among countries in the world, using a LINK model.
2. The transmission channels are spelled out in detail in Sweeney and Willett (1974). Also see Turnovsky and Kaspura (1974) for a thorough discussion on imported inflation in a small country, and Johnson (1973), Laidler (1972), and Parkin (1972) for a monetarist view.
3. These hypotheses are used in some models in the LINK system. No import prices are included in the works of Gordon (1971) and Perry (1970) and the wage-price sectors in most U.S. models in Eckstein, ed. (1972).
4. This specification was applied in Kwack (1974) to explain both U.S. prices and wage rates during 1959I–1972IV. The specification seems to be quite satisfactory, regardless of whether the money stock and government spending are added. Equation 3 was used in Kwack (1973).
5. This is a limiting case of the general specification discussed above that is derived from solving the demand and supply equations, as applied by Amano (1974) to explain export price behavior in industrial countries. While the special form was used here for simplicity, further investigations will be undertaken to examine whether or not the general form reduces specification errors involved in the special form.
6. This assumption is restrictive as discussed by Balassa (1964) because of the difference between the movement of consumer prices (in which prices of nontraded goods are also reflected) and tradable goods prices. However, this assumption simplifies matters a great deal by enabling us to avoid constructing a complicated subsector to show how the two prices are determined.
7. Branson (1972, p. 21) showed that $0 \leq \beta_{1i} = \theta_j/(\theta_j - \epsilon_i) \leq 1$, where ϵ_i = own price elasticity of ith import demand and θ_j = own price elasticity of jth supply.
8. See Goldberger (1964, pp. 373–378) for a mathematical proof of the stability conditions and discussion on multipliers in general.
9. Clark (1974) found the import price to be marginally important in explaining the U.S. GNP deflator, when it was used with the money stock and government expenditures. As noted before, Kwack (1974) found that the coefficients on the import price variable were stable and significant in explaining U.S. deflators for consumption expenditures even in the presence of the money stock. The import prices were important in explaining U.S. and aggregate foreign CPI (consumer price index) behavior, in the study by Kwack (1973).
10. Braun (1974) provided a broad survey of some issues of incomes policy and

discussed actual implementations of incomes policy in industrial countries. One interesting point emerging from her survey is that incomes policies were frequently employed in connection with changes in currency values.

11. See Cooper (1969) for the policy choice of a country in an interdependent world through capital mobility. Duesenberry (1974) pointed out the importance of external factors even in the United States, which external sector was regarded as relatively small.
12. Exchange rates and unemployment rates are treated as exogenously determined, ignoring the activity effect of inflation that is likely to be present in a general equilibrium framework.
13. Nordhaus (1973) investigated how energy requirements will be satisfied and energy prices will affect prices of goods, and Popkin (1974) discussed the impact on the U.S. price level of increasing prices of raw material commodities in the world.

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COMMENTS

John Helliwell
University of British Columbia

INTRODUCTION

The principal objective of Sung Kwack's interesting paper is to specify and estimate a model of the direct transmission of price changes among a group of twelve industrial countries. He wishes to develop the simplest sort of model to explain foreign and domestic changes in prices induced by changes in activity or exchange rates. Monetary influences and changes in trade and capital flows are deliberately left out, while exchange rates come into play only to convert each country's domestic prices into the import prices of its trading partners. In keeping with the spirit of the Kwack paper, I shall share his concentration on the development of models that achieve interdependence while maintaining the simplest feasible structure. I shall proceed in four stages. First, I shall outline the basic structure of the Kwack model, and then describe and interpret his main empirical results. In the third and fourth parts of my presentation I shall first state generally the properties that a model should have if it is to adequately depict the international transmission of inflations, and then suggest some changes to the Kwack model intended to add to its structural aptness without adding unduly to its complexity.

1. BASIC STRUCTURE

For each country, there are three estimated equations; one for the consumer price, one for the price of imports, and one for the unemployment rate. The consumer price equation is intended to represent a price and wage equation pair solved to remove the wage, giving:

$$\dot{P}_i = \alpha_{0i} + \alpha_{1i}(1/U_i) + \alpha_{2i}\dot{Q}_i + \alpha_{3i}\dot{P}_{mi} + \alpha_{4i}\dot{P}_{i,t-1} + \alpha_{5i}D_i \tag{1}$$

where $\dot{P}_i$, $\dot{Q}_i$, and $\dot{P}_{mi}$ are the logarithms of the ratios of country i's consumer price, output in real terms, and import price to their values in the preceding year; U_i is the unemployment rate in country i; and the D_i are dummy variables with values chosen to improve particular equations.

The estimated import price equations are based on weighted averages of the consumer prices in the other eleven countries adjusted for exchange rate changes plus, for some countries, an output influence intended to represent an impact of demand on import prices. The equation is

$$\dot{P}_{mi} = \beta_{0i} + \beta_{1i}\sum_{j=1}^{11} a_{ij}\dot{P}_j\dot{F}_j - \beta_{1i}\dot{F}_j + \beta_{2i}\dot{Q}_j + \beta_{3i}D_j \tag{2}$$

where F_j is (approximately) the number of units of country i's currency required to purchase a unit of country j's currency, and the a_{ij} weights represent the proportion of country i's total 1971 value of imports from the other eleven countries that come from country j. The other variables are as defined for equation 1. This equation merits particular attention because it provides, in conjunction with the import price term in equation 1, the international linkage mechanism of the Kwack model. Note that exchange rate and consumer price changes in country j are assumed to have the same impact on the import prices of country i and that, in general, each country's export prices are assumed to have the same relationship to consumer prices. Note also that the import price being explained is for total imports of country i, while the composite price variable used to explain it comprises domestic prices in only eleven other countries. If prices in the excluded countries are correlated with prices in the included ones, the use of a limited range of country prices as proxies for all others will result in an upward bias of the estimate of the degree of price interdependence among the twelve countries included in the model.

The third equation in the Kwack model provides a tie for each

economy between domestic output and the unemployment rate, using the functional form

$$\Delta U_i = \gamma_{0i} + \sum_{K=0}^{I} \gamma_{I+K,i} \dot{Q}_{t-K} \tag{3}$$

For each country, the γ_K weights on Q are forced to decline linearly from the current year to the last year in the lag distribution, but the lag length itself is permitted to vary among countries; ranging from no lag at all for three countries, to two lagged years for five countries, three lagged years for three countries, and four lagged years for the remaining country. The purpose of the unemployment rate equation in the Kwack model is to reduce from three to two the number of exogenous variables for each country, so that it will be possible to simulate the domestic and foreign price consequences of a domestic shock by changing the actual value of a single variable, if the exchange rate is held fixed.

2. SUMMARY OF RESULTS

2.1 Estimated Equations

The single-equation results are shown in Sung Kwack's tables 2, 3, and 5 for the consumer price equations, import price equations, and unemployment rate equations, respectively.

Looking first at the consumer price equations, we note that Kwack's chosen equations contain lags for half of the countries, and that the impact and equilibrium elasticities for import prices are in almost all cases above the import content of consumption expenditure and, in about half the cases, several times the import content. In the light of the difficulties faced by most model builders in obtaining import price coefficients sufficiently high to be plausible, at least with data samples ending by 1970, Kwack's very high estimates are slightly surprising. The suspicion arises that the import prices may be mopping up the residual variance to the extent that import prices are correlated with the excluded variables, such as man-hours employed and capacity utilization, usually found in price equations. Differences in the relative importance of excluded variables are also likely to be part of the explanation for sharply differing coefficients on the lagged dependent variable, ranging from zero in five cases (on what grounds were the lagged dependent

variables excluded from these equations?) to 0.75 for Belgium and 0.86 for Canada. These varying lag patterns serve to exaggerate the differences among countries in the role of the import price, giving an equilibrium elasticity of over 2.4 for the effect of import prices on Canadian consumer prices. Kwack points this out as an implausible feature, but uses the equation anyway.

The negative effects of output on consumer prices are also somewhat troubling. Kwack intends output to have a negative sign in the price equation because his theoretical equation contains no capacity utilization term, but has unit labor cost defined with current output in the denominator. For most of the five models in which a negative influence of output enters the price equation, the suspicion arises that an increase in domestic aggregate demand could make prices rise rather than fall.

Turning to the import price equations in Table 3, we find, as one would expect, that foreign prices are the principal determinants. If the aggregate of foreign prices were constructed from just the right components, we would expect import prices to have an elasticity of 1.0 with respect to it. In the estimated equations, the elasticities range from 0.46 to 1.54. These estimates are likely to be subject to biases in opposite directions. On the one hand, export prices in the industrial countries have tended to rise more slowly than consumer prices, and this should produce negative constant terms or coefficients less than 1.0, or both, on the amalgam of foreign consumer prices. All the constant terms are negative, but the average coefficient on the foreign price term is above rather than below 1.0. On the other hand, the exclusion of exports of the nonindustrial world from the mixture of foreign consumer prices results in the omission of most of industrial raw materials, and prices of the latter have more variability than consumer prices.

Finally, in the unemployment, or "Okun's law," equations, there is a disturbing variance among countries in the length of lags and in the elasticities of unemployment with respect to output. In essence, these are employment equations adjusted for activity-induced changes in labor force participation. It would help the reader to assess the equations if these two elements could be separated, so that the comparison between average and marginal employment requirements could be assessed. Furthermore, separate treatment of the labor force would probably help to improve the fit and structural aptness of the equations; it is difficult to tell just what influence the demographic trends and cycles have on the present equations.

2.2 Simulation Results

The simulations reported in tables 6 through 9 are the main substance of the paper, given Kwack's concern with international interdependence rather than the separate structures of national economies.

The first simulation, in Table 6, reports the error characteristics of a control solution for the twelve-country model, using exchange rates, the dummy variables, and national unemployment rates as exogenous variables. The root-mean-square errors range from 0.6 percent to 2.7 percent for consumer prices, from 0.9 percent to 7.5 percent for import prices, and from 1.7 percent to 16.0 percent for output. It would be useful to see which single-equation errors are most responsible for these errors. The initial suspicion must fall on the unemployment equations, which in this model are solved for output changes.

Two types of policy simulation are reported by Kwack. Table 7 contains the results of separate 1 percent appreciations in the value of each country's currency, starting in 1968. In table 8 are found the results of separate simulations of 1 percent increases in national unemployment rates. The sizes of the international feedback effects in the simulations of tables 8 and 9 are shown in Table 9. Finally, Table 10 contains the results of a single simulation from 1971–1973 in which rates of exchange rates and of national unemployment are maintained at their 1970 values.

The appreciation simulations in Table 7 indicate own-country impact effects on consumer prices ranging from −0.1 percent for West Germany to −0.52 percent for the Netherlands. The equilibrium effects range from −0.1 percent for Austria to −0.92 percent for Canada. The differences between impact and equilibrium effects are largely due to cross-country differences in the coefficient of lagged price in the consumer price equation, and not to repercussions from other countries. The figures in Table 9 show that, on average, the own-country long-run price effects would be about 7 percent larger if there were no feedbacks from other countries.

The Table 8 simulations of the domestic and foreign price effects of changes in the unemployment rate show a disturbingly large number (four) of instances where the own-country price effects are initially positive. This result is due to the appearance of output changes with a negative sign in the price equations of the four countries concerned (Austria, Sweden, the United Kingdom, and the United States). In three of the four cases, a 1 percent increase

in the unemployment rate causes domestic prices to rise by more than 0.5 percent in the first year, with or without international feedbacks taken into account.

In my view, it would have been more natural to run the activity change simulations by using an output shock, and then tracing the unemployment and price effects of this (perhaps policy-induced) change. This would have given results rather different from those reported by Kwack because the lags in his unemployment-output relation run from output to unemployment rather than in the reverse direction. Using output change as the activity shock would have caused the "perverse" price effects (e.g., rising car prices when demand is falling) to last longer in the four main countries involved. Once the unemployment and output changes have caused changes in domestic prices, they then lead to foreign effects, following the pattern outlined above for Table 8. Since import prices provide the only international linkage in Kwack's system, the results of the activity change provide a poor representation of reality because the most important international effect is (in my view) usually provided by activity-induced trade flows, which in turn act as a means of transmitting inflationary effects abroad. Thus, further analysis of the international price responses of activity changes should await the addition of trade flows to this model, or should be studied within the context of the Project LINK system, in which primary emphasis is placed on activity-induced trade flows as a means of transmitting internationally the employment, output, and price effects of a domestic activity change.

To summarize my analysis of the equations and results of the present version of Sung Kwack's model:

1. The degree of direct price interdependence is probably overstated, for reasons outlined in section 2.1 above. This means that Table 7 probably provides a high estimate of the price effects of exchange rate changes.
2. The international interdependence of activity changes is left out of the model, with the result that the Table 8 results are not a very satisfactory guide to the international price effects of domestic activity changes.
3. Even though the size of the direct international price effects estimated by Kwack is probably overestimated, his calculations of the effects feeding back to the initiating country show them to be too small to substantially alter the domestic effects of the initiating country's policies. A much more important constraint that interdependence places on national policies comes about because of inconsistent policy targets: Country

A initiates a policy that has substantial effects on B, and B responds with a policy that has substantial effects on A. Thus, the main feedback on A arises through Country B's policy responses, which may be much larger (perhaps explosively so) than the reflected effects arising from models, such as Kwack's, that treat policies as exogenous.

3. GENERAL REQUIREMENTS FOR A MODEL OF THE INTERNATIONAL TRANSMISSION OF INFLATIONS

In section 4, I offer a set of specific suggestions for extensions of the Kwack model. The following are what I think to be the general requirements for a fully satisfactory model:

1. Even if the model cannot itself explain the prices of industrial materials from the nonindustrial world, it must allow their impact to be separately accounted for.
2. If the price effects of single or sequential exchange rate changes are to be analyzed effectively, some account must be taken of the effect of monetary policy on domestic price and output levels. Ideally, one would also like to specify the impacts of special drawing rights (SDRs) and other international money on national money supplies and price levels.
3. Minimum international linkage should include trade flows and trade prices, with capital flows left out only because of data limitations and the requirement that the model should be as small as possible.

4. SPECIFIC SUGGESTIONS FOR MODEL CHANGES

I shall start with changes that are either very easy to make or are likely to make a substantial improvement in relation to the effort or equations required.

1. The trade-weighted vector of foreign prices used to explain each country's import prices should use foreign export prices instead of consumer prices and, most important, should specifically include export prices from countries outside the industrial group of twelve, using the appropriate import weights in each case. The estimation of export price equations will facilitate the first step above, and will permit the estimation of feedbacks from exchange rate changes to export prices, or will at least permit the easy application of alternative pass-through assumptions.

2. The present likely overestimation of the effect of import prices in the consumer price equations should be guarded against by explaining the GNP deflator in terms of normal unit labor costs, monetary influences, capacity utilization, and world export prices (to include the possible influence of foreign prices on the domestic value added in tradable goods). The consumer price would then be explained by an appropriately weighted composite of the GNP deflator and the import price.

The following are more extensive revisions, proposed still with an eye to parsimony of structure:

3. Either replace the unemployment rate equations by separate employment and labor force equations, or else redefine the unemployment rate series to remove the variance induced by unusual shifts in the labor force population or in other exogenous factors influencing the measured number of unemployed persons.
4. Add import equations based on output, capacity utilization, and trade prices.
5. If the model is extended further, it would be necessary to develop expenditure equations for the main final demand components, including monetary influences acting directly or through interest rates. If the latter, then a money demand equation is also needed. Exports could be explained as a weighted sum of fractions of other countries' imports, using a trade share matrix based on exogenous or endogenous shares determined by one of the procedures developed in connection with the Project LINK system. If the linkage were further extended to include capital flows, then, but only then, the exchange rates themselves could be made endogenous. At this point, however, the model would begin to resemble an expanded Project LINK system more than a simple structural model of the world economy.

To continue my list any further would impose too much on the principle of model simplicity, overextend an already long commentary, and move too far afield from Kwack's existing model. Perhaps the correct moral to draw is that a structurally accurate model of international inflation must be inherently complex if it is to capture any substantial part of the interplay of raw materials prices and supplies, monetary and exchange market conditions, real supply and demand in national economies, and the roles of trade, capital, and migration movements in the creation and transmission of international inflation.