II

An International Macroeconomic Framework

3

Building a Multicountry Empirical Structure

Using the single-country model of the United States in Chapter 2 as a foundation, this chapter builds a rational expectations econometric model of the G-7 countries: Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States. Central to the multicountry model is a theory of the link between aggregate demand and production based on the staggered wage- and price-setting framework that is also central to the single-country model. Because a significant number of wage decisions are made in the spring and early summer in one of the G-7 countries, Japan, it is necessary to generalize that framework to allow some wages to be set in a synchronized fashion.

The single-country model offers a rudimentary description of aggregate spending and financial markets. Hence, that model cannot be used to evaluate the appropriate mix of fiscal policy and monetary policy or the choice of an exchange-rate policy. These limitations are removed in this chapter. As described below, the multicountry model disaggregates consumption, investment, import, and export decisions and explicitly shows how these depend on estimates of future income prospects, expected sales, real interest rates, and exchange rates. Interest rates and exchange rates are determined in a worldwide capital market in which capital flows freely between countries.

3.1 An Overview: Key Features of the Model

The seven-country model consists of ninety-eight stochastic equations and a number of identities. The parameters of the model are estimated by using quarterly data over a period that includes the worldwide recessions of the

1970s and early 1980s and part of the long expansion that ended in the early 1990s. The variables used in the model are listed in Box 3-1. No attempt is made to review the behavior of the time-series data here, although it should be emphasized that the model was formulated with these data series in mind, and as will be shown below, the equations fit the data very well. An easy-to-use data bank with all the series in the model is available on diskette for use with standard graphing and statistical packages. (See Appendix 1.) This makes it very easy to get a broad overview of the properties of the data in any country, if desired.

On an equations-per-country basis, this is not a large model in comparison with other econometric models, and the structure of the model is fairly easy to understand. Most of the assumptions of the model—financial capital mobility, sticky wages and prices, rational expectations, consumption smoothing, slowly adjusting import prices and import demands—have been discussed widely in the international economics or macroeconomic literature during the last ten years. The model is not a "black box" in which only the builders of the model know what is going on inside. Nevertheless, a rational expectations model with around 100 equations is technically difficult to solve and analyze and therefore, gaining an intuitive understanding of its properties requires a little work.

In attempting to gain such an understanding, it is helpful to stress several key features of the model. These assumptions all have sound economic rationales, although they are still the subject of continuing research and debate.

1. *An explicit microeconomic model of wage setting generates sticky aggregate nominal wages and prices.* As already mentioned, the specific model of nominal-wage determination is the staggered wage-setting model introduced in Chapter 2. Staggered wage-setting equations are estimated for each of the seven countries separately, and the properties of these equations differ from country to country. Wages adjust most quickly in Japan and most slowly in the United States. A significant fraction of wage setting is synchronized in Japan.

In all countries, prices are set as a markup over wage costs and imported input costs; however, the markup varies over time because prices do not adjust instantaneously to changes in either wage costs or other input costs. Moreover, import prices and export prices adjust with a lag to changes in domestic prices and to foreign prices denominated in domestic currency units. Because of these lags (and because of imperfect mobility of real goods and physical capital), purchasing-power parity does not hold in the short run. The lags and the short-run elasticities in these equations differ from country to country. Throughout the model, however, long-run neutrality conditions hold. All real variables are unaffected in the long run—after prices and wages have fully adjusted—by a permanent change in the money supply. There are a total of twenty-eight stochastic equations describing wage and price behavior, and these are discussed in Sections 3.2, 3.3, and 3.4.

Box 3-1 Key Variables in Each Country

Financial Variables

RS	short-term interest rate (the federal funds rate for the United States, the call-money rate for Canada, France, Germany, Japan, and the United Kingdom, and the 6-month treasury bill rate for Italy)
RL	long-term interest rate (long-term government bonds)
RRL	real interest rate (defined as *RL* less the expected percentage change in the GNP deflator over the next four quarters)
Ei	exchange rates (U.S. cents per unit of foreign currency) *E*1: Canada, *E*2: France, *E*3: Germany, *E*4: Italy, *E*5: Japan, *E*6: U.K.
M	money supply (billions of local currency units, *M*1 definition)

Real GNP (or GDP) and Spending Components

The variables are measured in billions of local currency units; base years are 1982 for the United States, 1981 for Canada, 1970 for France and Italy, 1980 for Germany, Japan, and the United Kingdom.

Y	real GNP (or GDP for France, Italy, and the United Kingdom)
C	consumption (total)
CD	durable consumption
CS	services consumption
CN	nondurables consumption
INS	nonresidential structures investment
INE	nonresidential equipment investment
IR	residential investment
II	inventory investment
IF	fixed investment (total)
IN	nonresidential investment (total)
IR	residential investment (total)
EX	exports in income-expenditure identity
IM	imports in income-expenditure identity
G	government purchases of goods and services

Variables Relating to GNP

YP	permanent income, a weighted sum of *Y* over eight future quarters
YW	weighted foreign output (of the other six countries)
YT	trend or potential output
T	time trend ($T = 1$ in 1971:1)
YG	percentage gap between real GNP and trend GNP

Wages and Prices

W	average wage rate
X	"contract" wage rate (constructed from average wage index)
P	GNP (or GDP) deflator
PIM	import-price deflator
PEX	export-price deflator
PW	trade-weighted foreign price (foreign currency units)
EW	trade-weighted exchange rate (foreign currency/domestic currency)
FP	trade-weighted foreign price (domestic currency units)

2. *Both the supply side and the demand side matter: shocks to aggregate demand affect production in the short run; if the shocks do not continue, production eventually returns to a growing long-run aggregate supply identified with potential GNP.* With aggregate wages and prices that are sticky in the short run, changes in monetary policy affect real-money balances and aggregate demand and thereby affect real output and employment. Aggregate demand is disaggregated into consumption (durables, nondurables, and services), investment (residential and nonresidential), exports, imports, and government purchases. Both consumption demand and investment demand are determined according to forward-looking models in which consumers attempt to forecast future income and firms attempt to forecast future sales. The demand for investment and consumer durables is affected by the real interest rate with rational expectations of inflation. Export and import demand respond to both relative price differentials between countries and income. For all components of private demand (consumption, investment, net exports), there are lagged responses to the relevant variables. There are a total of fifty stochastic equations devoted to explaining aggregate demand, and these are discussed in Sections 3.7, 3.8, 3.9, and 3.10.

3. *Financial capital is perfectly mobile across countries, as if there were one world capital market; however, time-varying "risk premia" exist for both foreign exchange and long-term bonds.* In particular, it is assumed that the interest-rate differential between any two countries is equal to the expected rate of depreciation between the two currencies plus a random term that may reflect a risk premium or some other factor affecting exchange rates.[1] The risk premia are modeled and estimated. In policy simulations, they are treated as serially correlated random variables with the same statistical properties as was observed during the sample period. Similarly, the long-term interest rate in each country is assumed to equal the expected average of future short-term interest rates plus a term that reflects a risk premium. This risk-premium term is also treated as a random variable. The monetary authorities in each country are assumed to set the short-term interest rate. They do this according to a "policy rule" that may depend on prices, output, or exchange rates.[2] There are a total of twenty stochastic equations explaining interest rates and exchange rates in the financial sector. These are discussed in Sections 3.5, 3.6, and 3.11.

4. *Expectations are assumed to be rational.* This assumption almost goes without saying, but expectations play a much bigger role in an international model than they do in a single-country model. The rational expectations

[1]It should be emphasized that "risk premium" is not the only interpretation of this term. Miller and Williamson (1988) refer to a similar term as a "fad."

[2]This chapter reports the money-demand equation in which the short-term interest rate appears. When solving the model, that equation is either inverted to get a policy rule for the interest rate or another interest-rate rule is used in simulation. Interest-rate targeting may lead to an indeterminate price level in rational expectations models. However, indeterminacy of the price level is avoided as long as the interest-rate rule pins down some nominal variable, as it does for all policy rules considered in this research. See McCallum (1983).

assumption is appropriate for examining issues such as the choice of an international monetary regime, which, one would hope, would remain in place for a relatively long period of time. It should be emphasized, however, that a rational expectations approach does not mean perfect foresight. As described below, all equations of the model undergo stochastic shocks that cannot be fully anticipated as well as expectations of future variables. For example, the investment and consumption equations feature expectations of future prices, incomes, and sales; the wage equations contain expectations of future wages and demand conditions; the term structure relations have expectations of future interest rates. Forecasts of the future are not perfect, and sometimes the errors can be quite large. Nevertheless, over the long run, the errors average out to zero.

Under the rational expectations assumption, these equations must be estimated either with full information methods that take account of the cross-equation restrictions imposed by the full model or with limited information methods. With a model of this size, it is a huge computational task—requiring supercomputing speeds—to obtain full-information estimates. Unlike what we saw in the preceding chapter, the estimation procedures in this chapter are single-equations oriented: they include two-stage least squares, the generalized method of moments, and a maximum-likelihood method in which many equations in the model are approximated by a linear autoregressive system. These estimates are consistent, but in general, they are not efficient. They are not as useful as the full information methods for testing and measuring the goodness of fit of the model.[3]

Although the equations are estimated by using single-equation techniques, once the parameter estimates are obtained, the model is simulated using systemwide solution techniques. This imposes constraints similar to the explicit cross-equation constraints on Chapter 2, although in this computer-intensive nonlinear model, the constraints are less visible. They cannot be written down with algebra.

3.2 Wage Determination: Synchronized and Staggered Wage Setting

Wages are determined in the model according to the staggered wage-setting approach described in Chapter 2. The wage-setting equation (2.1) is repeated below as Equation (3.1) in modified form with a change in notation necessary to represent many variables and countries:

$$\begin{aligned} LX_i = {} & \pi_{i0} LW_i + \pi_{i1} LW_i(+1) + \pi_{i2} LW_i(+2) + \pi_{i3} LW_i(+3) \\ & + \alpha_i(\pi_{i0} YG_i + \pi_{i1} YG_i(+1) + \pi_{i2} YG_i(+2) + \pi_{i3} YG_i(+3)), \end{aligned} \tag{3.1}$$

[3]Recent research reported in Fair and Taylor (1990) is concerned with finding approximate maximum-likelihood estimates that are computationally feasible.

Box 3-2 Ninety-Eight Stochastic Relationships

The subscripts indicate the country (0 = United States, 1 = Canada, 2 = France, 3 = Germany, 4 = Italy, 5 = Japan, and 6 = the United Kingdom). *Expectations* of future variables are indicated by a *positive* number in parentheses. Lagged variables are indicated by a *negative* number in parentheses. An "*L*" indicates a logarithm. The shocks to the equations are assumed to be serially uncorrelated unless otherwise indicated.

Ex Ante Interest-Rate Parity

$LE_i = LE_i(+1) + .25 * (RS_i - RS) + U_{ei}$
$U_{ei} = \rho_e U_{ei}(-1) + V_{ei}$

Term Structure

$RL_i = b_{i0} + (1 - b_i) \Rightarrow (1 - b_i^9) \sum_{s=0}^{8} b_i^s RS_i(+s)$

Consumption

$CX_i = c_{i0} + c_{i1} CX_i(-1) + c_{i2} YP_i + c_{i3} RRL_i$, where
$CX_i = CD_i, CN_i, CS_i$ for the United States, Canada, France, Japan, and the United Kingdom and
$CX_i = C_i$ for Germany and Italy.

Fixed Investment

$IX_i = d_{i0} + d_{i1} IX_i(-1) + d_{i2} YP_i + d_{i3} RRL_i$, where
$IX_i = INE_0, INS_0, IR_0$ in the United States ($i = 0$)
$IX_i = IN_i, IR_i$ in France, Japan, and the United Kingdom and
$IX_i = IF_i$ in Canada, Germany, and Italy

Inventory Investment

$II_i = e_{i0} + e_{i1} II_i(-1) + e_{i2} Y_i + e_{i3} Y_i(-1) + e_{i4} RRL_i$

where LX is the log of the contract wage, LW is the log of the average wage, and YG is the output gap (a measure of excess demand). Consider the notation carefully. A positive number in parenthesis after a variable represents the *expectation* of the variable over that number of periods in the future. For example, $LW(+3)$ is the *expectation* of the log of the average wage *three quarters ahead.* All expectations are conditional on information through the current quarter. Negative numbers in parentheses represent lags. The subscripts indicate each of the seven different countries. Also, *the error term in Equation (3.1) is suppressed in the notation, although it is part of the model.* Only when error terms are serially correlated are they shown explicitly in this chapter. Following Equation (2.2) of Chapter 2, the aggregate wage is given by the equation

$$LW_i = \pi_{i0} LX_i + \pi_{i1} LX_i(-1) + \pi_{i2} LX_i(-2) + \pi_{i3} LX_i(-3).$$

For ease of reference, Box 3-2 summarizes the equations of the model.

Box 3-2 (Continued)

Real Exports

$LEX_i = f_{i0} + f_{i1}LEX_i(-1) + f_{i2}(LPEX_i - LPIM_i) + f_{i3}LYW_i$

Real Imports

$LIM_i = g_{i0} + g_{i1}LIM_i(-1) + g_{i2}(LPIM_i - LP_i) + g_{i3}LY_i$

Wage Determination

$$LX_i = \pi_{i0}LW_i + \pi_{i1}LW_i(+1) + \pi_{i2}LW_i(+2) + \pi_{i3}LW_i(+3) + \alpha_i(\pi_{i0}YG_i + \pi_{i1}YG_i(+1) + \pi_{i2}YG_i(+2) + \pi_{i3}YG_i(+3),$$

where

$LW_i = \pi_{i0}LX_i + \pi_{i1}LX_i(-1) + \pi_{i2}LX_i(-2) + \pi_{i3}LX_i(-3)$

(π-weights vary by quarter in Japan)

Aggregate Price

$LP_i = h_{i0} + h_{i1}LP_i(-1) + h_{i2}LW_i + h_{i3}LPIM_i(-1) + h_{i5}T + U_{pi}$

$U_{pi} = \rho_{pi}U_{pi}(-1) + V_{pi}$

with $h_{i1} + h_{i2} + h_{i3} = 1$

Import Price

$LPIM_i = k_{i0} + k_{i1}LPIM_i(-1) + k_{i2}LFP_i + U_{mi}$

$U_{mi} = \rho_{mi}U_{mi}(-1) + V_{mi}$

with $k_{i1} + k_{i2} = 1$

Export Price

$LPEX_i = \beta_{i0} + \beta_{i1}LPEX_i(-1) + \beta_{i2}LP_i + \beta_{i3}LFP_i + \beta_{i4}T + U_{xi}$

$U_{xi} = \rho_{xi}U_{xi}(-1) + V_{xi}$

with $\beta_{i1} + \beta_{i2} + \beta_{i3} = 1$

Money Demand

$L(M_i \Rightarrow P_i) = a_{i0} + a_{i1}L(M_i(-1) \Rightarrow P_i(-1)) + a_{i2}RS_i + a_{i3}LY_i$

Some modification of the π-coefficients is required for the multicountry model because a significant amount of wage setting in Japan is synchronized during the spring quarter when the Shunto (spring wage offensive) occurs. The parameter a_{jt} in Equation (2.4) is the fraction of workers in the labor force in quarter t who have contracts of length j. Thus, a_{4t} measures the fraction of workers who sign contracts four quarters in length (annual contracts). If all contracts are annual and if there is *complete* synchronization of annual wage contracts with *all* wage changes occurring in the second (spring) quarter, then $a_{1t} = a_{2t} = a_{3t} = 0$ for all t and a_{4t} would equal 1 in the second quarter of each year and 0 in the other three quarters. This would imply that the π-weights would have a seasonal pattern: in the second quarter of each year π_0 would equal 1 and $\pi_1 = \pi_2 = \pi_3 = 0$, implying that $LW = LX$ in the second quarter when the wage is changed. In the third quarter, $LW = LX(-1)$, so that $\pi_1 = 1$, with the other π-weights equal to zero. In the fourth quarter, $LW = LX(-2)$, so that $\pi_2 = 1$, with the other π-weights equal to zero. In the first quarter $LW = LX(-3)$, so that $\pi_3 = 1$.

The contract-wage determination Equation (3.1) would have a similar seasonal pattern. In the second quarter, the contract wage $LX = LW + \alpha YG$, which implies that the expected value of YG was equal to zero. Wages would adjust in the second quarter, so that excess demand, as measured by the output gap YG, would be expected to be zero. In this sense, full synchronization would reduce the business-cycle persistence of output fluctuations; in the second quarter of each year, real output would bounce back to the full employment level. Hence, output fluctuations would last at most one year.

Of course, even in the Japanese economy, not all workers have wage adjustments in the second quarter. Some of the annual wage changes in the annual Shunto actually occur in the summer quarter. Moreover, not all annual wage contracts are adjusted as part of the Shunto, and wages for some workers change more frequently than once per year.

To allow for these possibilities, I estimate a seasonal pattern for the a_{4t} in Japan, but I do not impose the assumption that $a_1 = a_2 = 0$. These fractions are assumed to be fixed non-zero constants in each quarter. I assume in the multicountry model that there are no three-quarter contracts ($a_3 = 0$) either in Japan or in the other countries. Making the necessary changes to Equations (2.8) through (2.11), the π-weights are then given by

$$
\begin{aligned}
\pi_{0i} &= a_1 + a_2/2 + a_{4i-3} \\
\pi_{1i} &= a_2/2 + a_{4i} \\
\pi_{2i} &= a_{4i-1} \\
\pi_{3i} &= a_{4i-2},
\end{aligned}
$$

where the index i runs from the first quarter to the fourth quarter and a_{4i} has a seasonal pattern. For all countries except Japan, I assume that $a_{4i} = a_4$ for all i so that there is no synchronization. The remainder of the π-weights are assumed to be zero in the multicountry model. (Note that in the single-country model of Chapter 2 there are non-zero π-weights for contracts up to eight quarters in length. But for contracts longer than four quarters, the weights are very small.)

The π-weights were estimated with data on average wages in Japan that *excluded* the bonus payments (overtime is included in the wage measure but this is a fairly small percentage on average). If the Shunto is an important element in the overall Japanese economy, then we would expect to estimate a value for a_{42} that is high (though not as high as 1) and a relatively low value for the other a's.

The Estimation Procedure and Results

In Chapter 2, I estimated Equation (2.1) by using full-information maximum likelihood as part of the linear closed-economy model of the United

States. Because of the large size of the multicountry model, a simpler approach is taken here to estimate Equation (3.1).[4] An alternative scaled-down method is used, in which a simple autoregressive model approximates the relationship between wages and demand—the "aggregate-demand" equation—in each country. In other words, rather than estimate an entire aggregate-demand model jointly with the wage equation, a single reduced-form relation between wages and output is estimated jointly with the wage equation. In this reduced form, real GNP as a deviation from trend is assumed to depend on its own two lags and on the deviation of the average wage from a linear trend during the sample period 1973:1–1986:4. (There is a break in the trend as described below.) Several variations on this same autoregressive equation were tried, but the following, relatively simple, time-series model was able to describe the data very well. "Aggregate demand" for each country is given by

$$YG = \beta_1 YG(-1) + \beta_2 YG(-2) + \beta_3 LW(-1)$$

plus a serially uncorrelated disturbance. The parameters of this equation were estimated jointly with Equation (3.1) by using maximum likelihood.[5]

The estimation results for the synchronized case for Japan and the non-synchronized case for the other countries (United States, Canada, France, Germany, Italy, and the United Kingdom) are shown in Tables 3-1, 3-2, and 3-3.[6] Table 3-1 reports the estimates of Equation (3.1) along with the corresponding distribution of workers by contract length. Table 3-2 reports the results for the synchronized estimates in Japan. Table 3-3 reports the results for the autoregressive aggregate-demand equation. The maximum-

[4]An even simpler approach—the instrumental variable approach, whereby the four future expected wages and four future expected output terms are replaced by their actual values and two-stage least squares or Hansen's generalized method of moments (GMM) estimator is applied—turned out to give values for the sensitivity parameter that were the wrong sign. In other words, high expected future output would lead to lower wages, a property that neither makes economic sense nor is compatible with the model being stable. Timing of expectations in the staggered wage-setting model is important for the implied behavior of wages. Effectively, average wages today depend on expected past, current, and future wages, with a whole-term structure of viewpoint dates. Replacing the expected values with their actuals—as in the Hansen method—ignores these different viewpoint dates, and it is likely that this is the source of the problem with these limited information methods as applied to this model.

[5]Evaluation of the likelihood function is straightforward once the model is solved. Since the two-equation model is linear in the variables, the model can be solved by using methods like those in Chapter 2. For the estimates reported here, the model was solved by the factorization method of Dagli and Taylor (1984). Because the initial values of the contract wages are unobservable and figure into the calculation of the likelihood function, these values were estimated along with the other coefficients.

[6]The reporting conventions in this table and in all the following tables in this chapter are as follows: *SE* represents the standard error of the equation, *DW* is the Durbin-Watson statistic, and sample indicates first and last quarter. Standard errors are reported in parentheses. Fits of the equations are generally very good and unless otherwise indicated, the R^2 for the "non-detrended" variables are above .99.

TABLE 3-1 The Wage Equations

	Canada	*France*	*Germany*	*Italy*	*Japan*	*U.K.*	*U.S.*
α	0.0541	0.0368	0.0393	0.1084	0.2965	0.0528	0.0298
	(.043)	(.012)	(.025)	(.091)	(.111)	(.031)	(.011)
$\pi(0)$	0.4499	0.5117	0.5024	0.4991	*	0.5272	0.3270
$\pi(1)$	0.3173	0.2883	0.2892	0.3009	*	0.2728	0.2744
	(.033)	(.024)	(.029)	(.028)		(.029)	(.015)
$\pi(2)$	0.1164	0.1000	0.1042	0.1000	*	0.1000	0.1993
	(.045)		(.045)				(.013)
$\pi(3)$	0.1164	0.1000	0.1042	0.1000	*	0.1000	0.1993
% annual	46.6	40.0	41.7	40.0	87.5	40.0	79.7
% semi-annual	40.2	37.7	37.0	40.2	0.7	34.6	15.0
% quarter	13.3	22.4	21.3	19.8	11.8	25.4	5.3
SE	.0091	.0083	.0061	.0167	.0157	.0159	.0027
DW	1.9	1.7	2.1	.9	1.9	1.9	1.3
Sample	76.4	71.4	71.4	71.4	71.4	71.4	71.4
	86.4	86.2	86.3	86.3	86.3	86.3	86.4
Target shift	82.4	81.3	77.3	82.3	76.3	81.2	83.1
Initial Conditions							
$LX(-1)$	−0.4684	−1.2406	−0.7687	−1.3675	−0.8793	−1.3188	−0.4541
$LX(-2)$	−0.3628	−1.2491	−0.5475	−1.6123	−1.1033	−1.3935	−0.4031
$LX(-3)$	−0.2811	−1.1870	−0.6528	−1.7719	−1.0157	−1.3128	−0.3821

* Japanese estimates of π's by quarter allowing for synchronization are shown in Table 3-2.
Note: All equations were estimated with maximum likelihood. In France, Italy, and the United Kingdom, the number of annual contracts was constrained to equal 40 percent, which is not significantly different from the unconstrained likelihood for these countries. The target shift is the quarter in which it is assumed that the central banks reduce their "target" for wage inflation. Using the formula that relates the percentage of contracts to the weights, the standard error of the estimated percent annual contracts can be calculated. These standard errors of the percent annual contracts are 5.2 percentage points for the United States, 18.2 percentage points for Canada, and 16.6 percentage points for Germany.

likelihood approach generally gives sensible results for contract-length distributions. The equations fit the data well with relatively small standard errors.[7]

Focusing first on Japan, the estimates indicate that aggregate wages behave as if roughly 88 percent of wage contracts in Japan were adjusted

[7]For France, Italy, and the United Kingdom, the fully unconstrained maximum-likelihood estimates resulted in weights on the contract wages that declined very rapidly and implied an unrealistic distribution of contracts. For these three countries, I chose a contract-wage distribution close to that of Germany and that is not statistically different from the maximum-likelihood estimate for each of the other three countries. This distribution entails 40 percent annual contracts in France, Italy, and the United Kingdom. With this exception, all the other estimates in Tables 3-1, 3-2, and 3-3 are the maximum-likelihood estimates.

Table 3-2 Estimated Wage Coefficients for Japan

	Quarter			
	I	*II*	*III*	*IV*
$\pi(0)$	0.1533	0.5414	0.3857	0.2815
$\pi(1)$	0.1633	0.0351	0.4232	0.2675
$\pi(2)$	0.2638	0.1597	0.0314	0.4196
$\pi(3)$	0.4196	0.2638	0.1597	0.0314
% of workers changing wages in quarter (a_{4i})				
	3	42	26	16

annually, 12 percent were adjusted every quarter, and a negligible amount were adjusted every two quarters. The effect of the Shunto shows up clearly in the seasonal π-coefficients, which have the same general form as in the extreme case where all contracts are adjusted in the spring quarter. However, because some workers have more frequent wage adjustment, and because not all annual wage adjustments occur in the spring quarter, the coefficients do not have the exact 0-1 pattern. According to these estimates, aggregate wages in Japan adjust as if 42 percent of workers have their wages changed each spring, 26 percent each summer, 16 percent each fall, and 3 percent each winter. This general pattern is what one would expect from the Shunto system. About 77 percent of workers who have their wages adjusted annually receive the adjustments in the spring or summer quarters.

As already discussed, such synchronization would make aggregate wages appear more flexible in the sense that the aggregate wage would quickly adjust to eliminate excess demand or supply and that cyclical fluctuations would be short-lived. This greater aggregate wage flexibility with synchronization compared with nonsynchronization would occur even if the adjustment parameter α were the same.

Now compare these estimates with those in the other countries where it is assumed that wage setting is nonsynchronized, so that the coefficients do not have a seasonal pattern. The coefficients for the other countries indicate that annual contracts are the most common length of contract. Wages in the United States behave as if about 80 percent of workers have annual contracts. The fraction is smaller in all the other countries except

Table 3-3 Auxiliary Autoregressions for Aggregate Demand

The dependent variable is *YG*. The autoregressions were used to obtain estimates of the wage equation using a maximum-likelihood technique described in the text. The equations are *not* part of the multicountry model.

	Canada	*France*	*Germany*	*Italy*	*Japan*	*U.K.*	*U.S.*
$YG(-1)$	1.14	1.26	0.64	0.96	1.05	0.80	1.24
$YG(-2)$	−0.33	−0.33	−0.13	−0.14	−0.25	−0.02	−0.40
$LW(-1)$	−0.17	−0.03	−0.30	−0.05	−0.06	−0.05	−0.20

Japan. Although we know that some wage contracts, especially in the United States, Canada, and Italy, extend for more than one year, indexing in these longer contracts usually calls for adjustment in the second and third year. They therefore appear like a series of annual contracts.

It is important to note that the adjustment parameter is not the same in the different countries. In particular, the adjustment coefficient in Japan is much greater than in the other countries. As shown in the first row of Table 3-1 the Japanese coefficient is about 6 times greater than the average adjustment coefficient in the other countries. Even if the estimated equations showed no synchronization in Japan, the contract wages would adjust more quickly than in other countries. It appears, therefore, that a significant part of the high aggregate-wage responsiveness in Japan is not due to synchronization per se. Some other factor must be at work. Perhaps the Shunto bargaining process itself makes the individual wage adjustments at each date more responsive to demand and supply conditions. As part of the annual discussions between unions, firms, and the government, the rationale for wage changes given alternative forecasts for the aggregate economy could lead to a more flexible wage-adjustment process.

Note in Table 3-3 that for all the countries, the aggregate-demand equations have a negative coefficient on the average wage. The coefficient is relatively large in the United States, Canada, and Germany and relatively small in France, Italy, Japan, and the United Kingdom. This negative coefficient is important, for it ensures that the two-equation model is stable and has a unique rational expectations solution. It corresponds to the aggregate-demand curve (with the nominal wage rather than the price on the vertical axis) being downward sloping: when the nominal wage rises, real output falls. This negative effect is influenced by monetary policy and reflects how accommodative the central bank is to inflation. High absolute values of this coefficient represent less accommodative policies.

In interpreting these aggregate demand equations, it is important to note that the implicit target rate of wage inflation is assumed to have shifted down in the late 1970s or early 1980s. The exact date is shown in Table 3-1. The date was chosen to match as closely as possible the marked and visible break in the time series for wage inflation in each country. In other words, after the shift in the target rate of wage inflation, it is assumed that the central banks are not willing to tolerate as high a rate of inflation. According to the estimates in Table 3-1, Japan was the first of the seven countries to shift down its implicit inflation target.

3.3 Aggregate-Price Adjustment

Markup pricing underlies the aggregate-price equations. Prices are assumed to be set as a markup over wages and other costs. However, the markup is not a fixed constant. Higher import prices (in domestic currency units) increase the costs of inputs to production and raise the markup over wage costs. It is through this effect that depreciations of the currency have direct inflationary consequences in the depreciating country, and deflationary effects abroad. For each country i the price behavior is shown in Equation (3.2).

$$
\begin{aligned}
LP_i &= h_{i0} + h_{i1} LP_i(-1) + h_{i2} LW_i + h_{i3} LPIM_i(-1) + h_{i5} T + U_{pi} \\
U_{pi} &= \rho_{pi} U_{pi}(-1) + V_{pi} \\
&\text{with } h_{i1} + h_{i2} + h_{i3} = 1,
\end{aligned} \tag{3.2}
$$

where LP is the log of the aggregate price, LW is the log of the aggregate wage, $LPIM$ is the log of the import-price index, and T is a time trend. The lagged dependent variable is entered to capture slow adjustment of output prices to changes in costs. The relative importance of this lag and the relative importance of wages and import prices were estimated separately for each country. Homogeneity conditions were imposed on the price equations, in the sense that a 1-percent increase in both wages and import prices eventually leads to a 1-percent increase in output prices. (This condition was imposed during estimation by subtracting the lagged value of the dependent variable from the wage, the import price, and the dependent variable itself.)[8]

The details of the final estimated aggregate-price equations are shown in Table 3-4. Positive serial correlation was found in all countries except Germany and was corrected with a first-order autoregressive process. The negative coefficient on the time trend primarily reflects secular increases in the real wage, although trends in the import price may also affect that coefficient. The coefficient on the time trend is smallest for the United States, reflecting the poorer performance of real wages in the United States compared with the other countries. The effect of import prices on domestic prices is typically positive and significant. The large estimated coefficients on the lagged output price terms in each equation as well as the serially correlated errors indicate that there are large and persistent deviations from fixed markup pricing in practice. Higher wage or input costs translate into higher prices, but their full effect is not felt immediately. This is important for the policy analysis of later chapters: these equations imply that temporary appreciations or depreciations of the currency do not have a large impact on domestic prices in the short run.

3.4 Import and Export Prices

Imports into each country depend in part on the price of imports relative to the price of domestically produced goods. Similarly, exports from a country depend in part on the price of those exports compared with prices of

[8]In estimating each equation, the output gap was also entered as a variable. However, the effect was found to be quite small or insignificant and in the end was omitted from each equation.

Table 3-4 Aggregate Price Equations

The dependent variable is the log of the aggregate price *LP*, and the functional form is shown in Equation (3.2). For all countries except Germany, the equation was estimated with a first-order autoregressive error.

Country	*Constant*	*LP*(−1)	*LW*	*LPIM*(−1)	*T*	ρ	*SE*	*DW*
U.S.	−0.163	0.518	0.455	0.027	−0.016	0.57	0.003	2.1
	(0.039)	(0.089)	(0.091)	(0.007)	(0.007)			
Canada	0.089	0.874	0.100	0.026	−0.034	0.69	0.007	2.4
	(0.046)	(0.071)	(0.071)	(0.017)	(0.024)			
France	0.147	0.862	0.102	0.036	−0.077	0.26	0.006	2.0
	(0.038)	(0.027)	(0.032)	(0.017)	(0.024)			
Germany	0.085	0.848	0.132	0.019	−0.074	—	0.007	2.5
	(0.045)	(0.075)	(0.063)	(0.015)	(0.030)			
Italy	0.210	0.856	0.111	0.033	−0.086	0.33	0.009	2.0
	(0.072)	(0.029)	(0.042)	(0.022)	(0.032)			
Japan	0.033	0.932	0.053	0.015	−0.046	0.85	0.007	2.3
	(0.019)	(0.053)	(0.053)	(0.016)	(0.047)			
U.K.	0.037	0.752	0.160	0.088	−0.072	0.65	0.010	2.2
	(0.010)	(0.067)	(0.072)	(0.029)	(0.033)			

Notes:

1. For Germany and Canada, *LFP*(−1) replaces *LPIM*(−1).
2. The *T*-coefficients are .01 times those shown.
3. The sample is 71.2 to 86.3 for all countries except the United States (86.4) and France (86.2).
4. For Canada, Italy, and Japan, the time-trend coefficient was computed by including the trend in the real wage in the right-hand side wage variable.

competitive goods produced abroad. In order to have a complete model, we therefore need to describe the behavior of export prices and import prices.

Import Prices

Import prices are assumed to be related to an average of foreign prices translated into domestic currency units using the exchange rate. Consider, for example, the price of U.S. imports from Japan. The price of Japanese goods denominated in dollars equals P_5E_5. This price will tend to rise if the price of goods produced in Japan (P_5) rises or if the dollar exchange rate (E_5) depreciates. However, in a multicountry setting we must consider the price of general U.S. imports, not only those from Japan. The appropriate variable is thus a weighted average of foreign prices denominated in dollars, P_iE_i for $i = 1, \ldots, 6$, or in the currency of the other six G-7 countries. We call this weighted average FP_0 for the United States. Similar weighted averages can be computed for other countries. For each country, the theory is that the price of imports into the country PIM_i depends on the weighted average

Table 3-5 Import-Price Equations

The dependent variable is the log of the import price (*LPIM*), and the functional form is shown in Equation (3.3).

Country	*Constant*	*LPIM*(−1)	*LFP*	ρ	*SE*	*DW*	*Sample*
U.S.	−0.284	0.894	0.106	0.59	0.023	1.9	71.2
	(0.118)	(0.042)	(0.042)				86.2
Canada	0.296	0.894	0.106	0.74	0.016	2.2	71.2
	(0.008)						86.2
France	1.243	0.318	0.682	0.99	0.026	1.9	71.2
	(0.288)	(0.078)	(0.078)				86.2
Germany	0.422	0.820	0.180	0.83	0.020	2.2	71.2
	(0.160)	(0.069)	(0.069)				86.2
Italy	−1.241	0.581	0.419	0.91	0.027	1.6	71.2
	(0.268)	(0.088)	(0.088)				86.2
Japan	−1.890	0.454	0.546	0.91	0.040	1.5	71.2
	(0.364)	(0.106)	(0.106)				86.2
U.K.	1.655	0.553	0.447	0.92	0.021	1.8	71.2
	(0.204)	(0.055)	(0.055)				86.2

Note: For Canada, the coefficients on *LPIM*(−1) and *LFP* are constrained to be equal to those in the U.S. equation.

of foreign prices in terms of that country's currency FP_i. In the long run, we assume that the effect is one-for-one. Hence, the long-run elasticity of import prices with respect to foreign prices is assumed to be unity. As has been clear in recent years, however, import prices adjust with a long lag to changes in foreign prices, especially when the change is due to exchange-rate movements. This lagged response is captured statistically through the lagged dependent variable in the regressions.[9]

To summarize, the import-price equations have the following log-linear forms for each country:

$$\begin{aligned} LPIM_i &= k_{i0} + k_{i1} LPIM_i(-1) + k_{i2} LFP_i + U_{mi} \\ U_{mi} &= \rho_{mi} U_{mi}(-1) + V_{mi} \\ \text{with } & k_{i1} + k_{i2} = 1, \end{aligned} \tag{3.3}$$

where $LPIM_i$ is the log of the import price and LFP_i is the log of the foreign price. Note that the long-run elasticity is constrained to be 1.

The details of the estimated import prices are presented in Table 3-5. The lags between changes in exchange rates (which are reflected in *LFP*)

[9]Import prices may also be affected by domestic prices, but in preliminary data analysis the effect was small and statistically insignificant and for simplicity was omitted from the final equations.

and changes in import prices seem reasonable though fairly long for the United States, where, for example, a sustained 10-percent depreciation increases import prices by 1 percent in the first quarter, by 3.4 percent after a year, and by 5 percent after two years. The adjustment speed is about the same in Germany, but it is faster in the United Kingdom, France, Italy, and Japan. (The coefficient on the lagged dependent variable for Canada was estimated to be greater than one. To insure stability of the overall model, the coefficient was set equal to that in the United States, which is already fairly close to 1.) The shocks to import prices are highly serially correlated in France. It should be emphasized that for this equation and others, we are faced with the difficulty of effectively distinguishing between serial correlation and autoregressive variables.

Export Prices

The prices of exports from each country are assumed to be related to the average price of goods produced in each country. The rationale is very similar to that for import prices. However, in the case of export prices, we found the effect of prices in the country where the goods were sold to be a significant influence in several countries. This effect was accounted for in the general function form

$$\begin{aligned} LPEX_i &= \beta_{i0} + \beta_{i1} LPEX_i(-1) + \beta_{i2} LP_i + \beta_{i3} LFP_i + \beta_{i4} T + U_{xi} \\ U_{xi} &= \rho_{xi} U_{xi}(-1) + V_{xi} \\ \text{with } & \beta_{i1} + \beta_{i2} + \beta_{i3} = 1, \end{aligned} \tag{3.4}$$

where *LPEX* is the log of the price of exports, *LP* is the log of the domestic price index, and *LFP* is the log of the foreign price index.

The estimated export-price equations are shown in Table 3-6. For the United States, the lags are slightly shorter than in the case of the import prices, but there is more serial correlation of the errors. The domestic price level is highly significant for the United States and Canada. The foreign price term is not statistically significant for the United States, Canada, or France and was omitted from the final equations. However, foreign prices are important for Japan, Germany, Italy, and the United Kingdom. The finding for the United States reflects the common observation that foreigners price to the large U.S. market and tend to absorb exchange-rate changes more than U.S. firms selling abroad. Note that the size of the foreign price term in Japan is about the same size as the domestic price term (in Italy, it is larger).

3.5 Exchange Rates and Interest Rates

Uncovered interest-rate parity states that the difference between interest rates in each pair of countries is equal to the expected change in the exchange rate between the two countries over the near future. Time-varying

TABLE 3-6 Export-Price Equations

The dependent variable is the log of the price for exports (*LPEX*), and the functional form is shown in Equation (3.4).

Country	*Constant*	*LPEX*(−1)	*LP*	*LFP*	*T*	ρ	*SE*	*DW*
U.S.	0.122	0.566	0.434	—	−0.265	0.93	0.009	1.8
	(0.050)	(0.098)	(0.098)		(0.104)			
Canada	0.111	0.411	0.589	—	−0.312	0.92	0.015	2.0
	(0.070)	(0.117)	(0.117)		(0.150)			
France	0.011	0.704	0.296	—	−0.058	0.62	0.016	2.1
	(0.014)	(0.117)	(0.117)		(0.034)			
Germany	0.170	0.798	0.143	0.059	−0.069	0.82	0.007	1.8
	(0.068)	(0.087)	(0.091)	(0.026)	(0.032)			
Italy	−1.324	0.275	0.277	0.448	−0.273	0.88	0.020	2.0
	(0.351)	(0.115)	(0.161)	(0.107)	(0.133)			
Japan	−0.918	0.287	0.386	0.327	−0.431	0.88	0.015	1.5
	(0.187)	(0.106)	(0.087)	(0.058)	(0.105)			
U.K.	0.798	0.601	0.221	0.178	−0.309	0.94	0.013	1.8
	(0.162)	(0.101)	(0.099)	(0.040)	(0.158)			

Note:
1. The *T*-coefficients are .01 times those shown.
2. The Sample is 71.1 to 86.2 for all countries.

risk premia and other factors can shift this relation. Such relations, along with possible shifts, are shown in Equation (3.5):

$$\begin{aligned} LE_i &= LE_i(+1) + .25 * (RS_i - RS_0) + U_{ei} \\ U_{ei} &= \rho_e U_{ei}(-1) + V_{ei}, \end{aligned} \tag{3.5}$$

where LE_i is the log of the exchange rate between country i and the United States and $RS_i - RS_0$ is the short-term interest rate differential between each country and the United States. The coefficient .25 occurs because the interest rates are measured at annual rates, and the expected change in the exchange rate is over one-quarter. Coefficients were not estimated, but residuals were computed as described in Chapter 4 to be used in the policy analysis. Recall that the notation indicates that the *expected value* of the log of next quarter's exchange rate appears on the right-hand side. For the seven countries there are a total of six independent exchange-rate pairs and interest-rate differentials. All six of these are written relative to the dollar. For example, the expected change in the yen/dollar exchange rate is equal to the interest-rate differential between the short-term interest rate in Japan and the short-term interest rate in the United States. All other cross-exchange rates—say between the yen and the pound—can be derived from these six pairs.

These equations are the implications of financial capital mobility. Such an assumption seems warranted for most of these countries at this time (though not for Japan and Italy in the 1970s). There are still some restrictions on capital flows, but for most of the countries, covered interest-rate parity holds very closely.

Of course in the sample period, the simple uncovered interest-rate parity equations do not fit perfectly, and the residuals are serially correlated. (The residuals must be computed with measures of the expected exchange rate. As described in Chapter 4, we compute them assuming rational expectations.) The residuals may reflect risk premia or other deviations from pure market efficiency. They may also be due to the use of quarterly averages for the interest rates and the exchange rates and to the assumption that the time interval for the expected change is one quarter. In any case, these residuals should be an important consideration in any policy evaluation that is carried out with the model. As will be described later, these estimated residuals can be used to measure the size of shifts that are likely to continue to occur from time to time in the future. The estimated distribution of these residuals is used for stochastic simulations and policy evaluation.

3.6 Term Structure of Interest Rates

The basic assumption of this model is that the standard rational expectations model of the term structure of interest rates serves as a good approximation to the relationship between short- and long-term interest rates. For simplicity, a simple linear approximation of the term structure used by Shiller (1979) was employed. The numerical parameters of this functional form should be consistent with the data in each country, and this requires that they be estimated econometrically.

The basic linear term structure relationship estimated for each country is of the form:

$$RL_i = b_{i0} + \frac{1 - b_i}{1 - b_i^9} \sum_{s=0}^{8} b_i^s RS_i(+s), \tag{3.6}$$

where RL is the long-term interest rate, and values of RS represent expected future short-term interest rates. The parameters in Equation (3.6) must be estimated.

The estimation results are shown in Table 3-7. For these equations, the two-stage least squares method was used, where the actual values of RS replace the expected future values. This estimation procedure is consistent, but the standard error of the estimate of b_i is inconsistent because of the serial correlation of the error that arises due to the forecast errors in projecting interest rates. The last eight observations are lost because the actual leads of the short-term interest rate must appear in the equation.

All the results seem plausible with the exception of Italy where coefficient b is negative. Italian capital markets were relatively restricted during the

TABLE 3-7 Term Structure of Interest Rates

The dependent variable is the long-term interest rate *RL*. The equation was estimated with nonlinear two-stage least squares with instruments $RL(-1)$, $RL(-2)$, $RS(-1)$, $RS(-2)$, $LY(-1)$, $LY(-2)$, $LFP(-1)$, $LFP(-2)$, G.

Country	*Constant*	*b*	*SE*	R^2	*DW*	*Sample*
U.S.	−0.005	0.753	0.023	0.47	0.1	71.3
	(0.003)	(0.097)				84.4
Canada	0.011	0.464	0.017	0.78	0.4	71.3
	(0.002)	(0.154)				84.4
France	0.015	0.514	0.014	0.78	0.3	71.3
	(0.002)	(0.087)				84.4
Germany	0.015	0.641	0.018	0.49	0.2	71.3
	(0.002)	(0.084)				84.4
Italy	−0.006	−0.182	0.019	0.82	0.4	71.3
	(0.003)	(0.512)				84.4
Japan	0.004	0.738	0.016	0.37	0.2	71.3
	(0.002)	(0.062)				84.4
U.K.	0.023	0.895	0.029	0.01	0.1	71.3
	(0.004)	(0.133)				84.4

sample period, so perhaps it should not be surprising that the *b*-coefficient does not reflect the term-structure model. Since this coefficient is insignificantly different from zero, it was set to zero when simulating the model. Perhaps with recent changes in financial markets in Italy, a positive value for *b* could be obtained for more recent data. The standard errors in these equations are large (for example .023 for the United States, which means 2.3 percentage points). The errors are due either to forecast errors in projecting future interest rates or risk premia. In Chapter 4, we can attempt to separate these two components.

3.7 Consumption Demand

The consumption equations are based on the rational expectations forward-looking model of consumption as discussed, for example, in Hall and Taylor (1991). The forward-looking behavior is captured empirically by constructing a measure of permanent income which depends on rational expectations of actual future income. The consumption equations also include the real interest rate, which depends on the expected rate of inflation. The equations were estimated using the generalized method of moments (GMM) estimator (described in Appendix 3A), which gives consistent estimates of the parameters as well as consistent estimates of the standard errors of the estimates.

The equations are linear in the levels of the variables. For the United States, Canada, France, Japan, and the United Kingdom, consumption was broken down into durables, nondurables, and services. The degree of disaggregation was chosen because durables are more volatile than services and more sensitive to interest rates. Nondurables tend to lie in between on these volatility and sensitivity issues. (No attempt was made to isolate the flow of services on consumer durables.) For Germany and Italy, however, only total consumption was estimated because of data availability in the OECD sources. Overall, seventeen consumption equations were estimated—three for five countries and one for two countries. The general form for the equations is shown in Equation (3.7):

$$CX_i = c_{i0} + c_{i1} CX_i(-1) + c_{i2} YP_i + c_{i3} RRL_i, \tag{3.7}$$

where CX_i becomes consumer durables CD_i, consumer nondurables CN_i, and consumer services CS_i for the United States, Canada, France, Japan, and the United Kingdom, where CX_i becomes total consumption C_i for Germany and Italy, and where YP is permanent income and RRL is the real interest rate. The permanent-income variable is defined as

$$YP_i = \sum_{s=0}^{8} (.9)^s Y_i(+s).$$

Real output is assumed to be the measure of income in each country. The real interest rate is scaled so that its absolute effect grows with the estimated trend in the real economy to prevent the real interest-rate elasticity from declining as consumption grows. Hence, the real interest-rate variable RRL is the difference between the long-term interest rate and the expected rate of inflation multiplied by the exponentially growing trend. The trend equals 1 at the start of the sample and then grows at the same rate as potential output, that is,

$$RRL_i = (RL_i - LP_i(4) + LP_i) \exp(gT),$$

where g is the growth rate of potential GNP.

The details of the estimated consumption equations and regression statistics are shown in Table 3-8 (durables), Table 3-9 (nondurables), Table 3-10 (services), and Table 3-11 (total consumption for Germany and Italy). The interest-rate semi-elasticities—the percentage change in consumption associated with a percentage-point change in the interest rate—are shown in Appendix 3B. They are highest for durables, ranging as high as 1 in France and Japan. In other words, an increase in the real interest rate of 1 percentage point lowers French and Japanese durable consumption by 1 percent after adjustment lags. The impact is about one-half as large in the United States and Germany. The real interest rate enters significantly in all the consumer durables equations that were estimated, except in the

Table 3-8 Durables Consumption

The dependent variable is *CD*. The estimation method is the GMM, and the instruments are *CD*(−1), *Y*(−1), *Y*(−2), *RL*(−1), *LP*(−1), *LP*(−2), *T*, *G*.

Country	*Constant*	*CD*(−1)	*YP*	*RRL*	*SE*	R^2	*DW*	*Sample*
U.S.	−45.4	0.698	0.040	−29.3	8.37	0.95	1.8	71.3
	(23.7)	(0.072)	(0.013)	(41.2)				84.4
Canada	−5.79	0.632	0.047	−7.53	0.79	0.97	2.1	71.3
	(1.56)	(0.054)	(0.008)	(2.74)				84.3
France	−41.6	0.344	0.079	−34.5	1.51	0.98	1.4	71.3
	(5.9)	(0.077)	(0.010)	(9.1)				80.4
Japan	−4279	0.356	0.041	−4098	284.8	0.98	1.6	71.3
	(459)	(0.065)	(0.004)	(636)				84.3
U.K.	−10.2	0.516	0.073	—	1.04	0.72	2.1	71.3
	(3.5)	(0.118)	(0.021)					84.3

United Kingdom and in the total consumption equation estimated for Germany and for Italy. The real interest rate also enters negatively in consumer nondurables in the United States, Canada, and the United Kingdom but was not found to be significant in services consumption. Overall the effect of real interest rates on consumption is an important part of its effect on aggregate demand, though the effect differs widely among the countries.

The permanent-income variable is very significant in all the equations. Recall that this variable includes *current* income and expectations of future income based on information available in the *current* period. Hence, the

Table 3-9 Nondurables Consumption in Five Countries

The dependent variable is *CN*. The estimation method is the GMM, and the instruments are *CN*(−1), *Y*(−1), *Y*(−2), *RL*(−1), *LP*(−1), *LP*(−2), *T*, *G*.

Country	*Constant*	*CN*(−1)	*YP*	*RRL*	*SE*	R^2	*DW*	*Sample*
U.S.	63.2	0.508	0.098	−24.8	4.66	0.99	1.4	71.3
	(8.4)	(0.055)	(0.012)	(13.1)				84.4
Canada	3.19	0.899	0.015	−3.27	0.67	0.99	2.2	71.3
	(0.84)	(0.037)	(0.008)	(2.24)				84.3
France	25.09	0.330	0.196	—	2.45	0.99	2.1	71.3
	(4.66)	(0.091)	(0.028)					80.4
Japan	5180	0.822	0.026	—	821.5	0.98	2.5	71.3
	(1,019)	(0.043)	(0.007)					84.3
U.K.	3.44	0.666	0.090	−5.00	0.708	0.95	1.9	71.3
	(1.57)	(0.072)	(0.020)	(2.00)				84.3

TABLE 3-10 Services Consumption in Five Countries

The dependent variable is *CS*. The estimation method is the GMM, and the instruments are *CS*(−1), *Y*(−1), *Y*(−2), *RL*(−1), *LP*(−1), *LP*(−2), *T*, *G*.

Country	*Constant*	*CS*(−1)	*YP*	*SE*	R^2	*DW*	*Sample*
U.S.	−24.1	0.906	0.038	4.08	0.99	2.7	71.3
	(4.4)	(0.011)	(0.005)				84.4
Canada	−1.2	0.912	0.026	0.449	0.99	2.2	71.3
	(1.2)	(0.037)	(0.012)				84.3
France	−31.4	0.810	0.076	1.33	0.99	2.8	71.3
	(4.9)	(0.026)	(0.010)				80.4
Japan	−1725	0.692	0.093	809.3	0.99	2.4	71.3
	(524)	(0.072)	(0.020)				84.3
U.K.	−2.8	0.913	0.032	0.433	0.99	1.8	71.3
	(1.0)	(0.027)	(0.008)				84.3

significance of this term is not a contradiction of Hall's (1978) prediction of the forward-looking model that income does not Granger-cause consumption. Note, however, that with the lagged dependent variable, the short-run impact of a change in expected permanent income is smaller than the long-run impact. (See Appendix 3B for the size of the difference.) This could reflect habit persistence or errors in our permanent-income variable. The greater volatility of durables is reflected in the relatively smaller coefficient on the lagged durables consumption compared with lagged services consumption.

3.8 Fixed Investment

Investment demand is assumed to depend on the cost of capital, as measured by the real rate of interest, and on expected future sales. The measure of expected future sales is assumed to have the same form as the measure of expected future income in the consumption equations.

TABLE 3-11 Aggregate Consumption in Germany and Italy

The dependent variable is *C*. The estimation method is the GMM, and the instruments are *C*(−1), *Y*(−1), *Y*(−2), *RL*(−1), *LP*(−1), *LP*(−2), *T*, *G*.

Country	*Constant*	*C*(−1)	*YP*	*RRL*	*SE*	R^2	*DW*	*Sample*
Germany	−34.8	0.733	0.177	−95.0	9.19	0.98	2.5	71.3
	(14.7)	(0.057)	(0.039)	(41.3)				84.3
Italy	−388	0.877	0.085	−1204	260.3	0.99	1.1	71.3
	(655)	(0.037)	(0.028)	(609)				84.3

Table 3-12 Nonresidential Equipment Investment in the United States

The dependent variable is *INE*. The estimation method is the GMM, and the instruments are *INE*(−1), *INE*(−2), *Y*(−1), *Y*(−2), *RL*(−1), *LP*(−1), *LP*(−2), *G*.

Country	*Constant*	*INE*(−1)	*YP*	*RRL*	*SE*	R^2	*DW*	*Sample*
U.S.	−73.6	0.759	0.043	−98.7	7.05	0.96	1.1	71.3
	(15.3)	(0.052)	(0.007)	(23.6)				84.4

In the United States, fixed investment is disaggregated into three components: nonresidential equipment, nonresidential structures, residential structures. Because of data availability in the OECD publications, less disaggregation occurs in the other countries. Equipment and structures are added to get total nonresidential investment in France, Japan, and the United Kingdom. All three components of investment are added to get fixed investment for Canada, Germany, and Italy. Overall, twelve fixed-investment equations were estimated. The general form for all the fixed-investment equations is as follows:

$$IX_i = d_{i0} + d_{i1} IX_i(-1) + d_{i2} YP_i + d_{i3} RRL_i, \tag{3.8}$$

where IX_i is the nonresidential equipment (INE), the nonresidential structure (INS), and the residential structures (IR) in the United States, where IX_i is the nonresidential (IN) and residential (IR) investment in France, Japan, and the United Kingdom, and where IX_i is the total fixed investment (IF) in Canada, Germany, and Italy. The variables YP and RL are as defined for consumption. The equations are linear in the levels of investment. Lagged investment enters the equations, representing either the cost of adjusting capital or the periods of time to build capital. The details of the twelve estimated equations are shown in Tables 3-12 through 3-16. The real interest rate has a negative effect on investment in all the countries and for almost all components of investment. The semi-elasticity is shown in Appendix 3B and ranges as high as 6 for U.S. nonresidential structures. Of the twelve investment equations estimated, only one did not result in a negative coefficient on the real interest rate; for this equation—French total nonresidential investment—the real interest was omitted.

Table 3-13 Nonresidential Structures Investment in the United States

The dependent variable is *INS*. The estimation method is the GMM, and the instruments are *INS*(−1), *INS*(−2), *Y*(−1), *Y*(−2), *RL*(−1), *LP*(−1), *LP*(−2), *G*.

Country	*Constant*	*INS*(−1)	*YP*	*RRL*	*SE*	R^2	*DW*	*Sample*
U.S.	−16.2	0.963	0.007	−25.0	3.72	0.95	1.2	71.3
	(6.8)	(0.026)	(0.002)	(12.2)				84.4

TABLE 3-14 Total Nonresidential Investment in Three Countries

The dependent variable is *IN*. The estimation method is the GMM, and the instruments are *IN*(−1), *IN*(−2), *Y*(−1), *Y*(−2), *RL*(−1), *LP*(−1), *LP*(−2), *G*.

Country	*Constant*	*IN*(−1)	*YP*	*RRL*	*SE*	R^2	*DW*	*Sample*
France	11.9 (3.6)	0.812 (0.045)	0.020 (0.007)	—	3.10	0.95	1.7	71.3 84.2
Japan	−4755 (454)	0.899 (0.046)	0.041 (0.007)	−13454 (1,060)	538.6	0.99	1.5	71.3 84.3
U.K.	1.5 (4.1)	0.726 (0.142)	0.034 (0.012)	−4.0 (3.3)	0.921	0.65	2.1	71.3 84.3

TABLE 3-15 Residential Investment in Four Countries

The dependent variable is *IR*. The estimation method is the GMM, and the instruments are *IR*(−1), *IR*(−2), *Y*(−1), *Y*(−2), *RL*(−1), *LP*(−1), *LP*(−2), *G*.

Country	*Constant*	*IR*(−1)	*YP*	*RRL*	*SE*	R^2	*DW*	*Sample*
U.S.	−132.0 (32.5)	0.614 (0.062)	0.063 (0.013)	−269.5 (62.8)	9.61	0.87	0.9	74.1 84.4
France	9.2 (1.4)	0.858 (0.022)	—	−21.5 (2.5)	0.665	0.98	2.2	71.3 85.2
Japan	2835 (590)	0.823 (0.038)	—	−2578 (865)	733.9	0.72	2.1	71.3 85.3
U.K.	2.4 (0.7)	0.728 (0.075)	—	−1.33 (1.03)	0.429	0.71	2.0	71.3 85.3

TABLE 3-16 Total Fixed Investment in Three Countries

The dependent variable is *IF*. The estimation method is the GMM, and the instruments are *IF*(−1), *IF*(−2), *Y*(−1), *Y*(−2), *RL*(−1), *LP*(−1), *LP*(−2), *G*.

Country	*Constant*	*IF*(−1)	*YP*	*RRL*	*SE*	R^2	*DW*	*Sample*
Canada	−2.9 (2.5)	0.933 (0.049)	0.026 (0.015)	−9.70 (5.53)	1.61	0.98	1.4	71.3 84.3
Germany	−1.3 (13.4)	0.810 (0.038)	0.049 (0.016)	−213.8 (80.4)	10.4	0.74	2.2	71.3 84.3
Italy	−1128 (820)	0.907 (0.029)	0.030 (0.012)	−3016 (848)	299.8	0.89	1.1	71.3 84.3

The expected future sales term is significant in most of the equations, having the highest overall impact in the United States and the lowest in France. Over the sample period, there was little trend in the level of residential investment in these countries. Note that *residential* investment in France, Japan, and the United Kingdom showed no systematic relationship to the expected sales variable, and therefore, this term is omitted from the equations.

3.9 Inventory Investment

Inventory investment is assumed to have a different, less forward-looking, functional form than fixed investment. Current sales are assumed to affect the desired level of inventories. Hence, the change in inventories depends on the change in sales—the usual accelerator model. In addition, we considered the effect of real interest rates on inventory investment. The general equation for inventory investment is

$$II_i = e_{i0} + e_{i1}II_i(-1) + e_{i2}Y_i + e_{i3}Y_i(-1) + e_{i4}RRL_i, \tag{3.9}$$

where II is inventory investment, Y is real output, and RRL is again the real interest rate. The lagged dependent variable was included to reflect any adjustment cost. If $e_{i2} > 0$ and $e_{i2} = -e_{i3}$, then only the *change* in real output affects inventory investment.

The estimates are shown in Table 3-17. The real-output terms always enter with opposite signs, suggesting an accelerator model in all countries except Japan. In Japan, the signs are reversed, indicating a buffer stock role of inventories: when sales decline, inventories rise so that production does not fall so much. The real interest rate enters negatively in all the equations.

3.10 Exports and Imports

In each country, exports and imports are measured in real terms in the local currency and correspond to the export and import measures used to compute GNP or GDP by the expenditure approach in the national income accounts. Hence, these flows include not only merchandise trade but also services. For countries for which output is measured by GNP, the service component of exports and imports includes factor payments on nongovernment capital and labor because net factor payments from abroad are part of GNP. For countries for which GDP is the output measure, exports and imports do not include any factor services. Bilateral trade flows between the individual countries in the model were not modeled. In fact, a large part of exports and imports for each of the seven countries involves trade flows with developing countries and other countries not included in the G-7. Recall that the model is not a closed-world model in the sense that all countries or regions in the world are accounted for. Rather, it is an open-economy model of the seven countries as a group.

TABLE 3-17 Inventory Investment

The dependent variable is *II*. The estimation method is the GMM for all countries except Japan, for which 2*SLS* was used. The instruments are *II*(−1), *II*(−2), *Y*(−1), *Y*(−2), *RL*(−1), *LP*(−1), *LP*(−2), *G*.

Country	*Constant*	*II*(−1)	*Y*	*Y*(−1)	*RRL*	*SE*	R^2	*DW*
U.S.	−15.4	0.656	0.207	−0.201	−86.3	17.3	0.59	2.1
	(23.6)	(0.047)	(0.083)	(0.084)	(59.2)			
Canada	−8.4	0.715	0.632	−0.605	−24.3	2.7	0.67	2.2
	(3.3)	(0.043)	(0.107)	(0.104)	(7.6)			
France	−0.7	0.699	0.156	−0.151	−45.0	6.8	0.53	1.8
	(13.2)	(0.099)	(0.195)	(0.187)	(21.5)			
Germany	7.7	0.326	0.178	−0.171	−261	13.5	0.30	1.9
	(19.0)	(0.138)	(0.181)	(0.193)	(156)			
Italy	−3462	0.543	0.561	−0.515	−7551	752.0	0.65	1.9
	(1,089)	(0.147)	(0.191)	(0.200)	(2309)			
Japan	−1064	0.296	−0.306	0.323	−16349	1270	0.31	1.6
	(1,559)	(0.129)	(0.139)	(0.141)	(4994)			
U.K.	0.65	0.639	0.034	−0.036	−2.52	2.06	0.45	1.9
	(2.6)	(0.123)	(0.144)	(0.144)	(7.6)			

Note: Sample periods were 71.3 to 85.3 for all countries except the United States (85.4) and France (85.2).

The export and import-demand equations have the following log-linear form:

$$LEX_i = f_{i0} + f_{i1}LEX_i(-1) + f_{i2}(LPEX_i - LPIM_i) + f_{i3}LYW_i \quad (3.10)$$

$$LIM_i = g_{i0} + g_{i1}LIM_i(-1) + g_{i2}(LPIM_i - LP_i) + g_{i3}LY_i, \quad (3.11)$$

where *LEX* is the log of exports, *LPEX*, *LPIM*, and *LP* are the price deflators for exports, imports, and output respectively, and *LYW* is the log of a weighted average of output in the other countries.

The relative price variable for exports is the ratio of export prices *PEX* to import prices *PIM*. The ratio of the import price to the domestic price deflator is used in the import equation. Alternative relative price ratios (such as *LPEX-LP* for exports and *LPIM-LPEX* for imports) were tried in the preliminary statistical work. These measures were chosen simply because they gave more plausible and better-fitting equations on average in all the countries.[10]

[10]The log ratio *LFP-LP* was also used for both exports and imports but performed poorly compared to measures that explicitly included export or import prices. The fact that *LFP-LP* did not work well necessitated the estimation of equations *LPEX* and *LPIM* as already discussed in Section 3.4.

Table 3-18 Export Demand

The dependent variable is *LEX*, and the estimation method is OLSQ (ordinary least squares).

Country	*Constant*	*LEX*(−1)	*LPEX-LPIM*	*LYW*	*SE*	R^2	*DW*	*Sample*
U.S.	−0.70	0.794	−0.151	0.230	0.034	0.98	1.7	71.2
	(0.63)	(0.094)	(0.129)	(0.125)				86.2
Canada	−6.63	0.581	−0.325	1.015	0.033	0.98	2.0	71.2
	(1.34)	(0.088)	(0.104)	(0.205)				86.2
France	−5.69	0.509	−0.376	0.999	0.016	0.99	1.9	71.2
	(0.91)	(0.071)	(0.071)	(0.154)				86.2
Germany	−2.94	0.532	−0.340	0.684	0.024	0.99	2.0	71.2
	(0.66)	(0.080)	(0.103)	(0.129)				86.2
Italy	−1.79	0.704	−0.080	0.595	0.032	0.98	1.8	71.2
	(0.68)	(0.084)	(0.070)	(0.184)				86.2
Japan	−0.82	0.814	−0.153	0.372	0.029	0.99	1.5	71.2
	(0.72)	(0.043)	(0.039)	(0.139)				86.2
U.K.	−6.12	0.131	−0.370	1.129	0.031	0.96	2.1	71.2
	(0.86)	(0.112)	(0.076)	(0.151)				86.2

The demand variable in the import equations is measured by real output. The demand variable in the export equations is a trade-weighted average of real output in the other six countries. In all the equations, the role of the lagged dependent variable is to approximate the slow adjustment of importers and consumers to changes in relative prices.

The details of the estimated equations are listed in Tables 3-18 and 3-19. The equations are all estimated with ordinary least squares. Surprisingly, there appeared to be little relationship between relative prices and import demand in Germany and, hence, this term was omitted from the German import equation. With this exception, the sign of the price variable is negative for all of the export- and import-demand equations. The elasticities (shown in Appendix 3B) vary considerably across the countries. Long-run income elasticities are all greater than 1, reflecting the growing importance of trade during the last twenty years. The significant lagged dependent variable shows, however, that adjustments to either price or income changes occur with a lag.

3.11 Money Demand

Finally we consider the money-demand equation, which is assumed to have the traditional Cagan semi-log form for all countries just like in Chapter 1. The log of real-money demand is assumed to depend on the log of real

TABLE 3-19 Import Demand

The dependent variable is *LIM*, and the estimation method is OLSQ (ordinary least squares).

Country	*Constant*	*LIM*(−1)	*LPIM-LP*	*LY*	*SE*	R^2	*DW*	*Sample*
U.S.	−7.00	0.440	−0.216	1.275	0.032	0.98	1.7	71.2
	(0.97)	(0.080)	(0.036)	(0.177)				86.4
Canada	−1.48	0.679	−0.100	0.498	0.032	0.98	1.4	71.2
	(0.46)	(0.076)	(0.075)	(0.134)				86.3
France	−3.16	0.688	−0.148	0.698	0.024	0.99	1.6	71.2
	(0.94)	(0.079)	(0.044)	(0.196)				86.2
Germany	−5.39	0.291		1.325	0.024	0.98	2.2	71.2
	(0.81)	(0.100)		(0.191)				86.3
Italy	−7.57	0.414	−0.190	1.177	0.034	0.98	1.5	71.2
	(1.24)	(0.093)	(0.039)	(0.187)				86.3
Japan	−0.35	0.902	−0.081	0.111	0.032	0.97	1.7	71.2
	(0.32)	(0.059)	(0.026)	(0.051)				86.3
U.K.	−2.14	0.651	−0.061	0.657	0.036	0.94	2.0	71.2
	(0.70)	(0.097)	(0.041)	(0.194)				86.3

income, the level of the short-term interest rate, and on the log of lagged real-money balances. Using a common functional form for all countries permits easy comparison across countries and seems to work well as an approximation, although of course there have been large shifts in money demand because of technological and regulatory changes. The equation for money demand is given by

$$L(M_i/P_i) = a_{i0} + a_{i1}L(M_i(-1)/P_i(-1)) + a_{i2}RS_i + a_{i3}LY_i, \qquad (3.12)$$

where M is money supply ($M1$), and where all other variables have been defined previously. Real output is the measure of income or scale variable. Lagged real-money balances appear in the equation to account for slow adjustment. There are no lead variables in these equations. A time trend starting in 1982:1 was added to the U.S. and U.K. equations to capture the effects of regulatory change and financial innovation in the 1980s.

The estimates are shown in Table 3-20. The equations were estimated by two-stage least squares. The only significant sign of serial correlation in these equations is in Italy (but recall that there is a time-trend variable for the United States and United Kingdom). The signs on the interest rates and income variable are all correct and usually statistically significant. The large coefficient on the lagged dependent variable indicates that the short-run elasticities are much smaller than the long-run elasticities (shown in Appendix 3B).

Table 3-20 Money Demand

The dependent variable is *LMP*. The estimation method is two-stage least squares, and the instruments are *LM*(−1), *LM*(−2), *LP*(−1), *LP*(−2), *LY*(−1), *LY*(−2), *RS*(−1), *G*. A linear time trend starting in 1982:1 is included in the equations for the United States and the United Kingdom.

Country	*Constant*	*LMP*(−1)	*RS*	*LY*	*SE*	R^2	*DW*	*Sample*
U.S.	−0.009	0.953	−0.224	0.040	0.009	0.98	1.6	71.3
	(0.413)	(0.036)	(0.055)	(0.031)				86.4
Canada	0.060	0.937	−0.511	0.033	0.019	0.93	2.1	71.3
	(0.225)	(0.039)	(0.106)	(0.026)				86.3
France	0.671	0.683	−0.316	0.167	0.010	0.87	1.7	78.3
	(0.544)	(0.116)	(0.097)	(0.080)				86.2
Germany	−1.241	0.697	−0.646	0.403	0.020	0.98	2.5	71.3
	(0.497)	(0.090)	(0.120)	(0.133)				86.3
Italy	0.289	0.895	−0.387	0.077	0.016	0.93	1.2	71.3
	(0.386)	(0.037)	(0.068)	(0.030)				86.3
Japan	1.107	0.750	−0.479	0.139	0.016	0.99	1.8	71.3
	(0.194)	(0.059)	(0.090)	(0.043)				86.3
U.K.	−0.778	0.916	−0.778	0.212	0.020	0.97	1.9	71.3
	(0.662)	(0.034)	(0.173)	(0.116)				86.2

3.12 Identities and Potential GNP

The remaining equations of the model include several identities and the definition of aggregate supply. The income-expenditure identities are shown below in Equation (3.13), which is a useful summary of the degree of disaggregation of aggregate demand used in each country:

$$
\begin{aligned}
Y_0 &= CD_0 + CN_0 + CS_0 + INE_0 + INS_0 + IR_0 + II_0 + G_0 + EX_0 - IM_0 \\
Y_1 &= CD_1 + CN_1 + CS_1 + IF_1 + II_1 + G_1 + EX_1 - IM_1 \\
Y_2 &= CD_2 + CN_2 + CS_2 + IN_2 + IR_2 + II_2 + G_2 + EX_2 - IM_2 \\
Y_3 &= C_3 + IF_3 + II_3 + G_3 + EX_3 - IM_3 \\
Y_4 &= C_4 + IF_4 + II_4 + G_4 + EX_4 - IM_4 \\
Y_5 &= CD_5 + CN_5 + CS_5 + IN_5 + IR_5 + II_5 + G_5 + EX_5 - IM_5 \\
Y_6 &= CD_6 + CN_6 + CS_6 + IN_6 + IR_6 + II_6 + G_6 + EX_6 - IM_6.
\end{aligned}
\tag{3.13}
$$

Many of the equations in the model are estimated in log form, with the main exceptions being consumption and investment. These income-expenditure identities obviously need to be written in linear form. The mixture of linear

Box 3-3 Key Identities in Each Country

Income-Expenditure Identities

$$\begin{aligned}
Y_0 &= CD_0 + CN_0 + CS_0 + INE_0 + INS_0 + IR_0 + II_0 + G_0 + EX_0 - IM_0\\
Y_1 &= CD_1 + CN_1 + CS_1 + IF_1 + II_1 + G_1 + EX_1 - IM_1\\
Y_2 &= CD_2 + CN_2 + CS_2 + IN_2 + IR_2 + II_2 + G_2 + EX_2 - IM_2\\
Y_3 &= C_3 + IF_3 + II_3 + G_3 + EX_3 - IM_3\\
Y_4 &= C_4 + IF_4 + II_4 + G_4 + EX_4 - IM_4\\
Y_5 &= CD_5 + CN_5 + CS_5 + IN_5 + IR_5 + II_5 + G_5 + EX_5 - IM_5\\
Y_6 &= CD_6 + CN_6 + CS_6 + IN_6 + IR_6 + II_6 + G_6 + EX_6 - IM_6
\end{aligned}$$

Weighted Price of Other Six Countries (foreign currency units)

$$\begin{aligned}
LPW_0 &= .09LP_1 + .18LP_2 + .26LP_3 + .12LP_4 + .19LP_5 + .16LP_6\\
LPW_1 &= .27LP_0 + .14LP_2 + .21LP_3 + .10LP_4 + .15LP_5 + .13LP_6\\
LPW_2 &= .29LP_0 + .08LP_1 + .23LP_3 + .11LP_4 + .16LP_5 + .14LP_6\\
LPW_3 &= .31LP_0 + .08LP_1 + .16LP_2 + .12LP_4 + .18LP_5 + .15LP_6\\
LPW_4 &= .28LP_0 + .08LP_1 + .15LP_2 + .22LP_3 + .16LP_5 + .13LP_6\\
LPW_5 &= .29LP_0 + .08LP_1 + .15LP_2 + .23LP_3 + .11LP_4 + .14LP_6\\
LPW_6 &= .28LP_0 + .08LP_1 + .15LP_2 + .23LP_3 + .11LP_4 + .16LP_5
\end{aligned}$$

Weighted Exchange Rate (foreign currency/domestic currency)

$$\begin{aligned}
LEW_0 &= -.09LE_1 - .18LE_2 - .26LE_3 - .12LE_4 - .19LE_5 - .16LE_6\\
LEW_1 &= LE_1 - .14LE_2 - .21LE_3 - .10LE_4 - .15LE_5 - .13LE_6\\
LEW_2 &= -.08LE_1 + LE_2 - .23LE_3 - .11LE_4 - .16LE_5 - .14LE_6\\
LEW_3 &= -.08LE_1 - .16LE_2 + LE_3 - .12LE_4 - .18LE_5 - .15LE_6\\
LEW_4 &= -.08LE_1 - .15LE_2 - .22LE_3 + LE_4 - .16LE_5 - .13LE_6\\
LEW_5 &= -.08LE_1 - .15LE_2 - .23LE_3 - .11LE_4 + LE_5 - .14LE_6\\
LEW_6 &= -.08LE_1 - .15LE_2 - .23LE_3 - .11LE_4 - .16LE_5 + LE_6
\end{aligned}$$

Weighted Price of Other Six Countries (domestic currency units)

$$\begin{aligned}
LFP_0 &= LPW_0 - LEW_0\\
LFP_1 &= LPW_1 - LEW_1\\
LFP_2 &= LPW_2 - LEW_2\\
LFP_3 &= LPW_3 - LEW_3\\
LFP_4 &= LPW_4 - LEW_4\\
LFP_5 &= LPW_5 - LEW_5\\
LFP_6 &= LPW_6 - LEW_6
\end{aligned}$$

Weighted Output of Other Six Countries

$$\begin{aligned}
LYW_0 &= .09LY_1 + .18LY_2 + .26LY_3 + .12LY_4 + .19LY_5 + .16LY_6\\
LYW_1 &= .27LY_0 + .14LY_2 + .21LY_3 + .10LY_4 + .15LY_5 + .13LY_6\\
LYW_2 &= .29LY_0 + .08LY_1 + .23LY_3 + .11LY_4 + .16LY_5 + .14LY_6\\
LYW_3 &= .31LY_0 + .08LY_1 + .16LY_2 + .12LY_4 + .18LY_5 + .15LY_6\\
LYW_4 &= .28LY_0 + .08LY_1 + .15LY_2 + .22LY_3 + .16LY_5 + .13LY_6\\
LYW_5 &= .29LY_0 + .08LY_1 + .15LY_2 + .23LY_3 + .11LY_4 + .14LY_6\\
LYW_6 &= .28LY_0 + .08LY_1 + .15LY_2 + .23LY_3 + .11LY_4 + .16LY_5
\end{aligned}$$

equations and nonlinear equations means that the entire model cannot be reduced to either a log-linear or a linear form.

The remaining identities in the model simply define several weighted averages of other variables. These are shown in Box 3-3. They include the weighted price LPW_i, the weighted foreign price LFP_i, and the weighted output LYW_i in each country. Each of these variables has already been discussed.

Finally, potential output is assumed to be growing exponentially. For the purposes of simulation and structural residual calculation during the sample period, the exponential trend is assumed to be constant and was estimated by regressing the log of real output on a linear trend. The estimated growth rates in percent per year were 2.4 for the United States, 3.2 for Canada, 2.5 for France, 2.0 for Germany, 2.2 for Italy, 4.2 for Japan, and 1.5 for the United Kingdom. No explicit attempt was made in the simulations to change the potential growth rate either exogenously or as a function of policy. The focus of this model is on economic fluctuations around this potential level. Of course, this does not mean that potential output or its growth rate are unaffected by macropolicy. The volatility of inflation surely affects real output, for example. But in order to focus on fluctuations, I abstract from these effects. In my judgment, this abstraction does not detract from the analysis.

3.13 The Whole Model

Equations (3.1) through (3.13), along with the definitions of the weighted averages of prices, exchange rates, and output, define the entire multicountry model. There are a total of ninety-eight estimated stochastic equations: twenty-eight describing wage and price behavior, fifty describing aggregate demand, and twenty describing financial markets. These are summarized in Box 3-2. The estimation of most of these equations required econometric methods to deal with rational expectations that did not exist ten years ago. In addition, there are thirty identities, summarized in Box 3-3, and seven equations defining the long-run growth trend of GNP or GDP.

Although I have not emphasized it, there are a number of remarkable characteristics about these equations. For example, the real interest rate appears to be statistically and quantitatively significant in a large number of equations, including those relating to inventories and durables consumption. The signs of the price variables in the exports, imports, and money-demand equations are correct in virtually every country. Perhaps most remarkable is the fact that essentially the same functional form worked well for all countries.

Although I have presented the estimated stochastic equations, I have not yet described the stochastic disturbances to these equations, which are essential for policy analysis. This requires considering the model as a whole. In the next chapter I discuss how the entire model is put together, solved, and simulated, along with the estimation of the stochastic disturbance structure. In doing so I will rely on the nonlinear extended path method for solving and simulating rational expectation models as described in Chapter 1.

Reference Notes

The chapter makes no attempt to compare the structure of this model with other econometric models, either rational or conventional. Several such comparisons are available in the literature, however. An early version of the multicountry model was presented at the first Brookings Model Comparison Project conference in 1986 and published in Bryant, et al. (1988a). Along with many other things, that useful volume provides a brief comparison of this model with other multicountry models in existence as of that time. Several useful analytic comparisons of this model with conventional models are found in Helliwell, Cockerline, and Lafrance (1990) and Brayton and Marquez (1990), who focus on the financial sector, and in Visco (1991), who focuses on the wage-price sector.

The properties of most of the instrumental variable-estimation techniques used in this chapter are found in any advanced econometrics textbook. The generalized method of moments estimator designed to estimate rational expectations models in time-series applications is derived by Hansen (1982).

Many papers have been written on the estimation of single equations for the components of consumption and investment, inventories, and net exports, examining issues such as real-interest-rate sensitivity, lag structure, and income elasticities. No attempt has been made to compare systematically my equations with these others. Most of the other studies have focused on a single country and have used different data and different functional forms.