4 An Econometric Model

4.1 The United States (US) Model

4.1.1 Introduction

The construction of an econometric model is described in this chapter. This model is based on the theoretical model in Chapter 3, and thus the discussion in this chapter provides an example of the transition from a theoretical model to an econometric model. It will be clear, as stressed in Chapter 2, that this transition is not always very tight, and I will try to indicate where I think it is particularly weak in the present case. I have tried to maintain the three main features of the theoretical model in the econometric specifications, namely, the assumption of maximizing behavior, the explicit treatment of disequilibrium effects, and the accounting for balance-sheet constraints. The United States (US) model is discussed in this section, and the multicountry (MC) model is discussed in the next section. The presentation of the models in this chapter relies fairly heavily on the use of tables, especially the tables in Appendixes A and B. Not everything in the tables is discussed in the text, so for a complete understanding of the models the tables must be read along with the text.

4.1.2 Data Collection and the Choice of Variables and Identities

The Data and Variables

As discussed in Section 2.2.1, the first step in the construction of an empirical model is to collect the raw data, create the variables of interest from the raw data, and separate the variables into exogenous variables, endogenous variables explained by identities, and endogenous variables explained by estimated equations. I find it easiest to present this type of work in tables, which in the present case are located in Appendix A at the back of the book.

Table A-1 lists the six sectors of the model and some frequently used notation. The sectors are household *(h)*, firm *(f)*, financial *(b)*, foreign *(r)*, federal government *(g)*, and state and local government *(s)*. The household sector is the sum of three sectors in the Flow of Funds Accounts: (1) households, personal trusts, and nonprofit organizations; (2) farms, corporate and noncorporate; and (3) nonfarm noncorporate business. The firm sector comprises nonfinancial corporate business, excluding farms. The financial sector is the sum of commercial banking and private nonbank financial institutions. The federal government sector is the sum of U.S. government, federally sponsored credit agencies and mortgage pools, and monetary authority.

If the balance-sheet constraints are to be met, the data from the National Income and Product Accounts (NIA), which are flow data, must be consistent with the asset and liability data from the Flow of Funds Accounts (FFA). Fortunately, the FFA data are constructed to be consistent with the NIA data, so the main task in the collection of the data is merely to ensure that the data have been collected from the two sources in the appropriate way to satisfy the constraints. To review what these constraints are like, consider (3.13) and (3.14) of the theoretical model, which are repeated here:

$$(3.13) \qquad S_{ht} = Y_{ht} - T_{ht} - P_{ht}C_{ht},$$

$$(3.14) \qquad 0 = S_{ht} - \Delta A_{ht} - \Delta M_{ht},$$

where S denotes savings, Y denotes income, T denotes taxes, P denotes the price level, C denotes consumption, A denotes net assets other than money, and M denotes money. The data on S, Y, T, P, and C are NIA data, and the data on A and M are FFA data. The data must be consistent in the sense that both (3.13) and (3.14) must hold: the S_{ht} that satisfies (3.13) must be the same as the S_{ht} that satisfies (3.14). An additional restriction on the FFA data is that the sum of the A's across all sectors must be zero, since an asset of one sector is a liability of some other sector. Likewise, the sum of the M's across all sectors must be zero.

Table A-2 presents all the raw-data variables. The variables from the NIA are presented first in the table, in the order in which they appear in the *Survey of Current Business.* The variables from the FFA are presented next, ordered by the code numbers on the Flow of Funds tape. Some of these variables are NIA variables that are not published in the *Survey* but that are needed to link the two accounts. Interest rate variables are presented next, followed by employment and population variables. All the raw-data variables are listed in alphabetical order at the end of Table A-2 for ease of reference.

Given Table A-2 and the discussion of it in Appendix A, it should be possible to duplicate the collection of the data with no help from me.

Although one would seldom want to do this, since a tape of the data set can be easily supplied, this kind of detail should be presented if at all feasible; it has the obvious scientific merit of allowing for the reproducibility of the results, and in general it helps to lessen the "black box" nature of the discussion of many econometric models, especially large models.

Table A-3 presents the balance-sheet constraints that the data satisfy. This table provides the main checks on the collection of the data. If any of the checks are not met, one or more errors have been made in the collection process. Although the checks in Table A-3 may look easy, considerable work is involved in having them met: all the receipts from sector I to sector J must be determined for all I and J (I and J in the present case run from 1 to 6). Once the checks have been met, however, one can have considerable confidence that this part of the data base is correct.

Table A-4, the key reference table for the variables in the model, lists all the variables in alphabetical order. These are not in general the raw-data variables, but variables that have been constructed from a number of the raw-data variables. With a few exceptions, which are noted in the table, the variables that are not defined by identities are defined solely in terms of the raw-data variables. I have found that coding the variables in this way lessens the chances of error, since the order in which the variables are constructed does not matter. The present procedure also has the advantage of providing a clear indication of the links from the raw data to the variables in the model. Order does in general matter, of course, for the variables in the table that are defined in terms of the identities, so one must be careful with respect to these.

The Identities

Table A-5 lists all the equations of the model. There are 128 equations; the first 30 are stochastic and the remaining 98 are identities. One of the equations is redundant, and it is easiest to take Eq. 80 to be the redundant one. The 30 stochastic equations are discussed in Sections 4.1.4–4.1.9.

The identities in the table are of two types. One type simply defines one variable in terms of others. The identities of this type are Eqs. 31, 33, 34, 43, and 58–128. The other type defines one variable as a rate or ratio times another variable or set of variables, where the rate or ratio has been constructed to have the identity hold. The identities of this type are Eqs. 32, 35–42, and 44–57. Consider, for example, Eq. 49:

49. $T_{fg} = d_{2g}\pi_f,$

where T_{fg} is the amount of corporate profit taxes paid by f to g, π_f is the level of corporate profits of f, and d_{2g} is a "tax rate." Data exist for T_{fg} and π_f, and d_{2g} was constructed as T_{fg}/π_f. The variable d_{2g} is then interpreted as a tax rate and is taken to be exogenous. This rate, of course, varies over time as tax laws and other things that affect the relationship between T_{fg} and π_f change, but no attempt is made in the model to explain these changes. This general procedure was followed for the other identities involving tax rates.

A similar procedure was followed to handle relative price changes. Consider Eq. 38:

38. $$PIH = \psi_5 PD,$$

where PIH is the price deflator for housing investment, PD is the price deflator for total domestic sales, and ψ_5 is a ratio. Data exist for PIH and PD, and ψ_5 was constructed as PIH/PD. ψ_5, which varies over time as the relationship between PIH and PD changes, is taken to be exogenous. This procedure was followed for the other identities involving prices and wages. This treatment means that relative prices and relative wages are exogenous in the model. (Prices relative to wages are not, however, exogenous.) It is beyond the scope of an aggregated model like the present one to explain relative prices and wages, and the foregoing treatment is a simple way of handling these changes. Note, of course, that in actual forecasts with the model, assumptions have to be made about the future values of the ratios.

The last identity of the second type is Eq. 57:

57. $$BR = -g_1 M_b,$$

where BR is the level of bank reserves, M_b is the net value of demand deposits and currency of the financial sector, and g_1 is a "reserve requirement ratio." Data on BR and M_b exist, and g_1 was constructed as $-BR/M_b$. (M_b is negative, since the financial sector is a net debtor with respect to demand deposits and currency, and so the minus sign makes g_1 positive.) g_1 is taken to be exogenous. It varies over time as actual reserve requirements and other features that affect the relationship between BR and M_b change.

4.1.3 Treatment of Unobserved Variables

Expectations

For the most part I have followed the traditional approach in trying to account for expectational effects, namely by the use of lagged dependent variables (see the discussion in Section 2.2.2). A different approach was followed, however, in trying to estimate real interest rates for use as explanatory variables in a number of the stochastic equations. In order to estimate a real interest rate one needs an estimate of the expected rate of inflation over the particular period of the interest rate (for example, five years for a five-year rate). In the present case four different estimates of the expected rate of inflation were tried. Each estimate was taken to be the predicted values from a particular regression. For the first regression the actual rate of price inflation ($\dot{PX}$) was regressed on its first eight lagged values and a constant. For the second regression $\dot{PX}$ was regressed on the first four lagged values of four variables, a constant, and time. The four variables were $\dot{PX}$ itself, the rate of wage inflation ($\dot{W}_f$), the rate of change of import prices ($\dot{PIM}$), and a demand pressure variable (ZZ). For the third regression the actual rate of wage inflation ($\dot{W}_f$) was regressed on its first eight lagged values and a constant. For the fourth regression $\dot{W}_f$ was regressed on the same set of variables used for the second regression. The four equations are as follows (t-statistics are in parentheses).

(4.1)
$$\begin{aligned}\dot{PX} = {} & \underset{(1.57)}{.458} + \underset{(5.47)}{.526}\ \dot{PX}_{-1} + \underset{(2.30)}{.245}\ \dot{PX}_{-2} + \underset{(0.76)}{.083}\ \dot{PX}_{-3} \\ & + \underset{(1.65)}{.178}\ \dot{PX}_{-4} - \underset{(1.08)}{.120}\ \dot{PX}_{-5} - \underset{(0.33)}{.036}\ \dot{PX}_{-6} - \underset{(0.17)}{.018}\ \dot{PX}_{-7} \\ & + \underset{(0.41)}{.039}\ \dot{PX}_{-8}\end{aligned}$$

SE = 1.75, R^2 = .731, DW = 1.92, 1954II–1982III

(4.2)
$$\begin{aligned}\dot{PX} = {} & -\underset{(1.03)}{.548} + \underset{(1.80)}{.0151}\ t + \underset{(1.86)}{.172}\ \dot{PX}_{-1} + \underset{(1.98)}{.187}\ \dot{PX}_{-2} \\ & - \underset{(0.05)}{.004}\ \dot{PX}_{-3} + \underset{(1.14)}{.100}\ \dot{PX}_{-4} + \underset{(1.73)}{.102}\ \dot{W}_{f-1} + \underset{(2.12)}{.127}\ \dot{W}_{f-2} \\ & + \underset{(1.07)}{.062}\ \dot{W}_{f-3} + \underset{(0.36)}{.021}\ \dot{W}_{f-4} + \underset{(0.87)}{.016}\ \dot{PIM}_{-1} \\ & + \underset{(2.11)}{.050}\ \dot{PIM}_{-2} + \underset{(1.81)}{.045}\ \dot{PIM}_{-3} - \underset{(1.41)}{.030}\ \dot{PIM}_{-4} \\ & - \underset{(2.61)}{41.6}\ ZZ_{-1} + \underset{(0.96)}{23.1}\ ZZ_{-2} - \underset{(0.07)}{1.7}\ ZZ_{-3} \\ & + \underset{(0.40)}{6.3}\ ZZ_{-4}\end{aligned}$$

SE = 1.39, R^2 = .816, DW = 1.85, 1954I–1982III

$$
\begin{aligned}
(4.3)\qquad \dot{W}_f = {} & \underset{(2.43)}{1.78} + \underset{(1.40)}{.130}\ \dot{W}_{f-1} + \underset{(1.60)}{.150}\ \dot{W}_{f-2} + \underset{(1.60)}{.149}\ \dot{W}_{f-3} \\
& + \underset{(0.91)}{.084}\ \dot{W}_{f-4} + \underset{(1.40)}{.130}\ \dot{W}_{f-5} + \underset{(2.12)}{.196}\ \dot{W}_{f-6} + \underset{(0.99)}{.092}\ \dot{W}_{f-7} \\
& - \underset{(2.23)}{.206}\ \dot{W}_{f-8}
\end{aligned}
$$

$$\text{SE} = 2.49,\ R^2 = .332,\ \text{DW} = 2.05,\ 1954\text{II}-1982\text{III}$$

$$
\begin{aligned}
(4.4)\qquad \dot{W}_f = {} & \underset{(5.27)}{-5.10} + \underset{(0.65)}{.0115}\ t + \underset{(1.09)}{.505}\ \dot{PX}_{-1} - \underset{(0.47)}{.208}\ \dot{PX}_{-2} \\
& + \underset{(1.54)}{.544}\ \dot{PX}_{-3} - \underset{(0.03)}{.007}\ \dot{PX}_{-4} - \underset{(0.84)}{.080}\ \dot{W}_{f-1} - \underset{(1.24)}{.131}\ \dot{W}_{f-2} \\
& - \underset{(0.53)}{.062}\ \dot{W}_{f-3} - \underset{(1.15)}{.124}\ \dot{W}_{f-4} - \underset{(1.43)}{.041}\ \dot{PIM}_{-1} \\
& + \underset{(1.64)}{.060}\ \dot{PIM}_{-2} - \underset{(0.72)}{.030}\ \dot{PIM}_{-3} + \underset{(0.49)}{.020}\ \dot{PIM}_{-4} \\
& - \underset{(1.00)}{26.1}\ ZZ_{-1} + \underset{(0.02)}{.7}\ ZZ_{-2} - \underset{(0.02)}{1.0}\ ZZ_{-3} \\
& - \underset{(0.22)}{6.5}\ ZZ_{-4}
\end{aligned}
$$

$$\text{SE} = 2.18,\ R^2 = .472,\ \text{DW} = 1.96,\ 1954\text{I}-1982\text{III}$$

Let $\dot{PX}^e$ denote the predicted value from either the first or second equation, and let $\dot{W}_f^e$ denote the predicted value from either the third or fourth equation. If these predicted values are taken to be expected values, then an estimate of a real interest rate is the nominal rate minus the particular predicted value. For example, $RSA - \dot{PX}^e$ or $RSA - \dot{W}_f^e$ is an estimate of the real after-tax short-term interest rate, where RSA is the nominal after-tax short-term interest rate. Similarly, $RMA - \dot{PX}^e$ or $RMA - \dot{W}_f^e$ is an estimate of the real after-tax mortgage rate, where RMA is the nominal after-tax mortgage rate.

This treatment of expectations is somewhere in between the simple use of lagged dependent variables of the traditional approach and the assumption that expectations are rational. The expectations are not rational because (4.1)–(4.4) are not the equations that the model uses to explain actual wages and prices. The equations are, however (especially Eqs. 4.2 and 4.4), more sophisticated than the simple geometrically declining lag implicit in the traditional approach, and thus the expectations are based on somewhat more information.

The real interest rate was always entered linearly as an explanatory variable in the estimated equations, and therefore any error made in estimating the level of the expected inflation rate that is constant across time is merely absorbed in the estimate of the constant term. This approach does, however, have the problem of not distinguishing between short-term and long-term expected rates of inflation. The same expected inflation variable is subtracted from both the short-term rate and the long-term rates. This is a good example of a situation in which less structure is imposed on the expected rates than would be imposed by the assumption of rational expectations, where the expected inflation rates would in general differ by length of period (since the model would in general predict this).

The attempt to find real interest rate effects in the empirical work is consistent with the theoretical model. Although no mention was made of real interest rates in Chapter 3, their effects are in the model. Consider, for example, the household's maximization problem. The household's response to an interest rate change will be different if, say, the price level in periods 2 and 3 is expected to change than if it is not. Likewise, a firm's response to an interest rate change is a function of what it expects future prices to be.

Labor Constraint Variable for the Household Sector

An important feature of the theoretical model is the possibility that households may at times be constrained in how much they can work. This possible constraint poses a difficult problem for empirical work because the constraints are not directly observed. The approach that I have used is the following.

Let *CSUN* denote the expenditures on services that the household sector would make if it were not constrained in its labor supply, and let *CS* denote the actual expenditures made, where *CS* is observed. Assume that one has specified an equation explaining *CSUN*, that is, an equation explaining the unconstrained decision:

$$(4.5) \qquad CSUN = f(\ldots).$$

Assume that all the variables on the RHS of this equation are observed. If the household sector is not constrained, then *CS* equals *CSUN*, and there is no problem. If the household sector is constrained, then *CS* is less than *CSUN* if, as in the theoretical model, binding labor constraints cause the household sector to consume less than it would have consumed unconstrained. If one can find a variable, say *Z*, such that

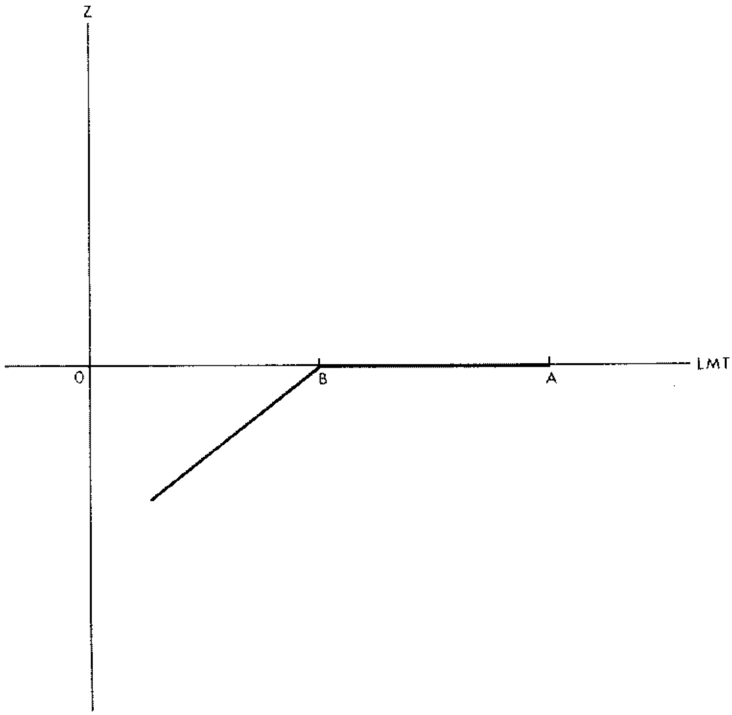

Figure 4-1 Desired shape of the labor constraint variable *(Z)* as a function of the measure of labor market tightness *(LMT)*

$$(4.6) \qquad CS = CSUN + \gamma Z, \qquad \gamma > 0,$$

then one has immediately from (4.5) and (4.6) an equation in observed variables. The problem of accounting for the constraint is thus reduced to a problem of finding a variable Z for which the specification in (4.6) seems reasonable.

The variable Z should take on a value of zero when labor markets are tight and households are not constrained and a value less than zero otherwise. When the variable is less than zero, it should be a linear function of the difference between the constrained and unconstrained decision values of the household sector. Let LMT denote some measure of labor market tightness. The desired shape of Z as a function of LMT is presented in Figure 4-1. Point A is some value that is larger than the largest value of LMT that is ever likely to be observed, and point B is the value of LMT above which it seems reasonable to assume that the household sector is not constrained. An approximation to the curve in Figure 4-1 that was used in the empirical work is the following:

$$(4.7) \qquad Z = 1 - \frac{A}{LMT}.$$

Z is zero when LMT equals A, and it is minus infinity when LMT equals zero.

There are a number of measures of labor market tightness that one might consider in the construction of Z. One obvious possibility is $1 - UR$, where UR is the unemployment rate. In the present case, however, a different measure was used, which is a detrended ratio of total hours paid for in the economy to the total population age 16 and over. This measure is defined by Eqs. 95 and 96 in Table A-5. Equation 95 determines the actual ratio (JJ), and Eq. 96 determines the detrended ratio (JJ^*). (The coefficient $-.00083312$ in Eq. 96 is the estimate of the coefficient of t in the regression of log JJ on a constant and t for the 1952I–1982III period.) Which measure of labor market tightness to use is largely an empirical question; I have found that JJ^* gives slightly better results than does $1 - UR$. The results are not, however, very different, and an example of the use of $1 - UR$ instead of JJ^* for the household sector is presented near the end of this section. The value of A that was used for JJ^* in (4.7) is 337.0, which is slightly larger than the largest value of JJ^* observed in the sample period. Equation (4.7) with this value of A is Eq. 97 in the model.

Demand Pressure Variables

In the theoretical model a firm's price and wage decisions are a function, among other things, of its expectations of the current and future demand curves for its goods and of the current and future supply curves of labor that it faces. These expectations are in turn a function, among other things, of lagged values of the demand for the firm's goods at the prices that it set and of the supply of labor that it received at the wage rates that it set. For the empirical work one needs some way of accounting for these demand and supply effects on prices and wages. A number of "demand pressure" variables were tried in the estimation of the price and wage equations. One might expect there to be a nonlinear relationship between demand and prices in the sense that as demand pressure rises, prices rise at an ever-increasing rate, and therefore a number of nonlinear specifications were tried. However, the data do not appear to be capable of distinguishing among different functional forms and demand pressure variables, and in the end two very simple variables were used, one in the price equation and one in the wage equation.

The demand pressure variable for the price equation, denoted ZZ, was taken to be

$$(4.8) \qquad ZZ = \frac{GNPR^* - GNPR}{GNPR^*},$$

where $GNPR^*$ is an estimate of a high activity level of $GNPR$. ($GNPR$ is real GNP.) $GNPR^*$ was constructed from peak-to-peak interpolations of $GNPR$. The peak quarters are presented in Table A-4. ZZ is simply the percentage difference between the high activity level of $GNPR$ and the actual level. Equation (4.8) is Eq. 98 in Table A-5. The demand pressure variable for the wage equation was taken to be the civilian unemployment rate (UR):

$$(4.9) \qquad UR \equiv \frac{U}{L1 + L2 + L3 - J_m}.$$

Equation (4.9) is Eq. 87 in Table A-5.

Measurement of Excess Labor and Excess Capital

In the theoretical model the amounts of excess labor and excess capital on hand have an effect on the decisions of the firm, particularly the investment and employment decisions. In order to test for this in the empirical work, one needs some way of estimating the amount of excess labor and excess capital on hand in each period. This in turn requires some way of estimating the technology of the firm sector.

Consider first the estimation of the capital stock and the postulation of a production function. The capital stock was constructed to satisfy the following equation:

$$(4.10) \qquad KK = (1 - \delta_K)KK_{-1} + IK_f,$$

where KK is the capital stock of the firm sector and IK_f is gross investment. The measurement of δ_K is discussed in Appendix A. The production function is postulated to be one of fixed proportions:

$$(4.11) \qquad Y = \min[\lambda(J_f H_f^j), \mu(KK \cdot H_f^{KK})],$$

where Y is production, J_f is the number of workers employed, H_f^j is the number of hours worked per worker, KK is the capital stock given above, H_f^{KK} is the number of hours each unit of KK is utilized, and λ and μ are coefficients that may change over time due to technical progress. The variables Y, J_f, and KK are observed; the others are not.

Equations (4.10) and (4.11) are not consistent with the putty-clay technology of the theoretical model; they are at best only good approximations. Each machine in the theoretical model wears out after m periods, but its productivity does not lessen as it gets older. Consequently, even if there were only one type of machine ever in existence, (4.10) would not be true. Rather, $KK - KK_{-1}$ would equal $IK_f - IK_{f-m}$, where IK_{f-m} is the number of machines that wear out at the beginning of the period. It is also the case that no technical change was postulated in the theoretical model, but even if it were, it would not enter in the way specified in (4.11); it would take the form of machines having different λ and μ coefficients according to when they were purchased. One could not write down an equation like (4.11) but instead would have to keep track of when each machine was purchased and what the coefficients were for that machine. This kind of detail is clearly not possible with aggregate data, and therefore one must resort to simpler specifications.

Given the above production function, excess labor was measured as follows. Output per paid-for worker hour, $Y/(J_f H_f)$, was first plotted for the 1952I–1982III period. (Data on hours paid for, H_f, exist, whereas data on hours worked, H_f^J, do not.) The peaks of this series were assumed to correspond to cases in which the number of hours worked equals the number of hours paid for, which implies that values of λ in (4.11) are observed at the peaks. The values of λ other than those at the peaks were then assumed to lie on straight lines between the peaks. Given an estimate of λ for a particular period and given the production function (4.11), the estimate of the number of worker hours required to produce the output of the period (denoted $JHMIN$) is simply Y/λ. (This is Eq. 94 in Table A-5.) The actual number of worker hours paid for can then be compared to $JHMIN$ to measure the amount of excess labor on hand. The exact form that this comparison takes in the model is discussed in Section 4.1.5. The peaks that were used for the interpolations are listed in Table A-4 under the description of λ.

With respect to the measurement of excess capital, there are no data on hours paid for or worked per unit of KK, and thus one must be content with plotting Y/KK. This is, from the production function (4.11), a plot of μH_f^{KK}, where H_f^{KK} is the average number of hours that each machine is utilized. If it is assumed that at each peak of this series H_f^{KK} is equal to the same constant, say $\bar{H}$, then one observes at the peaks $\mu\bar{H}$. Interpolation between peaks can then produce a complete series on $\mu\bar{H}$. If, finally, $\bar{H}$ is assumed to be the maximum number of hours per period that each unit of KK can be utilized, then $Y/(\mu\bar{H})$

is the minimum amount of capital required to produce Y (denoted $KKMIN$). (This is Eq. 93 in Table A-5.) The peaks that were used for the interpolations are listed in Table A-4 under the description of $\mu\overline{H}$.

4.1.4 Stochastic Equations for the Household Sector

The two main decision variables of a household in the theoretical model are consumption and labor supply. The determinants of these variables include the initial value of wealth and the current and expected future values of the wage rate, the price level, the interest rate, the tax rate, and the level of transfer payments. The labor constraint also affects the decisions if it is binding. The aim of the econometric work is to match the decision variables and the determinants of the variables to observed aggregate variables and then to estimate equations explaining the aggregate variables.

Expenditures of the household sector have been disaggregated into four types: consumption of services (CS), consumption of nondurable goods (CN), consumption of durable goods (CD), and investment in housing (IH_h). Four labor supply variables have been used: labor force of prime-age males ($L1$), labor force of prime-age females ($L2$), labor force of all others ($L3$), and the number of people holding more than one job, called "moonlighters" (LM). These eight variables are determined by eight estimated equations.

The explanatory variables that were tried for each equation are the following: (1) the initial value of wealth (AA_{-1}); (2) the after-tax wage rate (WA); (3) the price of the particular good in the case of the expenditure equations and a price index of all the goods in the case of the labor supply equations (PCS, PCN, PCD, PIH, or P_h); (4) the after-tax short-term and long-term interest rates, either nominal (RSA, RMA) or real (RSA or RMA minus an estimate of the expected rate of inflation, where the latter uses the predicted values $\dot{PX}^e$ from Eq. 4.1 or 4.2 or the predicted values $\dot{W}_f^e$ from Eq. 4.3 or 4.4); (5) nonlabor income (YN or YTR); (6) the labor constraint variable (Z); and (7) the lagged dependent variable.

The Searching Procedure

Much searching was done in arriving at the final estimated equations for the household sector. With respect to functional forms, both the linear and logarithmic forms of the equations were tried, and the decision was made fairly early in the process to use the linear form. In general the log form led to fewer significant coefficient estimates than did the linear form, and this was the main reason for dropping it. The results were, however, quite similar using both forms, and the main conclusions regarding the household sector would not be changed if the log form were used. All the equations were estimated in per-capita terms for both forms.

A basic set of explanatory variables was first tried for each equation. A number of changes from this set were then made to see if improvements could be found. The changes consisted of (1) trying each explanatory variable lagged one quarter rather than unlagged, (2) replacing *YN*, which was in the basic set, with *YTR* to see which nonlabor income variable worked better, (3) constraining the wage and price variables to enter the equation as the ratio of the wage rate to the price level rather than separately, (4) trying both the short-term and long-term interest rates together as well as separately, (5) trying both the nominal interest rates and the real interest rates (separately), and (6) estimating the equation under the assumption of first-order serial correlation of the error term. All this searching was done using the 2SLS technique. If in the process a particular variable in an equation continually had the wrong sign, it was finally dropped from the specification. With a few exceptions, the same was also true for variables that were of the right sign but had t-statistics less than one in absolute value.

This searching did not result in very many examples in which a variable was significant but of the wrong sign. Had this been true, I would probably not have stopped when I did but instead would have examined the theory and the data further. In order to give the reader a feeling for the kinds of equations that were rejected, some examples will be given later after the basic equations have been presented.

Special Treatment of Housing Investment

Before the estimated equations are presented, the special treatment of housing investment must be noted. Housing investment poses a problem with respect to the links from the theoretical model to the econometric specifications because the theoretical model is not set up to handle investment goods for a household. If consumption of housing services is proportional to the stock of housing, the variables from the theoretical model that affect consumption can be taken to affect the housing stock. If, however, the actual housing stock only adjusts slowly to some desired stock, this use of the theoretical model is incomplete; one needs in addition to specify the lagged adjustments. The following specification, which seems to give reasonable results, was used for this purpose.

Let KH^{**} denote the "desired" stock of housing. If housing consumption is proportional to the housing stock, then the determinants of consumption can be assumed to be the determinants of KH^{**}:

$$(4.12) \qquad KH^{**} = f(\ldots),$$

where the arguments of f are the determinants of consumption from the theoretical model. Two types of lagged adjustment were postulated. The first is an adjustment of the housing stock to its desired value:

$$(4.13) \qquad KH^{*} - KH_{-1} = \lambda(KH^{**} - KH_{-1}).$$

Given (4.13), "desired" gross investment is

$$(4.14) \qquad IH_h^{*} = KH^{*} - (1 - \delta_H)KH_{-1},$$

where δ_H is the depreciation rate. By definition $IH_h = KH - (1 - \delta_H)KH_{-1}$, and (4.14) is merely the same equation for the desired values. The second type of adjustment is an adjustment of gross investment to its desired value:

$$(4.15) \qquad IH_h - IH_{h-1} = \gamma(IH_h^{*} - IH_{h-1}).$$

Combining (4.12)–(4.15) yields:

$$(4.16) \qquad IH_h = (1 - \gamma)IH_{h-1} + \gamma(\delta_H - \lambda)KH_{-1} + \gamma\lambda f(\ldots).$$

This treatment thus adds to the housing investment equation both the lagged dependent variable and the lagged stock of housing. Otherwise, the explanatory variables are the same as they are in the other expenditure equations.

This treatment is an example of the ad hoc nature of theory with respect to lagged adjustments. "Extra" theorizing is involved in the specification of the housing investment equation, and the specification is not derived from the assumption of maximizing behavior.

In the empirical work, (4.16) was estimated in per-capita terms. In particular, IH_h was divided by POP, and IH_{h-1} and KH_{-1} were divided by POP_{-1}, where POP is population. If (4.12)–(4.15) are defined in per-capita terms, where current values are divided by POP and lagged values are divided by POP_{-1}, then the present per-capita treatment of (4.16) follows. The only problem with this is that the definition that was used to justify (4.14) does not hold if the lagged housing stock is divided by POP_{-1}. All variables must be divided by the same population variable in order for the definition to hold. This is, however, a minor problem, and it has been ignored. The alternative treatment is to divide all variables in (4.16) by the same population variable, say POP, but this is inconvenient to work with.

The Final Eight Consumption and Labor Supply Equations

All estimates presented in this chapter are two-stage least squares (2SLS) estimates if the equation contains RHS endogenous variables and ordinary least squares (OLS) estimates if it does not. Chapter 6 contains a discussion of all the estimates that have been obtained for the model; it also contains (in Table 6-1) a list of the first-stage regressors that were used for each equation for the 2SLS technique. The estimation period was 1954I–1982III (115 observations) for all equations except Eq. 15, where the period was 1956I–1982III (107 observations).

The final consumption and labor supply equations that were chosen are as follows:

1.
$$\frac{CS}{POP} = \underset{(0.06)}{.000188} + \underset{(61.48)}{.986}\left(\frac{CS}{POP}\right)_{-1} + \underset{(2.40)}{.000554}\left(\frac{AA}{POP}\right)_{-1} + \underset{(2.07)}{.0198}\, WA + \underset{(0.36)}{.00714}\,\frac{YN}{POP \cdot P_h} - \underset{(5.87)}{.00126}\, RSA + \underset{(1.92)}{.0231}\, Z$$

SE = .00190, R^2 = .999, DW = 2.45

2.
$$\frac{CN}{POP} = \underset{(3.96)}{.109} + \underset{(10.03)}{.666}\left(\frac{CN}{POP}\right)_{-1} + \underset{(5.05)}{.00227}\left(\frac{AA}{POP}\right)_{-1} + \underset{(2.48)}{.185}\, WA - \underset{(2.16)}{.0469}\, PCN + \underset{(2.14)}{.0637}\,\frac{YN}{POP \cdot P_h} - \underset{(1.05)}{.000610}\, RSA + \underset{(3.54)}{.0829}\, Z$$

SE = .00315, R^2 = .994, DW = 1.58

3.
$$\frac{CD}{POP} = \underset{(3.57)}{.0735} + \underset{(5.95)}{.458}\left(\frac{CD}{POP}\right)_{-1} + \underset{(6.18)}{.00235}\left(\frac{AA}{POP}\right)_{-1} + \underset{(4.08)}{.405}\, WA - \underset{(3.12)}{.104}\, PCD + \underset{(1.19)}{.0668}\,\frac{YTR}{POP \cdot P_h} - \underset{(7.96)}{.00617}\, RMA + \underset{(3.38)}{.123}\, Z$$

SE = .00445, R^2 = .989, DW = 1.77

4. $$\frac{IH_h}{POP} = \underset{(3.89)}{.0650} + \underset{(9.86)}{.738}\left(\frac{IH_h}{POP}\right)_{-1} - \underset{(3.18)}{.0157}\left(\frac{KH}{POP}\right)_{-1} + \underset{(3.73)}{.00182}\left(\frac{AA}{POP}\right)_{-1} + \underset{(2.61)}{.159}\, WA_{-1} - \underset{(1.88)}{.0178}\, PIH_{-1} + \underset{(0.99)}{.0356}\left(\frac{YN}{POP \cdot P_h}\right)_{-1} - \underset{(5.19)}{.00367}\, RMA_{-1}$$

$$\text{SE} = .00243,\ \text{R}^2 = .958,\ \text{DW} = 2.09,\ \hat{\rho} = \underset{(4.65)}{.551}$$

5. $$\frac{L1}{POP1} = \underset{(3.67)}{.230} + \underset{(12.20)}{.769}\left(\frac{L1}{POP1}\right)_{-1} - \underset{(3.56)}{.0278}\left(\frac{YN}{POP \cdot P_h}\right)_{-1}$$

$$\text{SE} = .00200,\ \text{R}^2 = .972,\ \text{DW} = 2.25$$

6. $$\frac{L2}{POP2} = \underset{(3.75)}{.0605} + \underset{(17.98)}{.832}\left(\frac{L2}{POP2}\right)_{-1} + \underset{(3.77)}{.160}\, WA - \underset{(2.95)}{.0200}\, P_h + \underset{(2.86)}{.0364}\, Z$$

$$\text{SE} = .00294,\ \text{R}^2 = .999,\ \text{DW} = 2.14$$

7. $$\frac{L3}{POP3} = \underset{(5.02)}{.133} + \underset{(17.53)}{.782}\left(\frac{L3}{POP3}\right)_{-1} - \underset{(3.76)}{.00121}\left(\frac{AA}{POP}\right)_{-1} + \underset{(4.14)}{.0930}\, WA - \underset{(4.25)}{.0318}\, P_h + \underset{(4.81)}{.0738}\, Z$$

$$\text{SE} = .00258,\ \text{R}^2 = .907,\ \text{DW} = 1.96$$

8. $$\frac{LM}{POP} = \underset{(7.17)}{.0150} + \underset{(11.96)}{.634}\left(\frac{LM}{POP}\right)_{-1} + \underset{(0.90)}{.00676}\, WA_{-1} - \underset{(1.48)}{.00374}\, P_{h-1} + \underset{(6.40)}{.0580}\, Z$$

$$\text{SE} = .00149,\ \text{R}^2 = .865,\ \text{DW} = 1.95$$

It will be useful in discussing these results to consider the effects of each explanatory variable across the eight equations. (1) The results for the asset variable $(AA/POP)_{-1}$ are good in the sense that this variable is significant in all four of the expenditure equations. It is significant (and of the expected negative sign) in one of the four labor supply equations. (2) The wage rate and price variables are significant in *all* four expenditure equations with the exceptions of the housing investment equation, where the t-statistic for the price variable is 1.88, and the consumption of services equation, where the price variable was dropped because of the wrong sign. The wage and price variables appear in three of the four labor supply equations and are significant in two of these three. (3) With respect to the interest rate variables, the short-term rate is in the first two equations and the long-term rate is in the third and fourth equations. The coefficient estimates are significant except for the estimate in Eq. 2, where the t-statistic is 1.05. (4) The results for the nonlabor income variables are not very strong. The YN variable (total nonlabor income) appears in the expenditure equations 1, 2, and 4, but with t-statistics of only 0.36, 2.14, and 0.99. It also appears in one labor supply equation (Eq. 5), with the expected negative sign and with a t-statistic of 3.56. The YTR variable (transfer payments) appears in expenditure equation 3, with a t-statistic of 1.19. (5) The labor constraint variable (Z) appears in three expenditure equations and three labor supply equations. It is significant in all but equation 1, where the t-statistic is 1.92.

With respect to the housing investment equation, the implied value of γ in (4.15) is $1 - .738 = .262$, which says that the adjustment of gross investment to desired gross investment is 26.2 percent per quarter. Given this estimate and given the value of δ_H of .00655, which was used to construct KH and which is the value used in the model, the implied value of λ in (4.13) is .066. This says that the adjustment of the housing stock to its desired value is 6.6 percent per quarter.

In general, these results seem fairly supportive of the theory. With the exception of the nonlabor income variables, the variables that one would expect from the theory to influence household expenditures and labor supply are significant in most of the equations. With respect to the equations themselves, the weakest results are for Eq. 5, which explains the labor force participation of prime-age males. Most prime-age males work, and their participation does not seem to be much affected by economic variables, with the possible exception of nonlabor income.

Other Results from the Searching Procedure

In the process of searching for the final equations to be used in the model, one gets a feeling for what the data do and do not support. This information is not always conveyed to the reader by merely presenting the final set of equations;

it is sometimes helpful to present a few of the intermediate results. This will now be done regarding the results for the household sector.

1. The results are not sensitive to the use of JJ^* as the measure of labor market tightness in the construction of the labor constraint variable Z. Very similar results were obtained using $1 - UR$ as the measure of labor market tightness and defining Z to be $1 - .975/(1 - UR)$, where .975 is slightly larger than the largest value of $1 - UR$ in the sample period. Consider, for example, the first three equations. The t-statistics for Z defined the new way were 1.91, 3.40, and 3.29, which compare to 1.92, 3.54, and 3.38 above. The SEs were .00189, .00318, and .00435, which compare to .00190, .00315, and .00445 above. It is clear that there is little to choose between the two measures, or to put it another way, the data cannot be used to decide between the two.

2. The data do not support the use of real interest rates in the expenditure equations. One way to test for the effects of real interest rates is to include the nominal interest rate and the expected rate of inflation as separate explanatory variables. If the real interest rate is the correct variable to use, the coefficient estimate of the expected rate of inflation variable should be of opposite sign and equal in absolute value to the coefficient estimate of the nominal interest rate variable. To test for this, the four estimates of the expected rate of inflation that were discussed in Section 4.1.3 were added (one at a time) to the four expenditure equations. For 10 of the 16 cases the coefficient estimate of the expected rate of inflation was of the wrong (negative) sign, and for the 6 cases in which it was of the right sign the largest t-statistic was only 0.52. In the 6 cases in which the signs were right, the sizes of the estimates were much smaller in absolute value than the sizes of the estimates of the coefficient of the nominal interest rate, and the other coefficient estimates in the equations changed very little. Two of the 12 negative estimates were significant, with t-statistics of 2.09 and 2.16. Use of the actual rates of inflation in place of the expected rates led to similar poor results.

It is clear that these results do not support the use of real interest rates in the expenditure equations. These negative results may be due, of course, to poor estimates of the expected rate of inflation. It may be, for example, that better estimates would be obtained under the assumption that expectations are rational, and until further work is done, these negative results are very tentative.

3. The data do not support the treatment of consumer durable expenditures as investment expenditures. When KD_{-1}/POP_{-1} was added to Eq. 3, its coefficient estimate was unreasonably small ($-.00968$ with a t-statistic of 2.23). Under the assumption that the treatment of housing investment

discussed earlier also pertains to consumer durable expenditures, the implied value of λ in (4.13) from this regression is .072. (The coefficient estimate of CD_{-1}/POP_{-1} was .525, and the value of the depreciation rate, δ_D, is .0515.) This says that the adjustment of the stock of durable goods to its desired value is 7.2 percent per quarter, which is only slightly larger than the 6.6 percent figure obtained for the housing stock. Given what seemed to be an unreasonably low value of λ, the decision was made to treat consumer durable expenditures like expenditures on services and nondurables.

4. The data provide mild support for the use of the after-tax wage rate rather than the before-tax wage rate in the equations. The wage rate variable that is used, WA, is equal to W_hQ, where $Q = (1 - d_{1g}^M - d_{1s}^M - d_{4g} - d_{4s})$. (This is Eq. 126 in Table A-5.) W_h is the before-tax wage rate. d_{1g}^M and d_{1s}^M are marginal personal income tax rates, and d_{4g} and d_{4s} are employee social security tax rates. To test that the appropriate wage rate variable is W_hQ rather than merely W_h, the wage rate variable can be included in the form αW_hQ^λ, where λ is a coefficient to be estimated along with the regular coefficient α. If the after-tax wage rate is the correct variable to use, the estimate of λ should be close to 1, and if the before-tax wage rate is correct, the estimate of λ should be close to 0.

When λ is estimated, the equation is nonlinear in coefficients. The estimation of such equations is discussed in Chapter 6. For the present results the 2SLS technique was used. The estimates of λ for the four expenditure equations were 2.8, 2.6, 0.3, and 0.7, with standard errors of the respective coefficient estimates of 2.12, 0.86, 0.58, and 1.00. (There is some collinearity between the estimates of α and λ. The t-statistics for the estimates of α changed from 2.07, 2.48, 4.08, and 2.61 to 0.91, 3.48, 2.78, and 2.09 respectively when λ was estimated rather than constrained to be 1. Except for the second equation, the t-statistics are lower in the unconstrained case.) One estimate of λ is significantly different from 0, and none are significantly different from 1. Although the estimates are obviously not precise, three of the four estimates are closer to 1 than to 0, and thus the results provide at least some support to the use of the after-tax wage rate.

5. The data again provide mild support for the use of the after-tax interest rates rather than the before-tax rates. The interest rate variable that is used in Eqs. 1 and 2, RSA, is equal to $RS \cdot Q$, where $Q = (1 - d_{1g}^M - d_{1s}^M)$. (This is Eq. 127 in Table A-5.) RS is the before-tax short-term rate. When the interest rate variable was included in these two equations as $\alpha RS \cdot Q^\lambda$, the estimates of λ were -2.6 and 2.5, with standard errors of the coefficient estimates of 4.35 and 11.72. The interest rate variable that is used in Eqs. 3 and 4, RMA, is

equal to $RM \cdot Q$. (This is Eq. 128 in Table A-5.) RM is the before-tax mortgage rate. When the interest rate variable was included in the two equations as $\alpha RM \cdot Q^{\lambda}$, the estimates of λ were 3.0 and 4.6, with standard errors of the coefficient estimates of 1.75 and 1.90. There is again some collinearity between the estimates of α and λ, and the estimates of λ are not precise. One of the four is significantly different from 0, and none are significantly different from 1. Given that three of the estimates are closer to 1 than to 0, there is some support for the use of the after-tax interest rates. The support here is weaker than it was in the wage rate case because the estimated standard errors of λ are larger.

6. It should also be noted with respect to the treatment of taxes that the nonlabor income variable, YN, is after-tax nonlabor income (Eq. 88). This treatment is again in keeping with the theoretical model. Given that the results using YN were not very good, no tests of this variable versus a before-tax version were made. It seemed quite unlikely that the data would be able to discriminate between the two.

The Demand-for-Money Equation

The final estimated equation for the household sector is a demand-for-money equation:

$$9. \quad \log \frac{M_h}{POP \cdot P_h} = \underset{(3.63)}{.0297} - \underset{(2.64)}{.000698}\, t + \underset{(19.22)}{.835} \log \left(\frac{M_h}{POP \cdot P_h}\right)_{-1} + \underset{(3.13)}{.123} \log \left(\frac{YT}{POP \cdot P_h}\right) - \underset{(3.81)}{.00416}\, RSA$$

$$SE = .0140,\ R^2 = .970,\ DW = 2.07$$

This is a standard demand-for-money equation in which the per-capita demand for real money balances of the household sector, $M_h/(POP \cdot P_h)$, is a function of per-capita real income, $YT/(POP \cdot P_h)$, and the after-tax short-term interest rate, RSA. A time trend has been added to the equation to account for possible trend changes in the relationship. This equation is consistent with the theoretical model, where the optimal level of money holdings of the household is a negative function of the interest rate.

Summary and Further Discussion

The following paragraphs provide a summary of the general features of the empirical model of household behavior. Not surprisingly, these features are similar to the general features of the theoretical model in Section 3.1.2, since the empirical model was constructed with this similarity in mind. The reader should keep in mind in the following discussion that the smaller the labor constraint, the larger is the labor constraint variable.

1. Household expenditures respond to the following variables: the after-tax wage rate (+), the price level (−), the after-tax short-term or long-term interest rate (−), after-tax nonlabor income (+), the initial value of wealth (+), and the labor constraint variable (+).

2. Labor supply responds to the following variables: the after-tax wage rate (+), the price level (−), after-tax nonlabor income (−), the initial value of wealth (−), and the labor constraint variable (+).

3. A decrease in tax rates (the marginal personal income tax rate and the employee social security tax rate) increases expenditures through the wage rate and nonlabor income variables. A decrease in tax rates also decreases expenditures through the interest rate variables. (A decrease in tax rates, other things being equal, raises the after-tax interest rate, which has a negative effect on expenditures.) The net effect of a decrease in tax rates is thus ambiguous, although it will be seen when the quantitative properties of the model are examined in Section 9.4 that the net effect is positive. Labor supply responds to a decrease in tax rates positively through the wage rate variable and negatively through the nonlabor income variable. It will be seen that the positive effect dominates in the model.

4. Transfer payments are part of nonlabor income, and thus an increase in transfer payments has a negative effect on labor supply. Therefore, a decrease in net taxes through an increase in transfer payments has a negative effect on labor supply, whereas a decrease in net taxes through a decrease in tax rates has a positive effect.

5. An increase in interest rates has a negative effect on expenditures, which, other things being equal, has a positive effect on the household savings rate *(SR)*. The savings rate is thus indirectly a positive function of interest rates.

6. An increase in the savings rate increases wealth *(AA)*, which in turn increases expenditures (with a lag of one quarter). The increase in expenditures in turn decreases the savings rate. There is thus a tendency for a change in the savings rate to reverse itself over time because of the effects of the wealth variable on expenditures.

7. The labor constraint variable is a nonlinear function of hours paid for. When labor markets are tight, this variable has very little effect on expenditures (since its value is close to zero). This is the unconstrained case in which consumption and labor supply decisions are simply a function of wage rates, prices, interest rates, nonlabor income, and wealth. When labor markets are

loose and households are constrained in their labor supply decisions, the labor constraint variable has an effect on expenditures. Because it is a function of hours paid for, its inclusion in the equations means that income is on the RHS of the equations in the form of separate wage-rate and hours-paid-for variables when the constraint is binding. In the constrained case the expenditure equations are thus closer than otherwise to typical consumption equations in which income is an explanatory variable.

8. The labor constraint variable also enters the labor supply equations. Three of the labor supply variables are labor force participation variables, and therefore the inclusion of the labor constraint variable in these equations means that labor force participation is predicted to be less in loose labor markets than in tight labor markets. This effect is sometimes called the "discouraged worker" effect. Given the functional form of the labor constraint variable, this effect is close to zero when labor markets are tight.

4.1.5 Stochastic Equations for the Firm Sector

Sequential Approximation to the Joint Decisions

The maximization problem of a firm in the theoretical model is fairly complicated, which is partly a result of the large number of decision variables. The five main variables are the firm's price, production, investment, demand for employment, and wage rate. In the theoretical model these five decisions are jointly determined, that is, they are the result of solving one maximization problem. The variables that affect this solution include (1) the initial stocks of excess capital, excess labor, and inventories, (2) the current and expected future values of the interest rate, (3) the current and expected future demand schedules for the firm's output, (4) the current and expected future supply schedules of labor facing the firm, and (5) expectations of other firms' future price and wage decisions.

The theoretical model of firm behavior is more difficult to handle empirically than is the theoretical model of household behavior, and, as will be seen, the links from the theory to the econometric specifications are weaker for firms. One of the key approximations that was made was to assume that the five decisions of a firm are made sequentially rather than jointly. The sequence starts from the price decision and then goes to the production decision, to the investment and employment decisions, and finally to the wage rate decision. In this way of looking at the problem, the firm first chooses its optimal price path. This path then implies a certain expected sales path, from which the optimal production path is chosen. Given the optimal production path, the optimal paths of investment and employment are chosen. Finally, given the optimal employment path, the optimal wage path is chosen, which is the path that the firm expects is necessary to attract the amount of labor implied by its optimal employment path.

Seven observed variables were chosen to represent the five decisions: (1) the price level of the firm sector (P_f), (2) production (Y), (3) investment in nonresidential plant and equipment (IK_f), (4) the number of jobs in the firm sector (J_f), (5) the average number of hours paid per job (H_f), (6) the average number of overtime hours paid per job (HO), and (7) the wage rate of the firm sector (W_f).

A Constraint on the Behavior of the Real Wage

Before the estimated equations are discussed, a constraint that was imposed on the relationship between the nominal wage rate (W_f) and the price level (P_f) needs to be explained. It does not seem sensible for the real wage rate (W_f/P_f) to be a function of either W_f or P_f separately, and in order to ensure that this not be true, a constraint on the coefficients of the price and wage equations must be imposed. The relevant parts of the two equations are

$$\text{(4.17)} \qquad \log P_f = \beta_1 \log P_{f-1} + \beta_2 \log W_f + \; . \; . \; . \; ,$$

$$\text{(4.18)} \qquad \log W_f = \gamma_1 \log W_{f-1} + \gamma_2 \log P_f + \gamma_3 \log P_{f-1} + \; . \; . \; . \; .$$

From these two equations, the reduced form equation for the real wage (ignoring the other endogenous variables in the two equations) is

$$\text{(4.19)} \qquad \begin{aligned} \log W_f - \log P_f = {} & \frac{1}{1-\beta_2\gamma_2}\gamma_1(1-\beta_2)\log W_{f-1} \\ & - \frac{1}{1-\beta_2\gamma_2}[\beta_1(1-\gamma_2) - \gamma_3(1-\beta_2)] \log P_{f-1} \\ & + \; . \; . \; . \; . \end{aligned}$$

In order for the real wage not to be a function of the wage and price levels, the coefficient of $\log W_{f-1}$ in (4.19) must equal the negative of the coefficient of $\log P_{f-1}$. This requires that

$$\text{(4.20)} \qquad 0 = (\gamma_1 + \gamma_3)(1-\beta_2) - \beta_1(1-\gamma_2).$$

This restriction was imposed in the estimation of the model. (The imposition of coefficient restrictions within the context of the various estimation techniques is discussed in Chapter 6.)

The Price and Wage Equations

The main variables that affect the solution of a firm's maximization problem in the theoretical model were mentioned at the beginning of this section. The empirical work for the price and wage equations consisted of trying these variables, directly or indirectly, as explanatory variables. Observed variables were used directly, and unobserved variables were used indirectly by trying observed variables that seemed likely to affect the unobserved variables.

As noted in Section 4.1.3, a number of demand pressure variables were tried in the price and wage equations. In the end the decision was made simply to use ZZ in the price equation and UR in the wage equation. The results of trying other variables are discussed later in this section.

It was argued in Section 3.2.3 that import prices are likely to affect domestic prices, and therefore the import price index *(PIM)* was tried in the price equation. With respect to accounting for the effects of expectations of other firms' price decisions on actual price decisions, the main variable that was tried was simply the lagged price level. It is difficult to think of variables that may help capture the effects of expectations of future price decisions on current decisions. The lagged price level is obviously one possibility; another is the wage rate. If wages are high, this may lead firms to expect prices to be high in the future, which may then affect their current price decisions. It is somewhat unclear whether one should use the current wage rate or the lagged wage rate in the price equation. Given that the data in the model are quarterly, some of the data on wages within the quarter may be used by firms in setting prices within the quarter. In the empirical work both the current wage rate and the wage rate lagged one quarter were tried; the current wage rate gave slightly better results.

The final equation that was chosen is the following:

10.
$$\begin{aligned}\log P_f = \underset{(7.32)}{.187} + \underset{(82.62)}{.922} \log P_{f-1} + \underset{(6.95)}{.0339} \log W_f(1 + d_{5g} + d_{5s}) \\ + \underset{(8.56)}{.0339} \log PIM - \underset{(4.22)}{.0810}\, ZZ_{-1},\end{aligned}$$

$$SE = .00406,\ R^2 = .999,\ DW = 1.46$$

where P_f is the price level set by the firm sector, W_f is the wage rate, d_{5g} and d_{5s} are employer social security tax rates, PIM is the import price deflator, and ZZ is the demand pressure variable. The price level is a function of the lagged price level, the wage rate inclusive of employer social security costs, the import price deflator, and the demand pressure variable, ZZ.

In the empirical work for the wage equation, the lagged wage rate and the current and lagged price level were used as proxies for the expectations of future wages of other firms. The unemployment rate, UR, was used as a proxy for expectations about the labor supply curve. In addition, a time trend was added to the equation to account for trend changes in the wage rate relative to the price level. The inclusion of the time trend is important, since the time trend is essentially the variable that identifies the price equation. Given that the demand pressure variable ZZ and the unemployment rate are highly correlated, the only variable not included in the price equation that is included in the wage equation is essentially the time trend. Another way of looking at the wage equation, especially given the restriction (4.20) that is imposed on the coefficients of the price and wage equations, is that it is a real wage equation.

The estimated wage equation is

$$\text{16.} \quad \log W_f = \underset{(3.52)}{-.423} + \underset{(45.75)}{.929} \log W_{f-1} + .427 \log PX$$
$$- \underset{(3.50)}{.382} \log PX_{-1} + \underset{(4.31)}{.000671}\, t - \underset{(1.53)}{.0760}\, UR.$$

$$SE = .00546,\ R^2 = .999,\ DW = 2.00$$

The wage rate is a function of the lagged wage rate, the current and lagged values of the price level, the time trend, and the unemployment rate. The price variable that is used in the wage equation is PX rather than P_f. PX is the price deflator for sales of the firm sector, and P_f is the price deflator for sales of the firm sector minus farm output. The two deflators are very similar, and for purposes of imposing the real wage constraint discussed above, the two were taken to be the same. Equation 16 was estimated under the coefficient restriction (4.20), where the values used for β_1 and β_2 are the values estimated in Eq. 10. (See Section 6.3.2 for further discussion of this.) The wage equation is numbered 16 rather than 11 to emphasize that in the sequential approximation to the joint decisions, the wage decision is considered to come last.

It is possible from the coefficients of Eqs. 10 and 16 to calculate the coefficients of the real wage equation (4.19). The lagged dependent variable coefficient (that is, the coefficient of $\log W_{f-1} - \log P_{f-1}$ in Eq. 4.19), for example, is .911. When Eq. 16 was estimated without the restriction (4.20) imposed, the fit was essentially unchanged and the coefficient estimates changed very little. The unrestricted estimates of the coefficients of $\log PX$ and $\log PX_{-1}$ were .461 and $-.411$, which compare to the restricted estimates of .427 and $-.382$. An F test accepted the hypothesis at the 95-percent confidence level that the restriction is valid. The F value was 0.12, which compares to the critical value of 3.93 (with 1,109 degrees of freedom).

Movements of the real wage in the model affect the division of income between profits and wages. (The level of profits of the firm sector is determined by a definition, Eq. 67 in Table A-5, where it is a positive function of prices and a negative function of the wage rate.) The coefficient of the current price variable in the wage equation is less than one, and thus when, say, the price level rises by 1 percent in the quarter, the wage rate rises by less than 1 percent, other things being equal. A shock to the price level thus means an initial fall in the real wage. If, for example, the price of imports (*PIM*) rises by 1 percent, this will lead to an increase in the price level of .0339 percent in the current quarter, but to an increase in the wage rate of only about half this amount. An increase in the price of imports thus has a negative effect on the real wage.

The results of searching for the price and wage equations will now be discussed. The only searching that was done for the wage equation was to try alternative measures of demand pressure. The use of $1/UR$ in place of UR led to almost identical results. The fits were essentially the same (SE = .00545 versus .00546 above), and the t-statistic for the coefficient of $1/UR$ was 1.55, which compares to 1.53 above. The use of ZZ in place of UR produced poorer results. The t-statistic for the coefficient of ZZ was only 0.39. The use of log $(ZZ + .04)$, which is a nonlinear transformation of ZZ that takes on a value of minus infinity when $GNPR$ exceeds $GNPR^*$ by 4.0 percent, in place of UR produced similar results to those for ZZ. The t-statistic for the coefficient of log $(ZZ + .04)$ was 0.34.

More searching was done for the price equation. (Results using the one-quarter-lagged values of the demand pressure variables rather than the current values gave better results, and only the results using the lagged values will be reported here.) A nonlinear transformation of ZZ_{-1}, log $(ZZ_1 + a)$, where a is some preassigned number, led to results that were almost identical to those using ZZ_{-1}. For values of a of .01, .04, and .10 the t-statistics were 3.82, 4.03, and 4.12 respectively, which compare to the value of 4.22 given above using ZZ_{-1}. The fits were very close. Three other candidates for the demand pressure variable did not lead to significant coefficient estimates. They were (1) the initial stock of excess labor on hand, (2) the initial stock of excess capital on hand, and (3) the initial ratio of the stock of inventories to the level of sales. The excess capital variable was closest to being significant, with a t-statistic of 1.91.

The use of UR_{-1} or $1/UR_{-1}$ in place of ZZ_{-1} produced slightly better results. The t-statistics were 6.36 and 5.59 respectively, compared to 4.22 for ZZ_{-1}, and the fits were somewhat better (SE = .00376 and .00387 respectively, compared to .00406 above). When UR_{-1} and ZZ_{-1} were both included in the equation, UR_{-1} was significant but ZZ_{-1} was not. A similar result was obtained when $1/UR_{-1}$ and ZZ_{-1} were both included in the equation. In spite of these results, I decided to use ZZ_{-1} as the demand pressure variable in the price equation. The unemployment rate is more difficult to predict than is $GNPR$ (and thus ZZ) because it is more sensitive to errors made in predicting the labor force variables. My general experience is that versions of the price equation that use an unemployment rate variable as the demand pressure variable lead to less accurate predictions of prices within the context of the overall model than do other versions. This is true even though the other versions may not have as good single-equation fits. These differences are generally small, however, and the use of ZZ_{-1} over UR_{-1} or $1/UR_{-1}$ is not an important issue. The results in this book would not be changed very much if UR_{-1} or $1/UR_{-1}$ were used instead.

Two dummy variables were added to the price equation to try to pick up possible effects of the price freeze in 1971IV and the removal of the freeze in 1972I. One dummy variable had a value of 1 in 1971IV and 0 otherwise, and the other had a value of 1 in 1972I and 0 otherwise. Neither of these variables was significant, and their inclusion had little effect on the other coefficient estimates. The coefficient estimates were of the expected signs (negative and positive, respectively), but the t-statistics were only 0.12 and 1.47. The price freeze thus appeared to have too small an effect on P_f to be picked up by an equation like Eq. 10, and therefore no price freeze variables were used. With the current wage rate included in the price equation, the wage rate lagged one quarter was not significant. The latter was thus not included in the final specification.

With respect to employer social security tax rates, the tax rates have a positive effect on the price level through the $W_f(1 + d_{5g} + d_{5s})$ term in Eq. 10. This term is the wage rate inclusive of employer social security taxes. The inclusion of these tax rates in the price equation means that an increase in the rates has a negative effect on the real wage. In other words, at least some of the increase in employer social security taxes is estimated to be passed along to workers in the form of a lower real wage. The inclusion of the social security tax rates in the price equation is not supported by the data. When the terms $\log W_f$ and $\log(1 + d_{5g} + d_{5s})$ are included separately in Eq. 10, the estimate of the tax variable is significant but of the wrong sign (−.529 with a t-statistic of 2.66). The main problem is that there is not much variation in the tax rates. Poor results are thus not surprising and are not necessarily to be trusted as indicating that the tax rates truly do not belong in the equation. The answer to this problem here was merely to assume that the tax rates affect the price level in the same way that the wage rate does.

No evidence could be found that profit taxes affect the price level. When, for example, the variable log $(1 + d_{2g} + d_{2s})$ was added to Eq. 10, its coefficient estimate was insignificant, with a t-statistic of 1.21 (d_{2g} and d_{2s} are the corporate profit tax rates). For the same variable lagged one quarter, the t-statistic was 1.12. Little evidence could thus be found that firms pass on profit taxes in the form of higher prices relative to wages. Again, however, there is not much variation in tax rates, so very little confidence should be placed on this negative result. Unlike the case for the social security tax rates, there is no obvious way to restrict the profit tax rates to enter the price equation, and therefore nothing was tried. The model thus has the property that a change in profit tax rates does not directly affect the real wage.

In previous versions of the US model, two cost-of-capital variables were included in the price equation, the bond rate *RB* and an investment tax credit variable denoted *TXCR*. In the theoretical model the interest rate affects the firm's decisions, and in the case of experiment 5 in Table 3-3 an increase in the interest rate led the firm to raise its prices in periods 2 and 3. The cost-of-capital variables were thus used to see if there was any empirical support for the proposition that these variables affect prices. When *RB* and *TXCR* are included in Eq. 10, they are significant, with t-statistics of 4.69 and 2.17 respectively. The coefficient estimate of *RB* is positive (.00249) and the coefficient estimate of *TXCR* is negative (−.00239), both as expected. (*TXCR* takes on a value of 1.0 when the credit of 7 percent is in full force — 1964I–1966III, 1967II–1969I, and 1971IV–1975I; a value of 1.43 when the credit of 10 percent is in force — 1975II on; a value of .5 when the credit of 7 percent is estimated to be half in force because of the Long amendment or timing considerations — 1962III–1963IV and 1971III; and 0.0 when the credit is not in force.)

With *RB* included in the price equation, the model has the property that high interest rates, other things being equal, are inflationary. A tight monetary policy defined as high interest rates has a direct positive effect on prices as well as the usual indirect negative effect on prices through the negative effect of high interest rates on demand. The direct positive interest rate effect on prices in this version is large, and for a number of experiments it dominates the indirect negative effect. I finally decided that the effect seems too large, and I have dropped the cost-of-capital variables from the price equation. It may be that some left-out variable from the price equation, such as inflationary expectations, affects both RB and P_f and that RB is spuriously picking up the effects of this variable on P_f. This decision does have a significant effect on the properties of the model, and it should not be taken lightly. If RB actually belongs in the price equation, then excluding it has seriously misspecified the model with respect to a number of policy properties.

The Production Equation

The specification of the production equation is the point at which the assumption that a firm's decisions are made sequentially begins to be used. The equation is based on the assumption that the firm sector first sets its price, then knows what its sales for the current period will be, and from this latter information decides on what its production for the current period will be.

In the theoretical model production is smoothed relative to sales, that is, the optimal production path of a firm generally has less variance than its expected sales path. The reason for this is the various costs of adjustment, which include costs of changing employment, costs of changing the capital stock, and costs of having the stock of inventories deviate from β_1 times sales. If a firm were only interested in minimizing inventory costs, it would produce according to the following equation (assuming that sales for the current period are known):

$$(4.21) \qquad Y = X + \beta_1 X - V_{-1},$$

where Y is the level of production, X is the level of sales, and V_{-1} is the stock of inventories at the beginning of the period. Since by definition, $V - V_{-1} = Y - X$, producing according to (4.21) would ensure that $V = \beta_1 X$. Because of the other adjustment costs, it is generally not optimal for a firm to produce according to (4.21). In the theoretical model there was no need to postulate explicitly how a firm's production plan deviated from (4.21) because its optimal production path just resulted, along with the other optimal paths, from the direct solution of its maximization problem. For the empirical work, on the other hand, it is necessary to make further assumptions.

The estimated production equation is based on the following three assumptions:

$$(4.22) \qquad V^* = \beta X,$$

$$(4.23) \qquad Y^* = X + \alpha(V^* - V_{-1}),$$

$$(4.24) \qquad Y - Y_{-1} = \lambda(Y^* - Y_{-1}),$$

where $*$ denotes a desired value. Equation (4.22) states that the desired stock of inventories is proportional to current sales. Equation (4.23) states that the desired level of production is equal to sales plus some fraction of the difference between the desired stock of inventories and the stock on hand at the end of the previous period. Equation (4.24) states that actual production partially adjusts to desired production each period. Combining the three equations yields

$$Y = (1-\lambda)Y_{-1} + \lambda(1+\alpha\beta)X - \lambda\alpha V_{-1}. \tag{4.25}$$

The estimated equation is

11.
$$\begin{aligned} Y = \underset{(4.36)}{11.4} + \underset{(3.67)}{.162}\ Y_{-1} &+ \underset{(19.59)}{1.011}\ X - \underset{(4.44)}{.193}\ V_{-1} \\ &- \underset{(1.86)}{2.06}\ D593 + \underset{(0.64)}{.793}\ D594 + \underset{(1.89)}{2.10}\ D601, \end{aligned}$$

$$\mathrm{SE} = 1.12,\ \mathrm{R}^2 = .999,\ \mathrm{DW} = 2.20,\ \hat{\rho} = \underset{(6.73)}{.605}$$

where $D593$, $D594$, and $D601$ are dummy variables for the 1959 steel strike. The implied value of λ is $1 - .162 = .838$, which means that actual production adjusts 83.8 percent of the way to desired production in the current quarter. The implied value of α is .230, which means that desired production is equal to sales plus 23.0 percent of the desired change in inventories. The implied value of β is .898, which means that the desired stock of inventories is estimated to equal 89.8 percent of the (quarterly) level of sales.

No searching was done for the production equation other than to try a few strike dummy variables.

The Investment Equation

The investment equation is based on the assumption that the production decision has already been made. In the theoretical model, because of costs of changing the capital stock, it may sometimes be optimal for a firm to hold excess capital. If there were no such costs, investment each period would merely be the amount needed to have enough capital to produce the output of the period. In the theoretical model there was no need to postulate explicitly how investment deviates from this amount, but for the empirical work this must be done.

The estimated investment equation is based on the following three equations:

$$(4.26) \qquad (KK - KK_{-1})^* = \alpha_0(KK_{-1} - KKMIN_{-1}) + \alpha_1\Delta Y + \alpha_2\Delta Y_{-1} + \alpha_3\Delta Y_{-2} + \alpha_4\Delta Y_{-3},$$

$$(4.27) \qquad IK_f^* = (KK - KK_{-1})^* + \delta_K KK_{-1},$$

$$(4.28) \qquad IK_f - IK_{f-1} = \lambda(IK_f^* - IK_{f-1}),$$

where * again denotes a desired value. IK_f is gross investment of the firm sector, KK is the capital stock, and $KKMIN$ is the minimum amount of capital needed to produce the output of the period. $(KK - KK_{-1})^*$ is desired net investment, and IK_f^* is desired gross investment. Equation (4.26) states that desired net investment is a function of the amount of excess capital on hand and of four change-in-output terms. If output has not changed for four periods and if there is no excess capital, then desired net investment is zero. The change-in-output terms are meant in part to be proxies for expected future output changes. Equation (4.27) relates desired gross investment to desired net investment. $\delta_K KK_{-1}$ is the depreciation of the capital stock during period $t-1$. By definition, $IK_f = KK - KK_{-1} + \delta_K KK_{-1}$, and (4.27) is merely this same equation for the desired values. Equation (4.28) is a stock adjustment equation relating the desired change in gross investment to the actual change. It is meant to approximate cost of adjustment effects.

Combining (4.26)–(4.28) yields

$$(4.29) \qquad IK_f - IK_{f-1} = \lambda\alpha_0(KK_{-1} - KKMIN_{-1}) + \lambda\alpha_1\Delta Y + \lambda\alpha_2\Delta Y_{-1} + \lambda\alpha_3\Delta Y_{-2} + \lambda\alpha_4\Delta Y_{-3} - \lambda(IK_{f-1} - \delta_K KK_{-1}).$$

Equation (4.29) has two restrictions that were not imposed in the empirical work. First, there is no constant term in (4.29), but one was used in the estimated equation. Second, from the last term in (4.29) the coefficients of IK_{f-1} and $\delta_K KK_{-1}$ are the same, and this constraint was not imposed.

The estimated equation is

$$12. \qquad \Delta IK_f = \underset{(0.11)}{-.0146} - \underset{(2.83)}{.0130}\,(KK - KKMIN)_{-1} + \underset{(5.70)}{.0967}\,\Delta Y + \underset{(0.02)}{.0004}\,\Delta Y_{-1} + \underset{(0.88)}{.0140}\,\Delta Y_{-2} + \underset{(1.24)}{.0196}\,\Delta Y_{-3} - \underset{(2.48)}{.107}\,IK_{f-1} + \underset{(2.59)}{.167}\,\delta_K KK_{-1}.$$

$$SE = .390,\ R^2 = .534,\ DW = 2.13$$

The estimated value of λ is .107 if taken from the IK_{f-1} term and .167 if taken from the $\delta_K KK_{-1}$ term. This means that gross investment adjusts between about 10.7 and 16.7 percent to its desired value each quarter. The implied value of α_0 is between $-.078$ and $-.121$, which means that between 7.8 and 12.1 percent of the amount of excess capital on hand is desired to be eliminated each quarter.

The estimate of the constant term in Eq. 12 is highly insignificant, and the results were little affected when the constant term was excluded. With respect to the other restriction, when the constraint on the coefficients of IK_{f-1} and $\delta_K KK_{-1}$ was imposed, the estimated value of λ was essentially zero (an estimate of .002, with a t-statistic of 0.12). This is the reason the restriction was not imposed, and it is a good example of the compromises that are sometimes made in empirical work. The theoretical restriction itself is, of course, not very tight in the sense that (4.29) only represents a rough approximation to the investment decision in the theoretical model.

Note that the interest rate does not appear as an explanatory variable in the investment equation. When the after-tax bond rate, *RBA*, was added to the equation, its coefficient estimate was significant but of the wrong sign (.209 with a t-statistic of 3.48). Similar results were obtained by lagging *RBA* one and then two quarters. The coefficient estimates and t-statistics were .223, 3.49 and .277, 3.92, respectively. There is thus no evidence that interest rates negatively affect investment in an equation like Eq. 12. Interest rates do, however, have important negative indirect effects on investment in the model. (See points 2 and 3 at the end of this section.) The investment tax credit variable discussed earlier, *TXCR*, was of the wrong expected sign and not significant when added to Eq. 12. Its coefficient estimate was $-.038$, with a t-statistic of 0.31.

The significance of the excess capital variable in Eq. 12 provides support for the proposition that firms spend time off their production functions. With respect to the output terms in the equation, only the current term is significant, and the results would not be much affected if the other three terms were dropped.

The Three Employment and Hours Equations

The employment and hours equations are similar in spirit to the investment equation. They are also based on the assumption that the production decision has already been made. Because of adjustment costs, it may sometimes be optimal in the theoretical model for firms to hold excess labor. Were it not for the costs of changing employment, the optimal level of employment would merely be the amount needed to produce the ouput of the period. In the theoretical model there was no need to postulate explicitly how employment deviates from this amount, but this must be done for the empirical work.

The estimated employment equation is based on the following three equations:

(4.30) $$\Delta \log J_f = \alpha_0 \log \frac{J_{f-1}}{J^*_{f-1}} + \alpha_1 \Delta \log Y + \alpha_2 \Delta \log Y_{-1} + \alpha_3 \Delta \log Y_{-2},$$

(4.31) $$J^*_{f-1} = \frac{JHMIN_{-1}}{H^*_{f-1}},$$

(4.32) $$H^*_{f-1} = \bar{H}e^{\delta t},$$

where $JHMIN$ is the number of worker hours required to produce the output of the period, H^*_f is the average number of hours per job that the firm would like to be worked if there were no adjustment costs, and J^*_f is the number of workers the firm would like to employ if there were no adjustment costs. The term $\log (J_{f-1}/J^*_{f-1})$ in (4.30) will be referred to as the "amount of excess labor on hand." Equation (4.30) states that the change in employment is a function of the amount of excess labor on hand and three change-in-output terms (all changes are changes in logs). If output has not changed for three periods and if there is no excess labor on hand, the change in employment is zero. As was the case for investment, the change-in-output terms are meant in part to be proxies for expected future output changes. Equation (4.31) defines the desired number of jobs, which is simply equal to the required number of worker hours divided by the desired number of hours worked per job. Equation (4.32) postulates that the desired number of hours worked is a smoothly trending variable, where $\bar{H}$ and δ are constants.

Combining (4.30)–(4.32) yields

(4.33) $$\Delta \log J_f = \alpha_0 \log \bar{H} + \alpha_0 \log \frac{J_{f-1}}{JHMIN_{-1}} + \alpha_0 \delta t + \alpha_1 \Delta \log Y + \alpha_2 \Delta \log Y_{-1} + \alpha_3 \Delta \log Y_{-2}.$$

The estimated equation is

13. $$\begin{aligned} \Delta \log J_f = {} & \underset{(3.76)}{-.885} - \underset{(3.75)}{.141} \log \frac{J_{f-1}}{JHMIN_{-1}} + \underset{(4.28)}{.000176}\, t \\ & + \underset{(8.33)}{.281} \Delta \log Y + \underset{(3.03)}{.119} \Delta \log Y_{-1} \\ & + \underset{(1.02)}{.033} \Delta \log Y_{-2} - \underset{(2.70)}{.00967} D593 + \underset{(0.50)}{.00174} D594, \end{aligned}$$

$SE = .00335$, $R^2 = .780$, $DW = 2.04$, $\hat{\rho} = .447$
(4.44)

where $D593$ and $D594$ are dummy variables for the 1959 steel strike. The estimated value of α_0 is $-.141$, which means that, other things being equal, 14.1 percent of the amount of excess labor on hand is eliminated each quarter. The implied value of $\overline{H}$ is 531.97, which at a weekly rate is 40.92 hours. The implied value of δ is $-.00125$. The trend variable t is equal to 9 for the first quarter of the sample period (1954I), and so the implied value of H^*_{f-1} for 1954I at a weekly rate is $40.92 \cdot \exp(-.00125 \times 9) = 40.46$. For 1982III t is equal to 123, and therefore the implied value for this quarter is $40.92 \cdot \exp(-.00125 \times 123) = 35.09$. In general these numbers seem reasonable. The significance of the excess labor variable in Eq. 13, like the significance of the excess capital variable in Eq. 12, provides support for the proposition that firms spend some time off their production functions.

The main hours equation is based on (4.31) and (4.32) and the following equation:

$$\text{(4.34)} \qquad \Delta \log H_f = \lambda \log \frac{H_{f-1}}{H^*_{f-1}} + \alpha_0 \log \frac{J_{f-1}}{J^*_{f-1}} + \alpha_1 \Delta \log Y.$$

The first term on the RHS of (4.34) is the (logarithmic) difference between the actual number of hours paid for in the previous period and the desired number. The reason for the inclusion of this term in the hours equation but not in the employment equation is that, unlike J_f, H_f fluctuates around a slowly trending level of hours. This restriction is captured by the first term in (4.34). The other two terms are the amount of excess labor on hand and the current change in output. Both of these terms have an important effect on the employment decision, and they should also affect the hours decision since the two are closely related. Past output changes might also be expected to affect the hours decision, but these were not found to be significant and thus are not included in (4.34).

Combining (4.31), (4.32), and (4.34) yields

$$\text{(4.35)} \qquad \Delta \log H_f = (\alpha_0 - \lambda)\log \overline{H} + \lambda \log H_{f-1} + \alpha_0 \log \frac{J_{f-1}}{JHMIN_{-1}} + (\alpha_0 - \lambda)\delta t + \alpha_1 \Delta \log Y.$$

The estimated equation is

$$\text{14.} \qquad \Delta \log H_f = \underset{(4.95)}{1.37} - \underset{(5.16)}{.284} \log H_{f-1} - \underset{(3.55)}{.0659} \log \frac{J_{f-1}}{JHMIN_{-1}} - \underset{(4.94)}{.000250}\, t + \underset{(4.40)}{.120} \Delta \log Y.$$

$$\text{SE} = .00285,\ \text{R}^2 = .398,\ \text{DW} = 2.18$$

The estimated value of λ is $-.284$, which means that, other things being equal, actual hours are adjusted toward desired hours by 28.4 percent per quarter. The excess labor term is significant, with an estimated value of α_0 of $-.0659$. The implied value of $\bar{H}$ is 534.60, which is 41.12 hours at a weekly rate. This compares closely to the value of 40.92 implied by Eq. 13. The implied value of δ is $-.00115$, which compares closely to the value of $-.00125$ implied by Eq. 13. No attempt was made to impose the restriction that $\bar{H}$ and δ are the same in Eqs. 13 and 14. Given the closeness of the estimates, it is unlikely that imposing this restriction would make much difference. Again, the significance of the excess labor variable is support for the theoretical model.

The second hours equation explains overtime hours *(HO)*. It is of considerably less importance than the employment equation and the other hours equation. One would expect HO to be related to total hours, H_f, in the manner indicated in Figure 4-2. Up to some point A (for example, 40 hours per week), HO should be zero or some small constant amount, and after point A, increases in HO and H_f should be roughly one for one. An approximation to the curve in Figure 4-2 is

$$(4.36) \qquad HO = \exp(\alpha_1 + \alpha_2 H_f),$$

which in log form is

$$(4.37) \qquad \log HO = \alpha_1 + \alpha_2 H_f.$$

The foregoing discussion is based on the implicit premise that H_f has no trend. In practice H_f has a negative trend, which means that A in Figure 4-2 is likely to be shifting left over time. In order to account for this effect, H_f was detrended before being included in (4.37). H_f was regressed on a constant and t for the 1952I–1982III period, which resulted in an estimate of the coefficient for t of $-.56464$. The variable included in the estimated equation was then $H_f + .56464t$, which is denoted H_f^*. (This is Eq. 100 in Table A-5.) The estimated equation is

$$15. \qquad \log HO = \underset{(5.15)}{-8.34} + \underset{(7.38)}{.0223}\, H_f^*.$$

$$\text{SE} = .0552,\ R^2 = .905,\ \text{DW} = 1.82,\ \hat{\rho} = \underset{(21.38)}{.909}$$

There is considerable serial correlation in this equation ($\hat{\rho} = .909$), but as a rough approximation it seems satisfactory.

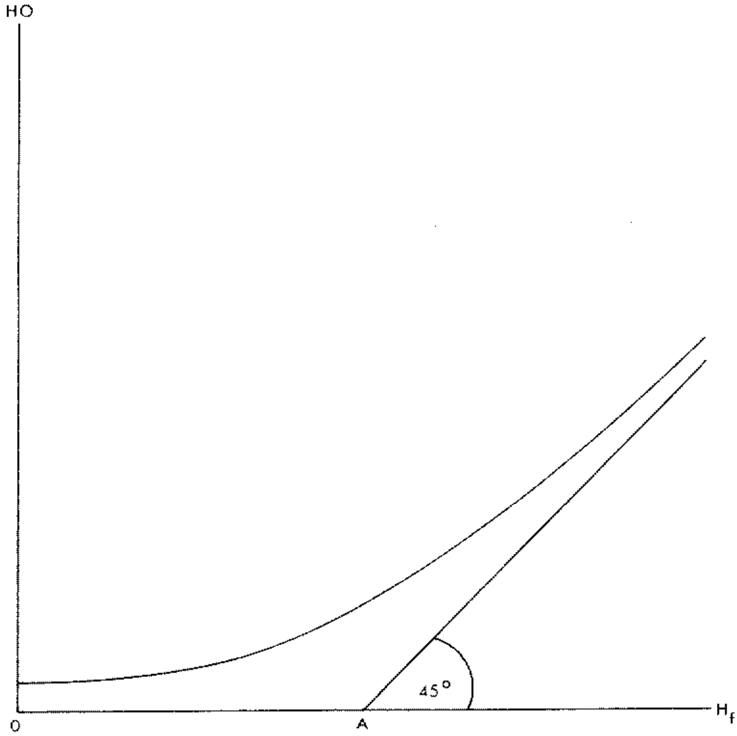

Figure 4-2 Expected relationship between overtime hours *(HO)* and total hours *(H_f)*

The Demand for Money Equation

The estimated demand for money equation for the firm sector is

$$17.\quad \log\frac{M_f}{PX} = \underset{(1.04)}{.106} + \underset{(26.10)}{.920}\ \log\left(\frac{M_f}{PX}\right)_{-1} + \underset{(2.39)}{.0477}\ \log X - \underset{(3.26)}{.00700}\ RS(1-d_{2g}-d_{2s}).$$

$$SE = .0237,\ R^2 = .936,\ DW = 2.06$$

The demand for real money balances, M_f/PX, is a function of sales, X, and the after-tax short-term interest rate, $RS(1 - d_{2g} - d_{2s})$. The tax rates used here are corporate tax rates, not personal tax rates as in Eq. 9. The level of sales is used as the transactions variable.

The Dividend Equation

The estimated dividend equation is

$$\text{18.} \quad \underset{(1.05)}{D_f = -.0227} + \underset{(108.28)}{.978}\ D_{f-1} + \underset{(5.64)}{.0201}\ (\pi_f - T_{fg} - T_{fs}),$$

$$SE = .125,\ R^2 = .999,\ DW = 1.58$$

where D_f is the level of dividends and $\pi_f - T_{fg} - T_{fs}$ is the value of after-tax profits. This is a standard dividend equation in which the current level of dividends is a function of current and past values of after-tax profits.

The Interest Payments Equation

The current level of interest payments of the firm sector is a function of its outstanding debt and of the interest rates that were in effect at the times of the relevant debt issues. The estimated equation that attempts to approximate this is

$$\text{19.} \quad \underset{(1.96)}{INT_f = -3.59} + \underset{(8.59)}{.746}\ INT_{f-1} + \underset{(1.91)}{.0200}\ (-A_f) + \underset{(4.25)}{.467}\ RB.$$

$$SE = .364,\ R^2 = .999,\ DW = 2.01,\ \hat{\rho} = \underset{(25.41)}{.954}$$

INT_f is the level of interest payments, A_f is the value of net financial assets of the firm sector, and RB is the bond rate. A_f is negative because the firm sector is a net debtor. Interest payments are estimated to be a function of the debt of the firm sector and the bond rate.

Equation 19 has rather poor statistical properties. The coefficient estimates are not robust to slight changes in the specification, and the estimated serial correlation coefficient is high ($\hat{\rho} = .954$). This is not necessarily unexpected, since the equation does not capture the fact that debt is issued in a variety of maturities at different interest rates. Fortunately, the equation does not have an important effect on the properties of the model except for one of the experiments in Chapter 11, which concerns a version of the model in which there are rational expectations in the bond and stock markets. The results of this experiment indicate that the coefficient estimate of RB in Eq. 19 may be too large. This issue is discussed in Section 11.7.3.

The Inventory Valuation Adjustment Equation

The equation explaining inventory valuation adjustment is

$$\text{20.} \quad \underset{(0.98)}{IVA = 1.52} - \underset{(3.51)}{95.2\ PX} + \underset{(3.34)}{92.2\ PX_{-1}},$$

$$SE = 1.24,\ R^2 = .865,\ DW = 1.71,\ \hat{\rho} = \underset{(12.45)}{.801}$$

where IVA is the value of the inventory valuation adjustment and PX is the price level. In the theoretical model IVA is equal to $-(PX - PX_{-1})V_{-1}$, and Eq. 20 is an attempt to approximate this. The coefficient estimates for PX and PX_{-1} are of opposite sign and close to each other in absolute value, which is as expected. The variable V_{-1} was added to the equation to see if any effect of the stock of inventories on IVA could be found. Its coefficient estimate was of the wrong sign ($-.0410$, with a t-statistic of 1.92), and therefore V_{-1} was not included in the equation.

The Capital Consumption Equation

The capital consumption of the firm sector (CC_f) is assumed to be a function of the current and past values of nominal investment expenditures ($PIK \cdot IK_f$), where the lag structure is geometrically declining. The estimated equation is

$$\text{21.} \quad CC_f = \underset{(3.69)}{-.0930} + \underset{(67.13)}{.966\ CC_{f-1}} + \underset{(4.69)}{.0447\ PIK \cdot IK_f} + \underset{(6.29)}{.562\ DD811}.$$

$$SE = .145,\ R^2 = .999,\ DW = 1.99$$

The dummy variable $DD811$ takes on a value of 1 from 1981I on and a value of 0 otherwise. Equation 21, like Eqs. 19 and 20, is only meant to be a rough approximation. Capital consumption is a function of current and past tax laws and accounting practices (as well as of current and past investment expenditures), both of which have changed over time. Equation 21 ignores these changes except for the inclusion of $DD811$. There appeared to be an important break in the relationship between capital consumption and investment expenditures beginning in 1981I, which could be captured fairly well by merely adding *DD*811 to the equation.

Summary and Further Discussion

The key equations of the firm sector are Eqs. 10–14 and 16. Some of the features of these equations are as follows.

1. Production is smoothed relative to sales. Investment, employment, and hours are smoothed relative to production. The buffer for production is the stock of inventories. The buffer for investment is the amount of excess capital on hand, and the buffer for employment and hours is the amount of excess labor on hand.

2. Although the bond rate is not an explanatory variable in the investment equation, interest rates have indirect negative effects on investment. Interest rates are explanatory variables in the consumer expenditure equations with negative coefficients, and thus an increase in interest rates directly lowers expenditures. This in turn lowers sales *(X),* which lowers production and then investment and employment. The main channel by which interest rates affect the economy is through their effects on consumer expenditures.

3. Although interest rates affect investment in the manner just discussed, there is no means in the model by which interest rates affect capital-labor substitution. Any changes in the substitution of capital for labor (or vice versa) brought about by changes in the cost of capital relative to the cost of labor are not explained. The effects of long-run changes in the relationship of capital to labor are captured in the model through the peak-to-peak interpolations that are involved in the construction of excess capital and excess labor, in particular of *KHMIN* and *JHMIN*. The interpolations are, however, exogenous, and thus nothing in the model is allowed to affect them.

The spirit of the model is that firms spend much of the time "off" their production functions, which means that for much of the time one is not directly observing the number of capital and labor hours that are actually needed in the production process. If this is true, it is obviously going to be difficult to pick up the effects of, say, interest rate changes on the capital-labor ratio. I have made no attempt to do this in the model. If capital-labor substitution is a fairly slow and smooth process, then little is likely to be lost by the present approach, even with the use of the model for periods as long as, say, five years. If, on the other hand, substitution is fast or erratic, then the present model is likely to be seriously misspecified and should not hold up well in tests.

4.1.6 Stochastic Equations for the Financial Sector

The stochastic equations for the financial sector consist of an equation explaining member bank borrowing from the Federal Reserve, two term structure equations, an equation explaining the change in stock prices, and a demand for currency equation.

The Bank Borrowing Equation

The variable *BO/BR* is the ratio of borrowed reserves to total reserves. This ratio is assumed to be a function of the difference between the three-month Treasury bill rate *(RS)* and the discount rate *(RD)*. The estimated equation is

$$22. \qquad \frac{BO}{BR} = \underset{(3.79)}{.0148} + \underset{(1.34)}{.00455}\,(RS - RD).$$

$$\text{SE} = .0162,\ \text{R}^2 = .382,\ \text{DW} = 2.32,\ \hat{\rho} = \underset{(7.93)}{.606}$$

This equation does not fit very well, and the estimate of the serial correlation coefficient is fairly high. There is, however, at least some slight evidence that bank borrowing responds to the interest rate differential.

The Two Term Structure Equations

The expectations theory of the term structure of interest rates states that long-term rates are a function of the current and expected future short-term rates. The two long-term interest rates in the model are the bond rate *(RB)* and the mortgage rate *(RM)*. These rates are assumed to be determined according to the expectations theory, where current and past values of the short-term interest rate are used as proxies for expected future values. The two estimated equations are

$$23. \qquad RB = \underset{(2.54)}{.114} + \underset{(53.00)}{.889}\ RB_{-1} + \underset{(10.82)}{.277}\ RS - \underset{(6.48)}{.218}\ RS_{-1} + \underset{(3.48)}{.074}\ RS_{-2},$$

$$\text{SE} = .171,\ \text{R}^2 = .997,\ \text{DW} = 1.74$$

24.
$$\begin{aligned} RM = {} & \underset{(3.36)}{.343} + \underset{(29.00)}{.846}\ RM_{-1} + \underset{(4.64)}{.178}\ RS + \underset{(0.80)}{.041}\ RS_{-1} \\ & - \underset{(1.23)}{.043}\ RS_{-2}. \end{aligned}$$

SE = .258, R^2 = .992, DW = 2.23

Note that the lagged dependent variable is included as an explanatory variable in each equation, which implies a fairly complicated lag structure relating each long-term rate to the past values of the short-term rate.

The expected rate of inflation variables that were discussed in Section 4.1.3 were tried in the equations, but no significant results were obtained. The best that was done from all the regressions tried was a t-statistic of 1.16 for the first expected wage inflation variable in the RB equation. One must thus conclude either that the expected inflation variables are poor measures of expectations or that any effects of expected future inflation rates on expected future nominal short-term interest rates are captured in the current and past short-term rates.

The Capital Gains Equation

The variable CG is the change in the market value of stocks held by the household sector. In the theoretical model the aggregate value of stocks is determined as the present discounted value of expected future after-tax cash flow, the discount rates being the current and expected future short-term interest rates. The theoretical model thus implies that CG should be a function of changes in expected future after-tax cash flow and of changes in current and expected future interest rates. In the empirical work the change in the bond rate, ΔRB, was used as a proxy for changes in expected future interest rates, and the current and one-quarter-lagged values of the change in after-tax cash flow, $\Delta(CF - T_{fg} - T_{fs})$, were used as proxies for changes in expected future after-tax cash flow. The estimated equation is

25.
$$\begin{aligned} CG = {} & \underset{(2.23)}{10.9} - \underset{(1.26)}{24.4}\ \Delta RB + \underset{(1.49)}{3.75}\ \Delta(CF - T_{fg} - T_{fs}) \\ & + \underset{(2.08)}{4.07}\ \Delta(CF - T_{fg} - T_{fs})_{-1}. \end{aligned}$$

SE = 48.4, R^2 = .145, DW = 1.90

The explanatory power of this equation is low, as would be expected, but at least some effect of interest rates and cash flow on stock prices seems to have been picked up.

The Demand for Currency Equation

The estimated demand for currency equation is

$$\text{26.} \quad \log \frac{CUR}{POP \cdot PX} = \underset{(3.87)}{-.106} - \underset{(0.79)}{.000133}\, t + \underset{(32.88)}{.897} \log \left(\frac{CUR}{POP \cdot PX} \right)_{-1}$$

$$+ \underset{(2.36)}{.0801} \log \frac{X}{POP}$$

$$- \underset{(4.00)}{.00313}\, RSA,$$

$$SE = .0103,\ R^2 = .937,\ DW = 2.69$$

where *CUR* is the value of currency. This equation states that the real per-capita demand for currency is a function of the real per-capita level of sales and of the after-tax short-term interest rate. A time trend is also included in the equation, although it is not significant.

4.1.7 The Stochastic Equation for the Foreign Sector

There is one estimated equation for the foreign sector, an equation explaining the demand for imports *(IM)*. Since this demand is demand by the domestic sectors, the position of the equation is somewhat arbitrary. It was put here to highlight the fact that the demand for imports has an important effect on the savings of the foreign sector.

It was argued in Section 3.2.2 that the demand for imports should be a function of the variables that affect a household's maximization problem. For the empirical work, this would mean trying the variables that were used in Section 4.1.4 to explain the expenditure and labor supply decisions of the household sector. The one problem with this is that in practice many imports are for use by the firm sector, and it is not possible to get a breakdown of imports by sector of purchase. As a compromise, I replaced (as possible explanatory variables) the wage rate variable, *WA*, and the labor constraint variable, *Z*, by per-capita domestic sales, *X/POP*. The explanatory variables that were tried included the wealth variable of the household sector, $(AA/POP)_{-1}$, the price of imports, the price of domestic goods, interest rates, and per-capita domestic sales. The wealth variable was not significant and thus was dropped. The equation that was chosen is

$$
\begin{aligned}
\text{27.}\qquad \frac{IM}{POP} = & -\underset{(4.44)}{.0277} + \underset{(15.31)}{.752}\left(\frac{IM}{POP}\right)_{-1} + \underset{(4.10)}{.0256}\,\frac{X}{POP} \\
& - \underset{(3.90)}{.0114}\,PIM_{-1} + \underset{(4.64)}{.0393}\,PX_{-1} - \underset{(2.59)}{.00126}\,RMA_{-1} \\
& - \underset{(2.18)}{.00654}\,D651 + \underset{(1.17)}{.00356}\,D652 - \underset{(3.65)}{.0109}\,D691 \\
& + \underset{(5.42)}{.0166}\,D692 - \underset{(2.64)}{.00798}\,D714 \\
& + \underset{(4.10)}{.0123}\,D721.
\end{aligned}
$$

$$\text{SE} = .00294,\ R^2 = .994,\ \text{DW} = 1.71$$

The dummy variables are for periods in which there was a dock strike or recovery from a strike.

Equation 27 is similar to the import equations that are estimated for the multicountry model in Section 4.2.5. The demand for imports is a positive function of domestic activity and of the domestic price level and a negative function of the price of imports and of the interest rate. The interest rate in this case is measured by the after-tax mortgage rate, RMA. The price variables and the interest rate are lagged one quarter.

4.1.8 The Stochastic Equation for the State and Local Government Sector

The stochastic equation for the state and local government sector explains unemployment insurance benefits (UB). The estimated equation is

$$\text{28.}\qquad \log UB = \underset{(0.69)}{.369} + \underset{(18.00)}{1.58}\,\log U + \underset{(6.06)}{.465}\,\log W_f.$$

$$\text{SE} = .0706,\ R^2 = .992,\ \text{DW} = 1.80,\ \hat{\rho} = \underset{(12.59)}{.761}$$

Unemployment insurance benefits are a function of the level of unemployment (U) and of the nominal wage rate. The inclusion of the nominal wage rate is designed to try to pick up the effects of increases in wages and prices on legislated benefits per unemployed worker.

4.1.9 Stochastic Equations for the Federal Government Sector

There are two estimated equations for the federal government sector: the first is an equation explaining the interest payments of the federal government, and the second is an equation explaining the short-term interest rate. The second equation is interpreted as an interest rate reaction function of the Federal Reserve.

The Interest Payments Equation

The current level of interest payments of the federal government is a function of current and past government security issues and of the values of the interest rates at the time of the issues. The estimated equation that attempts to approximate this is

$$29. \quad \log INT_g = \underset{(4.77)}{-.870} + \underset{(29.65)}{.873} \log INT_{g-1} + \underset{(4.95)}{.148} \log(-A_g) + \underset{(5.54)}{.0572} \log RS + \underset{(2.18)}{.0818} \log RB,$$

$$SE = .0270,\ R^2 = .999,\ DW = 1.89$$

where INT_g is the level of interest payments, A_g is the value of net financial assets of the federal government, RS is the current short-term interest rate, and RB is the current long-term interest rate. The federal government is a net debtor, and therefore A_g is negative. This equation has better statistical properties than does the equation explaining the interest payments of the firm sector (Eq. 19), although it is still only a rough approximation.

The Interest Rate Reaction Function of the Federal Reserve

A key question in any macro model is what one assumes about monetary policy. In the theoretical model monetary policy is determined by an interest rate reaction function, and in the empirical work an equation like this was estimated. This equation is interpreted as an equation explaining the behavior of the Federal Reserve (Fed).

In at least one respect, trying to explain Fed behavior is more difficult than, say, trying to explain the behavior of the household or firm sectors. Since the

Fed is run by a relatively small number of people, there can be fairly abrupt changes in behavior if the people with influence change their minds or are replaced by others with different views. Abrupt changes are less likely to happen for the household and firm sectors because of the large number of decision makers in each sector. Having said this, I have, however, found an equation that seems to explain Fed behavior fairly well from 1954 up to 1979III, which is roughly the beginning of the time of Paul Volcker as chairman of the Fed. Beginning with 1979III there seems to have been an abrupt change in behavior, although, as will be seen, even this change seems capable of being modeled.

The equation explaining Fed behavior has on the LHS the three-month Treasury bill rate *(RS)*. This treatment is based on the assumption that the Fed has a target bill rate each quarter and achieves this target through manipulation of its policy instruments. The RHS variables in this equation are variables that seem likely to affect the target rate. The variables that were chosen are (1) the rate of inflation as measured by the percentage change in the price deflator for domestic sales, $\dot{PD}$, (2) the degree of labor market tightness as measured by JJ^*, (3) the percentage change in real GNP, $G\dot{N}PR$, and (4) the percentage change in the money supply lagged one quarter, $\dot{M}1_{-1}$. What seemed to happen when Volcker became chairman was that the size of the coefficient of $\dot{M}1_{-1}$ increased substantially. This was modeled by adding the variable $DD793 \cdot \dot{M}1_{-1}$ to the equation, where $DD793$ is a dummy variable that is 0 before 1979III and 1 thereafter. The estimated equation is

$$
\begin{aligned}
30.\qquad RS = &-.946 + .858\ RS_{-1} + .0687\ \dot{PD} + .0296\ JJ^* \\
&\ \ (2.99)\quad\ (25.55)\qquad\quad (2.11)\qquad\quad (2.99) \\
&+ .0597\ G\dot{N}PR + .032\ \dot{M}1_{-1} + .131\ DD793 \cdot \dot{M}1_{-1}. \\
&\quad\ (2.92)\qquad\qquad (1.71)\qquad\quad (4.20)
\end{aligned}
$$

$$SE = .687,\ R^2 = .953,\ DW = 1.91$$

Equation 30 is a "leaning against the wind" equation in the sense that the Fed is predicted to allow the bill rate to rise in response to increases in inflation, labor market tightness, real growth, and money supply growth. What the results show is that the weight given to money supply growth in the setting of the bill rate target is much greater in the Volcker period than before (.032 + .131 = .163 versus .032 before). Aside from the change in the equation when Volcker became chairman, the coefficients do not appear to have changed much over time. A Chow test, for example, accepted the hypothesis that the coefficients are the same (aside from the Volcker change) for the periods before and after 1969I. (The F value was 1.17, which compares to the critical F value with 7,111 degrees of freedom of 2.10 at the 95-percent confidence level.) In other words, the test accepted the hypothesis that there was no structural change in Fed behavior when Arthur Burns became chairman.

4.1.10 Possible Assumptions about Monetary and Fiscal Policies

The main federal government fiscal policy variables in the model are the following:

C_g	Purchases of goods
d_{1g}	Personal income tax parameter
d_{2g}	Profit tax rate
d_{3g}	Indirect business tax rate
d_{4g}	Employee social security tax rate
d_{5g}	Employer social security tax rate
J_g	Number of civilian jobs
J_m	Number of military jobs
TR_{gh}	Transfer payments to households

Some of these variables appear as explanatory variables in the stochastic equations and thus directly affect the decision variables; others indirectly affect the decision variables by influencing variables (through identities) which in turn influence, directly or indirectly, the decision variables. The response of the model to changes in the various fiscal policy variables is examined in Section 9.4.

Monetary policy is less straightforward to discuss. It will be useful for present purposes to list some of the equations that are involved in determining the effects of monetary policy on the economy.

9. $M_h = f_9(RS, \ldots),$

17. $M_f = f_{17}(RS, \ldots),$

26. $CUR = f_{26}(RS, \ldots),$

22. $\dfrac{BO}{BR} = .0148 + .00455\,(RS - RD),$

57. $BR = -g_1 M_b,$

71. $0 = \Delta M_b + \Delta M_h + \Delta M_f + \Delta M_r + \Delta M_g + \Delta M_s - \Delta CUR,$

77. $$0 = S_g - \Delta A_g - \Delta M_g + \Delta CUR + \Delta(BR - BO) - \Delta Q - DIS_g,$$

81. $$M1 = M1_{-1} + \Delta M_h + \Delta M_f + \Delta M_r + \Delta M_s + MDIF.$$

The other key equation is the interest rate reaction function, Eq. 30, which explains RS.

In considering the determination of variables in the model, it is convenient to match variables to equations, and this will be done in the following discussion. It should be remembered, however, that this is done only for expositional convenience. The model is simultaneous, and nearly all the equations are involved in the determination of each endogenous variable.

Consider the matching of variables to equations in the block given above. The demand for money variables, M_h, M_f, and CUR, can be matched to the stochastic equations that determine them, 9, 17, and 26. Bank borrowing, BO, can be matched to its stochastic equation, 22, and total bank reserves, BR, can be matched to its identity, 57. M_b can be matched to Eq. 71, which states that the sum of net demand deposits and currency across all sectors is zero. $M1$ can be matched to its identity, 81. This leaves Eq. 77, the federal government budget constraint; the question is what endogenous variable is to be matched to this equation. The government savings variable, S_g, is determined elsewhere in the model and thus is not a candidate. If Eq. 30 is included in the model (and thus RS matched to it), the obvious variable to match to Eq. 77 is A_g, the net financial asset variable of the government. (A_g will be referred to as the "government security" variable. Remember that A_g is negative because the government is a net debtor.) This means that A_g is the variable that adjusts to allow RS to be the value determined by Eq. 30. In other words, the target bill rate is assumed to be achieved by the purchase or sale of government securities, that is, by open market operations.

If A_g is taken to be endogenous, the following variables in the block given above are then exogenous: the discount rate, RD; the reserve requirement ratio, g_1; demand deposit and currency holdings of the foreign sector, the state and local government sector, and the federal government sector, M_r, M_s, and M_g; gold and foreign exchange holdings of the federal government, Q; the discrepancy term, DIS_g; and the variable that is involved in the definition of $M1$, $MDIF$. Instead of treating A_g as endogenous, one could take either RD or g_1 to be endogenous and match it to Eq. 77. This would mean that the target bill rate was achieved by changing the discount rate or the reserve requirement ratio instead of the amount of government securities outstanding. Since the main instrument of monetary policy in practice is open market operations, it seems better to treat A_g as endogenous rather than RD or g_1.

One can also consider the case in which Eq. 30 is dropped from the model. In this case, RS is matched to Eq. 77 and A_g is taken to be exogenous. The interest rate is "implicitly" determined: it is the rate needed to clear the asset market given a fixed value of A_g. (In the numerical solution of the model in this case, RS is solved using, say, Eq. 9, M_h is solved using Eq. 71, M_b is solved using Eq. 57, and BR is solved using Eq. 77.) When Eq. 30 is dropped, monetary policy is exogenous, and the response of the model to changes in A_g can be examined.

In the exogenous monetary policy case, the main way in which monetary policy affects the economy is by changing interest rates. Changes in A_g change interest rates, which in turn change real variables. The main effects of interest rates on the economy are the direct effects on consumer expenditures (Eqs. 1, 2, 3, and 4). What this means is that the three instruments of monetary policy—A_g, RD, and g_1—all do the same thing, namely, they affect the economy by affecting interest rates. Using all three instruments is essentially no different from using one with respect to trying to achieve, say, some real output target. It also means that in the endogenous monetary policy case where A_g is endogenous and RD and g_1 are exogenous, changes in RD and g_1 have virtually no effect on the economy. Any effects that they might have are simply "undone" by changes in A_g in the process of achieving the target interest rate implied by Eq. 30.

It is also possible in the exogenous monetary policy case to take some variable other than A_g to be exogenous. One possible choice is the money supply, $M1$, and another is the level of nonborrowed reserves, $BR - BO$. Both of these are common variables to take as policy variables in monetary policy experiments. If either of these is taken to be exogenous, A_g must be endogenous.

To return to fiscal policy variables, it should be obvious that fiscal policy effects are not independent of what one assumes about monetary policy. For a given change in fiscal policy, there are a variety of assumptions that can be made about monetary policy. The main possible assumptions are (1) Eq. 30 included in the model and thus monetary policy endogenous, (2) the bill rate exogenous, (3) the money supply exogenous, (4) nonborrowed reserves exogenous, and (5) government securities outstanding, A_g, exogenous. In all but assumption 5, A_g is endogenous. It will be seen in Section 9.4.4 that fiscal policy effects are in fact quite sensitive to what is assumed about monetary policy. The reason for this is that the different assumptions have quite different implications for interest rates, and the latter have large effects on the real side of the economy.

4.1.11 General Remarks about the Transition

1. The links between the theoretical model and the econometric specifications are closer for the household sector than they are for the firm sector, although the specifications of the main equations for the firm sector are in the spirit of the theoretical model. An important simplification for the empirical work is the assumption that the firm sector's decisions are made sequentially, which is contrary to the case in the theoretical model. Also, the restriction that was imposed on the real wage rate in the empirical work, although it seems quite sensible to impose it in the aggregate, is not closely linked to the theoretical work, where the emphasis was on the behavior of individual firms.

2. There is a heavy use of lagged dependent variables in the model, and they are very important explanatory variables. They can be looked upon as accounting in part for expectational effects and in part for lagged adjustment effects, where it is not possible to separate out these two types of effects. This treatment is discussed in Section 2.2.2. The more sophisticated treatment that was tried for the estimation of expectations regarding future inflation rates was not successful. The expectations variables were not significant in the consumer expenditure equations, where they should be if real rather than nominal interest rates affect behavior, or in the term structure equations, where they should be if expected future inflation rates are not adequately captured in the current and lagged values of the short-term interest rate.

3. A number of the stochastic equations are not tied very closely (if at all) to decision variables in the theoretical model. These equations tend to be less important with respect to their effects on the main variables in the model. Equations in this category include the overtime hours equation, 15, the dividend equation, 18, the two interest payments equations, 19 and 29, the inventory valuation adjustment equation, 20, the capital consumption equation, 21, and the unemployment insurance benefits equation, 28. Some of these equations are simply approximations to definitions that would hold if sufficient data were available.

4. Equation 30 is more heroic than the other main behavioral equations in that it is an attempt to model the behavior of a small number of individuals. It can, of course, be dropped from the model and monetary policy taken to be exogenous. In this sense the equation is less important than the others.

5. Since the theoretical model was used to guide the specification of the econometric model, it is likely that the two models have similar qualitative policy effects. The policy properties of the econometric model are examined in Section 9.4, and it is true that the qualitative effects are similar. For

example, the disequilibrium features of the theoretical model are captured in the econometric model through the labor constraint variable, Z, and the interest rate effects on households' decisions in the theoretical model are captured in the econometric model through the interest rate variables in the expenditure equations.

6. Two important variables in the model are taken to be exogenous when in fact they should not be. They are the import price deflator, PIM, and exports, EX. This limitation is eliminated in the next section, where the US model is embedded in the multicountry model. In fact, one way of looking at the multicountry model is that it is a way of making PIM and EX endogenous.

4.2 The Multicountry (MC) Model

4.2.1 Introduction

The econometric model is extended to a number of countries in this section. Quarterly data have been collected or constructed for 64 countries (counting the United States), and the model contains estimated equations for 43 countries. The basic estimation period is 1958I–1981IV (96 observations). For equations that are relevant only when exchange rates are flexible, the basic estimation period is 1972II–1981IV (39 observations). The theoretical basis of the model was discussed in Section 3.2.

The model differs from previous models in a number of ways, and it will be useful to discuss these briefly here. First, linkages among countries with respect to exchange rates, interest rates, and prices appear to be more important in the present model than they are in previous models, which have been primarily trade linkage models. The LINK model (Ball 1973), for example, is of this kind, although some recent work has been done on making capital movements endogenous in the model. (See Hickman 1974, p. 203, for a discussion of this; see also Berner et al. 1976 for a discussion of a five-country model in which capital flows are endogenous.) Second, the theory on which the model is based differs somewhat from previous theories. This has been discussed in Section 3.2. Third, the number of countries in the model is larger than usual, and the data are all quarterly. Considerable work has gone into the construction of quarterly data bases for all the countries. Some of the quarterly data had to be interpolated from annual data, and a few data points had to be guessed. The collection and construction of the data bases are discussed in subsequent sections.

Finally, there is an important difference between the approach I have taken and an approach like that of Project LINK. I alone have estimated small models for each country and then linked them together, rather than, as Project LINK has done, taking models developed by others and linking them together. The advantage of the LINK approach is that larger models for each country can be used; it is clearly not feasible for one person to construct medium- or large-scale models for each country. The advantage of the present approach, on the other hand, is that the person constructing the individual models knows from the beginning that they are to be linked together, and this may lead to better specification of the linkages. It is unlikely, for example, that the specification of the exchange rate and interest rate linkages in the present model would develop from the LINK approach. Whether this possible gain in the linkage specification outweighs the loss of having to deal with small models of each country is an open question.

4.2.2 Further Theory

The theoretical model as represented by (T1)–(T17) in Section 3.2.5 cannot be implemented in practice. The main problem is that data on bilateral financial flows do not exist. In other words, data on domestic holdings of the securities of a particular foreign country do not exist, and therefore equations like (T13) and (T14) cannot be estimated. Moreover, data on the breakdown of the savings of a country between private and government savings (S_{pt} and S_{gt}) do not always exist. These and other data problems make the transition to a multicountry econometric model particularly difficult. In order to make the transition here, a special case of the theoretical model must be considered. This special case is discussed in this section. Since this discussion is an extension of the discussion of the theoretical model in Section 3.2, the t subscript has been retained for the variables. In the discussion of the econometric model, which begins in Section 4.2.3, the t subscript has been dropped.

Interest Rate Reaction Functions

The two monetary policy variables in the equation set (T1)–(T17) (other than the discount rates RD and rd, which are not of concern here) are A_{gt} and a_{gt}. If these two variables are taken to be exogenous, the two interest rates, R_t and r_t, are "implicitly" determined. An alternative to this treatment is to postulate interest rate reaction functions for both R_t and r_t:

(T18) $\quad R_t = f_{T18}(\ldots),$

(T19) $\quad r_t = f_{T19}(\ldots),$

where the arguments in the functions are variables that affect the monetary authorities' decisions regarding the interest rates. In this case A_{gt} and a_{gt} are endogenous.

Exchange Rate Reaction Functions

The policy variable most closely related to the exchange rate, e_t, is Q_t (or q_t), country 1's (or country 2's) holdings of the international reserve. If Q_t is taken to be exogenous, e_t is implicitly determined. An alternative to this is to postulate an exchange rate reaction function:

(T20) $\quad e_t = f_{T20}(. \ . \ .),$

where the arguments in the function are variables that affect the authorities' decisions regarding the exchange rate. In this case Q_t is endogenous.

Perfect Substitutability and the Forward Rate

The special case of the theoretical model used here includes the interest rate and exchange rate reaction functions. It also includes the assumption that the securities of the two countries are perfect substitutes. Perfect substitution is defined as follows. The covered interest rate from country 1's perspective on the bond of country 2, say r'_t, is $(e_t/F_t)(1 + r_t) - 1$, where F_t is the forward rate. If for $R_t = r'_t$ people are indifferent as to which bond they hold, the bonds will be defined to be perfect substitutes. In this case the equation system (T1)–(T17) is modified as follows. First, (T13) and (T14) drop out, since the private sector is now indifferent between the two bonds. Second, arbitrage will ensure that $R_t = r'_t$, and thus a new equation is added:

(T21) $\quad R_t = (e_t/F_t)(1 + r_t) - 1.$

Third, the model is underidentified with respect to A_{pt}, A^*_{pt}, a_{pt}, and a^*_{pt}, and one of these variables must be taken to be exogenous. (This indeterminacy is analogous to the indeterminacy that arises in, say, a two-consumer, two-firm model in which the two consumers are indifferent between the goods produced by the two firms. It is not possible in this model to determine the allocation of the two goods between the two consumers.)

Equation (T21) introduces a new variable, F_t, into the model, and therefore its determination must be specified. If it is assumed that F_t equals the expected future spot rate, one could try to estimate an equation explaining F_t, where the explanatory variables would be variables that one believes affect expectations. Instead of estimating an equation, one could assume that expectations are rational and estimate the model under this constraint. If F_t is determined in either of these two ways, it will be said to play an "active" role in the model.

If F is active, it is not possible to have R_t, r_t, and e_t all implicitly determined or determined by reaction functions. Given (T21) and the equation for F_t (implicit if there are rational expectations, explicit otherwise), only two of the three variables can be implicitly determined or determined by reaction functions. (Also, if F_t is active and exchange rates are fixed, it is not possible to have both R_t and r_t implicitly determined or determined by reaction functions.) An alternative case to F_t being active is the case in which R_t, r_t, and e_t are implicitly determined or determined by reaction functions and F_t is determined by (T21). In this case F_t will be said to play a "passive" role in the model. Given R_t, r_t, and e_t, F_t merely adjusts to ensure that the arbitrage condition holds. The special case of the theoretical model used here is based on the assumption that F_t is passive.

In summary, the special case of the theoretical model used here is based on the assumptions that (1) the interest rates are determined by reaction functions, (2) the exchange rate is determined by a reaction function, (3) the securities of the different countries are perfect substitutes, and (4) the forward rate is passive. The assumption that is most questionable in this choice is probably the assumption that e_t is determined by a reaction function. The alternative assumption is that e_t is implicitly determined, with reserves, Q_t, being exogenous. In practice there is obviously some intervention of the monetary authorities in the exchange markets, and therefore this alternative assumption is also questionable. The assumption that e_t is determined by a reaction function means that intervention is complete: the monetary authority has a target e_t each period and achieves this target by appropriate changes in Q_t. This assumption may not, however, be as restrictive as it first sounds. The monetary authority is likely to be aware of the market forces that are operating on e_t in the absence of intervention (that is, the forces behind the determination of e_t when e_t is implicitly determined), and it may take these forces into account in setting its target each period. If some of the explanatory variables in the reaction function are in part measures of these forces, then the estimated reaction function may provide a better explanation of e_t than one would otherwise have thought. Similar arguments apply to the assumption that R_t and r_t are determined by reaction functions.

The assumption that F_t is passive means that the forward market imposes no "discipline" on the monetary authority's choice of the exchange rate. Again, if the monetary authority takes into account market forces operating on e_t in the absence of intervention, including market forces in the forward market, and if the explanatory variables in the reaction function for e_t are in part measures of these forces, then the estimated reaction function for e_t may not be too poor an approximation.

Given the assumption that F_t is passive and given that F_t does not appear as an explanatory variable in any of the equations, F_t plays no role in the empirical model. For each country it is determined by an estimated version of the arbitrage condition, (T21), but the predictions from these equations have no effect on the predictions of any of the other variables in the model.

Fixed Exchange Rates

The assumption that F_t is passive is not sensible in the case of fixed exchange rates: for most observations F_t is equal to or very close to e_t when e_t is fixed. A different choice was thus made for the fixed rate case. This choice was designed to try to account for the possibility that the bonds of the different countries are not perfect substitutes as well as for the fact that F_t is not passive. The procedure that was followed in the fixed rate case is as follows. The United States was assumed to be the "leading" country with respect to the determination of interest rates. Assume in the above model that the United States is country 1. Consider the determination of r_t, country 2's interest rate. If exchange rates are fixed, bonds are perfect substitutes, and F_t is equal to e_t, then r_t is determined by (T21) and is equal to R_t. In other words, country 2's interest rate is merely country 1's interest rate: country 1 sets the one world interest rate and country 2's monetary authority has no control over country 2's rate. If the bonds are not perfect substitutes, (T21) does not hold and country 2's monetary authority can affect its rate. If, however, the bonds are close to being perfect substitutes, then very large changes in a_{gt} will be needed to change r_t very much.

In the empirical work, interest rate reaction functions were estimated for each country, but with the U.S. interest rate added as an explanatory variable to each equation. If the bonds are close to being perfect substitutes, the U.S. rate should be the only significant variable in these equations and should have a coefficient estimate close to 1.0. If the bonds are not at all close substitutes, the coefficient estimate should be close to zero and the other variables should be significant. The in-between case should correspond to both the U.S. rate and the other variables being significant.

This argument about the U.S. rate in the interest rate reaction functions does not pertain to the flexible exchange rate case. One would thus not expect the interest rate reaction functions to be the same in the fixed and flexible rate cases, and therefore in the empirical work separate interest rate reaction functions were estimated for each country for the fixed and flexible rate periods. The U.S. rate may still be an explanatory variable in the reaction functions for the flexible rate period. This would be, however, because the U.S. rate is one of the variables that affect the monetary authority's interest rate decision, not because the U.S. rate is being used to try to capture the degree of substitutability of the bonds.

Contrary to the case for the other countries, the U.S. interest rate reaction function was estimated over the entire sample period. This procedure is consistent with the assumption made above that the United States is the interest rate leader in the fixed rate period. If it is the leader, then it is not constrained as the other countries are, so there is no reason on this account to expect the function to be different in the fixed and flexible rate periods.

Aggregation

The final issue to consider regarding the special case of the theoretical model is the level of aggregation. The private and government sectors have been aggregated together for this case, and thus there is only one sector per country. In this case the budget constraint for country 1 is the sum of (T5) and (T6):

(T5)′ $\quad 0 = S_t - \Delta A_t - e_t \Delta a_t^* - \Delta Q_t.$

S_t is equal to $S_{pt} + S_{gt}$, ΔA_t is equal to $\Delta A_{pt} + \Delta A_{gt}$, and the p subscript has been dropped from a_t^* since it is now unnecessary. The budget constraint for country 2 is similarly the sum of (T7) and (T8):

(T7)′ $\quad 0 = s_t - \Delta a_t - \dfrac{1}{e_t}\Delta A_t^* - \dfrac{1}{e_t}\Delta q_t.$

Equations (T15) and (T16) are now written as follows:

(T15)′ $\quad 0 = A_t + A_t^*;$

(T16)′ $\quad 0 = a_t + a_t^*.$

Consider now a further type of aggregation. Let $\Delta A_t' = \Delta A_t + e_t \Delta a_t^* + \Delta Q_t$ and $\Delta a_t' = \Delta a_t + \dfrac{1}{e_t}\Delta A_t^* + \dfrac{1}{e_t}\Delta q_t$. In this notation (T5)′ and (T7)′ are

(T5)″ $\quad 0 = S_t - \Delta A_t',$

(T7)″ $\quad 0 = s_t - \Delta a_t'.$

If one adds the first difference of (T15)′, the first difference of (T16)′ multiplied by e_t, and (T17) in Section 3.2.5, the result is

$$\text{(T17)}' \qquad 0 = \Delta A_t' + e_t \Delta a_t'.$$

Equation (T17)′ is redundant, given (T5)″ and (T7)″, because S_t and s_t satisfy the property that $S_t + e_t s_t = 0$.

This aggregation is very convenient because it allows data on A_t' and a_t' to be constructed by summing past values of S_t and s_t from some given base period values. Data on S_t (the balance of payments on current account) are available for most countries, whereas data on A_t, A_t^* a_t, and a_t^* (that is, bilateral financial data) are generally not available. The cost of this type of aggregation is that capital gains and losses on bonds from exchange rate changes are not accounted for. Given the current data, there is little that can be done about this. The key assumption behind this aggregation is that the securities of the different countries are perfect substitutes. If this were not so, (T13) and (T14) would not drop out, and bilateral financial data would be needed to estimate them.

Final Equations

To summarize, the special case of the theoretical model consists of the following equations:

(T1)′	$S_t = f_{T1'}(\ldots)$,	[savings of country 1]
(T3)′	$s_t = f_{T3'}(\ldots)$,	[savings of country 2]
(T5)″	$0 = S_t - \Delta A_t'$,	[budget constraint of country 1]
(T7)″	$0 = s_t - \Delta a_t'$,	[budget constraint of country 2]
(T18)	$R_t = f_{T18}(\ldots)$,	[interest rate reaction function of country 1]
(T19)	$r_t = f_{T19}(\ldots)$,	[interest rate reaction function of country 2]
(T20)	$e_t = f_{T20}(\ldots)$,	[exchange rate reaction function]
(T21)	$R_t = (e_t/F_t)(1 + r_t) - 1.$	[arbitrage condition]

This is the model that has guided the econometric specifications.

It should finally be noted that although nothing has been said about the determination of S_t and s_t in this section, this determination is a critical part of the model. Equations (T1)′ and (T3)′ are merely a convenient way of summarizing part of the model. In the complete model S_t and s_t are determined by definitions and are affected by nearly every variable in the model.

4.2.3 Data Collection and Choice of Variables and Identities

The discussion in this section relies heavily on the tables in Appendix B, located at the end of the book. It is assumed that these tables will have been studied carefully before this section is read.

The Data and Variables (Tables B-1, B-2, B-7)

The raw data were taken from two of the four tapes that are constructed every month by the International Monetary Fund: the International Financial Statistics (IFS) tape and the Direction of Trade (DOT) tape. The way in which each variable was constructed is explained in brackets in Table B-2 of Appendix B. Some variables were taken directly from the tapes, and some were constructed from other variables. When "IFS" precedes a number in the table, this refers to the variable on the IFS tape with that particular number. Some adjustments were made to the raw data, and these are explained in Appendix B. The main adjustment was the construction of quarterly National Income Accounts (NIA) data from annual data when the quarterly data were not available. Another important adjustment concerns the linking of the Balance of Payments data to the other export and import data. The two key variables involved in this process are S^* and TT^*. The variable S_i^* is the balance of payments on current account, and TT_i^* is the value of net transfers. The construction of these variables is explained in Table B-7 in Appendix B. Most of the data are not seasonally adjusted.

Note that two interest rates are listed in Table B-2, the short-term rate, RS_i, and the long-term rate, RB_i. For many countries only discount rate data are available for RS_i, and this is an important limitation of the data base. The availability of interest data by country is listed in Table B-1 in Appendix B.

The variable A_i^* in Table B-2, which is the net stock of foreign security and reserve holdings, was constructed by summing past values of S_i^* from a base period value of zero. The summation began in the first quarter for which data on S_i^* existed. This means that the A_i^* series is off by a constant amount each period (the difference between the true value of A_i^* in the base period and zero). In the estimation work the functional forms were chosen in such a way that this error was always absorbed in the estimate of the constant term. It is important to note that A_i^* measures only the net asset position of the country vis-à-vis the rest of the world. Domestic wealth, such as the domestically owned housing stock and plant and equipment stock, is not included.

The Identities (Table B-3)

Table B-3 contains a list of the equations for country i. There are up to 11 estimated equations per country, and these are listed first in the table. Equations 12–21 are definitions. This section provides a discussion of these equations except for the specification of the explanatory variables in the stochastic equations, which is discussed in Section 4.2.5.

It will first be useful to consider the matching of the equations in Table B-3 to the equations listed earlier at the end of Section 4.2.2. The level of savings of country i, which is represented by (T1)′ or (T3)′ above, is determined by Eq. 17, a definition, in the table. As noted earlier, the level of savings, S_i^*, is the balance of payments on current account. Almost every variable in the model is at least indirectly involved in its determination. Equation 17 states that S_i^* is equal to export revenue minus import costs plus net transfers. Given S_i^*, the asset variable A_i^* is determined by Eq. 18, which is analogous to (T5)″ or (T7)″ above. This is the budget constraint of country i.

Equations 7a and 7b are the interest rate reaction functions, which are analogous to (T18) or (T19), and Eq. 9b is the exchange rate reaction function, which is analogous to (T20). The "a" indicates that the equation is estimated over the fixed exchange rate period, and the "b" indicates that it is estimated over the flexible rate period. Equation 10b is an estimate of the arbitrage condition, (T21) above. The exchange rate e_i explained by Eq. 9b is the average exchange rate for the period, whereas the exchange rate ee_i in the arbitrage equation 10b is the end-of-period rate. ee_i is end-of-period because the forward rate, F_i, is also end-of-period. Equation 20 links e_i to ee_i, where ψ_{1i} in the equation is the historic ratio of e_i to $(ee_i + ee_{i-1})/2$. ψ_{1i} is taken to be exogenous. As noted in Section 4.2.2, F_i plays no role in the model, and therefore neither does ee_i. Equation 10b is included in the model merely to see how closely the data meet the arbitrage condition.

This completes the matching of the equations in Table B-3 to those at the end of Section 4.2.2. The other equations are as follows. Equation 1 determines the demand for merchandise imports, and Eq. 14 provides the link from merchandise imports to total NIA imports. Equations 2 and 3 determine the demands for consumption and investment, respectively. Equation 16 is the definition for final sales. The level of final sales is equal to consumption plus investment plus government spending plus exports minus imports plus a discrepancy term. Government spending is exogenous. Exports are determined when the countries are linked together. The key export variable is $X75\$_i$, and Eq. 15 links this variable to NIA exports. Equation 4 determines production, and Eq. 12 determines inventory investment, which is the difference between production and sales. Equation 13 defines the stock of inventories. Equation 5, the key price equation in the model, determines the GNP deflator. The other price equation in the model is Eq. 11, which determines the export price index as a function of the GNP deflator and other variables.

Equation 6 determines the demand for money. Even though the money supply does not appear in the budget constraint of the country because it is netted out in the aggregation, it does appear as an explanatory variable in the interest rate reaction functions and thus must be explained. The money supply is netted out in the aggregation because foreign holdings of domestic money are effectively ignored by being included in A_i^*. This had to be done because bilateral data on money holdings do not exist. Equation 8 determines the long-term interest rate, RB_i. It is a standard term structure equation.

Trade and Price Linkages (Table B-4)

The trade and price linkages are presented in Table B-4. Table B-4 takes as input from each country the total value of merchandise imports in 75$, $M75\$A_i$, the export price index, PX_i, and the exchange rate, e_i. It returns for each country the total value of merchandise exports in 75$, $X75\$_i$, the import price index, PM_i, and the world price index, $PW\$_i$. These last three variables are used as inputs by each country. The model is solved for each quarter by iterating between the equations for each country in Table B-3 and the equations in Table B-4.

Note from Table B-2 that the data taken from the DOT tape are merchandise exports from i to j in $, $XX\$_{ij}$. These data were converted to 75$ by multiplying $XX\$_{ij}$ by $e_i/(e_{i75}PX_i)$ (see $XX75\$_{ij}$ in Table B-2). This could only be done, however, if data on e_i and PX_i existed. Type A countries are countries for which these data exist, and type B countries are the remaining countries. The share variable α_{ji} that is used in Table B-4 is defined in Table B-2. α_{ji} is the share of i's total merchandise imports from type A countries imported from j in 75$. If j is a type B country, then α_{ji} is zero. Given the definition of $M75\$A_i$ in Table B-2, α_{ji} has the property that $\Sigma_j \alpha_{ji} = 1$. Table B-4 deals only with type A countries. Total merchandise imports of a country from type B countries, $M75\$B_i$ in Table B-2, is taken to be exogenous.

4.2.4 Treatment of Unobserved Variables

Expectations

As discussed earlier, an important expectational assumption in the multicountry model is that the forward rate is passive. No constraint has been imposed that it equals the expected future spot rate, and so in general this will not be true. It is not the case, for example, that the forward rate equals the future spot rate that the model predicts.

As was the case for the US model, expectations are assumed to be accounted for by the use of current and lagged values as proxies for expected future values. Nothing different from the standard procedure discussed in Section 2.2.2 was done.

The Demand Pressure Variable

A demand pressure variable, denoted ZZ_i, was used in the price equation for each country. It was constructed as follows. (Y_i is real gross national product or real gross domestic product, and POP_i is the level of population.) $\text{Log}(Y_i/POP_i)$ was first regressed on a constant, time, and three seasonal dummy variables, and the estimated standard error, $\widehat{SE}_i$, and the fitted values, $\widehat{\log(Y_i/POP_i)}$, from this regression were recorded. (The results from these regressions are presented in Table 4-13 later in the chapter.) A new series, $(Y_i/POP_i)^*$, was then constructed, where

$$(4.38) \qquad \left(\frac{Y_i}{POP_i}\right)^* = \exp\left[\widehat{\log\frac{Y_i}{POP_i}} + 4 \cdot \widehat{SE}_i\right].$$

ZZ_i was taken to be

$$(4.39) \qquad ZZ_i = \frac{(Y_i/POP_i)^* - Y_i/POP_i}{(Y_i/POP_i)^*}.$$

ZZ_i is similar to the demand pressure variable ZZ in the US model. In the US model ZZ is equal to $(GNPR^* - GNPR)/GNPR^*$, where $GNPR^*$ is constructed from peak-to-peak interpolations of the $GNPR$ series. In the present case, $(Y_i/POP_i)^*$ is not constructed from peak-to-peak interpolations but is instead a variable that is the antilog of a variable whose value each quarter is 4 standard errors greater than the value predicted by the regression of log (Y_i/POP_i) on a constant, time, and three seasonal dummy variables. The use of 4 standard errors in this construction is not critical; similar results would have been obtained had the number been, say, 2 or 3. To put it another way, as is the case for the US model, the data are not capable of discriminating among different measures of demand pressure.

4.2.5 Stochastic Equations for the Individual Countries (Tables 4-1 through 4-13)

The estimated equations for the individual countries are presented in Tables 4-1 through 4-13. Equations 1, 2, 4, 5, 6, and 8 were estimated by 2SLS for most countries; the other equations were estimated by OLS. The estimation technique for each equation is indicated in the tables. The first-stage regressors that were used for each equation estimated by 2SLS are not presented in this book, since this would take up too much space. (The list of these regressors is available from the author upon request.) The selection criterion for the first-stage regressors was the same as that used for the US model, which is explained in Chapter 6. Briefly, the main predetermined variables in each country's model were chosen to constitute a "basic" set for that country, and other variables were added to this set for each individual equation. The variables that were added depended on the RHS endogenous variables in the equation being estimated.

All equations except 10b and 11 were estimated with a constant and three seasonal dummy variables. To conserve space, the coefficient estimates of these four variables are not reported in the tables. Data limitations prevented all equations from being estimated for all countries and also required that shorter sample periods from the basic period be used for many countries. The main part of the model, excluding the United States, consists of the countries Canada through the United Kingdom.

The searching procedure for the stochastic equations was as follows. Lagged dependent variables were used extensively to try to account for expectational and lagged adjustment effects. Explanatory variables were dropped from the equations if they had coefficient estimates of the wrong expected sign. In many cases variables were left in the equations if their coefficient estimates were of the expected sign even if the estimates were not significant by conventional standards. There is considerable collinearity among many of the explanatory variables, especially the price variables, and the number of observations is fairly small for equations estimated only over the flexible exchange rate period. Many of the coefficients are thus not likely to be estimated very precisely, and this is the reason for retaining variables even if their coefficient estimates had fairly large estimated standard errors.

Both current and one-quarter-lagged values were generally tried for the

TABLE 4-1. The 40 demand for import equations

Equation 1: $\log \frac{M_i}{POP_i}$ is the LHS variable

Country	Explanatory variables: $\log PY_i$	$\log PM_i$	RS_i or RB_i	$\log \frac{Y_i}{POP_i}$	$\frac{A^*_{i-1}}{PY_{i-1}POP_{i-1}}$	LHS_{-1}	R^2	SE	DW	Sample period
Canada	.097[a] (0.68)	-.099[a] (0.92)	-.0050[ab] (1.20)	.88 (5.96)	.000070 (2.33)	.55 (7.35)	.992	.0366	1.95	581-821
Japan	.080 (0.79)	-.082 (1.60)	-.0028[a] (0.95)	.20 (2.17)	.00031 (1.16)	.81 (12.12)	.996	.0440	1.99	581-822
Austria	.30 (1.29)	-.18 (1.14)	-.011[a] (1.67)	.96 (2.95)	.0042 (1.52)	.45 (4.17)	.991	.0368	2.18	651-821
Belgium	.34 (3.55)	-.38 (5.06)	—	1.05 (6.07)	—	.45 (5.80)	.996	.0344	2.09	581-804
Denmark	.43[a] (4.03)	-.27[a] (3.31)	-.0029[a] (1.27)	.68 (3.59)	.024 (3.24)	.50 (6.59)	.987	.0429	2.33	581-814
France	.18 (1.70)	-.14 (1.96)	—	.65 (4.41)	—	.67 (10.23)	.995	.0416	1.73	581-814
Germany	—	—	-.0050[a] (3.46)	.90 (4.06)	—	.62 (6.54)	.995	.0305	1.87	611-821
Italy	.14 (1.01)	-.04 (0.44)	-.011[ab] (1.33)	1.20 (3.87)	—	.33 (3.21)	.971	.0681	2.13	611-814
Netherlands	.09 (0.77)	-.16 (2.59)	—	.75 (2.60)	—	.58 (5.57)	.991	.0336	2.23	611-814
Norway	.74[a] (3.54)	-.29[a] (2.25)	-.058[ab] (3.84)	.82 (2.77)	.017 (4.06)	.43 (5.16)	.970	.0566	2.38	621-814
Sweden	.16 (1.17)	-.12 (1.28)	-.0035[a] (0.72)	.60 (3.46)	.016 (1.62)	.60 (7.05)	.977	.0509	2.58	581-814
Switzerland	.08[a] (1.54)	-.16[a] (1.77)	-.014[ab] (1.29)	1.57 (7.00)	.021 (3.95)	.31 (3.37)	.994	.0298	2.40	581-814
United Kingdom	—	—	—	1.11 (5.91)	.00022 (1.84)	.40 (3.92)	.981	.0372	2.02	581-804
Finland	—	—	—	1.09 (6.39)	.000047 (3.35)	.38 (4.04)	.964	.0777	2.41	581-814
Greece	.29 (1.13)	-.11 (0.56)	-.012 (1.71)	.93 (5.71)	—	.20 (1.88)	.967	.0970	2.29	581-804
Ireland	.31[a] (2.65)	-.15[a] (1.77)	-.0044[ab] (1.02)	.91 (5.34)	.00042 (2.25)	.48 (6.20)	.988	.0496	2.40	581-804
Portugal	—	—	—	1.30 (7.34)	—	.10 (0.91)	.910	.163	2.20	581-804
Spain	.20 (2.55)	-.14 (1.75)	-.037 (1.76)	.67 (3.41)	—	.58 (6.66)	.980	.0578	2.23	621-794
Turkey[c]	—	—	—	1.28 (3.78)	.16 (3.88)	.48 (4.06)	.891	.109	1.88	691-784

Yugoslavia	—	—	—	.62 (4.52)	.056 (2.63)	.56 (5.84)	.958	.0818	2.04	611-794
Australia	—	—	-.015[ab] (2.58)	.52 (3.43)	.000074 (1.30)	.71 (10.20)	.848	.0632	1.69	603-814
New Zealand	—	—	—	.81 (5.59)	.00011 (3.06)	.52 (6.36)	.829	.0835	2.03	582-811
South Africa	—	—	-.027[a] (4.15)	.55 (3.51)	—	.82 (17.07)	.864	.0772	1.95	621-814
Libya	—	—	—	.12 (0.80)	—	.83 (9.88)	.926	.0739	2.39	721-774
Nigeria[c]	—	—	—	.31 (1.00)	.0022 (4.61)	.75 (12.20)	.977	.0778	1.69	712-781
Saudi Arabia[c]	—	—	—	.56 (2.05)	.043 (4.29)	.45 (3.36)	.994	.0545	2.00	721-792
Venezuela[c]	—	—	—	1.84 (3.64)	.000021 (2.23)	.46 (3.62)	.931	.0668	2.06	711-804
Brazil[c]	—	—	—	.10 (0.51)	.037 (0.35)	.86 (8.79)	.814	.0891	1.65	711-804
Chile[c]	—	—	—	1.29 (2.71)	—	.51 (3.99)	.618	.2344	2.31	711-804
Colombia	—	—	—	—	.000065 (3.51)	.64 (5.85)	.755	.1108	1.94	711-804
Mexico[c]	—	—	—	.66 (3.74)	—	.80 (10.62)	.954	.0525	1.45	711-804
Israel	—	—	—	.18 (0.79)	—	.49 (4.01)	.357	.1269	2.57	691-813
Jordan[c]	.56 (2.62)	-.58 (3.61)	—	.73 (3.09)	.0042 (1.51)	.41 (3.63)	.906	.1174	2.43	731-804
Syria	.68[a] (2.52)	-.24[a] (1.26)	—	.50 (1.73)	.00022 (1.42)	.28 (2.23)	.800	.1450	2.05	641-804
India	—	—	—	—	.32 (1.05)	.40 (3.76)	.252	.1303	2.01	611-794
Korea	.14 (0.89)	-.21 (1.65)	—	.70 (3.41)	.0012 (0.83)	.70 (7.73)	.982	.1077	2.01	641-814
Malaysia[c]	.39[a] (1.59)	-.03[a] (0.24)	—	.62 (2.38)	.00074 (5.91)	.00098 (0.13)	.931	.0506	0.74	711-814
Pakistan[c]	—	—	—	.65 (1.24)	—	.59 (3.29)	.673	.1148	2.59	731-812
Philippines	.95 (5.09)	-.53 (5.22)	-.011 (2.14)	.32 (1.06)	.00034 (3.96)	.30 (3.41)	.703	.0863	2.23	581-802
Thailand	.44 (1.99)	-.32 (2.47)	—	.35 (2.22)	—	.57 (6.36)	.883	.0503	2.08	654-814

Notes: a. Variable is lagged one quarter.
b. RB_i rather than RS_i is used.
c. Equation estimated by OLS rather than 2SLS.
• t-statistics in absolute value are in parentheses.

TABLE 4-2. The 38 consumption equations

Equation 2: $\log\frac{C_i}{POP_i}$ is the LHS variable

	Explanatory variables								
Country	RS_i or RB_i	$\log\frac{Y_i}{POP_i}$	$\frac{A^*_{i-1}}{PY_{i-1}POP_{i-1}}$	LHS_{-1}	$\hat{\rho}_1$	R^2	SE	DW	Sample period
Canada	-.0012 (2.61)	.11 (3.51)	.0000091 (1.55)	.90 (25.78)	—	.998	.00859	2.35	581-821
Japan	-.0026 (4.08)	.16 (2.84)	—	.80 (12.58)	—	.999	.0126	2.32	581-822
Austria	-.0059 (1.95)	.62 (7.49)	—	.36 (4.12)	—	.991	.0185	1.74	651-821
Belgium	-.0017[ab] (0.83)	.55 (9.11)	.00052 (4.41)	.39 (5.37)	—	.997	.0129	1.65	581-804
Denmark	—	.59 (9.19)	.0065 (2.96)	.38 (6.17)	—	.982	.0237	1.28	581-814
France	-.00066[a] (1.22)	.21 (5.40)	—	.80 (19.49)	—	.999	.0105	2.08	581-814
Germany	-.0019 (3.41)	.37 (5.06)	.0047 (1.12)	.66 (10.44)	—	.999	.00807	2.26	611-821
Italy	-.00072 (1.67)	.24 (2.68)	—	.80 (10.53)	—	.998	.0102	1.85	611-814
Netherlands	-.0032[ab] (1.64)	.43 (5.74)	.013 (3.09)	.64 (10.61)	—	.996	.0153	2.25	611-814
Norway	-.0074[b] (3.75)	.66 (10.48)	.00064 (0.82)	.26 (3.79)	—	.991	.0156	1.29	621-814
Sweden	—	.22 (3.24)	.0040 (1.65)	.73 (9.21)	-.70 (7.93)	.969	.0299	1.90	581-814
Switzerland	-.0043 (3.41)	.35 (6.70)	.0019 (2.13)	.70 (15.68)	—	.997	.0103	2.16	581-814
United Kingdom	—	.51 (8.75)	.00020 (4.43)	.40 (5.90)	—	.989	.0132	1.85	581-804
Finland	—	.28 (4.16)	.0000024 (0.52)	.74 (11.38)	—	.993	.0254	2.36	581-814
Ireland	-.0030[ab] (2.38)	.54 (10.69)	.000033 (0.67)	.42 (7.17)	—	.993	.0165	1.44	581-804
Portugal	-.0028[b] (2.45)	.30 (7.46)	—	.47 (7.05)	—	.973	.0306	2.11	581-804
Spain	-.0054 (1.08)	.25 (3.00)	—	.76 (10.86)	—	.989	.0267	2.20	621-794
Turkey[c]	—	.18 (1.93)	.044 (4.26)	.77 (8.79)	—	.965	.0228	1.66	691-784

Yugoslavia	—	.58 (9.16)	—	.35 (5.00)	—	.993	.0219	1.30	611-794
Australia	-.0014 (1.84)	.12 (1.25)	.0000061 (0.56)	.91 (10.43)	—	.997	.00877	1.81	603-814
New Zealand	—	.39 (1.62)	.000026 (1.11)	.67 (3.33)	.76 (4.35)	.986	.0158	1.73	582-811
South Africa	-.0027 (2.56)	.42 (4.47)	—	.74 (12.45)	—	.988	.0136	2.08	621-814
Libya	—	—	.000068 (1.02)	.88 (7.86)	.34 (1.05)	.991	.0322	1.98	651-774
Saudi Arabia[c]	—	.14 (0.34)	.0081 (1.19)	.81 (4.16)	.59 (1.97)	.979	.0503	1.76	721-792
Venezuela	—	.12 (1.24)	.0000025 (0.63)	.95 (22.01)	.50 (3.22)	.996	.0147	1.93	621-804
Argentina[c]	—	.31 (1.78)	—	.79 (10.12)	—	.746	.0711	1.78	671-804
Brazil	—	.17 (2.62)	—	.87 (16.58)	.32 (1.75)	.997	.0221	1.73	641-804
Colombia[c]	-.0029 (2.00)	.34 (2.16)	—	.69 (4.68)	.37 (1.73)	.927	.0165	1.92	711-804
Mexico	—	.53 (9.07)	—	.47 (7.97)	—	.989	.0228	1.64	581-804
Peru	—	.46 (4.29)	—	.65 (8.78)	—	.977	.0196	1.67	611-814
Israel	—	.30 (2.52)	.000045 (1.47)	.73 (7.52)	—	.931	.0300	1.73	691-814
Jordan[c]	—	.64 (6.46)	—	.33 (3.11)	—	.935	.0506	1.23	731-804
Syria	—	.77 (3.47)	—	.08 (0.36)	.85 (9.99)	.957	.0415	1.66	641-804
India[c]	-.0037[a] (3.08)	.33 (3.77)	—	.45 (2.75)	.49 (2.49)	.877	.0166	1.86	611-794
Korea	-.0016 (1.17)	.39 (7.46)	—	.45 (6.10)	—	.969	.0539	1.98	641-814
Malaysia[c]	—	.60 (11.02)	.00021 (7.82)	.38 (6.64)	—	.992	.0136	1.49	711-814
Philippines	-.0023[a] (1.74)	.64 (13.17)	.000053 (2.91)	.26 (4.76)	—	.969	.0252	1.17	581-802
Thailand	-.0037 (1.26)	.42 (1.68)	.012 (0.93)	.58 (2.27)	.41 (1.41)	.995	.0113	1.62	654-814

Notes: a. Variable is lagged one quarter.

b. RB_i rather than RS_i is used.

c. Equation estimated by OLS rather than 2SLS.

• t-statistics in absolute value are in parentheses.

TABLE 4-3. The 23 investment equations

Equation 3: ΔI_i is the LHS variable

Country	Explanatory variables									R^2	SE	DW	Sample period
	ΔI_{i-1}	I_{i-1}	ΔY_{i-1}	ΔY_{i-2}	ΔY_{i-3}	ΔY_{i-4}	constant	t	$\hat{\rho}_1$				
Canada	.13 (0.98)	-.104 (2.62)	.12 (1.67)	—	—	—	313.3 (2.54)	9.2 (2.59)	—	.148	190.5	1.86	581-821
Japan	—	-.051 (1.86)	.15 (2.41)	.13 (2.18)	.21 (3.37)	.13 (2.06)	25.1 (0.41)	5.4 (1.29)	—	.285	217.5	2.20	583-822
Belgium	—	-.199 (2.91)	—	.05 (1.64)	.07 (1.99)	—	9.6 (3.27)	.20 (2.65)	—	.151	3.14	1.84	582-804
Denmark	—	-.043 (2.19)	—	.04 (1.33)	.02 (0.73)	.05 (1.68)	.45 (2.15)	—	—	.603	.516	2.14	583-814
France	—	-.049 (1.17)	—	.03 (0.81)	.10 (2.15)	.02 (0.55)	2.0 (1.89)	.026 (0.81)	—	.114	1.48	2.29	583-814
Germany	.08 (0.72)	-.106 (2.46)	—	.09 (1.21)	.07 (0.93)	.18 (2.33)	3.3 (1.99)	.036 (1.99)	—	.191	1.82	1.99	643-821
Italy	.29 (2.87)	-.133 (3.21)	—	.07 (1.66)	.09 (2.22)	—	385.9 (2.89)	6.1 (3.05)	—	.247	159.6	2.05	612-814
Netherlands	—	-.122 (2.40)	—	.05 (1.29)	.13 (2.93)	.08 (1.72)	.83 (2.61)	.0068 (1.64)	—	.187	.354	2.24	613-814
Norway	—	-.106 (2.07)	—	.17 (2.49)	.13 (1.88)	—	.37 (1.55)	.011 (1.62)	—	.146	.573	2.18	623-814
Sweden	—	-.157 (3.32)	—	.22 (8.53)	.14 (5.35)	.27 (10.73)	1.3 (2.88)	.0099 (2.54)	-.36 (3.38)	.900	.681	1.99	583-814
Switzerland	—	-.066 (3.12)	.14 (2.15)	.11 (1.81)	.09 (1.38)	.15 (2.36)	.38 (2.87)	.0017 (1.30)	—	.359	.262	2.13	583-814

United Kingdom	—	-.103 (2.18)	.15 (4.25)	—	—	—	289.9 (2.37)	2.9 (1.83)	-.39 (3.53)	.642	150.9	2.12	581-804
Finland	—	-.160 (3.01)	—	—	.17 (3.12)	.32 (5.84)	383.2 (2.46)	7.7 (2.45)	—	.521	357.8	2.21	583-814
Greece	.16 (1.66)	-.153 (3.16)	—	.07 (2.01)	.03 (0.97)	.20 (5.94)	.80 (1.86)	.066 (2.78)	—	.553	1.66	1.99	583-814
Ireland	—	-.091 (2.19)	—	—	—	.20 (6.04)	2.6 (1.36)	.28 (2.20)	—	.728	7.62	1.91	583-804
Portugal	—	-.277 (3.93)	—	—	.02 (0.79)	.07 (3.12)	.91 (3.25)	.061 (3.89)	—	.299	.790	2.07	583-804
Spain	—	-.031 (0.76)	.03 (0.90)	.06 (1.39)	.08 (2.20)	—	6.7 (1.63)	.023 (0.16)	—	.266	8.15	1.92	622-794
Australia	—	-.071 (1.73)	.16 (2.78)	—	—	—	121.2 (1.67)	2.3 (1.90)	-.32 (2.87)	.197	87.4	1.96	603-814
New Zealand	.45 (4.22)	-.041 (1.93)	.22 (2.10)	—	—	—	12.1 (1.60)	.13 (1.24)	—	.371	14.7	2.04	582-811
South Africa	—	-.062 (1.19)	.07 (0.74)	.11 (1.11)	.07 (0.73)	.21 (2.27)	26.9 (0.96)	.88 (0.85)	-.23 (1.96)	.183	67.0	2.04	623-814
Argentina	.11 (0.62)	-.282 (2.85)	.04 (0.67)	—	—	—	4.2 (1.51)	.26 (2.55)	—	.709	4.49	1.87	671-804
Israel	—	-.243 (2.58)	—	.01 (0.69)	.04 (2.23)	—	107.7 (2.31)	.15 (0.27)	-.26 (1.70)	.395	60.0	2.12	692-814
India	.12 (0.93)	-.064 (1.81)	.07 (2.05)	—	—	—	.65 (1.60)	.022 (1.85)	—	.311	.814	2.05	611-794

Notes:
- All equations estimated by OLS.
- t-statistics in absolute value are in parentheses.

TABLE 4-4. The 13 production equations

Equation 4: Y_i is the LHS variable

Country	Explanatory variables X_i	V_{i-1}	LHS_{-1}	$\hat{\rho}_1$	Implied values λ	α	β	R^2	SE	DW	Sample period
Canada	.62 (6.14)	-.084 (1.49)	.45 (5.59)	.51 (3.78)	.55	.153	.83	.999	249.6	2.07	581-821
Austria	.63 (6.89)	-.055 (1.42)	.47 (5.64)	.18 (1.45)	.53	.104	1.81	.996	2.00	1.96	651-821
Belgium	1.03 (42.91)	-.125 (3.44)	.08 (4.64)	.74 (10.36)	.92	.136	.88	.999	1.90	1.73	581-804
Denmark	1.01 (53.81)	-.058 (1.83)	.03 (1.94)	.79 (10.20)	.97	.060	.69	.999	.218	1.73	581-814
France[a]	1.08 (15.25)	-.129 (2.67)	.13 (2.21)	.57 (5.80)	.87	.148	1.63	.999	2.08	2.12	581-814
Germany	1.01 (13.11)	-.133 (1.99)	.16 (2.90)	.67 (7.74)	.84	.158	1.28	.999	1.50	1.87	611-821
Netherlands	.99 (24.14)	-.064 (1.30)	.07 (2.27)	.83 (10.06)	.93	.069	.94	.999	.266	1.83	611-814
Sweden	.96 (29.90)	-.046 (1.30)	.10 (3.66)	.46 (5.05)	.90	.051	1.31	.996	.847	2.27	581-814
Switzerland	1.00 (11.85)	-.056 (2.45)	.17 (2.72)	.73 (10.01)	.83	.067	3.06	.999	.243	1.83	581-814
United Kingdom	1.00 (11.26)	-.124 (1.91)	.15 (2.52)	.40 (3.62)	.85	.146	1.21	.996	244.8	1.89	581-804
Finland	1.10 (13.09)	-.056 (1.31)	—	.65 (7.14)	1.00	.056	1.79	.993	483.1	1.92	581-814
Spain	.99 (29.01)	-.028 (0.99)	.05 (2.23)	.84 (11.21)	.95	.029	1.45	.999	5.87	1.86	621-794
Korea	1.01 (15.01)	-.156 (2.25)	.11 (1.53)	—	.89	.175	.77	.992	108.5	2.19	641-814

Notes: a. Equation estimated by OLS rather than 2SLS.
• t-statistics in absolute value are in parentheses.

explanatory price and interest rate variables, and the values that gave the best results were used. Similarly, both the short-term and long-term interest rate variables were tried, and the variable that gave the best results was used. A number of the equations were estimated under the assumption of first-order serial correlation of the error term. $\hat{\rho}$ in the tables denotes the estimate of the serial correlation coefficient.

Subject to data limitations, the specification of the stochastic equations follows fairly closely the specification of the equivalent equations in the US model. When it does not, this will be noted. The asset variable, A_i^*, is an important explanatory variable in a number of the equations, and one should be aware of its limitations. As noted earlier, this variable measures only the net asset position of the country vis-à-vis the rest of the world; it does not include the domestic wealth of the country. Also, its value for each country is off by a constant amount, and this required a choice for the functional form of the variable in the equations that one might not have chosen otherwise.

The following subsections present a brief discussion of the results in each table. For a complete picture of the results, the tables should be read carefully along with the discussion.

The 40 Demand-for-Import Equations (Table 4-1)

Equation 1 explains the real per-capita merchandise imports of country i. The explanatory variables include the price of domestic goods, the price of imports, the interest rates, per-capita income, and the lagged value of real per-capita assets. The variables are in logarithms except for the interest rates and the asset variable. These demand-for-import equations are similar to the demand-for-import equation in the US model, Eq. 27; the main differences are that Eq. 27 is not in log form and that the asset variable was not found to be significant for the United States and was thus dropped from the equation. The log versus linear difference is not important in that similar results would have been obtained had the US equation been in log form or the present equations in linear form.

The results in Table 4-1 seem fairly good. Most of the variables appear in the equations for the first 18 countries (Canada through Spain). The two price variables ($\log PY_i$ and $\log PM_i$) are expected to have coefficients of opposite signs and of roughly the same size in absolute value, and this was generally found to be the case. For the oil exporting countries Nigeria, Saudi Arabia, and Venezuela, the asset variable is highly significant. This means that as assets increase during rises in oil prices, the countries are predicted to increase their demand for imports, which then lessens their buildup of assets.

The 38 Consumption Equations (Table 4-2)

Equation 2 explains real per-capita consumption. The explanatory variables include the interest rates, real per-capita income, and the lagged value of real per-capita assets. The use of income as an explanatory variable in the consumption equations is inconsistent with the theoretical model of house-

TABLE 4-5. The 36 price equations

Equation 5: log PY_i is the LHS variable

Country	Explanatory variables: log PM_i	ZZ_i	t	LHS_{-1}	$\hat{\rho}_1$	R^2	SE	DW	Sample period
Canada	.053[a]	-.22[a]	.00023	.95	—	.999	.00562	1.56	581-821
	(3.67)	(7.02)	(2.45)	(51.91)					
Japan	.027	-.11[a]	.00014	.97	.55	.999	.00869	2.26	581-822
	(1.98)	(2.62)	(0.22)	(21.54)	(5.77)				
Austria	.11[a]	-.20	.0023	.76	—	.997	.0145	2.31	651-821
	(2.45)	(2.10)	(2.82)	(10.24)					
Belgium	.046	-.14[a]	.00068	.93	—	.999	.00644	1.61	581-804
	(3.84)	(5.12)	(4.06)	(46.33)					
Denmark	.065[a]	-.028[a]	.0025	.83	—	.999	.0125	1.98	581-814
	(3.19)	(0.55)	(3.41)	(16.55)					
France	.046[a]	—	.00058	.94	—	.999	.00838	1.81	581-814
	(3.42)		(2.70)	(39.22)					
Germany	.023[a]	-.21[a]	.00026	.96	-.29	.999	.00557	1.95	611-821
	(3.41)	(8.06)	(1.45)	(52.72)	(2.74)				
Italy	.065	-.18	.00042	.92	.39	.999	.00914	1.79	611-814
	(4.79)	(1.69)	(0.86)	(29.26)	(3.32)				
Netherlands	.030[a]	-.12[a]	.0013	.90	—	.999	.00935	1.77	611-814
	(2.03)	(2.42)	(2.58)	(24.07)					
Norway	.050	—	.0013	.90	—	.999	.0111	1.63	622-814
	(1.92)		(2.18)	(17.44)					
Sweden	.072[a]	-.042	.0012	.87	—	.999	.00770	1.73	581-814
	(4.80)	(0.97)	(3.12)	(24.62)					
Switzerland	.042[a]	-.12	.000095	.97	—	.999	.00783	1.86	581-814
	(2.83)	(5.83)	(0.38)	(42.86)					
United Kingdom	.081[a]	—	.00092	.89	—	.999	.0109	1.80	581-804
	(5.96)		(5.73)	(43.13)					
Finland	.056	-.063[a]	.00097	.90	—	.999	.0116	1.62	581-814
	(2.91)	(1.65)	(2.70)	(25.84)					
Greece	.068	-.023[a]	.00074	.92	—	.999	.0157	1.91	581-814
	(3.27)	(0.52)	(2.55)	(27.65)					
Ireland	.079[a]	-.11[a]	.0014	.88	—	.999	.0169	1.88	581-804
	(3.01)	(1.45)	(3.09)	(21.13)					
Portugal	.18	-.059[a]	.0011	.79	—	.999	.0206	2.17	581-804
	(4.08)	(0.97)	(3.23)	(13.99)					

Spain	.059 (5.09)	-.081[a] (1.16)	-.00011 (0.19)	.97 (35.41)	—	.999	.0122	2.10	621-794
Turkey	.071 (1.67)	—	.00033 (0.10)	.94 (12.62)	—	.997	.0287	1.86	691-784
Yugoslavia	—	-.19[a] (1.59)	.0018 (1.13)	.95 (19.21)	.22 (1.78)	.999	.0277	1.93	611-794
Australia	—	-.18[a] (2.36)	.0000059 (0.02)	1.02 (56.19)	—	.999	.0121	2.06	603-814
New Zealand	.049[a] (2.72)	—	.00068 (3.15)	.94 (36.07)	—	.999	.0154	1.95	582-811
South Africa	.031 (1.14)	—	.0012 (2.57)	.93 (18.90)	—	.999	.0169	1.93	621-814
Argentina	.35 (8.31)	—	.0089 (1.60)	.63 (15.32)	—	.999	.0716	1.50	711-804
Brazil	.097 (5.40)	—	.00085 (0.61)	.92 (31.63)	—	.999	.0165	1.56	711-804
Chile	.25 (6.97)	—	.016 (0.41)	.57 (5.20)	.94 (7.45)	.999	.0611	1.73	711-804
Colombia	.026 (0.71)	—	.011 (2.39)	.76 (9.22)	—	.999	.0176	1.94	711-804
Israel	.13 (2.79)	-.080[a] (0.62)	-.00049 (0.36)	.90 (16.48)	—	.999	.0299	2.14	691-813
Jordan	.068 (0.65)	—	.013 (2.81)	.51 (3.31)	—	.923	.0798	1.53	731-804
Syria	.081 (2.42)	—	.0023 (2.25)	.80 (12.18)	—	.992	.0380	2.22	641-804
India	.016[a] (0.72)	—	.0030 (1.80)	.81 (7.38)	.26 (1.54)	.997	.0236	2.12	611-794
Korea	.10 (3.46)	-.28[a] (3.62)	.0088 (3.26)	.70 (8.73)	—	.998	.0411	2.47	641-841
Malaysia[b]	.023 (0.54)	-.42 (2.65)	.0066 (3.54)	.62 (5.56)	—	.989	.0249	2.00	711-814
Pakistan	.058 (2.76)	—	.0036 (2.98)	.78 (15.68)	—	.997	.0147	2.49	731-812
Philippines	.038 (2.74)	-.15[a] (2.20)	.00092 (1.92)	.91 (36.68)	—	.999	.0196	1.53	581-802
Thailand	.019 (0.46)	—	.00099 (2.20)	.94 (13.23)	—	.997	.0189	1.21	654-814

Notes: a. Variable is lagged one quarter.
b. Equation estimated by OLS rather than 2SLS.
• t-statistics in absolute value are in parentheses.

hold behavior in Chapter 3. If a household is choosing consumption and labor supply to maximize utility, income is not the appropriate variable to use in the consumption equation. This procedure can be justified, however, if households are always constrained in their labor supply decision, and this is what must be assumed here. This is an important difference between the US model and the models of the other countries.

The results in Table 4-2 show that the interest rate and asset variables appear in most of the equations through the equations for Spain. It thus appears that interest rate and wealth effects on consumption have been picked up, as well as the usual income effect.

The interest rate variables in both the import and consumption equations are nominal rates. As was done in the estimation of the consumption equations for the US model, various proxies of expected future inflation rates were added to the equations (in addition to the nominal interest rate) to see if their coefficient estimates had the expected positive sign. The proxies consisted of various weighted averages of current and past inflation rates. As in the U.S. case, the results were not very good, which again may be due to the difficulty of measuring expected future inflation rates. More attempts of this kind should be made in future work, but for present purposes the nominal rates have been used.

The 23 Investment Equations (Table 4-3)

The explanation of investment is complicated by the fact that capital stock data were not constructed for the countries. (No benchmark capital stock data were available from the IFS tape.) This means that the specification of the investment equation for the US model, which relied on measures of the capital stock and of the amount of excess capital on hand, could not be used. What was done instead was to specify an investment equation that did not require a measure of the capital stock. The equations are as follows:

$$(4.40) \qquad K_i - K_{i-1} = I_i - DEP_i,$$

$$(4.41) \qquad DEP_i = \beta_0 + \beta_1 t,$$

$$(4.42) \qquad K_i^* = \alpha_1 Y_{i-1} + \alpha_2 Y_{i-2} + \alpha_3 Y_{i-3} + \alpha_4 Y_{i-4},$$

$$(4.43) \qquad (K_i - K_{i-1})^* = \lambda_1 (K_i^* - K_{i-1}), \qquad 0 < \lambda_1 \leq 1,$$

$$(4.44) \qquad I_i^* = (K_i - K_{i-1})^* + DEP_i,$$

$$(4.45) \qquad I_i - I_{i-1} = \lambda_2 (I_i^* - I_{i-1}), \qquad 0 < \lambda_2 \leq 1,$$

where K_i is the actual value of the capital stock, I_i is gross investment, DEP_i is depreciation, Y_i is the level of output, K_i^* is the desired value of the capital stock, $(K_i - K_{i-1})^*$ is desired net investment, and I_i^* is desired gross investment.

Equation (4.40) is a definition: the change in the capital stock equals gross investment minus depreciation. In the absence of data on depreciation, it is assumed in (4.41) that depreciation is simply a function of a constant and time. The desired capital stock in (4.42) is assumed to be a function of the past four values of output; the past output values are meant as proxies for expected future values. Desired net investment in (4.43) is some fraction λ_1 of the difference between the desired capital stock and the actual capital stock of the previous period. Desired gross investment in (4.44) is equal to desired net investment plus depreciation. Equation (4.44) is the same as the definition (4.40) except that it is in terms of desired rather than actual values. The actual change in gross investment in (4.45) is some fraction λ_2 of the difference between desired gross investment and actual gross investment of the previous period.

This specification is in the spirit of the theoretical model of firm behavior in Chapter 3 in the sense that the lagged adjustment equations (4.43) and (4.45) are meant to reflect costs of adjustment. It seems likely that λ_2 will be much larger than λ_1, and it may in fact be one, which would mean that there are no adjustment costs with respect to changing gross investment.

Combining (4.40)–(4.45) yields the following equation to estimate:

$$
\begin{aligned}
(4.46) \qquad \Delta I_i = {} & (1 - \lambda_2)\Delta I_{i-1} - \lambda_1\lambda_2 I_{i-1} + \lambda_1\lambda_2\alpha_1\Delta Y_{i-1} \\
& + \lambda_1\lambda_2\alpha_2\Delta Y_{i-2} + \lambda_1\lambda_2\alpha_3\Delta Y_{i-3} + \lambda_1\lambda_2\alpha_4\Delta Y_{i-4} \\
& + \lambda_2(\lambda_1\beta_0 - \lambda_1\beta_1 + \beta_1) + \lambda_1\lambda_2\beta_1 t.
\end{aligned}
$$

If $\lambda_2 = 1$, the lagged dependent variable, ΔI_{i-1}, drops out of the equation. If $\beta_1 > 0$, the coefficient of t is positive, and if $\beta_0 > 0$ and $\beta_1 > 0$, the constant term in the equation is positive. With respect to the stochastic specification, if an error term u_t is added to (4.45), then the error term in (4.46) is $u_t - u_{t-1}$. This means that the error term in (4.46) will be negatively serially correlated unless u_t is first-order serially correlated with a serial correlation coefficient greater than or equal to one. Note that by taking first differences the capital stock variable has been eliminated from (4.46).

The estimates of (4.46) are presented in Table 4-3 for 23 countries. (All these equations were estimated by OLS because there are no RHS endogenous variables.) All the estimates of the constant terms are positive. For most countries the estimate of the coefficient of ΔI_{i-1} was small and insignificant,

TABLE 4-6. The 26 demand for money equations

Equation 6: $\frac{M_i^*}{POP_i}$ is the LHS variable

Country	Explanatory variables							
	RS_i	$\frac{PY_iY_i}{POP_i}$	t	LHS_{-1}	R^2	SE	DW	Sample period
Canada	-8.4	.052	.45	.90	.994	21.0	2.53	581-813
	(5.41)	(3.79)	(1.46)	(18.04)				
Japan	-1.4	.20	.16	.82	.997	11.6	2.61	581-822
	(2.32)	(2.20)	(0.93)	(11.75)				
Austria	—	—	.019	.91	.994	.359	1.54	651-821
			(1.65)	(17.58)				
Belgium	-.37[a]	.29	.075	.59	.997	1.09	2.49	581-804
	(4.49)	(5.17)	(4.48)	(7.95)				
Denmark	-.090	.58	.0027	.33	.997	.229	1.57	581-814
	(6.90)	(12.24)	(1.00)	(5.56)				
France	-.013[a]	.34	.010	.56	.997	.181	2.25	581-814
	(1.35)	(5.28)	(3.37)	(6.10)				
Germany	-.020	.30	-.00056	.56	.998	.0463	2.51	611-821
	(6.37)	(5.23)	(0.49)	(7.49)				
Italy	-5.7	.45	2.1	.77	.996	55.8	2.34	611-814
	(2.01)	(2.24)	(2.48)	(6.27)				
Netherlands	-.039	.52	.0087	.19	.997	.074	2.07	611-814
	(6.77)	(7.36)	(5.30)	(1.92)				
Norway	-.011[a]	.25	.024	.46	.991	.308	2.35	621-814
	(0.42)	(5.33)	(4.15)	(4.70)				
Sweden	—	.37	-.013	.44	.993	.187	1.75	581-814
		(9.55)	(5.85)	(6.96)				
Switzerland	-.030	.15	.012	.79	.990	.280	1.59	581-814
	(0.94)	(1.26)	(1.59)	(10.84)				

United Kingdom	-1.9 (5.58)	.082 (3.59)	.17 (3.69)	.87 (19.66)	.998	5.17	2.18	581-804
Finland	-4.2 (0.40)	.21 (7.87)	-1.6 (2.51)	.39 (4.86)	.996	60.6	1.96	581-814
Greece	-.039 (0.94)	.59 (9.14)	.015 (2.49)	.09 (0.94)	.997	.507	2.14	581-814
Ireland	-1.8 (4.10)	.098 (3.39)	.097 (1.55)	.91 (18.94)	.997	6.60	1.64	581-804
Portugal	-.28 (2.57)	.76 (5.49)	.029 (2.67)	.55 (6.10)	.990	1.07	1.94	581-804
Spain	-.12[a] (0.28)	.51 (4.46)	.070 (2.49)	.49 (4.07)	.996	1.58	2.07	621-794
Turkey[b]	-.037 (1.20)	.25 (4.15)	-.00076 (0.21)	.76 (8.46)	.997	.0827	1.44	691-784
Australia	-7.1 (3.72)	.13 (3.84)	-.042 (0.21)	.79 (11.05)	.997	13.8	1.89	603-814
New Zealand	-13.7 (4.61)	.22 (5.60)	-.79 (3.10)	.67 (10.01)	.987	19.7	2.54	582-811
South Africa	-1.6 (3.85)	.06 (3.06)	.076 (1.01)	.90 (14.76)	.995	3.60	1.81	621-804
Colombia[b]	-7.1 (0.51)	.32 (5.28)	5.0 (0.73)	.29 (1.83)	.994	138.8	1.91	711-804
Peru	-.0035 (0.16)	.14 (5.04)	.0091 (2.42)	.78 (13.12)	.998	.344	1.66	611-804
Philippines	-.79[a] (1.67)	.070 (2.88)	.24 (2.66)	.73 (8.47)	.994	7.70	1.72	581-802
Thailand	-.0061[a] (1.47)	.10 (3.10)	.0028 (3.58)	.58 (4.79)	.989	.0351	1.70	654-814

Notes: a. Variable is lagged one quarter.
b. Equation estimated by OLS rather than 2SLS.
• t-statistics in absolute value are in parentheses.

and for most countries the variable was dropped. This means that the estimate of λ_2 is one for most countries. All the estimates of the coefficient of I_{i-1} are negative, as expected. The implied estimate of λ_1 ranges from .031 for Spain to .317 for Argentina. Most of the equations showed little evidence of serial correlation of the error term, which means that the error term in (4.45) has a high degree of positive serial correlation. The results for five countries showed enough evidence of negative serial correlation to warrant estimating the equations under the assumption of first-order serial correlation.

The output terms were left in the equations if their coefficient estimates were positive. There is generally a high degree of collinearity among the terms, and thus the coefficient estimates for the individual output terms are generally not very precise.

Although the results in Table 4-3 look reasonable, the results in general of estimating the investment equation are at best fair. There are two main problems: the first is that reasonable results could be found for only 23 countries; the second is that the results are highly sensitive to whether or not the current change in output, ΔY_i, is included in the equation. If the term $\alpha_0 Y_i$ is included in (4.42), so that the desired capital stock is also a function of the current level of output, then the term $\lambda_1\lambda_2\alpha_0\Delta Y_i$ is included in (4.46). When ΔY_i was included in the estimated equations, its coefficient estimate seemed much too large and the other coefficient estimates were substantially changed. Even though most of the equations were estimated by 2SLS, there still appeared to be substantial amounts of simultaneity bias. This problem existed almost without exception across the countries. In the end the decision was made to drop ΔY_i from all the investment equations, but this lack of robustness is not an encouraging feature of the results.

The 13 Production Equations (Table 4-4)

Equation 4 explains the level of production. It is based on the same three equations that were used for the US model—(4.22), (4.23), and (4.24). These equations are repeated here.

$$V^* = \beta X, \tag{4.22}$$

$$Y^* \equiv X + \alpha(V^* - V_{-1}), \tag{4.23}$$

$$Y - Y_{-1} = \lambda(Y^* - Y_{-1}). \tag{4.24}$$

Combining the three equations yields

$$Y = \lambda(1 + \alpha\beta)X - \lambda\alpha V_{-1} + (1 - \lambda)Y_{-1}, \tag{4.25}$$

which is the equation estimated.

The results of estimating (4.25) for 13 countries are presented in Table 4-4. The implied values of λ, α, and β are presented along with the actual coefficient estimates. The estimates of λ range from .53 for Austria to .97 for Denmark. (λ is 1.0 for Finland because Y_{i-1} was dropped from the equation; this variable was dropped because its coefficient estimate was highly insignificant.) The estimates of α range from .029 for Spain to .175 for Korea. The fact that the estimates of λ are much larger than the estimates of α implies that production adjusts much faster to its desired level than does the stock of inventories. Serial correlation of the error terms is quite pronounced in most of the equations.

Equation 4 is essentially an inventory investment equation, and these types of equations are notoriously difficult to estimate. Reasonable results were obtained for the 13 countries in Table 4-4, but only for these 13. Estimating the equation for other countries led to unreasonable implied values of at least one of the three coefficients, λ, α, and β. As with the investment results in the previous subsection, the production results must be interpreted with caution, although there is no equivalent problem here to the robustness problem encountered in the estimation of the investment equation.

The 36 Price Equations (Table 4-5)

Equation 5 explains the GNP deflator. It is the key price equation in the model for each country. The two main explanatory variables in the equation, aside from the lagged dependent variable, are the price of imports, PM_i, and the demand pressure variable, ZZ_i. Equation 5 is similar to the price equation for the US model, Eq. 10 in Table A-5; the main difference is that Eq. 10 includes the wage rate, which Eq. 5 does not. Sufficient data on wage rates do not exist to allow a wage equation to be estimated along with a price equation.

The results of estimating Eq. 5 for 36 countries are presented in Table 4-5. It is clear from the results that import prices have an important effect on domestic prices for most countries. The import price variable appears in 34 of the 36 equations with the expected positive sign. The demand pressure variable appears in the equation for most of the first 18 countries. Serial correlation of the error term is not a problem for most countries, and in general the results seem good.

The 26 Demand-for-Money Equations (Table 4-6)

Equation 6 explains the per-capita demand for money. Both the interest rate and the income variables are generally significant in this equation. For all

TABLE 4-7. The 23 interest rate reaction functions under fixed exchange rates

Equation 7a: RS_i in the LHS variable

Country	Explanatory variables										R^2	SE	DW	Sample period
	US rate: RS_1	German rate: RS_8	$\dot{PY}_{i-1}$	$\frac{\dot{M1}^*_{i-1}}{POP_{i-1}}$	ZZ_i	$\frac{A^*_i}{PY_i POP_i}$	$\frac{A^*_{i-1}}{PY_{i-1} POP_{i-1}}$	t	LHS_{-1}	$\hat{\rho}_1$				
Canada	.82 (4.75)	—	.059 (2.17)	—	—	—	—	.022 (0.62)	.13 (0.80)	.61 (3.88)	.965	.257	1.36	631-701
Japan	—	—	—	.015 (1.43)	-27.9[a] (2.54)	-.21 (3.03)	.22 (2.93)	-.12 (2.33)	.65 (7.76)	—	.762	.825	2.19	581-712
Austria[c]	—	.14 (4.64)	—	—	-7.9[a] (2.12)	—	—	-.017 (2.88)	.20 (1.48)	—	.912	.134	1.82	651-711
Belgium	.37 (4.13)	.20 (2.12)	.034 (1.29)	—	-6.6 (1.62)	-.21[ab] (2.23)	.21[ab] (2.23)	-.012 (0.96)	.56 (3.76)	—	.898	.462	1.91	581-712
Denmark[c]	.19 (3.12)	—	.033 (3.68)	—	-3.1 (1.47)	-.50[ab] (1.33)	.50[ab] (1.33)	-.0096 (1.22)	.74 (10.22)	—	.922	.342	1.50	581-712
France	.35 (3.67)	—	.065 (4.11)	—	—	-2.4[ab] (1.76)	2.4[ab] (1.76)	-.015 (1.71)	.73 (12.94)	—	.925	.494	2.00	581-712
Germany	.46 (3.90)	—	.085 (2.89)	—	-13.4[a] (3.38)	-2.4[ab] (1.33)	2.4[ab] (1.33)	-.015 (0.91)	.68 (11.15)	—	.950	.436	1.70	611-711
Italy[c]	—	.12 (5.91)	—	—	—	-.010 (3.07)	.011 (3.24)	—	.56 (8.47)	—	.937	.167	2.26	611-712
Netherlands	.66 (5.26)	—	.013 (0.72)	.025 (2.10)	—	-4.5[a] (2.15)	3.4[a] (1.75)	-.043 (1.75)	.65 (7.19)	—	.962	.404	1.79	611-711
Sweden[c]	.16 (2.76)	—	—	—	—	-1.5[ab] (2.34)	1.5[ab] (2.34)	.0037 (0.60)	.71 (9.97)	—	.882	.308	2.18	581-712
Switzerland[c]	.04 (1.28)	.04 (2.06)	—	—	—	—	—	.0041 (1.19)	.76 (11.09)	—	.928	.173	2.03	581-711

United Kingdom	.20 (2.28)	—	—	—	-12.7 (2.82)	-.039[a] (3.01)	.031[a] (2.15)	.0044 (0.40)	.67 (7.71)	—	.907	.418	1.69	581-712
Finland[c]	—	—	.017 (2.09)	—	—	—	—	.0018 (0.77)	.45 (2.81)	—	.224	.261	1.59	581-712
Greece[c]	—	—	.024 (3.29)	—	-6.4[a] (3.63)	—	—	-.013 (2.59)	.87 (25.46)	—	.927	.513	2.40	581-751
Ireland[c]	.15 (1.34)	—	—	—	—	—	—	.017 (1.61)	.62 (6.39)	—	.818	.610	1.91	581-712
Portugal[c]	—	—	—	.0027 (1.38)	—	—	—	.0031 (1.64)	.96 (14.80)	—	.940	.118	2.17	581-712
Spain[c]	.12 (3.36)	—	—	—	—	—	—	-.0064 (1.07)	.93 (13.12)	—	.937	.161	2.47	621-712
Australia	.07 (1.66)	—	.014 (1.81)	—	-5.6[a] (3.78)	-.0043[b] (2.86)	.0043[b] (2.86)	-.013 (2.40)	.93 (17.94)	—	.943	.175	2.03	603-712
South Africa	.11 (2.63)	—	—	—	-5.4[a] (1.80)	-.0090[b] (2.25)	.0090[b] (2.25)	.0036 (0.29)	.93 (8.13)	.65 (4.14)	.966	.364	2.06	621-814
Korea[c]	—	—	—	—	-13.8 (3.29)	—	—	-.023 (1.74)	.90 (18.30)	—	.845	2.23	1.75	641-814
Pakistan	—	—	.014 (0.88)	—	—	-.0079 (0.81)	.0057 (0.63)	-.065 (1.02)	.67 (4.75)	—	.742	.751	1.48	731-812
Philippines[c]	.21 (2.70)	—	—	—	—	—	—	-.0092 (1.41)	.86 (17.12)	—	.808	.971	2.01	581-802
Thailand[c]	.20 (4.11)	—	—	—	-3.1 (0.75)	—	—	.020 (2.70)	.59 (7.55)	—	.927	.582	1.79	654-814

Notes: a. Variable is lagged one quarter.
b. Coefficient of $A_i^*/(PY_i POP_i)$ (or its lagged value) constrained to be equal to minus the coefficient of $A_{i-1}^*/(PY_{i-1} POP_{i-1})$ (or its lagged value).
c. Only discount rate data available for RS_i.

- All equations estimated by OLS.
- t-statistics in absolute value are in parentheses.

countries except Austria and Sweden, the estimated coefficient of the interest rate variable is of the expected negative sign.

The per-capita money and income variables in Table 4-6 are nominal rather than real. This is contrary to the case for the money and income variables in the demand-for-money equations in the US model, which are in real terms. Some experimentation was done for the other countries using real variables, but on average the results did not seem to be as good. One of the reasons for this may be errors of measurement in the price deflators. More experimentation should be done in future work, but for present purposes the results in Table 4-6 seem reasonably good.

The Interest Rate Reaction Functions: 23 under Fixed Exchange Rates and 20 under Flexible Exchange Rates (Table 4-7 and 4-8)

The candidates for inclusion as explanatory variables in the interest rate reaction functions are variables that one believes may affect the monetary authorities' decisions regarding short-term interest rates. In addition, the U.S. interest rate may be an important explanatory variable in the equations estimated over the fixed exchange rate period if bonds are close substitutes. The variables that were tried include (1) the lagged rate of inflation, (2) the lagged rate of growth of the money supply, (3) the demand pressure variable, (4) the change in assets, (5) the lagged rate of change of import prices, (6) the exchange rate (Eq. 7b only), and (7) the German interest rate. The form of the asset variable that was tried is $A_i^*/(PY_iPOP_i)$. Except for division by PY_iPOP_i, the change in this variable is the balance of payments on current account. For some countries, depending on the initial results, the current and one-period-lagged values were entered separately. It may be that the monetary authorities respond in part to the level of assets and in part to the change, and entering the current and lagged values separately will pick this up.

The results of estimating Eqs. 7a and 7b are presented in Tables 4-7 and 4-8. Although the equations are estimated over fairly small numbers of observations because of the breaking up of the sample periods, many of the explanatory variables appear in the equations and many are significant. The overall results provide fairly strong support for the proposition that monetary authorities in other countries "lean against the wind." This conclusion is consistent with the results for the US model. The U.S. interest rate, as expected, is a more important explanatory variable in the fixed exchange rate period than it is in the flexible rate period. The variable that is least significant in Tables 4-7 and 4-8 is the lagged growth of the money supply. Contrary to the case for the United States, especially in the Volcker regime, the monetary authorities of other countries do not appear to be influenced very much in their setting of interest rate targets by the money supply growth itself. In other words, money supply growth does not appear to provide independent explanatory power for the interest rate setting behavior of most countries, given the other variables in the equations.

The 17 Term Structure Equations (Table 4-9)

Equation 8 is a standard term structure equation. The current and lagged short-term interest rates in the equation are meant to be proxies for expected future short-term interest rates. This is the same equation as the one that was estimated for the bond and mortgage rates in the US model (Eqs. 23 and 24 in Table A-5). The results of estimating equation 8 for 17 countries are presented in Table 4-9. The 17 countries are the ones for which data on a long-term rate exist. The current short-term rate is significant for all countries except Portugal and New Zealand. In general, the results indicate that current and lagged short-term rates affect long-term rates.

The 22 Exchange Rate Equations (Table 4-10)

Equation 9b explains the spot exchange rate. Candidates for inclusion as explanatory variables in this equation are variables that one believes affect the monetary authority's decision regarding the exchange rate. If, as mentioned in Section 4.2.2, a monetary authority takes market forces into account in choosing its exchange rate target, then variables measuring these forces should be included in the equation. The variables that were tried include (1) the price level of country i relative to the U.S. price level, (2) the short-term interest rate of country i relative to the U.S. rate, (3) the demand pressure variable of country i relative to the U.S. demand pressure variable, ZZ_i, (4) the one-quarter-lagged value of the change in real per-capita net foreign assets of country i relative to the change in the same variable for the United States, and (5) the German exchange rate.

The results of estimating Eq. 9b for 22 countries are presented in Table 4-10. It is clear from the current literature on exchange rates that no one explanation of exchange rates has emerged as being obviously the best. Whether the current explanation as reflected in the results in Table 4-10 turns out to be the best is clearly an open question. The sample period in the flexible exchange rate regime is still fairly short, and more observations are needed before much can be said. In general, the results in Table 4-10 do not seem too

TABLE 4-8. The 20 interest rate reaction functions under flexible exchange rates

Equation 7b: RS_i is the LHS variable

Country	Explanatory variables												R^2	SE	DW	Sample period
	US rate: RS_1	German rate: RS_8	$\dot{PY}_{i-1}$	$\frac{\dot{MI}^*_{i-1}}{POP_{i-1}}$	ZZ_i	$\frac{A^*_i}{PY_i POP_i}$	$\frac{A^*_{i-1}}{PY_{i-1} POP_{i-1}}$	$\dot{PM}_{i-1}$	e_i	t	LHS_{-1}	$\hat{\rho}_1$				
Canada	.70 (8.73)	—	—	.020 (2.30)	-19.3 (1.89)	-.017 (2.94)	.015 (2.70)	—	—	.060 (0.90)	.42 (4.10)	.63 (4.85)	.979	.604	1.99	711-821
Japan	—	—	—	.013 (1.55)	—	-.17 (3.24)	.18 (4.94)	—	9.0 (1.35)	—	.80 (5.50)	.40 (1.72)	.945	.655	1.75	722-822
Austria[c]	.17 (3.64)	—	.035 (2.31)	.011 (1.50)	-5.5 (0.91)	-.65[a] (2.57)	.70[a] (2.67)	—	—	.0047 (0.14)	.69 (8.28)	—	.795	.474	2.03	722-821
Belgium	.12 (0.75)	.13 (1.10)	—	—	-22.8 (2.30)	—	—	.042 (2.46)	187.3 (1.78)	.22 (3.50)	.51 (5.65)	—	.878	1.00	2.14	722-804
Denmark	—	—	.19 (2.94)	—	-22.5 (1.93)	-5.5[a] (2.49)	4.9[a] (2.50)	.047 (2.22)	—	.030 (0.26)	.48 (4.41)	—	.820	1.81	2.22	722-814
France	—	.35 (6.57)	.078 (1.35)	—	-22.6 (1.62)	-2.8[ab] (1.07)	2.8[ab] (1.07)	.017 (1.91)	1384.3 (3.60)	.12 (2.92)	.43 (4.89)	—	.931	.805	1.78	722-814
Germany	.28 (2.31)	—	.049 (0.81)	—	-29.9 (2.90)	-3.5[ab] (1.08)	3.5[ab] (1.08)	—	1091.9 (1.43)	.025 (0.52)	.73 (8.83)	—	.902	.957	2.10	722-821
Italy	—	—	.054 (1.40)	—	-19.3 (1.57)	-.079 (5.03)	.068 (4.31)	—	7.8 (2.90)	.038 (1.03)	.49 (5.37)	—	.944	1.06	1.58	722-814
Netherlands	—	.36 (2.92)	.099 (0.74)	—	-22.7 (1.60)	—	—	.037 (1.71)	—	.15 (2.53)	.39 (3.12)	—	.748	1.85	1.55	722-814
Norway	—	.31 (2.24)	—	—	—	-1.2 (2.21)	1.1 (2.21)	.017 (0.84)	720.2 (0.92)	.11 (1.89)	.32 (2.34)	—	.673	1.46	2.24	722-814

Sweden[d]	—	.09 (1.57)	.046 (1.34)	—	-26.9[a] (2.25)	-1.9 (1.52)	.9 (0.74)	.013 (1.50)	—	.041 (1.09)	.61 (6.17)	—	.914	.791	1.67	722-814
Switzerland[c]	.15 (4.93)	—	.026 (2.81)	—	-7.1 (2.52)	.55 (1.08)	-.79 (1.66)	.0070 (2.70)	702.1 (4.58)	.070 (2.40)	.69 (9.18)	—	.982	.217	2.06	722-814
United Kingdom	—	—	—	.040 (2.11)	-14.5[a] (1.25)	-.034 (0.94)	.053 (1.41)	.022 (1.36)	—	.15 (2.64)	.68 (3.76)	.44 (1.86)	.892	.965	1.94	722-804
Finland[c]	—	—	—	—	-8.0 (3.74)	—	—	.0024 (0.85)	—	.029 (3.20)	.84 (13.16)	—	.845	.316	1.72	722-814
Greece[c]	—	—	.047 (1.70)	—	-22.3[a] (2.57)	—	—	—	—	.28 (3.57)	.71 (5.19)	—	.971	.720	2.53	761-814
Ireland	.28 (1.84)	—	—	—	-8.7 (0.77)	—	—	—	—	.0073 (0.17)	.73 (6.95)	—	.810	1.34	1.28	722-804
Portugal[c]	—	—	.020 (1.73)	—	—	-.45[b] (1.06)	.45[b] (1.06)	—	196.5 (2.44)	-.041 (0.52)	.73 (6.91)	—	.969	1.00	2.18	722-804
Spain[c]	.09 (3.23)	—	.019 (3.09)	—	—	-.13[ab] (3.59)	.13[ab] (3.59)	—	16.8 (2.27)	.014 (0.99)	.66 (6.50)	—	.974	.167	2.28	722-794
Australia	.15 (3.80)	—	—	—	-21.0 (2.87)	-.0083[b] (1.83)	.0083[b] (1.83)	.0083 (2.30)	—	.064 (2.45)	.71 (8.73)	—	.960	.469	2.02	722-814
New Zealand[c]	—	—	—	—	-10.5 (1.32)	—	—	—	—	.15 (3.41)	.63 (4.23)	—	.953	.613	1.53	732-811

Notes: a. Variable is lagged one quarter.
b. Coefficient of $A_i^*/(PY_i POP_i)$ (or its lagged value) constrained to be equal to minus the coefficient of $A_{i-1}^*/(PY_{i-1} POP_{i-1})$ (or its lagged value).
c. Only discount rate data available for RS_i.
d. Only discount rate data available for RS_i before 743.

- All equations estimated by OLS.
- t-statistics in absolute value are in parentheses.

TABLE 4-9. The 17 term structure equations

Equation 8: RB_i is the LHS variable

Country	Explanatory variables				R^2	SE	DW	Sample period
	RS_i	RS_{i-1}	RS_{i-2}	LHS_{-1}				
Canada	.35 (6.10)	-.28 (3.59)	.07 (1.73)	.83 (18.72)	.985	.334	2.37	581-821
Belgium	.20 (5.69)	-.09 (2.12)	-.00 (0.05)	.89 (21.61)	.982	.222	1.73	581-804
Denmark	.25 (4.76)	-.09 (1.57)	-.06 (1.48)	.92 (23.29)	.975	.641	1.79	581-814
France	.22 (3.05)	-.13 (1.44)	-.03 (0.62)	.97 (24.77)	.988	.299	1.90	581-814
Germany	.26 (4.78)	-.16 (2.31)	.02 (0.41)	.80 (14.53)	.936	.358	1.73	611-821
Italy	.25 (4.72)	-.16 (2.19)	.04 (0.81)	.90 (27.90)	.991	.394	1.25	611-814
Netherlands	.15 (3.43)	-.10 (2.36)	.02 (0.76)	.93 (28.54)	.973	.330	1.92	611-814
Norway	.13 (3.15)	-.04 (1.42)	-.01 (0.27)	.93 (23.12)	.981	.267	1.58	621-814
Sweden	.20 (3.38)	-.14 (1.90)	-.01 (0.22)	.98 (52.62)	.994	.188	1.62	581-814
Switzerland	.44 (7.07)	-.31 (2.97)	-.05 (0.78)	.92 (25.78)	.973	.189	1.31	581-814
United Kingdom	.32 (3.45)	-.27 (2.17)	.02 (0.31)	.94 (29.38)	.982	.452	1.85	581-804
Ireland	.24 (2.07)	-.10 (0.69)	-.03 (0.43)	.92 (23.22)	.972	.670	2.51	581-804
Portugal	.18 (1.80)	.15 (1.54)	-.23 (4.08)	.88 (14.39)	.993	.363	1.80	581-804
Australia	.53 (7.93)	-.31 (3.51)	-.04 (0.81)	.84 (14.98)	.994	.205	1.73	603-814
New Zealand[a]	-.11 (1.67)	.53 (5.87)	-.40 (5.75)	.996 (23.39)	.988	.268	1.95	582-811
South Africa	.46 (3.26)	-.51 (2.19)	.05 (0.42)	.995 (29.15)	.988	.239	1.71	621-814
India[a]	.03 (3.07)	.00 (0.34)	-.01 (0.88)	.91 (36.70)	.980	.099	1.49	611-794

Notes: a. Equation estimated by OLS rather than 2SLS.
• t-statistics in absolute value are in parentheses.

bad. The German exchange rate is an important explanatory variable in the equations for the other European countries, which is as expected. The relative inflation variable appears in all but six of the equations, and it is the next most important variable after the German exchange rate and the lagged dependent variable. The next most important variable is the relative change in assets variable, which appears in half of the equations. (Note with respect to the relative change in assets variable in Table 4-10 that since $\Delta[A^*_{i-1}/(PY_{i-1}POP_{i-1})]$ is in 1975 local currency, the respective variable for the United States must be multiplied by the 1975 exchange rate, e_{i75}, to make the units comparable.) The relative interest rate variable and the relative demand pressure variable are of about equal importance, each appearing in 9 of the 22 equations.

Since the LHS variable is the log of the exchange rate, the standard errors are roughly in percentage terms. The standard errors for many European countries are very low—in a number of cases less than 2.0 percent—but this is misleading because of the inclusion of the German exchange rate in the equations. A much better way of examining how well the equations fit is to solve the overall model; the results of doing this are presented and discussed in Section 8.6. The standard error for the German equation in Table 4-10 is 3.94 percent, and the standard error for the Japanese equation, which does not include the German rate as an explanatory variable, is 3.60 percent. These errors do not seem bad, given the variability of exchange rates, but again one should wait for the results of solving the overall model.

The signs of the estimated effects are as follows. (Remember that an increase in the exchange rate is a depreciation and that all changes are relative to changes for the United States. Moreover, not all the effects operate for all countries). (1) An increase in a country's price level has a positive effect on its exchange rate (a depreciation). (2) As real output in a country increases, the demand pressure variable ZZ_i decreases, and a decrease in ZZ_i leads to an increase in the exchange rate. Therefore, an increase in real output has a positive effect on the exchange rate (a depreciation). (3) An increase in a country's short-term interest rate has a negative effect on its exchange rate (an appreciation). (4) An increase in a country's net foreign assets has a negative effect on its exchange rate (an appreciation).

The 13 Forward Rate Equations (Table 4-11)

Equation 10b is the estimated arbitrage condition. Although this equation plays no role in the model, it allows one to see how closely the quarterly data

TABLE 4-10. The 22 exchange rate equations

Equation 9b: $\log e_i$ is the LHS variable

Country	Explanatory variables: German rate: $\log e_8$	$\log\frac{PY_i}{PY_1}$	$\frac{1}{4}\log\frac{(1+RS_i/100)}{(1+RS_1/100)}$	$ZZ_i - ZZ_1$	$\Delta\frac{A^*_{i-1}}{PY_{i-1}POP_{i-1}} - e_{i75}\Delta\frac{A^*_{1-1}}{PY_{1-1}POP_{1-1}}$	LHS_{-1}	$\hat{\rho}_1$	R^2	SE	DW	Sample period
Canada	—	.15 (1.92)	-.89 (0.94)	—	—	.92 (16.10)	.33 (2.04)	.974	.0126	1.96	711-821
Japan	—	.10 (0.76)	-2.9 (1.68)	-.41 (1.68)	-.0039 (3.49)	.86 (6.68)	.23 (1.17)	.938	.0360	1.87	722-822
Austria	.95 (47.46)	.072 (0.94)	-.71 (2.04)	—	—	.02 (1.02)	.90 (12.74)	.999	.00566	1.51	722-821
Belgium	.84 (23.61)	—	—	—	-.0033 (1.60)	—	.76 (7.84)	.994	.0106	1.88	722-804
Denmark	.82 (18.71)	—	—	-.16 (1.99)	-.023 (2.45)	.09 (1.74)	.99 (41.25)	.979	.0136	1.22	722-814
France	.60 (8.13)	1.1 (5.94)	—	—	-.072 (1.04)	.35 (4.07)	.69 (5.19)	.938	.0214	1.72	722-814
Germany	—	.94 (2.44)	-3.1 (1.67)	-.45 (0.68)	-.40 (2.58)	.70 (6.26)	—	.949	.0394	1.92	722-804
Italy	.49 (6.49)	.71 (6.86)	—	—	—	.44 (4.44)	.66 (5.08)	.986	.0238	2.10	722-814
Netherlands	.87 (23.95)	—	—	—	—	.08 (2.09)	.85 (10.34)	.994	.0111	1.98	722-814

Norway	.63 (13.61)	—	-.89 (1.99)	—	—	.11 (1.60)	.98 (23.41)	.966	.0145	1.64	722-814
Sweden	.41 (7.52)	.77 (7.18)	-4.3 (4.53)	—	-.041 (1.39)	.56 (6.45)	—	.864	.0246	1.47	722-814
Switzerland	.91 (8.38)	.91 (4.01)	-3.6 (1.77)	-.33 (0.93)	-.084 (1.32)	.08 (0.65)	.75 (5.29)	.988	.0288	1.45	722-814
United Kingdom	.20 (2.67)	.30 (2.91)	—	-.52 (1.85)	-.0011 (1.85)	.82 (10.25)	—	.943	.0326	1.96	711-794
Finland	.52 (10.08)	—	-1.8 (1.81)	—	—	.14 (1.67)	.97 (30.89)	.919	.0161	1.74	722-814
Greece	.31 (2.78)	.70 (4.05)	-2.1 (1.56)	—	-.035 (3.44)	.46 (3.04)	.53 (2.18)	.989	.0166	1.61	761-814
Ireland	.33 (3.97)	.52 (4.03)	—	-.47 (1.95)	—	.70 (8.56)	—	.939	.0312	1.71	722-804
Portugal	.41 (5.43)	.63 (7.24)	—	—	—	.65 (10.62)	—	.991	.0269	1.97	722-804
Spain	.45 (3.66)	.44 (3.68)	—	—	-.0057 (0.93)	.71 (5.24)	—	.926	.0321	1.73	722-794
Australia	—	.21 (3.57)	—	-.22 (1.19)	—	.86 (11.77)	—	.912	.0288	1.75	722-814
New Zealand	—	.15 (1.60)	—	-.48 (2.15)	—	.76 (8.96)	—	.864	.0260	2.13	752-811
Brazil	—	.56 (4.25)	—	—	—	.38 (2.56)	.59 (3.96)	.998	.0414	1.65	641-804
India	—	—	—	-.29 (1.98)	-.12 (2.89)	.70 (8.10)	—	.819	.0238	2.38	722-794

Notes:
- All equations estimated by OLS.
- t-statistics in absolute value are in parentheses.

TABLE 4-11. The 13 forward rate equations

Equation 10b: $\log F_i$ is the LHS variable

Country	Explanatory variables: $\log ee_i$	Explanatory variables: $\frac{1}{4}\log\frac{(1+RS_i/100)}{(1+RS_1/100)}$	R^2	SE	DW	Sample period
Canada	.97670 (.00372)	.94 (.08)	.999	.00208	1.84	711-821
Japan	1.00138 (.00178)	1.31 (.28)	.990	.0154	1.18	722-822
Austria	.99966 (.00045)	.92 (.21)	.997	.00847	1.53	722-821
Belgium	.99936 (.00034)	1.33 (.21)	.998	.00648	2.15	722-804
Denmark	.99941 (.00046)	.84 (.19)	.989	.00992	2.08	722-814
France	1.00059 (.00014)	.96 (.11)	.998	.00380	2.00	722-814
Germany	1.00106 (.00014)	.71 (.13)	.999	.00470	1.47	722-821
Netherlands	1.00053 (.00014)	.92 (.13)	.999	.00514	1.88	722-814
Norway	.99894 (.00052)	.99 (.41)	.959	.0162	2.03	722-814
Sweden	.99979 (.00025)	1.08 (.23)	.989	.00765	1.41	722-814
Switzerland	1.00068 (.00029)	.82 (.13)	.999	.00580	1.54	722-814
United Kingdom	1.00046 (.00231)	1.43 (.20)	.998	.00627	1.33	722-804
Finland	1.00578 (.00130)	1.93 (.24)	.966	.0107	1.48	722-814

Notes:
- All equations estimated by OLS.
- Equations do not include a constant term and seasonal dummy variables.
- Standard errors are in parentheses.

match the arbitrage condition. The results are presented in Table 4-11. If the arbitrage condition were met exactly, the coefficient estimates of log ee_i and $\frac{1}{4}\log\frac{(1 + RS_i/100)}{(1 + RS_1/100)}$ in the table would be 1.0, and the fit would be perfect. As can be seen, the results do indicate that the data are consistent with the arbitrage condition, especially considering the poor quality of some of the interest rate data.

The 32 Export Price Equations (Table 4-12)

Equation 11 provides a link from the GNP deflator to the export price index. Export prices are needed when the countries are linked together (see Table B-4 in Appendix B). If a country produced only one good, then the export price would be the domestic price and only one price equation would be needed. In practice, of course, a country produces many goods, only some of which are exported. If a country is a price taker with respect to its exports, then its export prices would just be the world prices of the export goods. To try to capture the in-between case where a country has some effect on its export prices but not complete control over every price, the export price index was regressed on the GNP deflator and a world price index.

The world price index, $PW\$_i$, is defined in Table B-2 of Appendix B. It is a weighted average of the export prices (in dollars) of the individual countries. Type B countries and oil exporting countries (countries 26 through 35) are excluded from the calculations. The weight for each country is the ratio of its total exports to the total exports of all the countries. The world price index differs for different countries because the individual country is excluded from the calculations for itself.

Since the world price index is in dollars, it needs to be multiplied by the exchange rate to convert it into local currency before being used as an explanatory variable in the export price equation for a given country. (The export price index explained by Eq. 11 is in local currency.) For some countries, depending on the initial results, this was done, but for others the world price index in dollars and the exchange rate were entered separately.

The results of estimating Eq. 11 are presented in Table 4-12. They show, as expected, that export prices are in part linked to domestic prices and in part to world prices. Serial correlation of the error term is quite pronounced in nearly all the equations. It should be kept in mind that Eq. 11 is meant only as a rough approximation. If more disaggregated data were available, one would want to estimate separate price equations for each good, where some goods'

TABLE 4-12. The 32 export price equations

Equation 11: $\log PX_i$ is the LHS variable

Country	Explanatory variables					R^2	SE	DW	Sample period
	$\log PY_i$	$\log PW\$_i$	$\log e_i$	constant	$\hat{\rho}_1$				
Canada	.82	.33	.15	—	.96	.999	.0152	1.97	581-821
	(8.05)	(4.53)	(1.26)		(24.65)				
Japan	.86	.25	.57	.62	.98	.992	.0205	1.88	581-822
	(4.49)	(2.77)	(8.42)	(3.17)	(70.52)				
Austria	.38	.43[a]	.43[a]	1.7	.73	.989	.0216	2.08	651-821
	(4.67)	(4.41)	(4.41)	(4.29)	(9.00)				
Belgium	.30	.60[a]	.60[a]	2.0	.89	.995	.0173	1.83	581-804
	(3.31)	(6.42)	(6.42)	(6.41)	(20.07)				
Denmark	.09	.83	.55	2.9	.62	.997	.0192	1.82	581-814
	(2.38)	(17.64)	(9.23)	(9.34)	(7.40)				
France	.26	.69	.48	2.6	.64	.999	.0112	2.09	581-814
	(7.80)	(20.26)	(14.18)	(14.27)	(7.86)				
Germany	.37	.43	.24	1.4	.94	.998	.0090	1.81	611-821
	(3.86)	(7.88)	(6.90)	(6.79)	(28.41)				
Italy	.44	.60	.61	.23	.92	.999	.0179	2.27	611-814
	(4.41)	(5.82)	(7.29)	(5.18)	(24.17)				
Netherlands	.29	.76[a]	.76[a]	4.6	.93	.997	.0164	1.84	611-814
	(3.27)	(10.13)	(10.13)	(10.15)	(22.44)				
Norway	.16	1.15	1.00	5.2	.93	.996	.0251	2.06	621-814
	(1.29)	(6.54)	(6.10)	(6.17)	(14.79)				
Sweden	.46	.64	.32	1.7	.94	.999	.0122	2.00	581-814
	(6.26)	(9.03)	(5.20)	(5.14)	(26.93)				
Switzerland	.54	.31	.30	1.8	.61	.994	.0163	2.20	581-814
	(15.17)	(5.45)	(5.54)	(5.53)	(7.40)				
United Kingdom	.53	.56	.33	.30	.94	.999	.0099	2.01	581-804
	(11.76)	(10.55)	(8.30)	(7.66)	(24.95)				
Finland	.17	1.01	.78	-1.1	.83	.998	.0235	2.03	581-814
	(1.71)	(8.68)	(8.77)	(9.09)	(14.08)				
Greece	.09	.76	.76	2.6	.25	.982	.0661	2.21	581-814
	(0.61)	(5.16)	(5.28)	(5.20)	(2.50)				
Ireland	.46	.60	.41	.31	.93	.999	.0151	1.91	581-804
	(7.06)	(7.45)	(7.25)	(5.67)	(20.58)				

Spain	.10 (1.25)	.73 (6.75)	.66 (5.54)	1.9 (5.72)	.34 (3.11)	.986	.0441	1.94	621-794
Turkey	.18 (1.00)	.97 (3.58)	.61 (4.63)	2.6 (4.76)	.59 (4.32)	.989	.0571	1.59	691-784
Yugoslavia	.21 (3.76)	.75 (9.72)	1.00 (42.50)	4.0 (40.82)	.13 (1.14)	.999	.0369	1.94	611-794
Australia	.46 (2.97)	.46 (2.98)	.12 (0.77)	.077 (1.59)	.90 (19.23)	.994	.0330	1.50	603-814
New Zealand	.68 (4.67)	.24 (1.52)	.24 (1.84)	.19 (3.78)	.91 (18.02)	.995	.0337	1.18	582-811
South Africa	.13 (0.82)	.82 (4.86)	.38 (2.80)	.18 (3.27)	.87 (14.00)	.995	.0326	2.07	621-814
Brazil	—	1.00[a] (31.43)	1.00[a] (31.43)	4.8 (29.81)	.86 (13.37)	.998	.0554	1.78	641-804
Colombia	.68 (1.15)	.16 (0.28)	.60 (0.59)	-2.0 (0.57)	.88 (9.34)	.984	.0968	1.53	711-804
Israel	.02 (0.34)	.93 (7.84)	1.05 (14.49)	-1.9 (20.37)	.87 (13.46)	.999	.0305	1.85	691-814
India	—	.83 (34.44)	.83 (20.72)	4.0 (20.62)	.32 (2.88)	.992	.0415	1.85	611-794
Korea	.04 (0.79)	.76 (8.31)	.96 (16.05)	.82 (13.84)	.89 (14.91)	.998	.0292	1.50	641-814
Malaysia	.47 (1.50)	1.02 (3.50)	.76 (2.06)	-.59 (1.78)	.80 (8.35)	.979	.0593	1.33	711-814
Pakistan	.24 (0.70)	.57 (1.46)	.11 (0.08)	-.070 (0.02)	.79 (5.97)	.950	.0605	1.42	731-812
Philippines	—	.92 (8.01)	.91 (10.56)	-1.9 (10.92)	.87 (15.60)	.993	.0620	1.51	581-802
Thailand	.53 (1.83)	.57 (2.34)	.25 (0.42)	.90 (0.39)	.86 (12.86)	.987	.0498	1.85	654-814
US	.95 (16.83)	.15 (4.16)	—	.23 (12.72)	.93 (25.77)	.999	.0090	1.32	581-822

Notes: a. Coefficient of log $PW\$_i$ constrained to be equal to the coefficient of log e_i.

- All equations estimated by OLS.
- Equations do not include seasonal dummy variables.
- t-statistics in absolute value are in parentheses.

TABLE 4-13. Regressions for the construction of the demand pressure variable

$\log \frac{Y_i}{POP_i}$ is the LHS variable

Country	Explanatory variable: t	Implied value of the growth rate (annual rate)	R^2	SE	DW	Sample period
Canada	.00790 (66.36)	3.2	.978	.0328	0.12	581-821
Japan	.0168 (40.85)	6.9	.945	.115	0.02	581-822
Austria	.00949 (52.73)	3.9	.979	.0298	0.31	651-821
Belgium	.00967 (67.97)	3.9	.981	.0362	0.41	581-804
Denmark	.00758 (40.89)	3.1	.947	.0503	0.55	581-814
France	.00964 (73.71)	3.9	.983	.0355	0.19	581-814
Germany	.00781 (62.31)	3.2	.979	.0283	0.28	611-821
Italy	.00805 (47.61)	3.3	.964	.0375	0.15	611-814
Netherlands	.00825 (51.48)	3.3	.969	.0356	0.33	611-814
Norway	.00905 (79.10)	3.7	.987	.0236	1.20	621-814
Sweden	.00676 (34.53)	2.7	.928	.0531	1.25	581-814
Switzerland	.00541 (28.78)	2.2	.896	.0510	0.07	581-814
United Kingdom	.00554 (65.63)	2.2	.980	.0215	0.76	581-804
Finland	.00994 (54.95)	4.0	.969	.0491	0.47	581-814
Greece	.01345 (48.72)	5.5	.962	.0749	0.51	581-814
Ireland	.00841 (59.54)	3.4	.976	.0359	0.69	581-804
Portugal	.0126 (46.84)	5.1	.960	.0682	0.43	581-804
Spain	.0109 (41.51)	4.4	.960	.0463	0.25	621-794
Turkey	.0103 (37.24)	4.2	.972	.0200	0.13	691-784
Yugoslavia	.0134 (73.05)	5.5	.986	.0351	0.88	611-794

Australia	.00629 (40.81)	2.5	.951	.0355	0.15	603-814
New Zealand	.00453 (37.11)	1.8	.937	.0311	0.06	582-811
South Africa	.00337 (22.77)	1.4	.867	.0306	0.23	621-814
Libya	.0144 (14.62)	5.9	.805	.1061	0.20	651-774
Nigeria	.00847 (13.34)	3.4	.867	.0269	0.25	712-781
Saudi Arabia	.0120 (13.45)	4.9	.858	.0423	0.26	721-792
Venezuela	.00467 (31.17)	1.9	.928	.0286	0.10	621-804
Argentina	.00221 (6.10)	0.9	.733	.0438	0.70	671-804
Brazil	.0157 (53.34)	6.4	.977	.0476	0.16	641-804
Chile	.00127 (0.95)	0.5	.258	.0971	0.49	711-804
Colombia	.00686 (32.62)	2.8	.964	.0153	0.23	711-804
Mexico	.00796 (63.83)	3.2	.978	.0318	1.02	581-804
Peru	.00324 (15.18)	1.3	.733	.0474	0.04	611-814
Israel	.00494 (10.30)	2.0	.672	.0517	0.37	691-814
Jordan	.0205 (12.95)	8.5	.844	.0820	0.65	731-804
Syria	.00994 (14.73)	4.0	.762	.1090	0.18	641-804
India	.00336 (18.13)	1.4	.812	.0354	0.25	611-794
Korea	.0193 (37.05)	7.9	.967	.0916	2.34	641-814
Malaysia	.0118 (34.21)	4.8	.966	.0290	0.85	711-814
Pakistan	.00565 (9.55)	2.3	.909	.0338	1.37	731-812
Philippines	.00649 (34.57)	2.6	.930	.0463	1.07	581-802
Thailand	.0103 (70.72)	4.2	.987	.0220	0.11	654-814

Notes: • All equations estimated by OLS.
• t-statistics in absolute value are in parentheses.

prices would be strongly influenced by world prices and some would not. This type of disaggregation is beyond the scope of the present model.

The world price index for each country, $PW\$_i$, is an endogenous variable in the model because it is a function of other countries' export prices, which are endogenous.

4.2.6 The 2,388 Trade Share Equations

The variable to be explained in this section is α_{jit}, the share of country i's total merchandise imports from type A countries imported from country j (in units of 75\$). (The t subscript has been used for the discussion in this section.) Type A countries are countries for which data on exchange rates and on export prices exist. These data, as can be seen in Table B-2, are needed to construct α_{jit}. There are 47 type A countries out of the total of 64. The α_{jit} obey the property that $\Sigma_{j\epsilon A}\alpha_{jit} = 1$, where the summation is over type A countries. The data are quarterly, and t runs from 1971I through 1981IV for a total of 44 observations per ji pair.

One would expect α_{jit} to be a function of country j's export price relative to an index of export prices of all countries that export to country i. The empirical work consisted of trying to estimate the effects of relative prices on trade shares. A separate equation was estimated for each ji pair, which is the following:

$$\begin{aligned} (4.44) \qquad \alpha_{jit} &= \beta_{ji1} + \beta_{ji2}D1_t + \beta_{ji3}D2_t + \beta_{ji4}D3_t + \beta_{ji5}\alpha_{jit-1} \\ &\quad + \beta_{ji6}\frac{PX\$_{jt}}{\Sigma_{k\epsilon A}\alpha_{kit}PX\$_{kt}} + u_{jit}, \qquad t = 1, \ldots, 44. \end{aligned}$$

$D1_t$, $D2_t$, and $D3_t$ are seasonal dummy variables. $PX\$_{jt}$ is the price index of country j's exports, and $\Sigma_{k\epsilon A}\alpha_{kit}PX\$_{kt}$ is an index of all countries' export prices, where the weight for a given country k is the share of country k's exports to country i in the total imports of country i. The notation $k\epsilon A$ means that the summation is only over type A countries.

If equations for all ji pairs had been estimated, there would have been a total of $47 \times 64 = 3{,}008$ estimated equations. In fact, only 2,388 equations were estimated. Data did not exist for all pairs and all quarters, and if fewer than 21 observations were available for a given pair, the equation was not estimated for that pair. In a few cases observations were excluded from a particular regression because they were extreme; these observations were primarily at the beginning and end of the sample period. It seemed likely in these cases that measurement error was a serious problem, and this was the

TABLE 4-14. Summary results for the 2388 trade share equations

	Percentage of correct and incorrect signs for $\hat{\beta}_{ji6}$	
	All countries	Countries 1-15
Correct sign	72.0	75.3
Correct sign, t ≥ 2.0	21.9	28.2
Correct sign, t ≥ 1.0	46.2	53.4
Incorrect sign	28.0	24.7
Incorrect sign, t ≥ 2.0	3.0	2.3
Incorrect sign, t ≥ 1.0	10.2	9.2

	Average size of the coefficient estimates that were of the right sign			
			Weighted[a]	
	All countries	Countries 1-15	All countries	Countries 1-15
$\hat{\beta}_{ji6}$	-.0232	-.0100	-.0740	-.0604
$\hat{\beta}_{ji6}/(1-\hat{\beta}_{ji5})$	-.0587	-.0316	-.2184	-.1818

Note: a. Weight for each ji estimate is $\bar{\alpha}_{ji}$/SUM, where $\bar{\alpha}_{ji} = \frac{1}{T}\Sigma_{t=1}^{T}\alpha_{jit}$ and SUM is the sum of $\bar{\alpha}_{ji}$ over all ji pairs. T is the number of observations in the estimated equation for the particular ji pair.

reason for excluding the observations. The extreme observations were chosen from an examination of the plot of each dependent variable over its potential sample period. About 300 equations had one or more observations excluded by this procedure. Almost all these equations were for *ji* pairs where neither *j* nor *i* was an industrialized country.

I wrote a special computer program to estimate the 2,388 equations, since the use of a package program for this purpose would have been unwieldy. The total time to estimate the equations on an IBM 4341 was about 1.5 minutes.

It is not practical to present all 2,388 estimates of each coefficient, and therefore only a summary of the estimates is given. This summary is presented in Table 4-14. The main coefficient of interest is β_{ji6}, the coefficient of the relative price variable. The significance of the estimate of this coefficient is reported first in the table. Considering all countries, 72.0 percent of the estimates were of the correct sign; 21.9 percent were of the correct sign and had *t*-statistics greater than or equal to 2.0; and 46.2 percent were of the correct sign and had *t*-statistics greater than or equal to 1.0. These numbers are somewhat higher for the first 15 countries alone, which are the main countries in the model. Considering all countries, 3.0 percent were of the incorrect sign and had *t*-statistics greater than or equal to 2.0, and 10.2

percent were of the incorrect sign and had t-statistics greater than or equal to 1.0. These numbers are lower for the first 15 countries.

These results seem to provide some support for the hypothesis that relative prices affect trade shares. The estimates are not very precise, which is at least partly explained by the fairly small number of observations per estimated equation. One would hope for more precise estimates in the future as more observations become available.

Results on the average size of the coefficient estimates are presented in the second half of Table 4-14. For these results only the estimates with the correct sign are used. Both weighted and unweighted estimates are reported in the table. The weights are the means of the LHS variable in the estimated equations, normalized to add to 1.0. The term $\hat{\beta}_{ji6}/(1 - \hat{\beta}_{ji5})$ is the estimated long-run effect of relative prices on trade shares. $\hat{\beta}_{ji5}$ is the coefficient estimate of the lagged dependent variable. The short-run estimates vary from $-.0100$ to $-.0740$, depending on the weighting, and the long-run estimates vary from $-.0316$ to $-.2184$.

The trade share equations with the wrong sign for $\hat{\beta}_{ji6}$ were not used in the solution of the model. Instead, the equations were reestimated with the relative price variable omitted, and these new equations were used. This means that α_{jit} is simply determined by a first-order autoregressive equation if $\hat{\beta}_{ji6}$ is of the wrong sign for the particular ji pair.

It should also be noted regarding the solution of the model that the predicted values of α_{jit}, say, $\hat{\alpha}_{jit}$, do not obey the property that $\Sigma_{j\epsilon A}\hat{\alpha}_{jit} = 1$. Unless this property is obeyed, the sum of total world exports will not equal the sum of total world imports. For solution purposes each $\hat{\alpha}_{jit}$ was divided by $\Sigma_{j\epsilon A}\hat{\alpha}_{jit}$, and this adjusted figure was used as the predicted trade share. In other words, the values predicted by (4.44) were adjusted to satisfy the requirement that the trade shares sum to one. The overall solution of the MC model is discussed in Section 7.5.2.