6

Economic Fluctuations

The multiplier-accelerator model is introduced to explain economic fluctuations in general and national income in China in particular. In connection with the estimation of such a model for China, some important concepts in econometrics are set forth, including endogenous and predetermined variables, structural and reduced-form equations, and the two-stage least-squares method for estimating the parameters of structural equations.

6.1 The Multiplier-Accelerator Model of Economic Fluctuations

Supply and demand are two key concepts in economics. In the neoclassical model of economic growth discussed in chapter 5, output is assumed to be determined by factors on the supply side. The quantities of aggregate capital and labor inputs are assumed to determine aggregate output through the production function. In the multiplier-accelerator model discussed in this chapter, output is determined by aggregate demand. Both models are simplifications of the reality. One can combine the equations explaining both the supply and demand sides of the economy to build a model, but it is interesting to see how well each of these two simplified models performs in explaining economic data. The purposes of the two models are different. The model in chapter 5 was used to explain growth trends, ignoring year-to-year fluctuations. The model in this chapter is used to explain year-to-year fluctuations.

The neoclassical economic growth model in the last chapter is built upon the aggregate production function. The function shows how much output the economy can produce given the quantities of the two inputs and the state of technology as summarized by the total factor productivity (TFP). TFP may be assumed to be a constant or to follow an exponential trend. The aggregate production function shows capacity output, disregarding the fact that actual output may fall short of capacity output. It is an equation describing the supply or production side of the economy. Given the production function, we need to determine the amounts of the two inputs through time to explain GDP growth. Labor input is assumed to be given exogenously, or to grow at a given constant rate. Capital stock grows according to the identity equating capital stock at the end of period t to depreciated capital stock at the end of period $(t-1)$ plus gross investment. Gross investment is assumed to be a fraction of GDP. The idea behind this assumption is that the higher the output or national income, the more the economy can afford to invest. In this growth model, the larger the fraction of GDP devoted to investment at the expense of consumption, the higher the rate of capital formation and hence the higher the rate of GDP growth.

In this section, the model of economic fluctuations, or of national income determination in the short run, is based on the forces of aggregate demand. In the early 1930s, when the United States experienced the Great Depression, Keynes wrote the *General Theory of Employment, Interest and Money* (1936). The theory suggests that aggregate output in the short run cannot be explained by assuming full employment or the full utilization of resources – like the growth model in chapter 5. In the thirties, over 20 percent of the American labor force was unemployed. If actual output deviates substantially from the capacity output specified by the production function, what determines it? Keynes' answer is aggregate demand. By way of the national income identity, national output can be decomposed into outputs from different industries. National output can also be decomposed into expenditure by consumers C, on investment I, by government G, and on net exports X (exports minus imports). The familiar national income identity is

$$Y = C + I + G + X \tag{6.1}$$

If the four components on the righthand side of equation (6.1) can be explained, national income Y can be explained.

Keynes (1936) proposed the simple hypothesis that C is a linear function of Y, with a slope (called the marginal propensity to consume) of less than 1 and a positive intercept. The shortcomings of this Keynesian consumption function were pointed out by Friedman (1957), who proposed that C is proportional to permanent income under the permanent income hypothesis. Permanent income, as distinguished from current income Y used by Keynes, measures the long-run income of the individual during his lifetime. The relation of consumption to current income implies that individuals with higher incomes tend to consume proportionally less. Individuals with different levels of permanent income consume the same proportion of their permanent income. One approximation of the consumption function based on permanent income is

$$\begin{aligned} C_t &= a_0 Y_t + a_1 C_{t-1} = a_0 Y_t + a_1(a_0 Y_{t-1} + a_1 C_{t-2}) \\ &= a_0(Y_t + a_1 Y_{t-1} + a_1^2 Y_{t-2} + \ldots) \end{aligned} \tag{6.2}$$

The first equality sign introduces lagged consumption C_{t-1} as an explanatory variable affecting current consumption. If we use this consumption function to substitute for C_{t-1} and continue the process to eliminate past consumption, we obtain consumption as a weighted average of past incomes with geometrically declining weights. This weighted average is given by the term in parentheses on the second line of equation (6.2). The geometric average is used to measure permanent income in

Friedman (1957). Thus (6.2) states that consumption is proportional to permanent income.

The difference between the Keynesian consumption function and Friedman's consumption function has an important implication for the fate of capitalism. If consumption is a decreasing fraction of income, it does not generate sufficient aggregate demand for consumption when income increases. As an economy grows, the demand for consumable goods generated by the consumption function becomes proportionally less. Unless another component of aggregate demand, such as government expenditure, increases sufficiently to compensate for the deficiency generated by the demand for consumption goods, the economy will cease to grow. A capitalist economy is doomed to be stagnant as it grows richer. This does not happen if consumption is proportional to permanent income. As income increases, the same fraction of income will be generated by the demand for consumption expenditures.

To explain investment expenditures I by the acceleration principle, we assume that the desired capital stock K_t^* at the end of period t is a function $a + bY_t$ of current output, and that the change in capital stock $K_t - K_{t-1}$ is a fraction β of the difference $K_t^* - K_{t-1}$. These two assumptions imply

$$K_t = \beta(a + bY_t) + (1 - \beta)K_{t-1}$$

This equation, which explains capital stock K_t, has the same form as consumption function (6.2) explaining C_t. By definition, net investment is the rate of change of capital stock, or $I_t = K_t - K_{t-1}$. To obtain an equation for net investment we subtract an analogous equation for K_{t-1} from the above equation for K_t to yield

$$I_t = K_t - K_{t-1} = \beta b(Y_t - Y_{t-1}) + (1 - \beta)I_{t-1} \qquad (6.3)$$

According to equation (6.3), net investment is determined by the rate of change in national income and not by the level of income. Income is a flow, or output per unit of time, as speed is distance traveled per unit time. The rate of change in income corresponds to rate of change in speed, or acceleration. Hence (6.3) is said to satisfy the acceleration principle, as investment is explained by the rate of change in income.

The acceleration principle can explain why investment fluctuates more than consumption. Let income be 100, 105, and 106 in periods 1, 2, and 3 respectively. If consumption is proportional to income, it will be proportional to 100, 105, and 106, or will increase by 5 percent and by about 1 percent in periods 2 and 3 respectively. On the other hand the first component of investment according to equation (6.3) is proportional to 5 and 1 for periods 2 and 3 respectively, implying a drastic reduction from period 2 to period 3, instead of a small increase, as in the case of consumption. This drastic reduction is moderated by the effect of lagged investment, which enters as a second explanatory variable in equation (6.3). If we wish to explain gross investment $I^G_t = K_t - (1 - d)K_{t-1}$, where d is the rate of depreciation of capital stock, we subtract $(1 - d)K_{t-1}$ from K_t and use the same equation for K_t to obtain an equation similar to (6.3), except that the rate of change of income is replaced by $Y_t - (1 - d)Y_{t-1}$ and the lagged value of net investment is replaced by the lagged value of gross investment on the righthand side. To test the acceleration principle statistically, one can estimate a regression of investment on Y_t, Y_{t-1}, and I_{t-1}. The acceleration principle is considered confirmed if the coefficient of Y_{t-1} equals the negative of the coefficient of Y_t when net investment is the dependent variable, or equals $-(1-d)$ times the coefficient of Y_t when gross investment is the dependent variable. Such statistical evidence has been found by numerous studies of investment expenditure in the US and in China as reported in Chow (1957, 1960, 1967, 1985a, 1985b).

Equations (6.1), (6.2), and (6.3) provide three equations to explain the three endogenous variables Y, C, and I. The model for national income determination is complete if we assume that government expenditure G and net exports X are exogenous, namely determined outside the system. Alternatively we can apply the model to explain Chinese national income data if we define C to include both private and government consumption and if we exclude net exports X from our definition of national income. This is indeed what the Chinese official statistic on "national income available" before 1994 measures. National income available equals national income minus net exports. It is the sum of consumption C (which includes government consumption) and "accumulation" (which equals net investment).

6.2 Dynamic Properties of the Multiplier-Accelerator Model

Let us study the characteristics of the time path of "national income available" generated by the above version of the multiplier-accelerator model. In this model, Y denotes "national income available," which excludes net exports X, and C includes government consumption. Hence the variables G and X in equation (6.1) can be omitted. Equations (6.1), (6.2), and (6.3) determine the three endogenous variables Y_t, C_t, and I_t in each period t, given the values of the predetermined variables C_{t-1} and I_{t-1}. As a matter of terminology, variables are called endogenous variables if their values are determined by solving the system of equations used to describe the economy. Variables are called predetermined variables if their values are taken as given when the equations are solved for the values of the endogenous variables. Predetermined variables are either exogenous or are variables whose values are dated before the current period. The exogenous variables are assumed to be determined by factors outside the system which can affect the system but cannot be affected by it.

If we use equation (6.1) to eliminate the variable Y and solve equations (6.2) and (6.3) algebraically we can express C and I as linear functions of the predetermined variables as follows.

$$\begin{aligned} C_t &= \pi_{11}C_{t-1} + \pi_{12}I_{t-1} + \pi_{10} \\ I_t &= \pi_{21}C_{t-1} + \pi_{22}I_{t-1} + \pi_{20} \end{aligned} \tag{6.4}$$

These equations are known as "reduced-form" equations. Each reduced-form equation expresses an endogenous variable as a function of the predetermined variables. The original system of simultaneous equations (6.1), (6.2), and (6.3) are known as "structural" equations. Each structural equation can have more than one endogenous variable. The reduced-form equations are obtained by solving the structural equations algebraically for the endogenous variables. To appreciate how reduced-form equations can be obtained by solving the structural equations the reader should refer to question 2 at the end of this chapter.

As a numerical example of the reduced-form equations (6.4), consider the following parameter values, written in vector form, with each parameter on the lefthand side equal to the numerical value in the corresponding position on the righthand side.

$$\begin{aligned}(\pi_{11}\ \ \pi_{12}\ \ \pi_{10}) &= (-0.2\ \ 2.25\ \ 15)\\ (\pi_{21}\ \ \pi_{22}\ \ \pi_{20}) &= (-0.8\ \ 2.25\ \ 15)\end{aligned} \tag{6.5}$$

If the initial values $C_0 = 45.9$ and $I_0 = 13.0$ are given, we can use equations (6.4) to compute C_1 and I_1 for period 1, and given these, to compute the values of C_2 and I_2 for period 2, and so forth. Thus the time paths of C and I, and therefore of Y, can be generated by the model comprised of (6.1) to (6.3), after they are solved to obtain the reduced-form equation (6.4). The reader will find it instructive to trace out the time paths of C and I in this model as suggested in question 1 at the end of this chapter.

The above numerical exercise illustrates that the interaction of a consumption function specified by equation (6.2), and an investment equation (6.3) based on the acceleration principle, can generate oscillations in national income and its components. This important point was first discussed in Samuelson (1939) for deterministic models with no random residuals added to equations (6.2) and (6.3). On the importance of introducing random elements into economic models, Frisch (1933: 197, 202–3) writes:

> The examples we have discussed . . . show that when [a deterministic] economic system gives rise to oscillations, these will most frequently be damped. But in reality the cycles . . . are generally not damped. How can the maintenance of the swings be explained? . . . One way which I believe is particularly fruitful and promising is to study what would become of the solution of a deterministic dynamic system if it were exposed to a stream of erratic shocks . . . Thus, by connecting the two ideas: (1) the continuous solution of a determinate dynamic system and (2) the discontinuous shocks intervening and supplying the energy that may maintain the swings – we get a theoretical setup which seems to furnish a rational interpretation of those movements which we have been accustomed to see in our statistical time data.

Ragner Frisch was the first Nobel Prize winner in economic sciences (in 1969, shared with Jan Tinbergen), and these remarks were very perceptive and influential. A deterministic model can be converted into a stochastic model by adding random residuals to the structural equations (6.2) and (6.3). This would result in random residuals in the reduced-form equations (6.4), which are derived from (6.2) and (6.3) algebraically, using the identity (6.1). We can solve the reduced-form equations (6.4) forward in time by incorporating random draws of these residuals. The time path for each dependent variable is a stochastic time series.

The study of dynamic characteristics of stochastic time series generated by a system of simultaneous equations like (6.1) to (6.3), with random residuals added to (6.2) and (6.3), advanced rapidly in the late 1960s and 1970s. Some results are reported in Chow (1968, 1975). In Chow (1968) it was shown that a system of equations, which consists only of equations like (6.2) to describe different components of Y but does not include equations like (6.3) based on the acceleration principle, cannot generate oscillations. In other words, Samuelson (1939) shows that a combination of (6.2) and (6.3) can, but does not necessarily, generate oscillations, whereas Chow (1968) shows that the inclusion of acceleration-type investment equations is necessary. Chow (1968) and Chow (1975) discuss the meaning of business cycles for time series generated by a system of stochastic equations, while Chow (1975) also uses the tools to study the cyclical properties generated by a particular econometric model reported in Chow (1967).

6.3 An Econometric Method for Estimating Parameters of Linear Stochastic Equations

Since the parameters of the structural equations (6.2) and (6.3) and of the reduced-form equations (6.4) are unknown, an economist needs to estimate them from data on Y, C, and I. Prior to estimation we need to add random residuals u_{1t} and u_{2t} to equations (6.2) and (6.3) respectively. Such residuals are required because the equations cannot fit the data exactly without them. It is often assumed that these random residuals satisfy a multivariate normal distribution with zero means and some covariance matrix. The two residuals are correlated in general because some factors other than the predetermined variables included in the system may affect both consumption and investment. Once u_{1t} and u_{2t} are added to equations (6.2) and (6.3), some linear functions of them, denoted by v_{1t} and v_{2t}, will appear respectively in the reduced-form equations (6.4) for C_t and I_t as a result of the algebra in solving (6.2) and (6.3) for (6.4). If in doubt, the reader should solve (6.2) and (6.3) with residuals u_{1t} and u_{2t} added to obtain the reduced-form equations and examine the relation between the residuals v_{1t} and v_{2t} in (6.4) and the former residuals. Since the u's affect the values of the endogenous variables through affecting the values of the v's in the reduced-form equations, all endogenous variables are correlated with the residuals of the structural equations. For example, Y_t is an endogenous variable and is correlated with u_{1t} in the consumption equation (6.2) and also with u_{2t} in the investment equation (6.3).

A basic assumption justifying the use of the least-squares method for estimating the coefficients of a regression equation is that the residual will be uncorrelated with each of the explanatory variables. Without this assumption, the least-squares estimates will not equal the true values of the regression coefficients even if the sample size is infinitely large. This assumption is not satisfied if we apply the least-squares method to estimate the structural equations (6.2) and (6.3), because the explanatory variable Y_t on the righthand side is correlated with the residual in each equation. To overcome this problem, one can apply the two-stage least-squares method. In the first stage we estimate that part of Y_t, which is uncorrelated with the residuals u_{1t} and u_{2t}. In the second stage we apply least-squares to estimate (6.2) and (6.3) with Y_t replaced by the part estimated in stage 1. To estimate that part of Y which is uncorrelated with the u's, one can regress Y_t on the predetermined variables C_{t-1} and I_{t-1}. By assumption, a predetermined variable is uncorrelated with all u's and all v's. This is the first-stage regression in the two-stage least-squares method 2SLS for estimating the structural parameters in a system of linear stochastic equations. From this stage we compute the estimated value of Y_t using the linear regression function on C_{t-1} and I_{t-1}. In the second stage we use the estimated Y_t in lieu of the actual Y_t to estimate the structural equations (6.2) and (6.3) by the least-squares method. For example, to estimate consumption equation (6.2) we regress the variable C_t on the estimated Y_t and C_{t-1}. The estimated Y_t is uncorrelated with the residual u_{1t} because it is a linear function of the predetermined variables and the predetermined variables are assumed to be uncorrelated with the u_{1t}.

6.4 Estimating a Multiplier-Accelerator Model of the Chinese Economy

Chow (1985b) uses Chinese official data from 1952 to 1982 on national income available and its two components C (including government consumption) and I (called accumulation) to estimate equations (6.2) and (6.3) by the two-stage least-squares method. The estimated structural equations are

$$C_t = -5.0456 - 0.0935\, Y_t + 1.2502\, C_{t-1} \qquad R^2 = 0.9933$$
$$(2.7645) \quad (0.1358) \quad (0.2251) \qquad s^2 = 18.489$$

$$I_t = 1.5643 + 0.6656\, (Y_t - Y_{t-1}) + 0.8920\, I_{t-1} \qquad R^2 = 0.8787$$
$$(3.7992) \quad (0.2729) \quad (0.0722) \qquad s^2 = 103.027 \qquad (6.6)$$

In the second stage of applying the 2SLS method, the variable Y on the righthand side of each equation is replaced by its estimate obtained from the first-stage regression. In the consumption function the coefficient of income is statistically insignificant. This result is a piece of evidence leading one to reject equation (6.2) as an appropriate consumption equation, but it supports a different version of the permanent income hypothesis as formulated by Hall (1978).

In equation (6.2), permanent income is defined as a weighted average of current and past incomes with geometrically declining weights. This definition is consistent with the adaptive expectations hypothesis. According to this hypothesis, expected or permanent income Y^*_t is formed by a partial adjustment process. By a partial adjustment process in the formation of expectation, we mean that the change in expectation, in our case the change in expected income $Y^*_t - Y^*_{t-1}$, equals a fraction a of the forecasting error $Y_t - Y^*_{t-1}$, so that expectation Y^*_t is only partially adjusted to equal the actual Y_t. By using this equation to eliminate past expected incomes as in equation (6.2), we find expected income to be a weighted average of current and past incomes with geometrically declining weights, namely $a[Y_t + (1-a)Y_{t-1} + (1-a)^2 Y_{t-2} + \ldots]$, as specified in equation (6.2).

Another definition of permanent income is based on the rational expectation hypothesis. According to this hypothesis, the consumer chooses the consumption path which maximizes his lifetime expected utility. In the last period $t-1$ his consumption was proportional to his permanent income of that period. Since C_{t-1} already contains all information on permanent income in $t-1$ which is relevant in estimating permanent income in period t, no other variables observed at $t-1$ will have any effect on C_t. In the second-stage regression the estimated income variable is a linear function of C_{t-1} and Y_{t-1}. Given C_{t-1}, therefore, this income estimate will have no effect on C_t. In other words C_{t-1} is the only variable observed in period $t-1$ that affects C_t. This version of the permanent income hypothesis, as advanced by Hall (1978), is consistent with Chinese data, as the above estimated consumption function shows.

We have just reviewed two versions of the permanent income hypothesis for the explanation of consumption. The first version is based on the formation of permanent income by the adaptive expectation hypothesis. The second is based on the formation of permanent income by the rational expectation hypothesis. Which hypothesis is better for the study of which economic phenomena is an interesting question not yet resolved. The reader may wonder why either hypothesis is applicable to the explanation of aggregate consumption in China, where the economic institutions are different. In chapter 2, when we studied the Chinese economy during the period of planning, we pointed out that the behavior of Chinese consumers is not different. This point is empirically confirmed in chapter 9. The existence of rationed commodities should not affect total consumption expenditure, the variable which we wish to explain. It only limits the quantities of rationed commodities that can be purchased. In this discussion we do assume that total consumption expenditure is determined by the demand of consumers. One might argue that it is determined instead by the supply made available by Chinese economic planners. Such an issue cannot be settled by general arguments; an economist can only pursue his research by choosing hypotheses which he deems appropriate. If the results are consistent with the hypotheses, he will keep them in future research. Other researchers might choose different hypotheses to explain the same phenomena and proceed likewise. In the present case, the reader is welcome to start with a hypothesis based on the notion that aggregate consumption is determined by the supply side and formulate her model accordingly. The results can be compared.

The investment equation is consistent with the acceleration principle, showing the importance of the rate of change in income in explaining investment. This principle is applicable not only to the demand for investment expenditures but to the demand for the purchase of consumer durable goods. We can go through the same derivation to arrive at a demand function for the purchase of durable goods by first assuming that the desired stock of consumer durables, like the desired capital stock K^*, is a function of income or output. Second, we assume as before that the change in the stock of durable goods is a fraction of the difference between the desired stock and the actual stock at the end of the preceding period. The resulting equation explaining the purchase of durable goods is the same as the one explaining gross investment following the acceleration principle. This principle may help explain the slowdown in the purchase of consumer durables in China in 1998 after the Asian financial crisis had started in July 1997. Although real GDP continued to increase in 1998, it was increasing at a slower rate. Recall our numerical example with Y equalling 100, 105, and 106 in three consecutive periods. In period 3, Y continues to increase but at a slower rate than in period 2, leading to a decline of investment, as its first component in equation (6.3) is proportional to 5 in period 2 and to 1 in period 3. The rate of growth of real GDP in China in 1998 did not decrease as much as this numerical example, but it might be sufficient to explain the observed reduction in the purchase of consumer durables in China in 1998. To the extent that the acceleration principle can account for the reduction, it indicates that the phenomenon of weak demand is only temporary. Once the economy recovers, the demand for consumer durables will increase again.

After the structural equations (6.6) are estimated, we can solve them to obtain reduced-form equations (6.4). A second method of obtaining the reduced-form equations is simply to apply least-squares to estimate them directly. To understand the possible difference between the results obtained by these two methods, note that the first method obtains the parameters of the reduced-form equations by solving the structural equations algebraically. This means that the reduced-form parameters are functions of the structural parameters. As an example, let there be only one structural parameter β and two reduced-form parameters π_1 and π_2. If the latter two parameters can be calculated from the value of β this means that $\pi_1 = f_1(\beta)$ and $\pi_2 = f_2(\beta)$ for some functions f_1 and f_2. This also means that π_1 and π_2 are algebraically related. To see that, use the first equation to solve β as a function of π_1 and substitute this for β in the second equation for π_2, making π_2 a function of π_1. We can see from this example that in general if there are fewer parameters in the structural equations than in the reduced-form equations, the parameters of the reduced-form equations are subject to algebraic restrictions. In this case, solving for the reduced-form parameters gives a different result from estimating them directly by the least-squares method, as the latter imposes no such algebraic restrictions. When there are the same number of parameters in both the structural equations and reduced-form equations, the two methods give identical results. In our example, there are 6 parameters in both. (There cannot be more structural coefficients than reduced-form coefficients. If the model specifies more structural coefficients, some of them cannot be estimated even with a sample of infinite size, and these parameters are said to be unidentified.) The econometrics of simultaneous equations is discussed in Chow (1983).

Applying least squares to estimate the reduced-form equations directly gives

$$C_t = -4.2852 + 1.1225C_{t-1} - 0.0495I_{t-1} \qquad R^2 = 0.9933$$
$$\quad (2.12247)(0.0424) \qquad (0.0719) \qquad s^2 = 18.489$$

$$I_t = -3.8511 + 0.2439C_{t-1} + 0.5787I_{t-1} \qquad R^2 = 0.8787$$
$$\quad (5.0154)\ (0.1000) \qquad (0.1696) \qquad s^2 = 103.027 \qquad (6.7)$$

By examining the residuals from these reduced-form equations, one can measure the impacts of political shocks on consumption and investment (as in Chow 1985b). For example, the residuals of the reduced-form equation for investment show values of 11 and 19 (billion yuan) respectively in the years 1958 and 1959, while the standard deviation of the residuals is the square root of 103, or about 10. These residuals show the effect of the Great Leap in raising investment above what the equation indicates. In 1961 and 1962 the Cultural Revolution reduced investment by 26 and 14 according to the residuals. Consumption suffered a negative effect from the Great Leap of –5.6 and –8.0 in 1959 and 1961 respectively, compared with a standard deviation of the square root of 18.5, or 4.3.

The reader may have noticed that in estimating the model in this chapter, in contrast with the estimation of the model in chapter 5, data for the years 1959–69 are not excluded. The decision to include observations for these years is based on the judgment that, while these observations deviate too much from the production function which specifies the relation between capacity output and available inputs, they do not deviate from the short-run relations specified in equations (6.2) and (6.3), in which the dependent variable of the preceding period is included as an explanatory variable. The inclusion of a residual in each of these equations suffices to incorporate the effect of the Great Leap or the Cultural Revolution on period t, given that the effect on the variable in period $t-1$ is already included in the righthand side of the equation. Thus the estimated residual measures the effect of a political movement on the dependent variable of a period t, in addition to its effect on the same variable in the preceding period $t-1$. For a study of the long-run economic effects of the Great Leap Forward and the Cultural Revolution, the reader is referred to chapter 8.

More recent data are now available, in the light of which it would be interesting to re-estimate the consumption and investment equations. This is left as an exercise for the interested reader. (See questions 3 and 5.) The reduced-form equations can be used for forecasting, as C_t and I_t can be calculated from their values in the preceding period. (See question 6.)

6.5 Econometric Models of the Chinese Economy

Chapters 5 and 6 provide two simple models of the Chinese economy, each constructed with a different objective. Chapter 8 will provide another model constructed by a different method and for a different purpose. Econometric model-building in China started in the summer of 1980 when a group of seven American economists and statisticians, including the author, led by Professor Lawrence Klein of the University of Pennsylvania, went to Beijing to give a summer workshop on econometrics at the invitation of Vice-president Xu Dixin of the Chinese Academy of Social Science. Since then, econometric modeling has advanced and become an important activity in China. Foreign scholars have constructed econometric models of China, some in collaboration with Chinese colleagues.

Interested readers could refer to Klein and Ichimura (2000). The econometric models reported by them, like the two models in chapters 5 and 6, consist of a system of equations. There are more equations in the models reported. For example, to explain the macroeconomy, equations for both the supply side (production functions) and the demand side (consumption and investment) are included. There are also equations explaining the price level (a subject to be discussed in chapter 7 below), interest rates, exchange rates, exports, imports, and balance of payments, etc. There is also a Computable General Equilibrium Model that explains the outputs of different sectors by the demand and supply equations of each sector – hence the term "general equilibrium." Such a model was referred to in section 4.5, in our discussion of the economic impact of China's entry into the WTO on the rate of growth of GDP. There is a third kind of model: it is constructed under the assumption that economic decision-makers continuously optimize a multiperiod objective function over time in making their economic decisions. An example will be given in chapter 8 below.

References

Chow, Gregory C. *Demand for Automobiles in the United States: A Study in Consumer Durables.* Amsterdam: North-Holland Publishing Company, 1957.

Chow, Gregory C. "Statistical Demand Functions for Automobiles and Their Use for Forecasting." In A. C. Harberger: *Demand for Durable Goods.* Chicago: University of Chicago Press, 1960.

Chow, Gregory C. "Multiplier, Accelerator, and Liquidity Preferences in the Determination of National Income in the United States." *Review of Economics and Statistics,* 44 (Feb. 1967), pp. 1–15.

Chow, Gregory C. "The Acceleration Principle and the Nature of Business Cycles." *Quarterly Journal of Economics,* 82 (Aug. 1968), pp. 403–18.

Chow, Gregory C. *Analysis and Control of Dynamic Economic Systems.* New York: John Wiley, 1975.

Chow, Gregory C. *Econometrics.* New York: McGraw-Hill, 1983.

Chow, Gregory C. *The Chinese Economy.* New York: Harper and Row, 1985a.

Chow, Gregory C. "A Model of Chinese National Income Determination." *Journal of Political Economy,* 93 (Aug. 1985b), pp. 782–92.

Friedman, Milton. *A Theory of the Consumption Function.* Princeton: Princeton University Press, 1957.

Frisch, R. "Propagation Problems and Impulse Problems in Dynamic Economics." In *Economic Essays in Honour of Gustav Cassel.* London: Macmillan, 1933.

Hall, Robert E. "Stochastic Implications of the Life Cycle–Permanent Income Hypothesis," *Journal of Political Economy,* 86 (Dec. 1978), pp. 971–87.

Keynes, John Maynard. *General Theory of Employment, Interest and Money.* New York: Harcourt, Brace and Co., 1936.

Klein, Lawrence R. and Shinichi Ichimura. *Econometric Modeling of China.* Singapore: World Scientific Publishing Co., 2000.

Samuelson, Paul A. "Interactions Between the Multiplier Analysis and the Principle of Acceleration." *The Review of Economics and Statistics,* 21 (1939), pp. 75–8.

1 Using the reduced-form equations (6.4), the numerical parameters given in (6.5), and the initial values $C_0 = 45.9$ and $I_0 = 13.0$ of C and I, compute the paths of C and I up to period 11. Comment on the nature of these time paths. Does the variable I tend to fluctuate more than C? If so, why?

2 Solve structural equations (6.6) to obtain reduced-form equations for C_t and I_t. First eliminate Y_t and Y_{t-1} in the structural equations by using equation (6.1).

3 Using the data given in table 5.1 of chapter 5, construct Y = net domestic product, C = consumption, and I = net investment, all in constant 1978 prices. Estimate reduced-form equations (6.4), and compare the results with equation (6.7). Net investment in 1952 equals 130. Capital stock K_{1952} at the end of 1952 equals 2,213 as reported in table 5.1, implying that capital stock at the end of 1951 is 2,083. Net investment I_t is the difference between capital stocks at the end of year t and capital stock at the end of year $t - 1$. Net domestic product Y = gross domestic product minus depreciation. Depreciation in year t equals $0.04\,(K_{t-1} - 720)$, where

720 is land value, which does not depreciate. Consumption C_t can be approximated by the difference between net domestic product Y and net investment I_t; approximated because net domestic product also includes net exports.

4 Examine the residuals of the reduced-form equations in question 3 for 1989, 1990, and 1991. What can you conclude about the economic impact of the tragic Tiananmen event of 1989?

5 Using the data obtained in question 3, estimate structural equations (6.2) and (6.3). How do the results compare with those reported in Chow (1985b) and in equations (6.6), based on pre-1994 or pre-revised official data up to 1982?

6 Using the regressions obtained for question 3, forecast national output in China up to 2010. Compare the forecasts with those obtained, or at least discussed in the text, by using the neoclassical growth model of chapter 5. Even if you have not done a numerical projection of real GDP up to 2010 using the growth model of chapter 5, comment on the exponential rate of growth of real GDP from 1999 to 2010, computed from forecasts based on the reduced-form equations estimated in question 3.