A Short-Run Forecasting Model of the United States Economy

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Ray C. Fair
Princeton University

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Preface

The model that is described in this book was developed during 1968 and 1969. The money GNP sector was developed in early 1968, and the other sectors were developed during 1969. At the time of this writing, the model in one form or another has been used as an actual forecasting tool for about two years. Data through the fourth quarter of 1969 have been used for the results presented in this book.

The computations were performed on an IBM 360–91 computer at Princeton University. All of the estimation techniques that were used in this study were programmed into the TSP regression package program. The TSP program was originally designed by Robert E. Hall and has since been expanded by J. Philip Cooper, Dwight M. Jaffee, and the present author, among others.

I am indebted to a number of people for their help and advice throughout the course of this work. These include Stanley W. Black, William H. Branson, Stephen M. Goldfeld, Dwight M. Jaffee, and Richard E. Quandt. I would particularly like to thank Stephen Goldfeld and Dwight Jaffee, who read the entire manuscript in rough draft form and made many helpful suggestions. I, of course, assume responsibility for all errors.

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Ray C. Fair
Princeton, New Jersey
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1 Philosophical Considerations

1.1 Introduction

The advantages of accurate forecasts of future economic activity need hardly be emphasized. Such forecasts are desirable for government policy-makers in the formulation of economic policies as well as for corporate managers in the development of business plans. Decision-makers need accurate forecasts both for long periods ahead, such as a year or more, and for shorter monthly or quarterly periods. Since the timing of various actions can be quite important, accurate monthly or quarterly forecasts can be extremely useful.

The purpose of this book is to describe a short-run forecasting model of the United States economy that has been developed by the author. The model differs from most other econometric models in that it has been designed *almost exclusively for forecasting purposes.* The model has been kept relatively small, and an attempt has been made to make maximum use of the various expectational variables that are available. The econometric techniques used to estimate the model also differ somewhat from the techniques used to estimate previous models. In estimating the expenditure equations of the model, account has been taken of both simultaneous equation bias and serial correlation of the error terms. The technique that has been used for this purpose is described briefly in Chapter 2 below and in more detail in Fair [17]. The housing market has also been estimated in a different way in this study. The technique that has been used is described in Chapter 8 below and in more detail in Fair and Jaffee [20] and Fair [16].

The outline of this book is as follows. In this chapter the philosophy that underlies the construction of the model is discussed and the model is briefly outlined. In Chapter 2 the technique that has been used to estimate the expenditure equations of the model is explained and the data and periods of estimation are discussed. In Chapters 3 through 10 the various sectors of the model are examined and the equation estimates are presented. The expenditure equations are discussed in Chapters 3 through 7, the monthly housing starts equations in Chapter 8, the employment and labor force equations in Chapter 9, and the price equation in Chapter 10.

In Chapters 11, 12, and 13 the forecasting ability of the model is examined in detail. The within-sample forecasts or simulations are examined in Chapter 11, and various versions of the model are tested. In Chapter 12 the stability of the estimated relationships of the model is examined and a number of outside-sample forecasts are generated. Finally, in Chapter 13 the sensitivity of the forecasting performance of the model to errors made in forecasting the exogenous variables is examined. The forecasts in Chapter 13 are all outside-sample forecasts, and they come close to being forecasts that could have been generated *ex ante*. The examination of the performance of the model in Chapters 11, 12, and 13 is fairly extensive, and the results should give a good indication of the likely future performance of the model.

In Chapter 14 the forecasting results of the model are compared with the results achieved by others. In particular, the results are compared with the results achieved by the Wharton and Office of Business Economics (OBE) models and by the forecasters studied by Zarnowitz [48]. Comparisons of the results achieved by various models and methods must be interpreted with some caution, since the assumptions on which different forecasts are made generally differ from one model or method to the next; but the informal results in Chapter 14 indicate that the present model compares favorably with other models and methods.

In Chapter 15 a summary of the major results of this study is presented. There are two appendices to the book. In Appendix A the data series that have been used in the model and that are not readily available elsewhere are presented. In Appendix B the estimates of the expenditure equations obtained by using the technique described in Chapter 2 are compared with the estimates obtained by using simpler techniques.

1.2 Structural versus Forecasting Models

With respect to its sophistication as a forecasting tool, the present model lies somewhere between the rather informal and subjective methods practiced by many business economists and the use of large-scale econometric models. The model is free from the use of subjective methods in that, given data on the exogenous variables of the model, the forecasts can be generated in a deterministic way. The forecasting ability of the model can thus be analyzed in objective terms, with some confidence placed on the assumption that the past forecasting performance of the model will be capable of achievement in the future. The disadvantage with informal forecasting techniques is that they are difficult to quantify; and it is thus difficult to determine the likelihood of their future success given their past forecasting performance.

Aside from its size, the present model differs from large-scale structural models in two main ways. The first is the use of expectational variables in the model. Expectational variables, such as plant and equipment investment expectations and consumer attitudes and buying plans, are likely to be quite useful for forecasting purposes; but they have no real justification for being treated as exogenous in models that are designed to explain the structure of the economy. In structural models these variables should be (and generally are) explained within the model or else bypassed completely in the explanation of the other endogenous variables. For short-run forecasting purposes an understanding and explanation of the determinants of these variables is, of course, not as critical.

The second main way in which the present model differs from large-scale structural models relates to the choice of the other exogenous variables to be included in the model. For a forecasting model, the exogenous variables (aside from policy variables) must be chosen with the restriction that they be at least no more difficult to forecast than the variables they are designed to explain. Since the values of the exogenous variables in a model must be forecast ahead of the overall forecast, no forecasting accuracy is likely to be gained by including in the model exogenous variables that are to begin with as difficult to forecast as the endogenous variables themselves. For structural models this restriction is not relevant: exogenous variables should not be excluded from these models merely because they are difficult to forecast.

Ideally there should be no conflict between developing a model for purposes of explaining the structure of the economy and for purposes of forecasting. If the structure is correctly specified and is stable over time and if the model is large enough so that there are few truly exogenous variables, there should be no need, when using a model for purposes of forecasting, to rely on exogenous expectational variables or to omit any hard-to-forecast variables. Also, if the structure is well specified and is stable, the fact that large-scale models tend to be unwieldly to experiment with and costly to reestimate on a short-run basis should not hinder their forecasting ability. Unfortunately, the development of large-scale models has not yet reached a point in which confidence can be placed on their forecasting ability. There are still many sectors of the economy that are not well understood and explained, and large-scale models have yet to demonstrate that they can be useful for forecasting purposes.

Friend and Jones [22] argue a much stronger point in defense of small-scale models. They feel that it is unlikely that large-scale models will ever be superior to smaller models for purposes of forecasting. This view is based in part on their feeling that smaller models are likely to be associated with less proliferation of random errors than are larger models.[1] While it is true that

[1] Friend and Jones [22], pp. 279–280.

there are many nonsystematic factors affecting economic variables that it seems unlikely even large-scale models will ever be able to explain, it is by no means certain that because of these random elements, errors in large-scale models will proliferate and result in poorer forecasts than those achieved by smaller models. In the future the specification of large-scale models should improve, and there is no reason to believe that their very size alone will lead to more error proliferation and poorer forecasts.

Friend and Jones point out that it is an empirical question whether large-scale models currently are superior in their forecasting ability to smaller models.[2] It should perhaps be further pointed out that it is also an empirical question whether even if large-scale models currently are inferior to smaller models in their forecasting ability, they are forever doomed by their very nature to yield inferior forecasting results. It is also, of course, an empirical question whether econometric models in general can yield better forecasting results than other techniques. It may be, for example, that random elements are so significant or the structure of the economy and the behavioral relationships so unstable that econometric techniques cannot successfully be used for forecasting purposes. One of the purposes of analyzing in some detail the forecasting performance of the present model is to provide a standard of comparison for future large-scale models and other forecasting techniques.

1.3 The Present Model versus Other Forecasting Models

The Friend et al. Model

The model developed in this study in its primary emphasis on forecasting is more closely related to the model developed by Friend and various collaborators [6, 22, 23] than to any of the other published models. It differs from the Friend et al. model, however, in a number of ways. First, it is a quarterly model as opposed to an overlapping semiannual model.[3] Secondly, the basic estimation technique used in this study differs from the one used by Friend et al., who estimated their model in first differenced form using the two-stage least squares technique. The technique used here, by providing an estimate of the serial correlation coefficient of the error terms to be made

[2] Ibid., p. 280.

[3] Friend and Jones [22] did experiment with a quarterly model, but they gave it up in favor of an overlapping semiannual model. The semiannual model is the model discussed in Friend and Taubman [23] and Crockett and Friend [6].

for each equation of the model, is likely to be a substantial improvement over this method. Finally, the specification of the present model is quite different than that of the Friend et al. model; and the present model includes price and employment sectors, which the Friend et al. model does not.

The Wharton Model

The Wharton model, described in Evans and Klein [13] and Evans [12], is probably the most well known of all econometric forecasting models. The forecasts from the model are currently reported in *Business Week* and are generally followed by the financial press. The present model differs from the Wharton model in two main ways. First, the present model relies more exclusively on expectational variables. One of the two versions of the Wharton model, used for one- and two-quarter-ahead forecasts, does use expectational variables, but expectational variables are not in general as integral a part of the Wharton model as they are of the present model.

The second main way in which the present model differs from the Wharton model is in size. The Wharton model is larger and more complex than the present model: it consists of 47 behavioral equations and 29 identities, compared with 14 behavioral equations and 6 identities in the model developed here. These figures do exaggerate the degree of disaggregation of the Wharton model, however, since the Wharton model consists of only thirteen behavioral equations explaining national income expenditure components, compared with seven behavioral equations in the present model. The thirteen expenditure equations of the Wharton model include three consumption equations, three plant and equipment investment equations, one housing investment equation, two inventory investment equations, three import equations, and one export equation. The seven expenditure equations of the present model include three consumption equations, one plant and equipment investment equation, one housing investment equation, one inventory investment equation, and one import equation. Since the export and import sectors in the United States are of less importance than the other sectors, the basic difference in the degree of aggregation of the Wharton model and the present model is that the Wharton model includes three plant and equipment investment equations (manufacturing, regulated and mining, and commercial) and two inventory investment equations (manufacturing and nonmanufacturing), compared with one each for the present model.

Klein [33] in a far-ranging paper on the theory of economic prediction discusses some of the philosophy that underlies the Wharton model, and some of his views are quite contrary to the approach taken here. One view that Klein strongly supports is that "best predictions will be made from best structural models."[4] It was mentioned above that ideally there should be no conflict between structural models and forecasting models, but that at the present time this ideal seems far from being achieved. Certainly it would seem that a model should be much more disaggregated than the present Wharton model for there to be much confidence placed on the assumption that it is a reasonable approximation of the true structure of the economy. The Brooking model, described in Duesenberry et al. [9, 10], is a preliminary step in developing a realistic large-scale structural model of the United States economy; but it is still an open question whether a model as large as the Brookings model can be useful for forecasting purposes. It should perhaps be pointed out that it is not really computer restrictions that are likely to hinder the use of large-scale models for short-run forecasting purposes, but the large number of man hours involved in collecting new data and keeping the models updated.

Another view held by Klein is that models need to reach a certain critical size "in order to accommodate taxes, transfers, price level, wage rate, interest rate, foreign trade, and all the main components of GNP."[5] He holds this view partly because industrial users want more detail than merely forecasts of GNP components and partly because such things as tax law changes, shifts in monetary policy, and other "environmental changes" cannot readily be incorporated into small models.[6] The fact that industrial users want more detail than merely forecasts of the major components of GNP is beyond question, but forecasting the major components of GNP is still the main problem of economic forecasting, and accurate forecasts of these components should go a long way in helping individual users to forecast the particular economic variables they are interested in.

The argument that small-scale models cannot incorporate policy and other institutional changes is an important one; but, at least with respect to tax law changes, one major defense can be made for a model like the one developed in this study. This defense relates to the effects that tax law changes have on investment plans and on consumer attitudes and buying plans. Fiscal policy in the United States is not highly flexible, and generally many months pass between the initial proposal for a tax change and its actual passage into law. The debates in Congress and elsewhere on tax proposals and other economic legislation undoubtedly have effects on people's attitudes, expectations, and behavior; and to the extent that these effects are picked up

[4] Klein [33], p. 99.
[5] Ibid., p. 80.
[6] Ibid.

by the expectational variables, a small-scale forecasting model such as the present one is not completely impervious to policy changes.

What effects various policy measures have on economic activity and how these effects are distributed over time are not easy questions to answer—witness the surprise of most economists that the tax increase of June 1968 did not appreciably slow down economic activity in the last half of 1968—and they can only hoped to be answered within the context of structural models. Given the present state of knowledge, however, there may be some advantage in designing separate models for forecasting and policy purposes. For policy purposes, the question of the effects that various policy measures and the public discussion of these measures have on people's attitudes and behavior is critical—and as yet not well explored—but for forecasting purposes, given reasonably good expectational data, this question can more justifiably be ignored.

Related to the argument that small-scale models cannot incorporate environmental changes is the question of whether the relatively simple relationships that are specified to exist among the various aggregated variables in these models are stable enough in the short run to allow useful and reasonably accurate forecasts to be made. The estimated relationships in any model must be relatively stable over time if the model is to be at all useful for purposes other than descriptive history. In Chapter 12 the stability of the estimated relationships of the model developed in this study will be examined in some detail, and from the results a judgment can be made as to how useful the model is likely to be for future forecasting purposes.

The last view of Klein that will be discussed here is his view that purely mechanistic predictions can be improved upon by relying on such things as the recent history of error terms in the model and knowledge of special events that are likely to occur. He states that "as data are revised, behavior changes, or unforeseen variables begin to affect the economy's performance, the whole set of parameters [of the model] should be reestimated."[7] He then goes on to add that quarterly reestimation of a model the size of the Wharton model is not feasible and "therefore the scheme of *a priori* adjustment of constant terms is used to keep a given model in very close touch with reality on an updated basis."

The implications of this view are quite significant and pose a serious challenge to model builders. To begin with, if the structure of the economy is stable over time, a well-specified structural model should not need to be reestimated or updated frequently in order for its performance to be good. If, on the other hand, the structure of the economy is changing through time,

[7] Ibid., p. 50.

as Klein seems to be suggesting, the entire procedure of building structural models is called into question. For short-run forecasting models, an unstable structure may not be an extremely serious problem if the models are continuously updated and the estimated aggregate relationships of the models are reasonably stable in the short run. But building structural models has little meaning if the structure of the economy is not stable for periods longer than a year or so. The question as to the stability of the structure of the economy is still an open one, and in a more optimistic vein Klein's view can be interpreted to mean that the aggregate relationships estimated by a model the size of the Wharton model are not stable over long periods of time, but that for larger models the relationships will prove to be more stable.

Evans, Haitovsky, and Treyz [14] (hereafter referred to as Evans et al.) have analyzed the forecasting properties of the Wharton and OBE models rather extensively. The results that they achieved will be examined in Chapter 14, where the forecasting results of the present model are compared with the forecasting results of others; but the basic conclusion that they reached is worth mentioning now. Their basic conclusion is that "while econometricians may forecast very well, econometric models to date have had a most unimpressive record."[8] To understand this statement more clearly, a distinction that Evans et al. make between forecasts generated by econometric models and forecasts made by econometricians must be noted. Given the specification of a model, the values of the coefficient estimates, and the values of the exogenous variables, forecasts can be generated from the model. Depending on the nature of the experiment, the forecasts can either be within-sample forecasts or outside-sample forecasts and the values of the exogenous variables can either be the actual values or values determined in some other way. Evans et al. found that the forecasts generated in a mechanical way by the Wharton and OBE models were not very good, even when the forecasts were within-sample forecasts and the actual values of the exogenous variables were used. They also found, however, that the actual *ex ante* forecasts made by the people associated with the Wharton model and the OBE model were much more accurate than any forecasts generated *ex post* from the models. In actual forecasting situations the Wharton and OBE models are "fine tuned" by adjusting the constant terms in individual equations and by adjusting the values of the exogenous variables used. This fine tuning is apparently quite important for the forecasting accuracy of the models, since without it Evans et al. found that the models do not appear to be very useful for forecasting purposes. Evans et al. conclude that: "From the previous results it should be obvious that econometric models cannot generate good

[8] Evans et al. [14], p. 158.

forecasts if they are used only in a mechanical fashion. The art of forecasting still requires that a great deal of fine tuning be used with any econometric model presently in existence."[9]

It should be noted that fine tuning a model is a very subjective procedure. The constant adjustments that are made are not purely mechanical adjustments. Rather, the forecasters look at the initial set of forecasts from the model and decide which forecasts do not look reasonable to them. They then adjust the constant terms (or the values of the exogenous variables) in the appropriate equations and run a new set of forecasts. This new set of forecasts is then examined in the same way, and the procedure is repeated until the set of forecasts is consistent with the forecaster's views.[10] This procedure is to be contrasted with mechanical constant adjustment procedures, which are not subjective in the above sense.

The above conclusion of Evans et al. is, of course, consistent with Klein's view that purely mechanistic predictions can be improved upon. While the conclusion may be true with respect to the Wharton and OBE models, it is nonetheless disturbing. First, the fact that the two models have to be fine tuned in order to produce reasonable results calls into question either the accuracy of their specification or the stability of the structure of the economy over time. Secondly, the more the models are fine tuned, the more subjective the forecasts become (in the extreme a model can be fine tuned to produce almost any forecast the forecaster desires); and thus the harder it is to place confidence on the assumption that the past forecasting performance of the model builders will be capable of achievement in the future. If it turns out to be the case that any econometric model must be extensively fine tuned in order to produce reasonably accurate forecasts, then it would appear that econometric models have a very limited role to play in forecasting work. If the models must be extensively fine tuned, the forecasts produced by model builders will differ little in terms of their subjectivity from the forecasts produced by other groups. This is not to argue that forecasts from econometric models should be completely devoid of human judgment—obviously human judgment is involved in the choice of the values of the exogenous variables—but only that forecasts from econometric models should not have to be based on extensive constant-term adjustments and other fine tuning devices of the model builder. The model developed in this study does not rely on constant-term adjustments and the like. An attempt has been made in the work below to present forecasting results that, aside from the specification of the values for the exogenous variables, are free of individual judgment.

[9] Ibid., p. 160.

[10] See Evans et al. [14], p. 136, for a confirmation that this is in fact the procedure they have in mind when referring to the fine tuning of a model.

Taking the Wharton model as a purely forecasting tool, the present model has certain advantages over it. The present model can be easily reestimated and updated each quarter, and as was mentioned above, the stability over time of the estimated aggregate relationships can be carefully examined. The present model has fewer exogenous variables that must be forecast ahead of the overall forecast, and forecast errors from this source should therefore be less. Finally, the present model has been estimated on the assumption that the error terms in the individual equations are (first order) serially correlated, and the estimates of the serial correlation coefficients have been used in generating the forecasts. Many equations of the Wharton model appear to have serially correlated errors, and this is one of the reasons why the constant terms of the model are adjusted in actual forecasting situations. On the assumption of first order serial correlation of the error terms, the technique used in this study is likely to be more efficient than the Wharton constant-adjustment technique, and it has the further advantage that the forecasts produced by the model are less subjective than those produced by the Wharton model.

The OBE Model

The results of the OBE will be examined in Chapter 14, along with the results of the Wharton model and the present model, and so the OBE model will be briefly examined here. The present version of the OBE model is described in Green, Liebenberg, and Hirsch [25]. The OBE model is larger and more complex than the present model: the present version consists of 50 behavioral equations, compared with 14 in the model developed here. Again, however, these numbers exaggerate the degree of disaggregation of the OBE model relative to the present model. There are only eleven equations of the OBE model that explain national income expenditure components (four consumption equations, two plant and equipment investment equations, one housing investment equation, two inventory investment equations, and two import equations), compared with the seven equations of the present model. Ignoring the import sector, the OBE model consists of one more consumption equation, one more plant and equipment investment equation, and one more inventory investment equation than the present model.

As a forecasting tool, the model developed in this study has the same advantages over the OBE model as it does over the Wharton model. In particular, many of the equations of the OBE model appear to have serially correlated errors, and in actual forecasting situations the constant terms in the model are often adjusted in an attempt to account for this correlation.

1.4 Further Philosophy Behind the Construction of the Model

Before proceeding with the outline of the model, two further tenets that guided the construction of the model should be mentioned. One tenet is that when highly aggregated data are used, such as in this model and in most of the other macroeconomic models that have been developed so far, it is asking too much of the data to expect that they can distinguish among various sophisticated hypotheses or specifications. It is too much, for example, to expect that highly aggregated national income accounts data can distinguish at all clearly among various theories of consumer or investment behavior.

The second tenet, which is closely related to the first, is that it is unlikely that highly aggregated data can distinguish among various complicated lag structures. Griliches [26], for example, has shown that quite small changes in coefficient estimates (within, say, a 95 percent confidence region) can lead to quite substantial changes in the implied lag structure. With highly aggregated data these problems are likely to be especially serious. Consequently, the specification of the individual equations in this study has been kept relatively simple: in general the equations have been specified to be linear, and only a few simple lag structures have been tested for each equation.

1.5 *Outline of the Model*

The model consists of seven equations explaining expenditure components of gross national product (GNP), two equations explaining the level of housing starts, one employment equation, one equation explaining the difference between the establishment-based employment data and the household-survey employment data, two labor force participation equations, one price equation, six identities, and one production function. There are nineteen endogenous variables in the model and about sixteen basic exogenous variables.

The seven expenditure equations and the GNP identity form a self-contained part of the model. The equations are in money (current dollar) terms, and this part of the model will be referred to as the "money GNP sector" of the model. In the money GNP sector the seven expenditure equations include three consumption equations, one each for durable, nondurable, and service consumption; one equation explaining nonresidential fixed investment; one equation explaining nonfarm residential fixed investment; one equation explaining the change in total business inventories; and one equation explaining total imports. The sum of government spending, exports, and farm residential fixed investment is treated as exogenous; and GNP is by definition equal to this sum plus the sum of the seven endogenous expenditure variables. The other variables that are exogenous to the money GNP sector are the OBE–SEC plant and equipment investment expectations variable, the Michigan Survey Research Center index of consumer sentiment, and the quarterly level of housing starts.

The endogenous variables in the money GNP sector are simultaneously determined, since current GNP is included as an explanatory variable in six of the seven behavioral equations of the sector and since current durable plus nondurable consumption is included in the inventory investment equation. There are also lagged endogenous variables included among the explanatory variables in the sector, and the error terms in the individual equations are assumed to be first order serially correlated. The estimation technique that is described in Chapter 2 allows consistent estimates of a sector or model that is characterized by these properties to be made, and this technique has been used to estimate the money GNP sector in this study.

The model does not have any income side. GNP is used as the income variable in the consumption equations instead of disposable personal income (DPI). It is thus unnecessary to have an income side in the model in order to determine consumption expenditures. The use of GNP instead of DPI in the consumption equations will be discussed in more detail in Chapter 3.

The level of housing starts is determined from two monthly housing starts equations. The housing market is assumed to be a market that is not always in equilibrium and the way the model is specified, there are two equations—one supply equation and one demand equation—that explain the same housing starts variable. For forecasting or simulation purposes, the forecast of housing starts for a given month is taken to be the average of the two forecasts generated by the supply and demand equations. These monthly forecasts are then used to construct forecasts of quarterly housing starts to be used in the housing investment equation in the money GNP sector. The monthly housing starts sector is thus peripheral to the money GNP sector. The monthly housing starts forecasts are used merely to construct values of the quarterly housing starts variable, which are treated as exogenous in the money GNP sector. There is, in other words, no feedback from the money GNP sector to the monthly housing starts sector.

The price sector consists of one behavioral equation and three identities. The change in the private output deflator is taken to be a function of current and lagged values of a demand pressure variable. The demand pressure variable is discussed in Chapter 10. It is a function of the current level of money GNP, among other things, but not of the current level of real GNP. The specification of the price equation thus allows the forecast of money GNP from the money GNP sector to be used in the forecast of the private output deflator. Government output in both real and money terms is taken to be exogenous in the model, and one of the identities in the price sector is used to relate money GNP and the private output deflator to real GNP. Real GNP is thus the "residual" in the model, since it is merely determined from the identity after money GNP and the price level have been determined. Real agricultural output is taken to be exogenous in the model, and the second identity in the price sector determines real nonfarm output as real GNP less real government and agricultural output. The third identity in the price sector defines the demand pressure variable.

The employment and labor force sector consists of four behavioral equations, two identities, and one production function. The six endogenous variables in the sector are the number of private nonfarm workers employed (from the establishment-based data), the difference between the establishment-based employment data and the household-survey employment data, the number of civilian workers employed (from the household-survey data), the total labor force of primary workers (males 25–54), the total labor force of secondary workers (all others over 16), and the civilian unemployment rate. The exogenous variables in the sector include the number of civilian government workers employed, the level of the armed forces, the number of farm workers employed, the population of males 25–54, and the population of all others over 16. Feeding into the employment and labor force sector is real private nonfarm output from the price sector. The four behavioral equations explain the number of private nonfarm workers employed, the difference between the establishment-based employment data and the household-survey employment data, the labor force participation of primary workers, and the labor force participation of secondary workers. The identities define the number of civilian workers employed and the civilian unemployment rate. The production function relates private nonfarm output to private nonfarm man-hour requirements.

There is no feedback in the model from the employment and labor force sector to any of the other three sectors. The causality in the model thus runs from the monthly housing starts sector, to the money GNP sector, to the price sector, to the employment and labor force sector.

Almost all of the quarterly variables in the model are seasonally adjusted. For a model such as this one, where the level of aggregation is quite high and where the specification of the individual equations is relatively simple, an attempt to explain and forecast seasonal fluctuations would probably prove futile. It is not at all clear, however, that seasonally adjusted data should be used for large-scale structural models. A considerable amount of information about short-run fluctuations of various economic variables is lost when the data are seasonally adjusted, and for a model attempting to explain the detailed structure of the economy this may be undesirable.[11]

The seasonality in the monthly housing starts sector is treated somewhat differently, and this will be discussed in Chapter 8. The published seasonally adjusted housing starts series was not used in this study because the series is not adjusted for the number of working days in the month.

In most macroeconomic models the expenditure equations are in real terms, and a defense needs to be made as to why the expenditure equations of the present model are specified in money terms. Whether a given expenditure equation in a model should be specified in real or money terms depends on whether the people doing the spending take money income and other money variables as given and determine how much money to spend as a function of these (and other) variables, or whether they deflate money income and the other money variables by some price level and determine how many goods to purchase as a function of these "real" (and other) variables. In the first case the number of goods purchased is the residual variable (people plan to spend a given amount of money, and real expenditures are determined merely as money expenditures divided by the price level); in the second case the money value of goods purchased is the residual variable (people plan to purchase a given number of goods, and money expenditures are determined merely as real expenditures times the price level).

In the long run it seems clear that real expenditures are determined by real variables, as standard economic theory suggests, but in the short run the case is not as clear. Given the uncertainty that exists in the short run and the lags involved in the collection and interpretation of information on price changes, people may behave in the short run in a way that is closer to the first case described above than it is to the second. An argument can thus be made for specifying expenditure equations in short-run models in money terms, although even for short-run models it may be the case that some equations should be specified in real terms. In the present model the expenditure equations were specified to be in money terms partly because of convenience and partly because of the feeling that real expenditures are closer to being determined as the residual in the short run than are money expenditures.

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[11] See Bonin [3] for an interesting article discussing the disadvantages of using seasonally adjusted data.

It should finally be stressed that the above discussion of the present model versus large-scale structural models was not meant to imply that the present model is completely nonstructural. It differs from large-scale structural models in its use of exogenous expectational variables, in its choice of the other exogenous variables to be included in the model, and in its size, but not in lack of any structure. Some equations of the model are more structural than others, but in general an attempt has been made to base the specification of each equation on plausible theoretical grounds.

2 Econometric Considerations

2.1 Introduction

Three of the major features that are likely to characterize an aggregate quarterly time series model such as the one developed in this study are the simultaneous determination of the endogenous variables, the inclusion of lagged endogenous variables among the predetermined variables, and serial correlation of the error terms in the equations. Serial correlation is likely in the present model because of the relatively simple specification of the equations. Many relevant variables have doubtlessly been excluded from the equations, and if these excluded variables are autocorrelated, it is likely that the error terms in the equations will be autocorrelated as well.

With respect to the estimation of dynamic multiperiod forecasting models, Klein in his paper on economic prediction points out that there is a contradiction between the assumptions of traditional estimation theory and those of prediction theory.[1] In estimation theory lagged endogenous variables are treated as though they were predetermined, whereas for multiperiod forecasts lagged endogenous variables can be considered to be predetermined only for the first period forecasts, since after the first period the values of the lagged endogenous variables must be generated within the model. Klein suggests that these models might be estimated in a nontraditional manner by minimizing the sum of the multiperiod forecast errors. An alternative suggestion would be to minimize a weighted average of these errors if more distant forecast errors were of less concern to the investigator than the more recent ones. Klein further points out, however, the properties of these types of techniques are not well understood, and the techniques are not easy to use.[2]

Because of these difficulties, no attempt was made in this study to use the less-traditional techniques. The technique that has been used is based on the assumptions of traditional estimation theory. The technique is described in Fair [17]. It is designed for the estimation of simultaneous equation models with lagged endogenous variables and first order serially correlated errors—the properties that are assumed to characterize the money GNP sector in the present model. The technique yields consistent parameter estimates and

[1] Klein [33], p. 56.
[2] Ibid., p. 65.

allows an estimate of the serial correlation coefficient of the error terms to be made for each equation of the model.

In this chapter the statistical properties that are assumed to characterize the money GNP sector of the model will be made more explicit and the technique that has been used to estimate the sector will be briefly described. The data that have been used in the money GNP sector will then be discussed and the notation that has been used for each of the variables will be presented. The chapter concludes with a discussion of the periods of estimation used. Some of the discussion in the next section follows closely the discussion in Fair [17], Sections 2 and 3.

2.2 The Technique Used to Estimate the Money GNP Sector[3]

The money GNP sector of the model can be written in matrix notation as follows:

$$AY + BX = U, \tag{2.1}$$

where

$$U = RU_{-1} + E. \tag{2.2}$$

Y is an $h \times T$ matrix of the endogenous variables of the sector; X is a $k \times T$ matrix of the predetermined (i.e., both exogenous and lagged endogenous) variables included in the sector; U and E are $h \times T$ matrices of error terms; and A, B, and R are $h \times h$, $h \times k$, and $h \times h$ coefficient matrices respectively. T is the number of observations, h is the number of endogenous variables in the sector, and k is the number of predetermined variables. The subscript -1 for U_{-1} denotes the one-quarter-lagged values of the terms of U.

The following basic assumptions about the sector are made. Write E as

$$E = (e(1)\, e(2) \ldots e(T)), \tag{2.3}$$

where $e(t) = (e_1(t)\, e_2(t) \ldots e_h(t))'$ is an $h \times 1$ vector of the tth value of the error terms. It is assumed that

$$\mathcal{E}(E) = 0 \tag{2.4}$$

$$\mathcal{E}e(t)\, e'(t) = \textstyle\sum, \qquad (t = 1, 2, \ldots, T), \tag{2.5}$$

$$\mathcal{E}e(t)\, e'(t') = 0, \qquad (t, t' = 1, 2, \ldots, T;\ t \neq t'). \tag{2.6}$$

[3] This section is more difficult than the rest of the text, and it can be skipped without too much loss of continuity.

In other words, it is assumed that the error terms in E have zero expected values and are uncorrelated with their own past values and with each other's past values. The contemporaneous error terms, however, can be correlated across equations.

It is further assumed that

$$\text{plim } T^{-1}XE' = \text{plim } T^{-1}X_{-1}E' = \text{plim } T^{-1}Y_{-1}E' = 0, \qquad (2.7)$$

i.e., that the error terms in E are uncorrelated with the contemporaneous and one-quarter-lagged values of the predetermined variables and with the one-quarter-lagged values of the endogenous variables. Finally, the inverse of A is assumed to exist, and R is assumed to be a diagonal matrix of elements between minus one and one. The assumption made in equation (2.2) of first order serial correlation and the further assumption that R is a diagonal matrix are not as general as one might hope for, but they are necessary if the following estimation technique is to yield consistent estimates.

The technique used to estimate the money GNP sector is a version of the two-stage least squares technique. It is essentially a combination of the standard two-stage least squares technique for dealing with simultaneous equation bias and the Cochrane–Orcutt iterative technique for dealing with serially correlated errors. Care must be taken when using the technique to be sure that the proper instrumental variables are included in the first stage regression to insure consistent estimates. In the following explanation of the technique, attention will be concentrated on the estimation of the first equation of (2.1).

The first equation of (2.1) will be written as

$$y_1 = -A_1 Y_1 - B_1 X_1 + u_1, \qquad (2.8)$$

where

$$u_1 = r_{11} u_{1_{-1}} + e_1. \qquad (2.9)$$

y_1 is a $1 \times T$ vector of the values of y_{1t}, the endogenous variable explained by the first equation; Y_1 is an $h_1 \times T$ matrix of the endogenous variables (other than y_1) included in the first equation; X_1 is a $k_1 \times T$ matrix of predetermined variables included in the first equation; u_1 and e_1 are $1 \times T$ vectors of error terms; r_{11} is the element in the first row and first column of R; and A_1 and B_1 are $1 \times h_1$ and $1 \times k_1$ vectors of coefficients corresponding to the relevant elements of A and B respectively.

Two further equations will be useful in the following analysis. First, from (2.1) and (2.2) the reduced form for Y, expressed in terms of the error E only, is

$$Y = -A^{-1}BX + A^{-1}RAY_{-1} + A^{-1}RBX_{-1} + A^{-1}E. \qquad (2.10)$$

Secondly, equations (2.8) and (2.9) imply for any value of r:

$$y_1 - ry_{1_{-1}} = -A_1(Y_1 - rY_{1_{-1}}) - B_1(X_1 - rX_{1_{-1}}) + [(r_{11} - r)u_{1_{-1}} + e_1]. \tag{2.11}$$

In equation (2.11), e_1 is correlated with Y_1, and $u_{1_{-1}}$ is correlated with $Y_{1_{-1}}$ and with the lagged endogenous variables in X_1 and $X_{1_{-1}}$. The equation can be consistently estimated, however, by the following procedure:

First stage regression: Choose a set of instrumental variables that are uncorrelated with e_1 and that at least include $y_{1_{-1}}$, $Y_{1_{-1}}$, X_1, and $X_{1_{-1}}$. Regress each row of Y_1 on this set and calculate the predicted values of Y_1 (denoted as $\hat{Y}_1$) from these regressions.

Second stage regression: For a given r, estimate equation (2.11) by ordinary least squares, using $\hat{Y}_1 - rY_{1_{-1}}$ in place of $Y_1 - rY_{1_{-1}}$, and calculate the sum of squared residuals of the regression.

Scanning or iterative procedure: Repeat the second stage regression for various values of r between minus one and one (or use an iterative procedure) and choose that r and the corresponding estimates of A_1 and B_1 that yield the smallest sum of squared residuals of the second stage regression. An iterative procedure that can be used here—and which was in fact used in this study—is the following. From initial estimates of A_1 and B_1 (say, $A_1^{(0)}$ and $B_1^{(0)}$), calculate

$$r^{(1)} = \frac{(y_{1_{-1}} + A_1^{(0)}Y_{1_{-1}} + B_1^{(0)}X_{1_{-1}})(y_1 + A_1^{(0)}Y_1 + B_1^{(0)}X_1)'}{(y_{1_{-1}} + A_1^{(0)}Y_{1_{-1}} + B_1^{(0)}X_{1_{-1}})(y_{1_{-1}} + A_1^{(0)}Y_{1_{-1}} + B_1^{(0)}X_{1_{-1}})'};$$

use this value of $r^{(1)}$ to compute new estimates, $A_1^{(1)}$ and $B_1^{(1)}$, of A_1 and B_1 from the second stage regression; use these estimates to compute $r^{(2)}$; and so on until two successive estimates of r are within a prescribed tolerance level. (This is essentially the standard Cochrane–Orcutt [5] iterative procedure adjusted to take into account simultaneous equation bias.) The tolerance level used in this study was .005, and for almost all of the equations that were estimated, the technique converged in less than five iterations.

Consistency of the above estimating procedure can be seen heuristically as follows. Let $\hat{V}_1 = Y_1 - \hat{Y}_1$. Then the equation estimated in the second stage regression is

$$\begin{aligned} y_1 - ry_{1_{-1}} = {} & -A_1(\hat{Y}_1 - rY_{1_{-1}}) - B_1(X_1 - rX_{1_{-1}}) \\ & + [(r_{11} - r)u_{1_{-1}} + e_1 - A_1\hat{V}_1]. \end{aligned} \tag{2.12}$$

Setting r equal to r_{11}, equation (2.12) can then be written:

$$\begin{aligned} y_1 = r_{11}y_{1_{-1}} - A_1\hat{Y}_1 + r_{11}A_1Y_{1_{-1}} - B_1X_1 \\ + r_{11}B_1X_{1_{-1}} + (e_1 - A_1\hat{V}_1). \end{aligned} \tag{2.13}$$

The general estimation method outlined above consists in choosing estimates of r_{11}, A_1, and B_1 (say, $\hat{r}_{11}$, $\hat{A}_1$, and $\hat{B}_1$) such that the sum of squared residuals in (2.13) is at a minimum. The case where r_{11} is assumed to be zero corresponds to the ordinary two-stage least squares method. The error term $e_1 - A_1\hat{V}_1$ in (2.13) has zero expected value ($\hat{V}_1$ has zero mean by the property of least squares) and is not correlated with $y_{1_{-1}}$, $\hat{Y}_1$, $Y_{1_{-1}}$, X_1, and $X_{1_{-1}}$ ($\hat{V}_1$ is orthogonal to these variables by the property of least squares, since $y_{1_{-1}}$, $Y_{1_{-1}}$, X_1, and $X_{1_{-1}}$ are used as instruments in the first stage regression). Equation (2.13) can thus be considered to be a nonlinear equation with an additive error term whose properties are sufficient for insuring consistent estimates by minimizing the sum of squared residuals.

It is now clear why $y_{1_{-1}}$, $Y_{1_{-1}}$, X_1, and $X_{1_{-1}}$ have to be used as instruments in the first stage regression in order to insure consistent estimates. The error term $\hat{V}_1$ in (2.13) must be uncorrelated with $\hat{Y}_1$, $y_{1_{-1}}$, $Y_{1_{-1}}$, X_1, and $X_{1_{-1}}$ in order to insure consistent estimates, and using $y_{1_{-1}}$, $Y_{1_{-1}}$, X_1, and $X_{1_{-1}}$ as instruments in the first stage regression insures that $\hat{V}_1$ will be uncorrelated (in fact, orthogonal) with these variables. Otherwise, there is no guarantee that $\hat{V}_1$ will be uncorrelated with the right-hand-side variables in (2.13).

With respect to the iterative procedure described above, minimizing the sum of squared residuals of (2.13) with respect to r_{11}, A_1, and B_1 yields the following equation for $\hat{r}_{11}$:

$$\hat{r}_{11} = \frac{(y_{1_{-1}} + \hat{A}_1Y_{1_{-1}} + \hat{B}_1X_{1_{-1}})(y_1 + \hat{A}_1\hat{Y}_1 + \hat{B}_1X_1)'}{(y_{1_{-1}} + \hat{A}_1Y_{1_{-1}} + \hat{B}_1X_{1_{-1}})(y_{1_{-1}} + \hat{A}_1Y_{1_{-1}} + \hat{B}_1X_{1_{-1}})'}.$$

Since $\hat{Y}_1 = Y_1 - \hat{V}_1$ and since $\hat{V}_1$ is orthogonal to $y_{1_{-1}}$, $Y_{1_{-1}}$, and $X_{1_{-1}}$, this equation can be written:

$$\hat{r}_{11} = \frac{(y_{1_{-1}} + \hat{A}_1Y_{1_{-1}} + \hat{B}_1X_{1_{-1}})(y_1 + \hat{A}_1Y_1 + \hat{B}_1X_1)'}{(y_{1_{-1}} + \hat{A}_1Y_{1_{-1}} + \hat{B}_1X_{1_{-1}})(y_{1_{-1}} + \hat{A}_1Y_{1_{-1}} + \hat{B}_1X_{1_{-1}})'},$$

which is the formula used to calculate successive values of r in the iterative procedure.

The choice of instruments to be used in the first stage regression is discussed in Fair [17]. It has already been seen that $y_{1_{-1}}$, $Y_{1_{-1}}$, X_1, and $X_{1_{-1}}$ must be used as instruments to insure consistent estimates. In a method proposed by Sargan [39], all of the predetermined and lagged variables in the model are used as instruments (i.e., all of the variables in X, X_{-1}, and Y_{-1}).[4] From (2.10) it is seen that these are all of the variables that enter the reduced form for Y_1. In general, some lagged endogenous variables are included in both Y_{-1} and X, but they are obviously counted only once as instruments. The disadvantage of Sargan's method for even moderately sized models is the large number of instrumental variables that are used, and the question of how the number of instrumental variables can be decreased with zero or perhaps small loss of asymptotic efficiency is discussed in [17]. The small sample properties of the estimators are also briefly discussed in [17], and the asymptotic covariance matrices are presented.

For the money GNP sector in this study the need to decrease the number of instrumental variables from that proposed by Sargan is not as critical as it would be for larger models, since the number of variables in the present model is not large. Nevertheless, not all of the instrumental variables proposed by Sargan were used in estimating the equations of the sector. One of the exogenous variables in the sector, for example, is the sum of government spending and farm housing investment (denoted below as G_t), and this variable is included in the GNP identity. Sargan's choice of instrumental variables would thus suggest that G_{t-1} should be used as an instrument. Since the identity has a zero error term, however, and since lagged GNP is not among the predetermined variables of the sector, G_{t-1} does not enter the reduced form equation (2.10) and so does not need to be used as an instrument.

Sargan's method also suggests that all of the lagged endogenous variables should be included as instruments. In this study, however, those lagged endogenous variables that were not among the predetermined variables (i.e., those that were not in the X matrix above) were not used as instruments except in those equations in which it was necessary to do so to insure consistent estimates. (As mentioned above, when estimating an equation like (2.8), the variables $y_{1_{-1}}$, $Y_{1_{-1}}$, X_1, and $X_{1_{-1}}$ must be included as instruments to insure consistent estimates, and this was always done in the study.) The analysis in [17] indicated that using a large number of instruments is likely to increase the small sample bias of the estimates, and thus an attempt was made in this study to avoid the use of instruments that did not have to be included to insure consistent estimates and that on theoretical grounds were not considered to be too important in the explanation of the endogenous variables. The instrumental variables that were used for each of the equation estimates in the following chapters are listed in brackets underneath each

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[4] See Sargan [39], p. 422.

equation. Also, a "hat" is put over each endogenous variable in the equation (i.e., over each variable for which fitted values rather than actual values were used in the second stage regression). The basic instrumental variables that were used for nearly all of the estimates are discussed in Section 2.3.

In [17] the asymptotic variance-covariance matrix of the above estimator is presented and a suggestion is made as to how the approximate variance-covariance of the estimator may be estimated. With respect to equation (2.8), let $\hat{A}_1$, $\hat{B}_1$, and $\hat{r}_{11}$ denote the estimates of A_1, B_1, and r_{11} respectively. Let $\hat{C}_1$ denote the $1 \times (h_1 + k_1)$ vector $(\hat{A}_1 \quad \hat{B}_1)$. Then the suggestion made in [17] is that the approximate variance-covariance matrix of $\hat{C}_1$ be estimated as $\hat{\sigma}_{11}(\hat{Q}_1\hat{Q}_1')^{-1}$, where $\hat{Q}_1$ is the $T \times (h_1 + k_1)$ matrix $(\hat{Y}_1 - r_{11}Y_{1_{-1}} \quad X_1 - r_{11}X_{1_{-1}})$, where

$$\hat{\sigma}_{11} = T^{-1}\hat{u}_1\hat{u}_1',$$
$$\hat{u}_1 = y_1 - \hat{r}_{11}y_{1_{-1}} + \hat{A}_1(Y_1 - r_{11}Y_{1_{-1}}) + \hat{B}_1(X_1 - \hat{r}_{11}X_{1_{-1}}),$$

and that the approximate variance of $\hat{r}_{11}$ be estimated as $T^{-1}(1 - \hat{r}_{11}^2)$. These are the formulas that have been used to estimate the approximate variances and covariances in this study. The t-statistic of a coefficient estimate is defined in this study to be the ratio of the coefficient estimate to the estimate of its approximate standard error, the approximate standard error being defined as the square root of the approximate variance.

In the discussion below a coefficient estimate will be said to be significant if the absolute value of its t-statistic is greater than two. A variable will be said to be significant if its coefficient estimate is significant. Because the distribution of the t-statistic defined above is not known, no precise statistical statements can be made, and so it is merely *assumed* in the work below that a coefficient is different from zero if the absolute value of the coefficient estimate is more than twice the size of the estimate of its approximate standard error.

For each estimated equation in Chapters 3 through 7, the coefficient estimates and the absolute values of their t-statistics are presented, including the estimate and t-statistic of the serial correlation coefficient. The standard error of the regression and the number of observations are also presented. The standard error has been adjusted for degrees of freedom, i.e., it has been estimated as $\sqrt{[\hat{u}_1\hat{u}_1'/(T - K)]}$, where K has been taken to be the number of coefficients estimated in the individual equation not including the serial correlation coefficient, and where $\hat{u}_1$ is defined above. The multiple correlation coefficient R is dependent on what form the variable on the left hand side is in, and the R-squared that is presented in Chapters 3 through 7 is the R-squared taking the dependent variable in first differenced form. This R-squared is thus a measure of the percent of the variance of the *change* in the dependent variable explained by the estimated equation. It will be denoted as $R\Delta^2$. The $R\Delta^2$s have not been adjusted for degrees of freedom.

For some of the equations that were estimated in Chapters 3 through 7 there were no endogenous variables among the explanatory variables. For these equations there were thus no problems of simultaneous equation bias, and they were estimated by the simple Cochrane–Orcutt iterative technique. Also, the technique described above and the Cochrane–Orcutt iterative technique were used in the estimation of the equations in the employment and labor force sector. A nonlinear technique was used in the estimation of the equation in the price sector, and this technique will be described in Chapter 10. A different technique was also used in the estimation of the monthly housing starts equations, and this technique will be described in Chapter 8.

In order to see how the estimates of the seven expenditure equations in the money GNP sector achieved using the technique described at the beginning of this section compare with the estimates achieved using the simple Cochrane–Orcutt iterative technique, both sets of estimates are presented and discussed in Appendix B. The ordinary least squares estimates of the seven equations are also presented in Appendix B. The results in Appendix B should thus indicate how important it is to account for serial correlation problems relative to accounting for problems of simultaneous equation bias.

2.3 The Data Used for the Money GNP Sector

Most of the variables that have been considered in the money GNP sector are listed in Table 2–1. Data for most of the variables are seasonally adjusted at annual rates in billions of current dollars (abbreviated as SAAR in the table). The national income accounts data are based on the July 1969 revisions. The nature of the data for the remaining variables is given in the table. Table 2–1 is meant to be used as a guide for reading Chapters 3 through 7. Each time a variable is introduced for the first time in the following text its symbol is defined, and after that the symbol is used to refer to the variable.

A few adjustments were made in some of the data, and these adjustments will be discussed in the relevant chapters. In Appendix A data on the variables listed in Table 2–1 that are not readily available elsewhere are presented, as well as any adjustments that were made in the data. The variables presented in Appendix A include $MOOD_t$, $PE1_t$, $PE2_t$, $ECAR_t$, $VE1_t$, $VE2_t$, and VH_t.

Table 2–1. List and Description of the Variables Considered in the Money GNP Sector.

Endogenous Variables	
GNP_t	= Gross National Product, NIA, SAAR.
CD_t	= Personal Consumption Expenditures for Durable Goods, NIA, SAAR.
CN_t	= Personal Consumption Expenditures for Nondurable Goods, NIA, SAAR.
CS_t	= Personal Consumption Expenditures for Services, NIA, SAAR.
IP_t	= Nonresidential Fixed Investment (Plant and Equipment Investment), NIA, SAAR.
IH_t	= Nonfarm Residential Fixed Investment (Housing Investment), NIA, SAAR.
$V_t - V_{t-1}$	= Change in Total Business Inventories (Inventory Investment), NIA, SAAR.
IMP_t	= Imports of Goods and Services, NIA, SAAR.
Exogenous Variables Used in the Final Version of the Sector	
G_t	= Government Expenditures plus Farm Residential Fixed Investment, NIA, SAAR.
EX_t	= Exports of Goods and Services, NIA, SAAR.
$MOOD_t$	= Michigan Survey Research Center Index of Consumer Sentiment in Units of 100.
$PE1_t$	= One-Quarter-Ahead Expectation of Plant and Equipment Investment, OBE–SEC data, SAAR.
$PE2_t$	= Two-Quarter-Ahead Expectation of Plant and Equipment Investment, OBE–SEC data, SAAR.
HSQ_t	= Quarterly Nonfarm Housing Starts, Seasonally Adjusted at Quarterly Rates in Thousands of Units.
Other Variables Considered in the Sector	
$ECAR_t$	= Bureau of the Census Index of Expected New Car Purchases, Seasonally Adjusted in Units of 100.
DPI_t	= Personal Consumption Expenditures plus Personal Saving, NIA, SAAR
	= Disposable Personal Income less Interest Paid and Transfer Payments to Foreigners.
$VE1_t$	= One-Quarter-Ahead Expectation of Manufacturing Inventory Investment, OBE data, SAAR.
$VE2_t$	= Two-Quarter-Ahead Expectation of Manufacturing Inventory Investment, OBE data, SAAR.
VH_t	= Percent of Manufacturing Firms Reporting Inventory Condition as High minus the Percent Reporting as Low, OBE data.

Notes: SAAR = Seasonally Adjusted at Annual Rates in Billions of Current Dollars.
NIA = National Income Accounts Data.
OBE = Office of Business Economics, Department of Commerce.
SEC = Securities and Exchange Commission.

2.4 The Periods of Estimation Used for the Money GNP Sector

The basic period of estimation used for the equations of the model was the first quarter of 1956 through the fourth quarter of 1969.[5] As discussed briefly in Chapter 1, there is always a danger in econometric work of this kind that the structure of the economy (and thus quite likely the simple aggregate relationships that are specified in the present model) has changed from one point in time to another. Within an unchanged structure, it is, of course, desirable to have as large a sample as possible in order to achieve the most efficient estimates possible. There is thus to some extent a trade off between the length of the sample period and the confidence that one places on the assumption of an unchanged structure during the sample period. The choice of the basic sample period for the model was made largely on intuitive grounds. It seemed desirable to exclude the Korean War years and give the economy some time to settle down after the war. In addition, it was felt that 1955 may have been an unusual year in some respects, especially in the demand for automobiles. The first quarter of 1956 was thus chosen as the beginning of the sample period. Some of the data from 1955 were actually used, however, since there were lags in the estimated equations.

There were two significant strikes between 1956 and 1969: the steel strike from 15 July 1959, to 7 November 1959, and the automobile strike from 25 September 1964, to 25 November 1964. These strikes clearly had an effect on GNP and its components, and so it was decided to omit these strike observations from the period of estimation. Since one-quarter-lagged values of GNP and other variables were included in many of the estimated equations, observations for one extra quarter for each of the two strike periods were omitted as well. For the steel strike, observations for 593, 594, and 601 were omitted, and for the automobile strike observations for 644, 651, and 652 were omitted. The reason observations for 652 were omitted, even though the automobile strike ended in 644, was the extremely strong reaction of consumers in 651 (due at least in part to the automobile strike of the previous quarter).

There were also two significant dock strikes during the 1956–1969 period—one from 16 June 1965, to 1 September 1965, and one from 20 December 1968, to 3 June 1969—which had a serious effect on imports but little overall effect on GNP. Consequently, observations for 653, 684, 691, 692, and 693 were omitted from the sample period for the import equation, as well as the

[5] In the rest of the text the following notation will be adopted. The first quarter of 1956 will be denoted as 561, the second quarter of 1956 as 562, and so on through the fourth quarter of 1969, 694.

already excluded observations for 593, 594, 601, 644, 651, and 652. For the rest of the equations of the sector, observations for 653, 684, 691, 692, and 693 were not omitted.

Because of data limitations, a shorter period of estimation was used for a few of the equations. The data on housing starts before 1959 are notoriously bad, for example; and so these data were not considered in this study. Data on some of the other variables listed in Table 2–1 were also not available before about 1959. Consequently, for the equations that used these variables the period of estimation was taken to begin in 602 rather than in 561 (with the observations for 644, 651, and 652 continuing to be omitted from the sample period). 602 was chosen as the initial quarter, since observations for 593, 594, and 601 were omitted from the basic period of estimation because of the steel strike. In the following chapters the period of estimation that was used is indicated by the number of observations used: 50 for the basic period of estimation, 45 for the import equation, and 36 when data only after 1959 were available.

The procedure of excluding particular quarters from the sample period because of strikes is a little unusual. The common procedure is to use dummy variables that take on values of one during the strike quarters and zero otherwise. Unless a separate dummy variable is used for each quarter, however, the dummy variable procedure implies that only the constant term in the equation is affected by the strike. Using a separate dummy variable for each strike quarter is equivalent to excluding each strike quarter from the sample period, except that the summary statistics (the R-squared, the standard error of the regression, etc.) are different. Unless one has reason to believe that only constant terms are affected by strikes, the most straightforward approach seems to be to just omit the strike quarters from the sample period; and this was the procedure followed here.

Because of the unavailability of data on housing starts before 1959, the quarterly housing starts variables, HSQ_t, HSQ_{t-1}, and HSQ_{t-2}, which were included among the final predetermined variables of the sector, could not be used as instruments in most of the equations estimated. In practice, these variables were used as instruments only in the particular equations in which they appeared. Using the notation in Table 2–1, the following variables were used as instruments in nearly all of the equations: GNP_{t-1}, CD_{t-1}, CD_{t-2}, CN_{t-1}, CN_{t-2}, CS_{t-1}, CS_{t-2}, V_{t-1}, V_{t-2}, G_t, $MOOD_{t-2}$, $PE2_t$, $PE2_{t-1}$, and the constant term (denoted as 1 in the following chapters).

With respect to the basic set of instrumental variables used, government spending plus exports ($G_t + EX_t$) should be used in place of G_t as one of the basic instruments. This was not done in this study, however, because exports were seriously affected by the dock strikes. Unless the (shorter) sample period used for the import equation was used for all of the equations, $G_t + EX_t$ could not be used as an instrumental variable, and it was felt that it was better to omit EX_t from the sum than to use the shorter sample period for all of the equations.

In the final version of the sector, both $MOOD_{t-1}$ and $MOOD_{t-2}$ are included among the predetermined variables, and so following Sargan's suggestion above, $MOOD_{t-1}$, $MOOD_{t-2}$, and $MOOD_{t-3}$ should have been used as instruments for all of the equations estimated. In order to decrease the number of instrumental variables used, however, only $MOOD_{t-2}$ was included in the basic set of instrumental variables. In order to insure consistent estimates, $MOOD_{t-1}$ and $MOOD_{t-3}$ were, of course, used as instruments in those equations in which $MOOD_{t-1}$ and $MOOD_{t-2}$ appeared as explanatory variables.

3 Consumption

3.1 Introduction

In this chapter the three consumption equations of the model will be discussed. The emphasis in the chapter is on examining the role that consumers' general feelings and attitudes play in influencing their short-run behavior. An attempt has also been made to examine what effect consumer buying expectations have on consumer expenditures. In the next section the theory behind the present model will be briefly discussed and the data on consumer sentiment and consumer buying expectations that have been used will be described. The three consumption categories—durable goods, nondurable goods, and services—will then be examined in Sections 3.3, 3.4, and 3.5 respectively. Section 3.6 concludes with a summary of the major results of the chapter.

3.2 Consumer Sentiment, Consumer Buying Expectations, and Short-Run Consumption Functions

An adequate explanation of short-run consumer behavior is essential in a short-run forecasting model, and yet it is one of the most difficult to achieve. There has been an enormous amount of work in the area of consumer behavior, but unfortunately no very accurate equations for explaining short-run changes in consumption appear to have been developed.[1] The work in this chapter is based on the theory that general feelings of optimism or pessimism on the part of consumers are likely to be important determinants of their short-run behavior. The average consumer in the United States has considerable discretion in how much he purchases in any given quarter (i.e., the average consumer in the United States is far above the level of subsistence), and if he is worried about the future, he is likely to spend less and save more than he would if he were more sanguine about the future. The main attempt in this chapter has thus been to examine how useful the available data on consumer sentiment are in explaining short-run changes in consumption.

[1] See, for example, Suits and Sparks [41], p. 217, for a discussion of the poor short-run explanatory power of the consumption equations of the Brookings model.

The main series on consumer sentiment is compiled by the Michigan Survey Research Center.[2] In 1952 the Research Center began to conduct surveys on consumer attitudes. From 1954 through 1961 the surveys were taken approximately three times a year, and from 1962 to the present the surveys have been taken quarterly. The sample size has varied from 1000 to 3000 observations. Questions are asked regarding attitudes about personal financial conditions, business conditions, and market conditions.[3] The series used in this study is an index of consumer sentiment that is based on five questions about consumer attitudes.[4] The index will be denoted as $MOOD_t$ in the discussion that follows.

While the main attempt in this study has been to see how the $MOOD_t$ index affects consumer expenditures, an attempt has also been made to see how consumer buying expectations affect consumer expenditures. To the extent that buying expectations are realized, they should be significant in explaining actual expenditures. The main series on consumer buying expectations is compiled by the Bureau of the Census.[5] The data are compiled from a quarterly household survey of approximately 11,500 households. The survey is designed to measure consumer buying expectations rather than general feelings or attitudes: each respondent is asked to select his chances of purchasing certain items during a specified time period (usually 12 months) from an answer sheet that is scaled from 0 to 100. The survey was considerably changed in 1967, and the data before 1967 are not strictly comparable with the more recent data. The questionnaire of the old survey was less detailed regarding the probability breakdown and was thus more qualitative in nature.[6]

The index of consumer buying expectations that has been considered in this study is the index of expected new car purchases. This index is available from the old survey from the first quarter of 1959 through the third quarter of 1967 and from the new survey from the first quarter of 1967 to the present.[7] Although the old and new survey indices are not strictly comparable, they

[2] See, for example, Katona et al. [32].
[3] See Katona et al. [30], p. 175.
[4] See Katona et al. [32], Table II–1, pp. 243–244, for a tabulation of this series through 1966. The series was revised slightly in 1968, but the revisions were quite small. For the work in this study the prerevised figures were used before 1967. Before 1962, quarterly observations were obtained for this study by interpolating (when necessary) between the given observations. From 1955 through 1961 ten observations had to be constructed in this way. The data and the interpolation figures are presented in Appendix A.
[5] See, for example, U.S. Bureau of the Census [46].
[6] U.S. Bureau of the Census [44], p. 2.
[7] See U.S. Bureau of the Census [45], p. 25, for a tabulation of the data from the old survey and U.S. Bureau of the Census [46], p. 2, for a tabulation of the data from the new survey (through the fourth quarter of 1969).

were treated as one continuous series in this study. Data from the old survey were used for the series from the first quarter of 1959 through the fourth quarter of 1966, and data from the new survey were used for the series from the first quarter of 1967 on. This series on expected new car purchases will be denoted as $ECAR_t$. Data on $ECAR_t$ are presented in Appendix A.

In addition to consumer sentiment and buying expectations, consumption is likely to be influenced by present and lagged values of income. Indeed, much of the previous work in the area of consumer behavior, including the work relating to the permanent income hypothesis, can be incorporated into the general problem of determining the lag structure of consumption on income. As discussed in Chapter 1, one tenet of this study is that it is too much to expect that the highly aggregated data used here can distinguish among various complicated lag structures. Consequently, only two simple lag structures were estimated for each of the consumption equations. In the first case consumption was assumed to be a linear function of current income and income lagged one quarter, and in the second case consumption was assumed to be a linear function of current income and consumption lagged one quarter. The second case can be interpreted as implying that consumption is a geometrically declining function of current and all past values of income, or that desired consumption is a linear function of current income, with actual consumption being subject to a simple lagged adjustment process. Again, due to the aggregative nature of the model, no strict interpretation will be placed on the results regarding the "true" lag structure or adjustment process. The results are only approximate at best.

In the work that follows consumption has been disagregated into consumption of durables, consumption of nondurables, and consumption of services. Due to the postponeable nature of consumption of durables, changes in consumer feelings and attitudes are likely to have more influence on changing the consumption of durables than on changing the consumption of nondurables and services. Unlike the other two, consumption of services is subject to very little short-run variation. Treating these three kinds of consumption separately is thus likely to improve the explanatory power and forecasting ability of the model.

3.3 Consumption of Durables

Various equations explaining the consumption of durables were estimated using current and lagged values of the consumer sentiment variable, MOOD, and the consumer buying expectations variable, ECAR. When ECAR was used in the equations, the shorter sample period beginning in 602 had to be used since data on ECAR were not available before 1959. Of the many equations estimated, two equations emerged as candidates for further consideration.

The first equation, estimated over the longer sample period, was

$$\begin{aligned} CD_t = \underset{(4.22)}{-25.43} + \underset{(39.78)}{.103}\ \widehat{GNP_t} + \underset{(1.88)}{.110}\ MOOD_{t-1} + \underset{(1.54)}{.092}\ MOOD_{t-2} \end{aligned}$$

$$\hat{r} = \underset{(6.01)}{.648}$$

$$\text{SE} = 1.125 \qquad (3.1)$$

$$R\Delta^2 = .554$$

$$\text{50 observ.}$$

$$[1, GNP_{t-1}, CD_{t-1}, CD_{t-2}, CN_{t-1}, CN_{t-2}, CS_{t-1}, CS_{t-2}, V_{t-1}, V_{t-2}, G_t, MOOD_{t-1}, MOOD_{t-2}, MOOD_{t-3}, PE2_t, PE2_{t-1}].$$

CD_t denotes expenditures on durable consumption goods during quarter t seasonally adjusted at annual rates in billions of current dollars, GNP_t denotes gross national product during quarter t seasonally adjusted at annual rates in billions of current dollars, and $MOOD_{t-i}$ denotes the Michigan Survey Research Center index of consumer sentiment during quarter $t-i$. The variables in brackets are the variables that were used as instruments for the endogenous GNP_t variable in the first stage regression. The variables are defined in Table 2–1, and the ones that have not yet been discussed will be discussed in the relevant sections or chapters below. The "hat" over the GNP_t variable denotes the fact that it was treated as endogenous in the estimation of equation (3.1).

The meaning of the results that are presented in (3.1) was discussed in Chapter 2. The absolute values of the t-statistics are given in parentheses. $R\Delta^2$ is the R-squared that has been calculated taking the dependent variable to be in first differenced form, and so it is a measure of the percent of the variance of the *change* in CD_t explained by the equation. $\hat{r}$ is the estimate of the first order serial correlation coefficient of the error terms.

The income variable, GNP_t, is highly significant in equation (3.1).[8] Neither of the lagged values of the consumer sentiment variable is significant

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[8] Remember from Chapter 2 that a coefficient estimate is said to be significant if its t-statistic is greater than two in absolute value, and that a variable is said to be significant if its coefficient estimate is significant.

in the equation, due to the collinearity between the two values, but including them both in the equation resulted in a better fit, even after adjusting for degrees of freedom, than including either of them separately. When included separately, both $MOOD_{t-1}$ and $MOOD_{t-2}$ were significant. The estimate of the serial correlation coefficient is fairly high, which perhaps indicates that the lag structure is not well specified or that relevant variables have been omitted from the equation. The fit is reasonably good for this series, with 55.4 percent of the variance of the change in CD_t being explained.

The second equation that seemed worthy of further consideration, this time estimated over the shorter sample period, was

$$\begin{aligned} CD_t = \underset{(4.38)}{-32.09} + \underset{(35.33)}{.105}\ \widehat{GNP_t} + \underset{(2.35)}{.164}\ MOOD_{t-1} + \underset{(1.64)}{.084}\ ECAR_{t-2} \\ \hat{\rho} = \underset{(3.08)}{.456} \\ SE = 1.155 \qquad (3.2) \\ R\Delta^2 = .527 \\ 36 \text{ observ.} \end{aligned}$$

$[1, GNP_{t-1}, CD_{t-1}, CD_{t-2}, CN_{t-1}, CN_{t-2}, CS_{t-1}, CS_{t-2}, V_{t-1}, V_{t-2}, G_t, MOOD_{t-1}, MOOD_{t-2}, ECAR_{t-2}, ECAR_{t-3}, PE2_t, PE2_{t-1}]$.

$ECAR_{t-2}$ denotes the Bureau of the Census index of expected new car purchases during quarter $t-2$. The serial correlation is reduced in equation (3.2) from equation (3.1); the coefficient estimate of $MOOD_{t-1}$ is somewhat larger; and the $ECAR_{t-2}$ variable is nearly significant.

A number of equations were estimated in arriving at equations (3.1) and (3.2). In particular, various combinations of current and lagged values of MOOD and ECAR were tried in the equations. Neither the current value of MOOD nor the current value of ECAR was significant in the equations estimated, even when included separately. With respect to the lagged values of MOOD and ECAR, $MOOD_{t-1}$ appeared to be more significant that $MOOD_{t-2}$ in the various equations estimated, and $ECAR_{t-2}$ appeared to be more significant than $ECAR_{t-1}$. Because of collinearity problems, adding $MOOD_{t-2}$ or $ECAR_{t-1}$ (or both) to equation (3.2) resulted in insignificant coefficient estimates for these variables, as well as for $MOOD_{t-1}$ and $ECAR_{t-2}$. When included separately, each of the four lagged variables was significant. $MOOD_{t-3}$ and $ECAR_{t-3}$ were not significant, even when included separately. Both indices thus appear to have a lagged effect on durable consumption of between one and two quarters. It should be pointed out that both indices are based on surveys that are conducted near the beginning of the quarter.

Equation (3.2) has less serial correlation than equation (3.1) and has a larger estimate of the coefficient of $MOOD_{t-1}$. This is not due to the fact that $ECAR_{t-2}$ has replaced $MOOD_{t-2}$ in equation (3.2), however, but to the fact that different sample periods have been used. When equation (3.1) was estimated for the shorter period, the results were:

$$\begin{aligned} CD_t = \underset{(4.33)}{-34.72} + \underset{(47.73)}{.107}\ \widehat{GNP}_t + \underset{(2.17)}{.160}\ MOOD_{t-1} + \underset{(1.31)}{.100}\ MOOD_{t-2} \\ \hat{\rho} = \underset{(2.68)}{.408} \\ SE = 1.170 \qquad\qquad (3.3) \\ R\Delta^2 = .515 \\ 36 \text{ observ.} \\ [\text{variables same as for (3.1)}]. \end{aligned}$$

Equation (3.3) is similar to equation (3.2) with respect to the size of the coefficient estimate of $MOOD_{t-1}$ and the size of the estimate of the serial correlation coefficient. The fits of (3.3) and (3.2) are nearly the same, with the use of $ECAR_{t-2}$ instead of $MOOD_{t-2}$ in (3.2) resulting in a slightly better fit.

Since MOOD and ECAR are in approximately the same units (index numbers to the base 100), the larger coefficient estimate for $MOOD_{t-1}$ than for $ECAR_{t-2}$ in equation (3.2) implies that $MOOD_{t-1}$ has a larger influence on CD_t than does $ECAR_{t-2}$. In general, for all of the equations estimated in this study the MOOD variable appeared to be more significant than the ECAR variable in explaining CD_t. This result is consistent with the results of Adams [1] and Katona et al [31], who seem to find that consumer attitudes are more important in the explanation of consumption over time than are consumer buying expectations.

Equations (3.1) and (3.2) were chosen to be tested within the context of the overall model. The result of these tests are described in Chapter 11. There is little to choose between the two equations on the basis of the results for the individual equations, and fortunately the present model is small enough so that the different equations can be easily tested within the context of the overall model to see which one gives the best results. It turned out that equation (3.1) gave slightly better results on this basis, and so it was chosen as the basic equation explaining the consumption of durables. In other words, the Bureau of the Census index of expected new car purchases was not included among the final predetermined variables of the model. This is not to say that the index is not significant in explaining consumption of durables, but only that it does not appear to add new information from that already contained in the index of consumer sentiment variable.

Two other issues were involved in the choice of equation (3.1) as the basic equation explaining the consumption of durables. The first relates to the question of the lag structure of consumption on income. As mentioned in Section 3.2, two basic lag structures were estimated for each of the consumption equations—one in which lagged income was added to the equation and one in which lagged consumption was added. It turned out for durable consumption that neither lagged income nor lagged consumption was significant. For example, when lagged income and then lagged consumption were added to equation (3.1), the results were:

$$\underset{}{CD_t} = \underset{(4.17)}{-26.43} + \underset{(1.08)}{.060}\, \widehat{GNP_t} + \underset{(1.97)}{.124}\, MOOD_{t-1} + \underset{(1.39)}{.086}\, MOOD_{t-2} + \underset{(.78)}{.044}\, GNP_{t-1}$$

$$\hat{\rho} = \underset{(5.91)}{.641} \qquad \text{SE} = 1.163 \qquad R\Delta^2 = .533 \qquad \text{50 observ.} \tag{3.4}$$

[variables same as for (3.1) plus GNP_{t-2}].

$$CD_t = \underset{(4.12)}{-\ 28.70} + \underset{(8.44)}{.118}\, \widehat{GNP_t} + \underset{(1.98)}{.115}\, MOOD_{t-1} + \underset{(1.76)}{.108}\, MOOD_{t-2} - \underset{(1.10)}{.147}\, CD_{t-1}$$

$$\hat{\rho} = \underset{(7.34)}{.720} \qquad \text{SE} = 1.120 \qquad R\Delta^2 = .567 \qquad \text{50 observ.} \tag{3.5}$$

[variables same as for (3.1)].

Neither the lagged income term in equation (3.4) nor the lagged consumption term in equation (3.5) is significant, and the fit has not been noticeably improved in either equation from that in equation (3.1). These two lag structures were thus rejected in favor of the simpler specification in equation (3.1).

The other issue involved in the choice of equation (3.1) as the equation explaining durable consumption relates to the use of GNP as the income variable. In equation (3.1), as well as in the equations explaining nondurable and service consumption, GNP has been used as the income variable instead of disposable personal income (DPI). One reason this has been done is that it is difficult to explain or predict disposable personal income, even given knowledge of GNP. The relationship between the change in DPI and the change in GNP appears to be far from stable in the short run. The relationship is in part a function of tax rate changes, which could perhaps be incorporated into the model.[9] but in part it is also a function of the dividend policies of corporations. When GNP levels off or turns down, corporate profits are much more affected than are dividend payments, and much of the decrease in corporate profits is absorbed by undistributed corporate profits. A similar conclusion holds when GNP increases rapidly: undistributed corporate profits increase with little short-run change in dividend payments. The short-run relationship between DPI and GNP, in other words, does not appear capable of being explained in any simple way.

In order to explain DPI it thus appears that it would be necessary to develop an income side of the model. Because of a desire to keep the model as simple as possible, an income side was not developed, and no attempt was made to explain or include disposable personal income within the model. In order to see the consequences of using GNP as the income variable, however, equation (3.1) was estimated using DPI in place of GNP. The results were:

$$\begin{aligned} CD_t = \underset{(4.93)}{-33.26} + \underset{(35.04)}{.161}\,\widehat{DPI_t} + \underset{(2.08)}{.133}\,MOOD_{t-1} + \underset{(1.70)}{.111}\,MOOD_{t-2} \end{aligned}$$

$$\hat{r} = \underset{(6.21)}{.660}$$

$$SE = 1.237 \qquad (3.6)$$

$$R\Delta^2 = .460$$

$$\text{50 observ.}$$

$$[1, DPI_{t-1}, CD_{t-1}, CD_{t-2}, CN_{t-1}, CN_{t-2}, V_{t-1}, V_{t-2}, G_t, MOOD_{t-1}, MOOD_{t-2}, MOOD_{t-3}, PE2_t, PE2_{t-2}].$$

DPI_t denotes disposable personal income (personal consumption plus personal saving) during quarter t seasonally adjusted at annual rates in billions of current dollars. The estimate of the coefficient of DPI_t is larger in equation (3.6) than the estimate of the coefficient of GNP_t in equation

[9] See Crockett and Friend [6] for an attempt to do this.

(3.1), as expected, but surprisingly the fit of equation (3.6), which uses DPI, is worse than the fit of equation (3.1), which uses GNP. No explanatory power has been gained using DPI in place of GNP.

Although no definitive reason can be given why the fit of the equation worsens when DPI is used, it may be related to the effect of corporate profits on consumption. When corporate profits are high, confidence and business optimism are likely to be high, and this general optimism may have an effect on consumption that is not picked up in the values of the consumer sentiment variable. (As mentioned above, higher corporate profits are not necessarily turned into higher dividend payments in the short run, and thus disposable personal income does not necessarily increase in the short run when corporate profits increase. GNP, of course, does increase.) Likewise, when profits are low, feelings of doubt and pessimism are likely to prevail, and this may have an independent negative effect on consumption. This is not to say that consumption is directly influenced by undistributed corporate profits, but that general conditions that cause undistributed corporate profits to be high or low may also influence consumption in the same direction.

This argument, that GNP is in part acting as a proxy for consumer confidence, is really no more than a conjecture, but what can be concluded from the above results is that at least for the type of durable consumption equations considered in this study, the use of GNP instead of DPI as the income variable does not result in any loss of explanatory power. Equation (3.1) is certainly not a structural equation in the strict sense of the word, but for short-run forecasting purposes the equation does appear to give an adequate explanation of durable consumption. A more complete examination of the question of whether DPI should be included in the model could have been undertaken by developing an income side and testing it (along with the consumption equations that use DPI as the income variable) within the context of the overall model in the manner done for other versions of the model below. Given the rather positive results achieved below in explaining consumption, however, the benefits that might have resulted from examining this question were not considered to be worth the cost.

3.4 Consumption of Nondurables

Equations similar to those for the consumption of durables were estimated for the consumption of nondurables. The lag structure appeared to be different for nondurables than for durables in that the one-quarter-lagged value of nondurable consumption was highly significant in all of the non-durable equations. With respect to the consumer sentiment variable and the consumer buying expectations variable, the consumer sentiment variable emerged as the most significant of the two. In particular, $MOOD_{t-2}$ emerged as the most significant variable, and the two best equations for the two different sample periods were:

$$\begin{aligned} CN_t = \underset{(5.40)}{.081}\ \widehat{GNP_t} + \underset{(9.30)}{.646}\ CN_{t-1} + \underset{(4.67)}{.147}\ MOOD_{t-2} \\ \hat{r} = \underset{(2.47)}{-.381} \\ SE = 1.383 \\ R\Delta^2 = .550 \\ \text{36 observ.} \end{aligned} \tag{3.7}$$

$[1, GNP_{t-1}, CD_{t-1}, CD_{t-2}, CN_{t-1}, CN_{t-2}, CS_{t-1}, CS_{t-2},$
$V_{t-1}, V_{t-2}, G_t, MOOD_{t-2}, MOOD_{t-3}, PE2_t, PE2_{t-1}]$.

$$\begin{aligned} CN_t = \underset{(3.50)}{.034}\ \widehat{GNP_t} + \underset{(19.71)}{.866}\ CN_{t-1} + \underset{(2.56)}{.049}\ MOOD_{t-2} \\ \hat{r} = \underset{(2.47)}{-.330} \\ SE = 1.436 \\ R\Delta^2 = .402 \\ \text{50 observ.} \end{aligned} \tag{3.8}$$

[variables same as for (3.7)].

CN_t denotes expenditures on nondurable consumption goods during quarter t seasonally adjusted at annual rates in billions of current dollars.

Although equations (3.7) and (3.8) are the same except for the different sample periods, the coefficient estimates are quite different. For the shorter period of estimation the estimates of the coefficients of GNP_t and $MOOD_{t-2}$ are much larger and the estimate of the coefficient of CN_{t-1} somewhat smaller. There is negative first order serial correlation of the error terms in both equations. When both equations were tested in Chapter 11 within the context of the overall model, equation (3.7), which is estimated over the shorter sample period, gave decidedly better results. There definitely seems to have been a shift in the nondurable consumption relationship between the beginning of the longer sample period (561) and the beginning of the shorter sample period (602). Equation (3.7) was thus chosen as the basic equation explaining nondurable consumption.

A number of equations were estimated in arriving at equation (3.7) as the basic equation explaining nondurable consumption. With respect to the MOOD and ECAR indices, the MOOD index gave better results. This is not too surprising, since ECAR, the buying expectations variable, relates only to expectations of new car purchases. $ECAR_{t-1}$ and $ECAR_{t-2}$ were significant when each was included in place of $MOOD_{t-2}$ in equation (3.7), however, which indicates that expected new car purchases are positively correlated with nondurable purchases as well. Neither $ECAR_{t-1}$ nor $ECAR_{t-2}$ was significant when included with $MOOD_{t-2}$ in equation (3.7) (although $MOOD_{t-2}$ remained significant), and the fits of the equations that included $ECAR_{t-1}$ or $ECAR_{t-2}$ in place of $MOOD_{t-2}$ were worse than the fit of equation (3.7). $MOOD_{t-2}$, in other words, clearly dominated $ECAR_{t-1}$ and $ECAR_{t-2}$ in the explanation of nondurable consumption.

With respect to the lagged values of MOOD, $MOOD_{t-1}$ was significant when included in place of $MOOD_{t-2}$ in equation (3.7), but when both $MOOD_{t-1}$ and $MOOD_{t-2}$ were included in the equation, $MOOD_{t-1}$ became highly insignificant, while $MOOD_{t-2}$ retained its significance. Contrary to the case for durable consumption, $MOOD_{t-1}$ and $MOOD_{t-2}$ did not appear to have independent explanatory power in the nondurable equation.

The constant term was not significant in equation (3.7) (as well as in almost all of the other nondurable equations estimated), and so the constant term was not included in the final equation estimated. Excluding the constant term had very little effect on the other coefficient estimates.

With respect to the lag structure of nondurable consumption on income, the choice in favor of using the lagged consumption variable was quite clear. When, for example, an equation like (3.7) was estimated using lagged income in place of lagged consumption, the results were not as good:

$$\underset{}{CN_t} = \underset{(3.02)}{29.74} + \underset{(1.00)}{.079}\,\widehat{GNP}_t + \underset{(1.75)}{.142}\,GNP_{t-1} + \underset{(1.20)}{.118}\,MOOD_{t-2}$$

$$\underset{(3.11)}{\hat{r} = .460} \qquad (3.9)$$

$$\text{SE} = 1.544$$

$$R\Delta^2 = .456$$

36 observ.

[variables same as for (3.7) plus GNP_{t-2}].

Only the constant term and the serial correlation coefficient are significant in equation (3.9), and the fit is worse than that in equation (3.7). Note that dropping CN_{t-1} from equation (3.7) increased the estimate of the serial correlation coefficient from $-.381$ to .460.

Finally, with respect to the possible use of DPI instead of GNP as the income variable, an equation like (3.7) was estimated using DPI in place of GNP to see how the results compared. The results were:

$$\begin{aligned}
CN_t = \underset{(7.00)}{.144}\,\widehat{DPI_t} + \underset{(9.73)}{.594}\,CN_{t-1} + \underset{(5.90)}{.137}\,MOOD_{t-2} \\
\hat{\rho} = -\underset{(3.31)}{.483} \\
\text{SE} = 1.216 \qquad\qquad (3.10) \\
R\Delta^2 = .652 \\
36 \text{ observ.}
\end{aligned}$$

$$[1, DPI_{t-1}, CD_{t-1}, CD_{t-2}, CN_{t-1}, CN_{t-2}, CS_{t-1}, CS_{t-2}, V_{t-1}, V_{t-2}, G_t, MOOD_{t-2}, MOOD_{t-3}, PE2_t, PE2_{t-1}].$$

Contrary to the results achieved for durable consumption, the fit of equation (3.10), which uses DPI, is better than the fit of equation (3.7), which uses GNP. The coefficient estimates are all significant in equation (3.10), and as expected, the estimate of the coefficient of DPI_t in (3.10) is larger than the estimate of the coefficient of GNP_t in (3.7).

The results in this chapter thus indicate that nondurable consumption is more closely tied in the short run to disposable income and previous consumption behavior than is durable consumption. Durable consumption, in other words, appears to be more influenced by consumer feelings and attitudes in the short run than is nondurable consumption. This is not unexpected, of course, since durable purchases are in general more postponable than nondurable purchases. Despite the better fit obtained in equation (3.10) by using DPI, the equation was not included in the model for the reasons presented above.

3.5 Consumption of Services

Consumption of services has very little short-run variability and is easier to forecast than the other two components of aggregate consumption. The equation that was finally chosen to be used as the equation explaining consumption of services is

$$CS_t = \underset{(4.15)}{.022}\ \widehat{GNP}_t + \underset{(47.77)}{.945}\ CS_{t-1} - \underset{(7.37)}{.023}\ MOOD_{t-2}$$

$$\hat{r} = - \underset{(0.55)}{.077} \qquad (3.11)$$

$$SE = .431$$

$$R\Delta^2 = .891$$

50 observ.

[variables same as for (3.6)].

CS_t denotes the consumption of services during quarter t seasonally adjusted at annual rates in billions of current dollars. Except for the estimate of r (which is effectively zero), the coefficient estimates in equation (3.11) are significant and the fit is quite good. Equation (3.11) explains 89.1 percent of the variance of the change in CS_t. The estimate of the constant term was not significant, and the constant term was omitted in the final estimate. Excluding the constant term had very little effect on the other coefficient estimates. The estimate of the coefficient of GNP_t is quite small and the estimate of the coefficient of CS_{t-1} quite large: consumption of services appears to be only slightly affected by current income changes.

The estimate of the coefficients of the consumer sentiment variable in equation (3.11) is significant but negative, which is contrary to what might be expected. There is one reason, however, why the coefficient of $MOOD_{t-2}$ might be expected to be negative. It was seen above that $MOOD_{t-2}$ had a positive effect on the consumption of durables and nondurables: periods of consumer optimism correspond, other things being equal, to large durable and nondurable purchases. Now it may be that these periods also correspond to slightly smaller expenditures for services. A family that has just purchased a large durable item, for example, may be inclined, other things being equal, to spend a little less on entertainment activities for a few months.[10] If there are any of these kinds of substitution effects between the consumption of services and the consumption of durables and nondurables in the short run, there are, of course, more sophisticated ways of specifying them. These more complicated specifications are beyond the scope of this study, however, and for present purposes the results in equation (3.11) appear to be adequate.

Again, a number of equations were estimated in arriving at equation

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[10] Depressed consumers, on the other hand, may not feel like buying a large durable item, but may be inclined to engage in more entertainment activities in an attempt to cheer themselves up.

(3.11) as the basic equation explaining the consumption of services. With respect to the lagged values of MOOD, $MOOD_{t-1}$ was tried in place of $MOOD_{t-2}$ in equation (3.11), and while its coefficient estimate was significant (and negative), the fit was slightly worse. When $MOOD_{t-1}$ and $MOOD_{t-2}$ were included together in the equation, neither was significant and the fit was not improved. With respect to the ECAR index, equation (3.11) was reestimated for the shorter period of estimation, and the results of this equation were compared with the results achieved by replacing $MOOD_{t-2}$ with $ECAR_{t-1}$ or $ECAR_{t-2}$ in the equation. The coefficient estimates of $ECAR_{t-1}$ or $ECAR_{t-2}$ were significant (and negative), but the fits were not as good. Again, the index of consumer sentiment appeared to have more explanatory power than did the index of expected new car purchases. The services equation was quite stable in the sense that estimating equation (3.11) for the shorter period of estimation resulted in little change in the coefficient estimates.

With respect to the lag structure of service consumption on income, the choice in favor of using the lagged consumption variable was clear. When an equation like (3.11) was estimated using lagged income in place of lagged consumption, the results were much worse:

$$\underset{(1.58)}{CS_t = 13.23} + \underset{(4.38)}{.196}\ \widehat{GNP_t} + \underset{(1.52)}{.067}\ GNP_{t-1} - \underset{(3.12)}{.166}\ MOOD_{t-2}$$

$$\hat{r} = \underset{(18.59)}{.935}$$

$$\text{SE} = 1.066 \qquad (3.12)$$

$$R\Delta^2 = .349$$

50 observ.

$[1, GNP_{t-1}, GNP_{t-2}, CD_{t-1}, CD_{t-2}, CN_{t-1}, CN_{t-2}, CS_{t-1}, V_{t-1}, V_{t-2}, G_t, MOOD_{t-2}, MOOD_{t-3}, PE2_t, PE2_{t-1}]$.

The results in (3.12) are quite poor, as might have been expected from the significance of CS_{t-1} in equation (3.11). The $R\Delta^2$ has dropped from .891 in equation (3.11) to .349 in equation (3.12).[11] Serial correlation is extremely pronounced in (3.12), reflecting in this case the omission of the lagged dependent variable.

Finally, with respect to the possible use of DPI as the income variable,

[11] When the R-squared was computed in terms of levels rather than changes, it only dropped from .9999 in (3.11) to .9995 in (3.12), which indicates the conceptual advantage of computing the R-squared in terms of changes.

an equation like (3.11) was estimated using DPI in place of GNP as the income variable. The results were:

$$CS_t = \underset{(4.05)}{.034}\ \widehat{DPI_t} + \underset{(47.14)}{.946}\ SC_{t-1} - \underset{(6.50)}{.030}\ MOOD_{t-2}$$

$$\hat{r} = \underset{(.38)}{-.054}$$

$$SE = .441 \qquad (3.13)$$

$$R\Delta^2 = .886$$

50 observ.

$$[1, DPI_{t-1}, CD_{t-1}, CD_{t-2}, CN_{t-1}, CN_{t-2}, CS_{t-1}, CS_{t-2}, V_{t-1}, V_{t-2}, G_t, MOOD_{t-2}, MOOD_{t-3}, PE2_t, PE2_{t-1}].$$

The fit of equation (3.13), which uses DPI, is slightly worse than the fit of equation (3.11), which uses GNP. No explanatory power has been lost by using GNP in place of DPI in the equation explaining the consumption of services.

3.6 Summary

The emphasis in this chapter has been on examining the role that consumer sentiment and buying expectations play in influencing short-run changes in consumption. This role appears to be an important one, since both the Michigan Survey Research Center index of consumer sentiment and the Bureau of the Census index of expected new car purchases were significant in the consumption equations when considered separately. When considered together, the consumer sentiment index dominated the buying expectations index, and the latter was not used in the final versions of the equations. The buying expectations index did not appear to contain information not already contained in the consumer sentiment index.

In addition to the use of the consumer sentiment index, consumption has been explained by income and, in two of the three cases, by lagged consumption. GNP was used as the income variable in the equations instead of disposable personal income. No loss of explanatory power in the durable consumption and service consumption equations resulted from this procedure, but some loss of explanatory power did occur in the nondurable consumption equation. It was conjectured that GNP may be in part serving as a proxy for consumer confidence in the short run and that this may be why no explanatory power was lost in the durable equation by using GNP as the income variable. Because of the desire to keep the model as simple as possible, an income side was not developed to explain disposable personal income, and thus disposable personal income was not included in any of the final equations of the model.

There was some slight evidence that durable and nondurable consumption and service consumption are substitutes in the short run, since the consumer sentiment variable had a negative influence in the services equation and a positive influence in the other two equations. Consumption of services was also less influenced by current income changes than were the other two consumption categories, and it was clearly the easiest to explain of the three.

The results in this chapter actually have a bearing on the specification of large-scale structural models. The results indicate that some measure of consumer attitudes should be included in short-run consumption functions. In large-scale structural models, consumer attitude variables should probably not be treated as exogenous, but this does not mean that they should be excluded from the analysis altogether. What needs to be done is to discover the factors that determine consumer attitudes and then to incorporate these factors directly into the models.

4 Plant and Equipment Investment

4.1 Introduction

In this chapter the equation explaining plant and equipment investment will be discussed. Forecasting plant and equipment investment is greatly facilitated by the use of the OBE–SEC survey of expected investment expenditures, and the work in this chapter relies heavily on this survey. In Section 4.2 the survey will be briefly described and the series that has been used for the work here will be explained. In Section 4.3 the final equation will be derived, and in Section 4.4 the results of estimating the equation will be presented. The possible effects of monetary policy on investment expenditures and expectations will then be briefly discussed in Section 4.5.

4.2 The OBE–SEC Survey of Expected Investment Expenditures

The OBE–SEC survey is conducted in January–February, April–May, July–August, and October–November of each year, and at each of these times firms are asked to estimate their plant and equipment investment expenditures for the next one to four quarters ahead. These expectations are then adjusted when necessary for "systematic tendencies" and published in the March, June, September, and December issues of the *Survey of Current Business.* The usefulness of these expectations for predicting plant and equipment investment is well known, and the data have been widely used.[1]

In the March issue of the *Survey of Current Business*, data on expectations are available for the first and second quarters and for the second half of the year; in the June issue data are available for the second, third, and fourth quarters; in the September issue data are available for the third and fourth quarters; and in the December issue data are available for the fourth, first, and second quarters.[2] There are thus two expectations published for the first quarter, three for the second quarter, two for the third quarter, three for the fourth quarter, and one for the third and fourth quarters

[1] See, for example, Eisner [11], Evans and Klein [13], Friend and Taubman [23], and Jorgenson [29].

[2] The data are, of course, available somewhat before the issues are actually published.

combined. Since continuous series are needed for purposes of estimation, only two expectation series are available for use in this regard, the one-quarter-ahead expectation series and the two-quarter-ahead expectation series.

In the last few years the OBE–SEC has been expanding the survey, and in 1969 for the first time they began collection of three-quarter-ahead expectations for the first and third quarters.[3] (As mentioned above, three-quarter-ahead expectations were already being collected for the second and fourth quarters.) In the future one should thus be able to construct a continuous series on three-quarter-ahead expectations, but for present purposes only two continuous series could be constructed. It should be noted, however, that for present purposes the three-quarter-head expectations that are available can be used as proxies for the two-quarter-ahead expectations. The use of these expectations for this purpose is discussed in Chapter 13, where the sensitivity of the model to errors made in forecasting the exogenous variables is examined. It should also be noted that four-quarter-ahead expectations of the fourth quarter will be available in the future. Since the March issue already publishes expectations for the second half of the year and since collection of three-quarter-ahead expectations for the third quarter has begun, this implies that four-quarter-ahead expectations of the fourth quarter will be available. Collection of expectations for the second half of the year has also begun to be made in the October–November survey, which means that four-quarter-ahead expectations for the second half of the year will also be available.[4] In short, the OBE–SEC expectations survey should be even more useful in the future than it has been in the past, but for purposes of estimation in this chapter, attention will have to be concentrated on the one-quarter-ahead and two-quarter-ahead expectation series.

Comparing the two expectations, the one-quarter-ahead expectation should be more accurate than the two-quarter-ahead expectation, since it is made three months later. For the one-quarter-ahead expectation, firms should have had a chance to revise their two-quarter-ahead expectation in the light of more recent developments. For forecasting purposes, however, the two-quarter-ahead expectation has the advantage of being available three months earlier, and for this reason most of the emphasis in this study has been placed on the two-quarter-ahead expectation series. The one-quarter-ahead expectation series has been used only for some of the work in Chapter 13.

It should perhaps be mentioned, although it does not directly affect the work in this study, that at the beginning of 1970 the OBE–SEC revised the

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[3] Wimsatt and Woodward [47], p. 19, fn. 1.
[4] Ibid.

expectation series in what seems to be an undesirable way. In the February 1970 issue of the *Survey of Current Business* [47], they issued "revised" estimates of the one-quarter-ahead and two-quarter-ahead expectation series. The revised estimates were obtained by first taking the raw data and regressing over the entire sample period (for each industry) the ratio of actual expenditures to expected expenditures on seasonal dummy variables, time, and time-squared. These estimates were then used (when significant) to obtain the "corrected" expected expenditure numbers. The corrected expenditure numbers were then seasonally adjusted.

There are a number of things wrong with this procedure, not the least of which is the use of time and time-squared in the regressions. By using these variables, the OBE–SEC is beginning to estimate a realizations function (assuming that time and time-squared are picking up some of the cyclical pattern of the economy), and it is not the stated intention of the survey to present expected expenditure numbers that have been fed through a cyclical realizations function. Also, it seems unlikely that the estimates of the coefficients of time and time-squared in the regressions will remain constant over time. The use of the entire sample period to estimate the regressions is also a questionable procedure, since in actual forecasting situations data are available only up to the initial quarter being forecast. The revised estimates published in the February 1970 issue are not numbers that could have been obtained at the time the expected expenditure numbers were first published.

The revised expected expenditure numbers were not used in this study. Rather, the numbers that were first published in the *Survey of Current Business* were used. These numbers were adjusted for "systematic tendencies" (mostly seasonal tendencies) at the time they were published, but these adjustments are less questionable than the ones described above, and they obviously were based only on data that were actually available at the time the numbers were being published. The numbers that have been used are presented in Appendix A.

The revised numbers were in fact used to estimate equations like the ones below, and the results were distinctly inferior to the results presented below. In particular, the use of the one-quarter-ahead expectation series led to poorer results than the use of the two-quarter-ahead expectation series, which does not seem reasonable and which is not consistent with the results below.

With respect to the future use of the OBE–SEC series, it should prove to be possible, if necessary, to use the OBE–SEC raw data each quarter to construct expected expenditure numbers that are similar to those that were constructed in the past. From personal correspondence with the OBE, however, it appears that the time and time-squared regressions are not going to be mechanically extrapolated into the future in adjusting the raw data. In practice, therefore, the new published numbers may actually be adjusted in a way that is closer to the way the "unrevised" numbers were adjusted than to the way the revised numbers were adjusted.

4.3 A Simple Realizations Function

Given that the OBE–SEC expectation series is to be used in the explanation of plant and equipment investment, the question arises as to what other variables, if any, should be included in the equation. The following is a simple model relating actual investment expenditures to expected investment expenditures.

It seems likely that firms have some flexibility in changing their investment expenditures from what they had originally expected them to be as the economic situation changes from what it was originally expected to be. Let GNP_t^e denote the level of gross national product expected by the firms for quarter t, the expectations being made at the same time the plant and equipment investment expectations are made, and let GNP_t continue to denote the actual level of gross national product during quarter t. The equation explaining actual plant and equipment investment is then postulated to be (using the two-quarter-ahead expectation variable):

$$IP_t = a_0 + a_1(GNP_t - GNP_t^e) + a_2 PE2_t + u_t. \tag{4.1}$$

IP_t is the actual investment during quarter t, $PE2_t$ is the two-quarter-ahead expectation for quarter t, and u_t is an error term. The coefficient a_1 in equation (4.1) is expected to be positive: if GNP is larger than expected for a given quarter, this should have a positive effect on actual investment for that quarter, and conversely if GNP is smaller than expected. The coefficient a_2 in equation (4.1) should perhaps be constrained to be one; but it makes no difference in the following analysis whether this is done or not.

Data are available on IP_t, GNP_t, and $PE2_t$ in (4.1), but data are not directly available on GNP_t^e. Consequently, a further assumption is necessary in order to eliminate GNP_t^e from the equation. As a rough approximation it is postulated that

$$PE2_t = b_0 + b_1 GNP_t^e, \tag{4.2}$$

i.e., that the expected amount of plant and equipment investment for quarter t is a function of the expected level of gross national product for quarter t. (Remember that the expectations of investment and GNP have been assumed to be made at the same time.) This is admittedly a crude hypothesis, since expected plant and equipment investment is also likely to be a function of monetary variables and of expected levels of GNP for quarters beyond t. Given the highly aggregative nature of the data, however, the hypothesis may be adequate for present purposes.

Equation (4.2) can be solved for GNP_t^e and substituted into equation (4.1) to eliminate GNP_t^e from (4.1). This yields:

$$IP_t = \left(a_0 + \frac{a_1 b_0}{b_1}\right) + a_1 GNP_t + \left(a_2 - \frac{a_1}{b_1}\right) PE2_t + u_t. \qquad (4.3)$$

Equation (4.3) states that actual investment in quarter t is a function of GNP in quarter t and of the amount of investment expected for quarter t. Due to the likelihood that many relevant variables have been omitted from the analysis, the error term in equation (4.3) is likely to be serially correlated.

4.4 The Equation Estimates

Equation (4.3) was taken as the basic equation relating expected expenditures to actual expenditures, and the following equation was estimated using the two-quarter-ahead expectation variable:

$$\begin{gathered} IP_t = \underset{(4.86)}{-\ 8.50} + \underset{(8.87)}{.063}\ \widehat{GNP_t} + \underset{(8.34)}{.687}\ PE2_t \\ \hat{r} = \underset{(6.72)}{.689} \\ \text{SE} = 1.011 \\ R\Delta^2 = .633 \\ \text{50 observ.} \\ [1, IP_{t-1}, GNP_{t-1}, CD_{t-1}, CD_{t-2}, CN_{t-1}, CN_{t-2}, CS_{t-1}, CS_{t-2}, \\ V_{t-1}, V_{t-2}, G_t, MOOD_{t-2}, PE2_t, PE2_{t-1}]. \end{gathered} \qquad (4.4)$$

IP_t is the amount of nonresidential fixed investment during quarter t seasonally adjusted at annual rates in billions of current dollars, and $PE2_t$ is the two-quarter-ahead expectation of plant and equipment investment for quarter t seasonally adjusted at annual rates in billions of current dollars.[5] Both the

[5] Actually, the IP_t and $PE2_t$ series do not refer to the same thing. IP_t, which is the estimate of fixed nonresidential investment for the national income accounts, includes agricultural investment and certain equipment and construction outlays charged to current expense that the $PE2_t$ series does not. For 1968 IP was 88.8 billion dollars, while the actual P (plant and equipment investment corresponding to the PE2 series) was 67.76 billion dollars.

It turned out that the results using IP_t were better than the results obtained by treating P_t and $IP_t - P_t$ as separate variables, and so it was decided not to disaggregate IP_t any further. The results of treating P_t and $IP_t - P_t$ as separate variables will not be reported here.

expectation variable and the GNP variable are highly significant in equation (4.4), and the fit is fairly good. Because of the significance of the GNP variable, firms do appear to have some flexibility in changing their expected investment expenditures in light of current short-run developments. As expected, there is a rather large amount of positive serial correlation of the residuals in equation (4.4).

In an attempt to test for a more complicated lag structure, lagged GNP and then lagged investment were added to equation (4.4). The results were:

$$\begin{aligned} IP_t = &-9.31 - .073\,\widehat{GNP_t} + .143\,GNP_{t-1} + .630\,PE2_t \\ &(4.54) \quad (1.31) \qquad (2.48) \qquad (6.52) \\ &\hat{r} = .695 \\ &\quad (6.84) \\ &\text{SE} = 1.159 \\ &R\Delta^2 = .528 \\ &50 \text{ observ.} \\ &[\text{variables same as for (4.4) plus } GNP_{t-2}]. \end{aligned} \tag{4.5}$$

$$\begin{aligned} IP_t = &-6.47 + .045\,\widehat{GNP_t} + .217\,IP_{t-1} + .590\,PE2_t \\ &(4.30) \quad (5.12) \qquad (1.95) \qquad (5.56) \\ &\hat{r} = .582 \\ &\quad (5.06) \\ &\text{SE} = 1.013 \\ &R\Delta^2 = .640 \\ &50 \text{ observ.} \\ &[\text{variables same as for (4.4) plus } IP_{t-2}]. \end{aligned} \tag{4.6}$$

Equation (4.5) is clearly not an improvement over equation (4.4), since the current GNP variable is no longer significant in the equation and the fit has not been improved.[6] In equation (4.6) the lagged investment variable is nearly significant, but the fit has not been noticeably improved (the standard error of the regression has actually risen slightly). Since the theoretical justification of including IP_{t-1} in the equation is to begin with somewhat

[6] Notice that the (unadjusted) R-squared actually decreased when GNP_{t-1} was added to the equation, a situation which can happen when using two-stage least squares techniques. Since GNP_{t-1} dominated GNP_t in equation (4.5), an equation like (4.4) was estimated with GNP_{t-1} replacing GNP_t to see if the use of GNP_{t-1} led to better results. The fit of the resulting equation ($R\Delta^2 = .620$) was slightly worse than the fit of equation (4.4).

weak, equation (4.6) was dropped from further consideration.[7] Equation (4.4) was thus taken to be the basic equation determining plant and equipment investment expenditures.

To see how the results compared, an equation like (4.4) was also estimated using the one-quarter-ahead expectation variable:

$$\begin{aligned} IP_t = &-6.36 + .046\,\widehat{GNP}_t + .874\,PE1_t \\ &\ (5.59)\quad (7.76)\qquad\quad (12.65) \\ &\hat{r} = .572 \\ &\quad\ (4.94) \\ &SE = .873 \\ &R\Delta^2 = .727 \\ &50 \text{ observ.} \end{aligned} \tag{4.7}$$

$$[1, IP_{t-1}, GNP_{t-1}, CD_{t-1}, CD_{t-2}, CN_{t-1}, CN_{t-2}, CS_{t-1}, CS_{t-2}, V_{t-1}, V_{t-2}, G_t, MOOD_{t-2}, PE1_t, PE1_{t-1}].$$

$PE1_t$ is the one-quarter-ahead expectation of plant and equipment investment for quarter t seasonally adjusted at annual rates in billions of current dollars. The fit of this equation is better than the fit of equation (4.4), which uses the two-quarter-ahead expectation variable; the coefficient estimate of the expectation variable is larger; and the coefficient estimate of the income variable is smaller (but is still highly significant). All of these results are as expected. Firms still appear to have some flexibility in changing their expected investment expenditures, but not as much as for the longer (6-month) adjustment period implied by equation (4.4). Equation (4.7) was taken to be the basic equation determining plant and equipment investment for some of the work in Chapter 13, but otherwise the equation has not been considered in the work below.

4.5 The Effect of Monetary Policy on Investment

So far little mention has been made of the possible effect of monetary policy on investment expenditures. To the extent that monetary policy (as reflected, say, through interest rates) affects investment expectations, this is reflected

[7] Presumably IP_{t-1} should be picking up the effect of lagged values of GNP and PE2, but the effect of lagged values of GNP from at least quarter $t-2$ on back should already be reflected in the $PE2_t$ variable, and there is little reason for believing that lagged values of PE2 have much effect on IP_t.

through the $PE2_t$ variable in equation (4.4). Equation (4.4) thus incorporates some of the effects of monetary policy on IP_t because of the inclusion of the $PE2_t$ variable. Since data on $PE2_t$ are available about 5 months ahead of the forecast period and since proxies for $PE2_t$ are available up to about a year ahead, it does not appear to be too important to specify more directly the effects of monetary policy on IP_t.

There is still the question, however, whether short-term credit conditions affect the relationship between $PE2_t$ and IP_t specified in equation (4.4). It may be, for example, that tight credit conditions cause less investment to be realized, other things being equal, than do loose credit conditions. In an effort to test for this, a number of short-term interest rates and other measures of short-term credit conditions were tried in equations like (4.4). None of these variables proved to be significant, however, and no evidence could be found that the relationship between $PE2_t$ and IP_t in (4.4) is affected by short-term credit conditions.

It should also be mentioned that in the initial phases of this study an equation explaining $PE2_t$ was developed. $PE2_t$ was taken to be a function of a lagged capital stock variable, of lagged values of GNP, and of lagged values of the (long-term) corporate bond rate. The coefficients were all significant and of the expected signs, and in particular the corporate bond rate had a significantly negative effect on $PE2_t$. This equation could have been used in the model to forecast values of $PE2_t$ for those quarters in which data for $PE2_t$ were not available. Experimentation with this equation indicated, however, that using the proxies for $PE2_t$ that are available from the OBE–SEC survey and then using extrapolated values for the remaining values gave better results than using the estimated $PE2_t$ equation to forecast the values of $PE2_t$. The estimated $PE2_t$ equation did not appear to be good enough to warrant its inclusion in the model, and so it was decided to treat $PE2_t$ as a completely exogenous variable. Since the corporate bond rate entered the $PE2_t$ equation with an average lag of only about three quarters, it would also have been necessary for the four-quarter-ahead forecasts and beyond to forecast the bond rate exogenously or else explain it within the model. It appeared to be at least as accurate in this case to forecast $PE2_t$ directly. For a policy model, of course, it would not have been appropriate to drop the $PE2_t$ equation. For forecasting purposes, however, the results achieved in this study indicated that little accuracy is likely to be lost by not incorporating the effects of monetary policy directly in the model.

5 Housing Investment

5.1 Introduction

In this chapter the equation explaining housing investment will be discussed. Housing starts have been treated as exogenous in the chapter, and housing investment has essentially been taken to be a function of current and lagged values of housing starts. Given housing starts, housing investment is rather easy to explain, and so this chapter can be brief. Much more substantiative issues regarding the housing sector will be discussed in Chapter 8, where equations explaining the monthly level of housing starts are developed. In Section 5.2 the basic equation explaining housing investment will be derived, and in Section 5.3 the results of estimating the equation will be presented.

5.2 Determining Housing Investment from Housing Starts

The OBE constructs the quarterly figures on housing investment for the national income accounts from monthly figures. The monthly figures on housing investment are constructed by applying a set of given weights, extending over a seven-month period, to the (seasonally unadjusted) number of housing units started each month times the average cost per start for that month. The investment figures constructed in this way are then seasonally adjusted.

Using the *value* of seasonally adjusted quarterly housing starts (at annual rates) and quarterly housing investment, Maisel [35] takes .41, .49, and .10 to be the respective weights for current, one-quarter-lagged, and two-quarter-lagged housing starts in his housing investment equation. These weights are derived from the monthly weights used by the OBE to construct the unseasonally adjusted housing investment figures.

Let HS_i denote the number of housing starts during month i. Since seven months is assumed by the OBE to be the time taken to build a house, IH_i is

$$IH_i = a_0 HS_i + a_1 HS_{i-1} + a_2 HS_{i-2} + a_3 HS_{i-3} + a_4 HS_{i-4} + a_5 HS_{i-5} + a_6 HS_{i-6}, \tag{5.1}$$

where a_0 is the average expenditure per house in month i for houses started in month i, a_1 is the average expenditure per house in month i for houses started in month $i-1$, and so on. The specification in (5.1) is not meant to imply that the $a_0, a_1, \ldots, a_6$ coefficients are constant over time: they will certainly vary as the average cost of a house varies.

Equation (5.1) implies that quarterly housing investment is

$$\begin{aligned} IH_i + IH_{i-1} + IH_{i-2} = {} & a_0 HS_i + (a_0 + a_1)HS_{i-1} + (a_0 + a_1 + a_2)HS_{i-2} \\ & + (a_1 + a_2 + a_3)HS_{i-3} + (a_2 + a_3 + a_4)HS_{i-4} \\ & + (a_3 + a_4 + a_5)HS_{i-5} + (a_4 + a_5 + a_6)HS_{i-6} \\ & + (a_5 + a_6)HS_{i-7} + a_6 HS_{i-8} \; . \end{aligned} \tag{5.2}$$

Equation (5.2) states that quarterly housing investment is a function of the number of housing starts of the three months of the current quarter and the number of starts of the previous six months. In the work of Maisel referred to above, quarterly housing investment is taken to be a weighted average of the number of housing starts for the current quarter, $HS_i + HS_{i-1} + HS_{i-2}$, the number of starts of the previous quarter, $HS_{i-3} + HS_{i-4} + HS_{i-5}$, and the number of starts of the quarter before that, $HS_{i-6} + HS_{i-7} + HS_{i-8}$, each of the quarterly housing starts figures being seasonally adjusted and multiplied by the average cost of a house for that quarter.

To use the particular weighted average discussed above requires knowledge of the average cost per house in each quarter. For large-scale models this variable could be explained within the model, as Maisel does for the Brookings model, but an explanation of this variable is beyond the scope of the model developed in this study. Rather than attempt to use the above weights, therefore, a somewhat cruder approach was followed.

Let HS_{it} denote the number of housing starts during the ith month of quarter t, i running from 1 to 3. Then the quarterly seasonally adjusted level of housing starts for quarter t, HSQ_t, is defined to be:

$$HSQ_t = (HS_{1t} + HS_{2t} + HS_{3t})SQ_t, \tag{5.3}$$

where SQ_t is the quarterly seasonal adjustment factor.[1] Quarterly seasonally adjusted housing investment, IH_t, is then assumed to be a linear function of

[1] For the work below, the HSO_t series was seasonally adjusted by a simple ratio to moving average process. For purposes that will be explained in Chapter 12, only data through 652 were used in the construction of the seasonal adjustment coefficients. (The coefficients were actually quite insensitive to changes in the sample period.) The figures for SQ_t are presented in Appendix A.

HSQ_t, HSQ_{t-1}, HSQ_{t-2}, and of the current level of GNP:

$$IH_t = b_0 HSQ_t + b_1 HSQ_{t-1} + b_2 HSQ_{t-2} + c_1 GNP_t + c_0 + u_t, \quad (5.4)$$

where c_0 is the constant term and u_t is the error term. Since the HSQ variables in equation (5.4) are not in dollar terms and since the average cost per house is likely to be a function of the level of money GNP, the GNP variable has been added to the equation in an attempt to pick up the influence of prices on quarterly housing investment.

It is admittedly a long step from equation (5.1) to equation (5.4). The b_i coefficients in equation (5.4) cannot be derived from the weights used by the OBE to construct the housing investment figures because the housing starts variables in equation (5.4) are not in value terms. The a_j coefficients in equation (5.1) are in units of expenditures per house per month, and in the specification of equation (5.4) it is implicitly assumed that the a_j coefficients are of such a nature that the quarterly aggregate HSQ can be used and that the effects of price changes can be adequately reflected in the GNP variable. There is, of course, no guarantee that the coefficients in equation (5.4) will be stable over time. A detailed examination of the housing sector should certainly attempt to explain fluctuations in the price of houses and should also disaggregate housing starts into at least single and multiple dwelling units. For present purposes, however, the results presented below of estimating equation (5.4) appear to be adequate.

5.3 The Results

Because of the lack of good data on housing starts before 1959, equation (5.4) was estimated for the shorter sample period. The results were:

$$\underset{}{IH_t} = \underset{(5.37)}{.0242 HSQ_t} + \underset{(4.45)}{.0230 HSQ_{t-1}} + \underset{(1.66)}{.0074 HSQ_{t-2}} + \underset{(13.12)}{.016\ \widehat{GNP_t}} - \underset{(2.31)}{3.53}$$

$$\hat{r} = \underset{(3.01)}{.449}$$

$$\text{SE} = .582 \quad (5.5)$$

$$R\Delta^2 = .792$$

36 observ.

$[1, IH_{t-1}, GNP_{t-1}, CD_{t-1}, CN_{t-1}, CS_{t-1}, V_{t-1}, V_{t-2}, G_t, MOOD_{t-2},$
$PE2_t, PE2_{t-1}, HSQ_t, HSQ_{t-1}, HSQ_{t-2}, HSQ_{t-3}]$.

IH_t is the amount of nonfarm residental fixed investment during quarter t

seasonally adjusted at annual rates in billions of current dollars.[2] HSQ is defined in (5.3) and is seasonally adjusted at quarterly rates in thousands of units. It refers only to nonfarm housing starts.

All of the variables except HSQ_{t-2} are significant in equation (5.5) and the fit is good. About 80 percent of the variance of the change in IH_t has been explained by the equation, and the standard error is low relative to the accuracy expected of the overall model. Serial correlation is moderate. HSQ_{t-2} was left in equation (5.5) even though it was not significant because theoretically it belongs in the equation: the data that make up HSQ_{t-2} are used by the OBE in the construction of IH_t.

Equation (5.5) was chosen as the basis equation determining housing investment, but other equations were estimated before arriving at this decision. A time trend was added to equation (5.5) to see if there were trend factors affecting the relationship specified in (5.5). This did not appear to be the case, since the time trend was not significant. An equation similar to (5.2) was also estimated, in which quarterly housing investment was regressed against the one current and the eight lagged values of the *monthly* housing starts variables.[3] Current GNP and a constant term were also included in the equation, as they were in equation (5.5). Current GNP was added in an attempt to pick up the influence of prices on housing investment. The basic difference between this equation and equation (5.5) was that this equation did not put any constraints on the coefficients of the monthly housing starts variables, as does equation (5.5).[4] Considering the large number of variables included and the relatively small number of observations, the results of estimating this equation were reasonably good. The results did not, however, appear to be an improvement over the results in (5.5). The constraints imposed by (5.5), in other words, did not appear to be very restrictive. The standard error of the regression, which is adjusted

[2] Actually, the housing starts series is strictly relevant only for the new nonfarm dwelling unit component of nonfarm residential fixed investment. Since investment in new nonfarm dwelling units is by far the largest and most volatile component of nonfarm residential fixed investment and since at least some of the other components (such as broker's commissions) are likely to fluctuate with housing starts as well, it was decided not to disaggregate nonfarm residential fixed investment any further.

[3] As above, let HS_{it} denote the number of housing starts during the ith month of quarter t, i running from 1 to 3. Then IH_t was regressed against HS_{3t}, HS_{2t}, HS_{1t}, HS_{3t-1}, HS_{2t-1}, HS_{1t-1}, HS_{3t-2}, HS_{2t-2}, and HS_{1t-2}. IH_t is seasonally adjusted, but the HS_{it} series are not, and so in the regression three seasonal dummy variables were added to pick up any seasonality in the relationship between the HS_{it} variables and IH_t.

[4] Aside from the question of seasonal adjustment, equation (5.5) constrains the coefficients of HS_{3t}, HS_{2t}, and HS_{1t} to be equal, as well as the coefficients of HS_{3t-1}, HS_{2t-1}, and HS_{1t-1}, and the coefficients of HS_{3t-2}, HS_{2t-2}, and HS_{1t-2}. This can be seen from the discussion in footnote 3 and the definition of HSQ in equation (5.3).

for degrees of freedom, was actually smaller for equation (5.5) than for the other equation. Equation (5.5) was thus chosen over this other equation as the basic equation determining housing investment.

Notice that fewer of the basic instrumental variables were used for equation (5.5) than were used for the equations estimated in the previous two chapters: CD_{t-2}, CN_{t-2}, and CS_{t-2} were omitted from the list of instruments. Since four extra variables (the current and the three lagged values of HSQ) had to be added to the list for equation (5.5), CD_{t-2}, CN_{t-2}, and CS_{t-2} were omitted from the list in order to keep the number of instrumental variables reasonably small relative to the number of observations. As discussed in Fair [17], using a large number of instruments to estimate the equations may increase the small sample bias of the estimates. In the particular case of the housing investment equation, it actually made little difference how many instrumental variables were used, since there was little evidence of simultaneous equation bias in the equation. This can be seen from the results in Appendix B.

6 Inventory Investment

6.1 Introduction

In this chapter the inventory investment equation will be discussed. Inventory investment has much in common with consumption in the sense that it is extremely important in the determination of short-run fluctuations in GNP and at the same time difficult to explain. An eclectic point of view was taken in developing the inventory investment equation in this chapter. Essentially four basic approaches were tried before arriving at the final version. In Section 6.2 the basic theoretical model will be presented and the four approaches will be described. In Section 6.3 the results of following the four approaches will be discussed and the final equation will be presented. A summary of the results of the chapter will be presented in Section 6.4

6.2 The Four Approaches

The Basic Theoretical Model

Let V_t denote the aggregate stock of inventories at the end of period t and let V_t^* denote the desired stock for the end of period t. A basic model of inventory investment that has been widely used is the following simple stock adjustment model:

$$V_t - V_{t-1} = q(V_t^* - V_{t-1}), \qquad 0 \leqq q \leqq 1, \tag{6.1}$$

where

$$V_t^* = a_0 + a_1 SALES_t. \tag{6.2}$$

$SALES_t$ in (6.2) denotes the level of aggregate sales during period t. Equation (6.1) states that the change in the stock of inventories during period t is a function of the difference between the desired stock for the end of period t and the actual stock on hand at the end of period $t - 1$, and equation (6.2) states that the desired stock for the end of period t is a function of the level of sales for the period.

Combining equations (6.1) and (6.2) yields

$$V_t - V_{t-1} = qa_0 + qa_1 SALES_t - qV_{t-1}. \tag{6.3}$$

In other words, inventory investment in period t is a function of the level of sales in period t and of the stock of inventories on hand at the end of period $t-1$. The variable that has been used to measure sales in this study will be discussed in Section 6.3 below.

There are a number of directions in which one can go from this simple model to more complicated and perhaps more realistic models. The four approaches that have been tried in this study are the following.

The First Approach: Disaggregation

V_t as defined above is an aggregate of inventories from manufacturing, retail trade, wholesale trade, construction, and others. Each of these in turn is an aggregate of many dissimilar firms; and, for the manufacturing sector, finished goods inventories, work in progress, and materials and supplies are aggregated together as well. One would not expect the determinants of inventory investment to be the same for all firms and types of inventories, and so disaggregating may prove to be quite helpful.

The Second Approach: The Effect of Expectations

It is well known that expectations play an important role in the determination of inventory investment. The $SALES_t$ variable in equation (6.2) really should be expected sales, since decisions on inventory investment are presumably made before the sales of period t are known. A simple model, which is in the spirit of the work of Lovell [34] and others, is the following.

Let $PROD_t$ denote the aggregate amount produced during period t (as opposed to the amount sold, $SALES_t$). By definition

$$V_t - V_{t-1} = PROD_t - SALES_t, \tag{6.4}$$

i.e., the change in inventories during period t is the difference between production of that period and sales. Planned production, $PROD_t^e$ (the plans being made at the beginning of period t) is assumed to be

$$PROD_t^e = SALES_t^e + b_0(V_t^* - V_{t-1}), \qquad 0 \leqq b_0 \leqq 1, \tag{6.5}$$

where $SALES_t^e$ denotes the expected level of sales for period t, the expectations also being made at the beginning of period t. Equation (6.5) states that planned production is equal to expected level of sales plus an amount that reflects the partial adjustment of the stock of inventories to its desired level.

As the period progresses, actual sales deviate from expected sales, and firms may have enough flexibility in their production plans to change them as a result of the unexpected change in sales. It is thus assumed that

$$PROD_t - PROD_t^e = b_1(SALES_t - SALES_t^e), \qquad 0 \leqq b_1 \leqq 1. \qquad (6.6)$$

If b_1 is equal to 1 in equation (6.6), then firms have complete flexibility in their production plans and never produce more or less than they would like to given the level of sales that actually occurs during period t. If b_1 is equal to 0, then firms have no flexibility and produce what they decide to produce at the beginning of the period regardless of what happens to sales. Most firms, of course, are probably somewhere between these two extremes.

Adding equations (6.5) and (6.6), solving equation (6.4) for $PROD_t$, and substituting the resulting expression for $PROD_t$ into the sum of (6.5) and (6.6) yields

$$V_t - V_{t-1} = (1 - b_1)(SALES_t^e - SALES_t) + b_0(V_t^* - V_{t-1}). \qquad (6.7)$$

If desired inventories are then taken to be a function of expected sales (which is similar to the assumption made in (6.2)),

$$V_t^* = c_0 + c_1 SALES_t^e, \qquad (6.8)$$

then equation (6.7) gives inventory investment as a function of expected sales, the stock of inventories at the end of the previous period, and the difference between expected and actual sales:

$$V_t - V_{t-1} = b_0 c_0 + b_0 c_1 SALES_t^e - b_0 V_{t-1} + (1 - b_1)(SALES_t^e - SALES_t). \qquad (6.9)$$

Equation (6.9) cannot be estimated directly because expected sales are not directly observed. A simple assumption that can be made about how expectations are formed is the following:

$$SALES_t^e = SALES_{t-1} + \bar{S}, \qquad (6.10)$$

where $\bar{S}$ is a constant. Equation (6.10) states that the level of sales expected for period t is equal to the observed level of sales for period $t - 1$ plus some constant amount. In other words, the *change* in sales is expected to be constant from quarter to quarter. The assumption in (6.10) has been used in the empirical work below. While the assumption is quite simple, it is unlikely that the aggregate data used in this study are capable of distinguishing among more complicated expectational hypotheses. Indeed, even the concept of an aggregate level of expected sales is somewhat vague.

The expression for $SALES_t^e$ in equation (6.10) can be substituted into equation (6.9) to eliminate $SALES_t^e$ from the equation. This yields:

$$V_t - V_{t-1} = [b_0 c_0 + b_0 c_1 \bar{S} + (1 - b_1)\bar{S}] + b_0 c_1 SALES_{t-1} \\ - b_0 V_{t-1} + (1 - b_1)(SALES_{t-1} - SALES_t). \qquad (6.11)$$

Equation (6.11) is now in a form that can be estimated, given the measure of sales that is to be used.

The Third Approach: A More Complicated Adjustment Process

A third way in which the model introduced at the beginning of this section can be expanded is by assuming a more complicated adjustment process than (6.1) for inventory investment. Assume first of all that desired inventory investment for period t, denoted as $(V_t - V_{t-1})^d$, is

$$(V_t - V_{t-1})^d = q_0(V_t^* - V_{t-1}), \qquad 0 \leqq q_0 \leqq 1, \qquad (6.12)$$

where V_t^* still denotes the desired stock of inventories for the end of period t. V_t^* is assumed to be a function of $SALES_t$ as postulated in equation (6.2). It is now further assumed that desired inventory investment is subject to an adjustment process:

$$(V_t - V_{t-1}) - (V_{t-1} - V_{t-2}) = q_1[(V_t - V_{t-1})^d - (V_{t-1} - V_{t-2})], \\ 0 \leqq q_1 \leqq 1. \qquad (6.13)$$

In other words, it is assumed that, due to adjustment costs and the like, only part of the desired inventory investment is actually achieved during any one period.

Combining equations (6.2), (6.12), and (6.13) yields

$$V_t - V_{t-1} = q_1 q_0 a_0 + q_1 q_0 a_1 SALES_t - q_1 q_0 V_{t-1} + (1 - q_1)(V_{t-1} - V_{t-2}), \qquad (6.14)$$

which is equivalent to adding the lagged dependent variable, $V_{t-1} - V_{t-2}$, to the basic equation (6.3). Equation (6.14) can be further complicated by making the above assumptions about how expectations effect inventory investment. Doing this results in the variable $V_{t-1} - V_{t-2}$ being added to equation (6.9).

The Fourth Approach: Adding Other Variables

A fourth way of trying to improve the explanatory power of equation (6.3), especially for forecasting purposes, is to add various expectational variables. One of the more successful attempts in this area has been the work of Friend and Taubman [23]. They add the plant and equipment investment expectation variable, $PE2_t$, to an equation like (6.3) and find that this variable is highly significant and improves the fit of the equation considerably. This is probably due to the fact that capital goods require a relatively long time to complete, so that large plant and equipment expenditures require that large stocks of inventories be held during the construction period. $PE2_t$ is a particularly desirable variable to use in a forecasting model because data or proxies on it are available ahead of the prediction period. In other studies, variables like unfilled orders, the change in unfilled orders, and Department of Defense obligations (either current or lagged values) have been added to equations like (6.3), with partial success in some cases. (See, for example, Darling and Lovell [7].) These variables are of limited use in a forecasting model, however, because of the difficulties involved in trying to explain them within the model or else forecast them exogenously.

Two new series that may prove to be useful for forecasting purposes have recently become available from a quarterly survey of manufacturing firms conducted by the OBE. The survey is conducted in February, May, August, and November of each year, and firms are asked to estimate the level of inventories they expect for the current quarter and the forthcoming quarter. In addition, they are asked to evaluate the condition of their inventories (high, about right, or low) relative to their sales and their unfilled orders position as of the last day of the previous quarter (December 31, March 31, June 30, and September 30, respectively). The inventory expectations series are adjusted for "systematic tendencies," and the figures are published in March, June, September, and December issues of the *Survey of Current Business*. Also published in these issues are series on the percent of firms (weighted by inventory book values) reporting their inventory conditions as high, about right, and low. The two series on inventory expectations are available from the third quarter of 1961 to the present, and the series on inventory conditions are available from the first quarter of 1959 to the present.

For purposes of the discussion below, $VE1_t$ will denote the one-quarter-ahead expectation of the stock of inventories for quarter t for all of manufacturing, $VE2_t$ will denote the two-quarter-ahead expectation for quarter t, and VH_t will denote a variable which is defined as the percent of firms reporting their inventory conditions as high minus the percent reporting their conditions as low (for all manufacturing). For VH_t the t refers to the quarter for which the evaluation was made. (For example, for the evaluation concerning inventory conditions as of 31 December 1967, the t is 674.) VH_t is meant to be a measure of how dissatisfied manufacturing firms are with their stock of inventories.

6.3 The Results

In developing the inventory equation for the present model, essentially all four of the above approaches were tried. With respect to the disaggregation question (the first approach), an attempt was made in the initial phases of this study to disaggregate total inventory investment into that for durable manufacturing, nondurable manufacturing, retail trade, wholesale trade, and all other. This attempt failed. The estimates of the individual equations were of dubious quality, and when tests like those described in Chapter 11 were performed, the versions of the model that included the disaggregated inventory investment equations yielded poorer results than the versions that included only one aggregated inventory equation. The results of this attempt will not be presented here.

There are two probable reasons why this attempt failed. In the first place, the disaggregation was not a true disaggregation, since an aggregate sales variable was used for each equation rather than the sales of the individual sector. This is admittedly a questionable procedure, but attempting to forecast or explain sales of individual sectors of the economy is beyond the scope of the present model. Secondly, the "all other" category of necessity included the inventory valuation adjustment figures of the OBE. This variable is subject to large short-run fluctuations and is difficult to explain, at least within the context of this model. The failure here, therefore, does not necessarily indicate that it is undesirable to disaggregate inventory investment, but only that to do so requires a considerably larger model than the one developed here.

The second approach, determining the effect of sales expectations on inventory investment, did meet with some success. In following the approach, it was necessary to decide which variable to use for the aggregate sales variable in equation (6.11). A number of variables were tried, and the one that gave the best results was the sum of durable and nondurable consumption, $CD_t + CN_t$. Adding variables such as consumption of services, CS_t, plant and equipment investment, IP_t, and the federal government defense component of G_t to $CD_t + CN_t$ did not improve the results. The sales variable defined as total GNP less inventory investment, $GNP_t - (V_t - V_{t-1})$, was also tried in place of $CD_t + CN_t$, and again the results were not as good. It definitely appeared to be the case that the sum of durable and nondurable consumption was the primary sales variable affecting aggregate inventory investment.

For all of the estimates, the simple assumption in equation (6.10) about expectations was made: the level of expected sales for period t was assumed to be equal to the actual level of sales in period $t - 1$ plus a constant amount. Equation (6.11) was thus the basic equation estimated. Using $CD_t + CN_t$ as the sales variable, the results of estimating equation (6.11) over the larger sample period were:

$$\begin{aligned} V_t - V_{t-1} = \underset{(6.09)}{-114.76} + \underset{(4.27)}{.728}\,(CD_{t-1} + CN_{t-1}) - \underset{(3.94)}{.357}\,V_{t-1} \\ + \underset{(0.42)}{.095}(CD_{t-1} + CN_{t-1} - \widehat{CD}_t - \widehat{CN}_t) \\ \hat{r} = \underset{(9.15)}{.791} \\ SE = 2.540 \qquad\qquad (6.15) \\ R\Delta^2 = .589 \\ \text{50 observ.} \end{aligned}$$

$$[1, GNP_{t-1}, CD_{t-1}, CD_{t-2}, CN_{t-1}, CN_{t-2}, CS_{t-1}, CS_{t-2}, V_{t-1}, V_{t-2}, G_t, MOOD_{t-2}, PE2_t, PE2_{t-1}].$$

$V_t - V_{t-1}$ is the change in total business inventories during quarter t seasonally adjusted at annual rates in billions of current dollars, and V_{t-1} is the sum of past inventory investment (the origin being arbitrary[1]). The results in (6.15) definitely indicate that one-quarter-lagged sales are more important in determining inventory investment than are current sales. The coefficient for lagged sales is .728 + .095, while the coefficient for current sales is −.095. The coefficient for current sales is negative, as expected, but it is small and not significant. This implies from equation (6.11) that b_1 is close to 1, which implies from equation (6.6) that firms have considerable flexibility in changing their short-run production plans. This conclusion is, of course, dependent on the validity of the assumption about expectations in equation (6.10).

The other coefficient estimates in (6.15) are of the expected sign (the constant term is expected to be negative because of the zero origin chosen for

[1] The arbitrary value for the origin is merely reflected in the estimate of the constant term in the equation. For the work in this study V_t was assumed to be zero in 534.

the V_t series). The standard error of 2.540 billion dollars in (6.15) is larger than the standard errors for any of the other expenditure equations of the model, which reflects the volatile nature of the inventory investment series. The $R\Delta^2$ is .589 in (6.15), which means that 58.9 percent of the variance of the change in inventory investment (i.e., of $(V_t - V_{t-1}) - (V_{t-1} - V_{t-2})$) has been explained. Note that serial correlation is quite pronounced in (6.15): the estimate of the serial correlation coefficient is .791.

Using equation (6.15) as a base, the third and fourth approaches were then tried. With respect to the third approach, the variable $V_{t-1} - V_{t-2}$ was added to equation (6.15) to test for the more complicated adjustment process specified in equation (6.13). The results were:

$$\begin{aligned} V_t - V_{t-1} = & \underset{(4.37)}{-118.33} + \underset{(4.56)}{.751}\,(CD_{t-1} + CN_{t-1}) - \underset{(4.23)}{.372}\,V_{t-1} \\ & + \underset{(0.55)}{.126}\,(CD_{t-1} + CN_{t-1} - \widehat{CD}_t - \widehat{CN}_t) \\ & + \underset{(0.72)}{.093}\,(V_{t-1} - V_{t-2}) \\ & \hat{r} = \underset{(9.04)}{.788} \\ & \text{SE} = 2.541 \\ & R\Delta^2 = .597 \\ & \text{50 observ.} \\ & \text{[variables same as for (6.15) plus } V_{t-3}\text{].} \end{aligned} \qquad (6.16)$$

The $V_{t-1} - V_{t-2}$ variable is not significant in equation (6.16), and the fit of the equation has not been improved from the fit in (6.15). Also, using $V_{t-1} - V_{t-2}$ in (6.16) has not decreased the estimated amount of serial correlation in the equation to any extent. There is thus little evidence of a more complicated adjustment process than the one specified in (6.1), and so equation (6.16) was dropped from further consideration.

With respect to the fourth approach, a number of equations were estimated using $VE1_t$ or $VE2_t$ or the change in these variables, and the results were not very good.[2] The variables did not appear to have any independent

[2] Data on the VE series were available only from 614 on, and the period of estimation included only 27 observations (622 through 694, excluding the three strike quarters). The series was revised in 634, but since the effect of the revision for total manufacturing was slight, the prerevised and revised figures were taken here as one continuous series. The data for $VE1_t$ and $VE2_t$ are presented in Appendix A.

explanatory power in equations like (6.15). Not too much emphasis should be put on these results, however, since the period of estimation was short and since the VE series is actually relevant only for manufacturing inventory investment and not for the aggregate inventory investment series considered here. What can be concluded from these results is that for purposes of forecasting aggregate inventory investment the VE series at present appears to be of little use.

The use of the inventory condition series (the VH series) also did not produce good results. The current and various lagged values of VH were added to equations like (6.15), and none of the results appeared to be an improvement over the results in (6.15).[3] Again, however, the VH series pertains only to manufacturing inventory investment, so that the negative results here should be interpreted with some caution.

The use of the plant and equipment investment expectation series (the PE2 series) produced somewhat better results. When $PE2_t$ was added to equation (6.15), the results were:

$$
\begin{aligned}
V_t - V_{t-1} = \underset{(4.52)}{-122.28} &+ \underset{(4.45)}{.695}\,(CD_{t-1} + CN_{t-1}) - \underset{(4.33)}{.403}\, V_{t-1} \\
&+ \underset{(0.55)}{.121}\,(CD_{t-1} + CN_{t-1} - \widehat{CD_t} - \widehat{CN_t}) \\
&+ \underset{(1.93)}{.470}\, PE2_t \\
&\hat{r} = \underset{(7.38)}{.722} \qquad\qquad (6.17) \\
&\text{SE} = 2.470 \\
&R\Delta^2 = .620 \\
&50 \text{ observ.}
\end{aligned}
$$

[variables same as for (6.15)].

$PE2_t$ is nearly significant in equation (6.17), and adding it to the equation has had only slight effect on the coefficient estimates of the other variables. The estimate of the serial correlation coefficient has dropped slightly from .791 in (6.15) to .722 in (6.17). The fit of equation (6.17) is only slightly better than the fit of equation (6.15), however, and in general adding $PE2_t$ to the inventory equation has been of only marginal benefit.

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[3] The period of estimation used for these regressions was the basic period beginning in 602 (36 observations). The data for the VH_t series are presented in Appendix A.

Aside from its marginal significance in (6.17), there were two main reasons why $PE2_t$ was not included in the final equation explaining inventory investment. The first was that the estimate of the coefficient of $PE2_t$ was not very stable for changes in the sample period. For the sample period ending in 684, for example, the estimate was .696, whereas in equation (6.17) for the sample period ending in 694 the estimate is only .470. The importance of $PE2_t$ in the inventory investment equation clearly decreased throughout 1969. The second reason $PE2_t$ was not included in the final equation is that including $PE2_t$ in the inventory equation means that in the reduced form equation for GNP_t, the coefficient of $PE2_t$ is quite large (since $PE2_t$ also enters with a fairly large coefficient in the plant and equipment investment equation). For forecasting purposes, the model is then quite sensitive to errors made in forecasting $PE2_t$. Because of the marginal significance of $PE2_t$ in equation (6.17) anyway, this sensitivity did not appear to be particularly desirable (even though, as mentioned in Chapter 4, proxies for $PE2_t$ are sometimes available as far as four quarters ahead).

None of the variables considered in the fourth approach, therefore, were included in the final equation, and the basic equation determining inventory investment was taken to be equation (6.15). One other equation was also considered before equation (6.15) was finally chosen, however, and this equation is worth mentioning. Somewhat by accident, both current GNP_t and the current change in durable and nondurable consumption were included, along with V_{t-1}, in the inventory equation. The results were:

$$\begin{aligned} V_t - V_{t-1} = {} & \underset{(5.66)}{-94.48} + \underset{(6.25)}{.241}\,\widehat{GNP}_t - \underset{(5.88)}{.368}\,V_{t-1} \\ & \underset{(5.04)}{-.568}\,(\widehat{CD}_t + \widehat{CN}_t - CD_{t-1} - CN_{t-1}) \\ & \hat{r} = \underset{(13.24)}{.882} \qquad\qquad (6.18) \\ & \text{SE} = 1.927 \\ & R\Delta^2 = .763 \\ & \text{50 observ.} \end{aligned}$$

[variables same as for (6.15)].

The fit of equation (6.18) is much improved over the fit of equation (6.15). The standard error has changed from 2.540 in (6.15) to 1.927 in (6.18), and the $R\Delta^2$ has risen from .589 to .763. Equation (6.18) has little theoretical justification—presumably the GNP_t variable is reflecting expected sales of some kind and the change in consumption variable is reflecting unexpected sales—but the better fit is impressive. The better fit may, of course, reflect the fact that $V_t - V_{t-1}$ is part of GNP_t, but the two-stage estimation technique should have removed any simultaneous equation bias.

Both equations (6.15) and (6.18) were tested within the context of the overall model in Chapter 11, and somewhat surprisingly, equation (6.15) gave better results. These results will be discussed in Chapter 11. It is encouraging that equation (6.15) performed better, since it is based on much stronger theoretical grounds.

6.4 Summary

The approach taken in this chapter in explaining inventory investment has been an eclectic one. Building on the basic stock adjustment model, an attempt was made to disaggregate total inventory investment into five different components; an attempt was made to account for the effect of sales expectations on inventory investment; a more complicated lag adjustment model was tested; and an attempt was made to add other kinds of expectational results to the basic equation.

The attempt at disaggregation failed, and there was no evidence of a more complicated adjustment process than that specified by the basic model. The attempt to account for sales expectations was fairly successful, and the sales variable that gave the best results was the sum of durable and non-durable consumption. The attempt to add the three inventory expectational variable, $VE1_t$, $VE2_t$, and VH_t, was not successful, although the results were based on relatively few observations. The attempt to add the plant and equipment expectational variable, $PE2_t$, was marginally successful, but $PE2_t$ was not included in the final equation.

7 Imports

For forecasting purposes, explaining the level of imports is of somewhat less importance than explaining the other expenditure variables discussed above. Short-run fluctuations in imports are for the most part small and not too difficult to forecast from the point of view of the accuracy expected of the overall model.

The level of imports is likely to be a function of current and lagged values of income, and the problem again arises of estimating the appropriate lag structure. In line with the discussion in Chapter 1, only two simple lag structures were estimated. For the first, the level of imports was taken to be a linear function of current and one-quarter-lagged income, and for the second, the level of imports was taken to be a linear function of current income and the level of imports lagged on quarter.

Branson [4] in a detailed study of imports has found the level of imports to be a function, among other things, of cyclical variables such as capacity utilization. An attempt was made in the initial phases of this study to include capacity utilization variables in the import equation, but the results were not very good. No effect of capacity utilization on total imports could be found, and so the capacity utilization variables were dropped from further consideration.

Serial correlation of the error terms was very pronounced in the import equations, with some of the estimates of the serial correlation coefficient being slightly greater than one. The most meaningful results seemed to occur when the serial correlation coefficient was constrained to be one (constraining the serial correlation coefficient to be one is equivalent to estimating the equation in first differenced form), and this constraint was used for the final equation estimates. The two estimated equations, using respectively lagged income and lagged imports, were:

$$\begin{aligned} IMP_t = {} & \underset{(2.09)}{.050}\,\widehat{GNP}_t + \underset{(1.31)}{.030}\,GNP_{t-1} \\ & r = 1.0 \\ & \text{SE} = .608 \\ & R\Delta^2 = .499 \\ & \text{45 observ.} \end{aligned} \tag{7.1}$$

$[1, IMP_{t-1}, GNP_{t-1}, GNP_{t-2}, CD_{t-1}, CD_{t-2}, CN_{t-1}, CN_{t-2}, CS_{t-1}, CS_{t-2}, V_{t-1}, V_{t-2}, G_t, MOOD_{t-2}, PE2_t, PE2_{t-1}]$.

$$IMP_t = \underset{(5.59)}{.078} \; \widehat{GNP_t} - \underset{(0.06)}{.009} \; IMP_{t-1} \tag{7.2}$$

$r = 1.0$

$\text{SE} = .644$

$R\Delta^2 = .437$

45 observ.

[variables same as for (7.1) less GNP_{t-2} and plus IMP_{t-2}].

IMP_t is the aggregate level of imports of goods and services during quarter t seasonally adjusted at annual rates in billions of current dollars.

The current GNP variable in both equations (7.1) and (7.2) is significant, but neither the lagged GNP variable in equation (7.1) nor the lagged import variable in equation (7.2) is significant. The equations have no constant term estimates since they were estimated in first differenced form.

Since neither lagged income nor lagged imports was significant, the import equation was reestimated using only the current GNP variable, with the following results:

$$IMP_t = \underset{(8.70)}{.078} \; \widehat{GNP_t} \tag{7.3}$$

$r = 1.0$

$\text{SE} = .637$

$R\Delta^2 = .437$

45 observ.

[variables same as for (7.1) less GNP_{t-2}].

No explanatory power has been lost by dropping the lagged import variable from equation (7.2), but a slight loss of power has resulted from dropping lagged GNP from equation (7.1). There is actually very little to choose between equations (7.1) and (7.3), and so both of these equations were tested within the context of the overall model in Chapter 11 below. It turned out that equation (7.3) gave slightly better results on this basis, and so it was taken as the basic equation explaining the level of imports.

Note that less than half of the variance of the change in imports has been explained in equation (7.3). Also, the fact that the error terms were so strongly serially correlated in all of the import equations that were estimated in this study may indicate that the lag structure has not been adequately specified or that many relevant variables have been omitted from the equation. The standard error of the estimate of equation (7.3) is small relative to the errors in the other expenditure equations of the model, however, and the equation appears to be accurate enough for present purposes.

8 Monthly Housing Starts

8.1 Introduction

In order to use the housing investment equation in the money GNP sector for forecasting purposes, housing starts have to be explained within the model or else forecast exogenously. The theoretical and empirical work explaining the level of housing starts is still in its infancy [35, 40], and only limited success has been achieved in developing reliable housing starts equations. The approach taken in this study is to treat the housing market as a market that is not always in equilibrium and to estimate supply and demand schedules of housing starts under this assumption. It seems to be a widespread view that the housing and mortagage market is not always in equilibrium,[1] and one of the advantages of the technique used in this chapter is that this view can be tested.

The outline of this chapter is as follows. In the next section the basic model of the housing market is presented and discussed. The technique that has been used to estimate the model is then described in Section 8.3. The technique is based on the work in Fair and Jaffee [20] and Fair [16]. The data are discussed in Section 8.4, and the results of estimating the model are presented in Section 8.5. The chapter concludes with a discussion in Section 8.6 of how the housing starts equations can be used for forecasting purposes.

8.2 A Model of the Housing and Mortgage Market

The housing and mortgage market is a difficult market to specify. The interaction between the financial (mortgage) side of the market and the real side of the market is complex, and it does not as yet appear to be well understood. In this section an attempt is made at a reasonable specification of the housing and mortgage market and of the interaction between the two sides of the market, but a number of simplifying assumptions have been made in order to keep the analysis as tractable as possible. To begin with, the present model is concerned only with the market for *new* houses (i.e., housing starts) and for the mortgage funds associated with these houses.

[1] See, for example, de Leeuw and Gramlich [8], pp. 482–483.

Looking first at the demand side of the market, let HS_t^D denote the demand for housing starts (new houses) during period t. Then the demand schedule for housing starts is taken to be

$$HS_t^D = f(X_t^D, \varepsilon_t^D), \tag{8.1}$$

where X_t^D denotes the vector of variables that determine HS_t^D and where ε_t^D is an error term. The variables that have been included in the X_t^D vector in the present model will be discussed below, but in general the X_t^D vector should include such variables as population, income, the number of houses already in existence, the purchase price of new houses, and the cost of obtaining mortgage funds to finance the purchase of a house (i.e., the mortgage rate).

An important simplifying assumption will now be made concerning the relationship between the demand for housing starts and the demand for the mortgage funds associated with these starts. Let $MORT_t^D$ denote the demand for mortgage funds associated with HS_t^D. Then it is assumed that

$$\frac{MORT_t^D}{HS_t^D} = a_0 + a_1 t, \tag{8.2}$$

where t is a time trend. Equation (8.2) states that the ratio of the demand for new mortgage funds to the demand for housing starts is equal to some constant value plus a time trend. The time trend is designed to pick up any trend increase in the average size of mortgages per housing start. The assumption made in (8.2) is admittedly a highly simplifying one, since the mortgage-fund–housing-starts ratio is likely to fluctuate in the short run in response to such things as the mortgage rate, but for purposes of this study, ignoring these fluctuations may not be too serious. Equations (8.1) and (8.2) imply that the demand for new mortgage funds is, aside from a trend term, merely a function of the variables in X_t^D and the error term ε_t^D.

Turning next to the supply side of the market, let HS_t^S denote the supply of housing starts during period t. Then the supply schedule of housing starts is taken to be

$$HS_t^S = g(X_t^S, \varepsilon_t^S), \tag{8.3}$$

where X_t^S denotes the vector of variables that determines HS_t^S and where ε_t^S is an error term. In general, the X_t^S vector should include such variables as the price of houses, the cost of building houses (materials and supplies plus labor costs), and the cost of short-term credit. Home builders, in other words, are likely to decide how many new houses to build on the basis of the price of houses vis-à-vis their building cost and on the basis of the cost of short-term credit. Note that it is the cost of short-term credit that is likely to affect the supply of housing starts and not the cost of long-term credit, as reflected in, say, the mortgage rate. Home builders generally need a mortgage commitment from one of the financial intermediaries before they can get short-term loans from commercial banks; but, providing that commitments are available, the mortgage rate associated with these commitments should not directly concern them. The mortgage cost is incurred by the person who buys the house and takes out the mortgage, not by the person who builds the house.

Finally, let $MORT_t^S$ denote the supply of new mortgage funds during period t. Then the supply schedule of mortgage funds is taken to be

$$MORT_t^S = h(Z_t^S, \eta_t^S), \tag{8.4}$$

where Z_t^S denotes the vector of variables that determines $MORT_t^S$ and where η_t^S is an error term. The variables that have been included in the Z_t^S vector in this study will be discussed below; but in general the vector should include such variables as deposit flows into financial intermediaries, the mortgage rate, and interest rates on competing assets. Since mortgages are supplied primarily by financial intermediaries, deposit flows into these intermediaries should have a positive effect on the supply of mortgages. Also, for a given flow of deposits, financial intermediaries are likely to put more of the flow into the mortgage market the higher is the mortgage rate relative to other interest rates.

The demand and supply sides of the housing and mortgage market differ in that the people who demand new houses are essentially the same people who demand mortgage funds, whereas the people who supply (build) new houses are in general not the same people who supply mortgage funds. There are thus three groups of people or institutions under consideration: the consumers, the home builders, and the financial intermediaries. If the housing and mortgage market were always in equilibrium, then it would be the case that:

$$HS_t = HS_t^D = HS_t^S, \tag{8.5}$$

and

$$MORT_t = MORT_t^D = MORT_t^S, \tag{8.6}$$

where HS_t is the actual number of housing starts during period t and $MORT_t$ is the actual value of new mortgage funds during period t. In equilibrium, the purchase price of houses would clear the housing side of the market, as in (8.5), and the mortgage rate would clear the mortgage side of the market, as in (8.6). Note that the assumption made in (8.2) above implies that in equilibrium,

$$\frac{MORT_t}{HS_t} = a_0 + a_1 t.$$

If the housing and mortgage market is not always in equilibrium, then (8.5) and (8.6) obviously do not always hold, and the question arises as to how the disequilibrium aspects of the market should be specified. In this study the specification is as follows. It is first assumed that the actual ratio of new mortgage funds to housing starts is always equal to $a_0 + a_1 t$. It was seen above that, given (8.2), the ratio is equal to $a_0 + a_1 t$ in equilibrium; and it is now assumed that the actual ratio is equal to $a_0 + a_1 t$ even if the market is not in equilibrium. Because of this assumption, the supply of mortgages from the financial intermediaries in (8.4) can be translated into an equivalent supply of housing starts. The equivalent supply is $MORT_t^S/(a_0 + a_1 t)$. There are thus two supply schedules of housing starts under consideration—the supply schedule from the home builders and the supply schedule from the financial intermediaries. It is finally assumed that the observed quantity of housing starts is equal to the minimum of the *ex ante* demand and supply schedules:

$$HS_t = \min\left\{HS_t^D, HS_t^S, \frac{MORT_t^S}{a_0 + a_1 t}\right\}. \tag{8.7}$$

Equation (8.7) implies that there are three possible constraints in the housing market. Either demand is the constraint (HS_t^D is the minimum) so that home builders and financial intermediaries go unsatisfied at prevailing prices, or supply from the home builders is the constraint (HS_t^S is the minimum) so that demanders and financial intermediaries go unsatisfied, or supply from the financial intermediaries is the constraint ($MORT_t^S/(a_0 + a_1 t)$ is the minimum) so that demanders and home builders go unsatisfied. It appears to be commonly accepted that most of the "supply" constraint in the housing market comes from the financial sector, and thus as a simplifying approximation in this study, HS_t^S is assumed always to be greater than or equal to the minimum of HS_t^D and $MORT_t^S/(a_0 + a_1 t)$. This assumption simplifies matters in that the supply schedule of home builders in (8.3) does not have to be specified. In a more detailed study of the housing market it would, of course be desirable to specify and estimate the home builders' side of the market as well.

What remains to be done, then, is to specify equations (8.1) and (8.4). With respect to equation (8.1), the demand for housing starts is assumed to be a function of (1) population growth and trend income, both of which are approximated by a time trend; (2) the number of houses in existence or under construction during the previous month; (3) the mortgage rate lagged two months; and (4) seasonal factors.

Let H_t denote the number of houses in existence or under construction during month t and let HS_t continue to denote the number of housing starts during month t. Then H_t is approximated as follows. It is assumed that the number of houses removed (i.e., destroyed) each month is constant from month to month, which implies that

$$HS_t = H_t - H_{t-1} + b_0, \tag{8.8}$$

where b_0 is the constant number of removals each month. Equation (8.8) then implies that for any base period 0:

$$H_t = H_0 + \sum_{i=1}^{t} HS_i - b_0 t, \tag{8.9}$$

where H_0 is the number of houses in the base period. In other words, the number of houses at the end of month t is equal to the sum of past housing starts less the sum of past removals, the sum of past removals being approximated by a time trend, as implied by the assumption in equation (8.8).

With respect to seasonal factors, the housing starts series does have a pronounced seasonal pattern in it, due in large part to the weather, and in an attempt to account for this pattern eleven seasonal dummy variables were included in the equation.[2] An alternative approach would have been to use the seasonally adjusted housing starts series that is published by the Department of Commerce, but the Department of Commerce does not adjust the series for the number of working days in the month. This causes the month-to-month changes in the seasonally adjusted series to be more erratic than is really warranted. In an attempt to account in this study for the influence of the number of working days in the month on the number of housing starts for that month, a working-day variable was included in the equation. The variable was constructed by adding up all of the weekdays in the month less any holidays that fell on these days. The holidays were excluded in the following manner. One day was always excluded for January, September, November, and December, and one day was also excluded for May and July unless May 30 or July 4 respectively fell on a Saturday. The data on this variable, denoted as W_t, are presented in Appendix A.

The demand schedule for housing starts is thus taken to be

$$HS_t^D = \sum_{I=1}^{11} d_I DI_t + d_{12} W_t + b_1 H_{t-1} + b_2 t + b_3 RM_{t-2} + \varepsilon_t^D, \tag{8.10}$$

where DI_t is the seasonal dummy variable for month I, $b_2 t$ is the trend term,

[2] Dummy variable 1 being equal to one in January, minus one in December, and zero otherwise; dummy variable 2 being equal to one in February, minus one in December, and zero otherwise; and so on. A constant term was included in the equation, which is the reason why only eleven dummy variables were included. The values for December were set equal to minus one instead of zero so that the seasonal factors could be more readily identified from the estimates of the coefficients of the dummy variables.

and RM_{t-2} is the mortgage rate lagged two months. Using the definition of H_t in equation (8.9), equation (8.10) becomes

$$HS_t^D = \sum_{I=1}^{11} d_I DI_t + d_{12} W_t + (b_1 H_0 + b_1 b_0) + b_1 \sum_{i=1}^{t-1} HS_i + (b_2 - b_1 b_0)t + b_3 RM_{t-2} + \varepsilon_t^D, \qquad (8.11)$$

which introduces the constant $b_1 H_0 + b_1 b_0$ in the equation and changes the interpretation of the coefficient of the time trend. The data that have been used to estimate equation (8.11) will be discussed below.

It should be noted that the purchase price of houses has not been included as an explanatory variable in the demand equation. Theoretically the price of houses (or, more specifically, the price of houses deflated by some general price index) should be included in the equation, but this was not done for the work here because of the difficulty that would be involved in forecasting the price of houses exogenously. To the extent that the influence of the (relative) price of houses on the demand for housing starts is not picked up by the time trend in equation (8.11), the equation is misspecified, but for short-run forecasting purposes this misspecification is not likely to be too serious. It should also be noted that various lagged values of the mortgage rate were tried in the work below, and the mortgage rate lagged two months gave the best results for the demand equation.

With respect to equation (8.4), the supply of new mortgage funds is assumed to be a function of (1) lagged deposit flows into Savings and Loan Associations (SLAs) and Mutual Savings Banks (MSBs), (2) lagged borrowings by the SLAs from the Federal Home Loan Bank (FHLB), (3) the mortgage rate lagged one month, and (4) seasonal factors. Let DSF_t denote the flow of private deposits into SLAs and MSBs during month t, and let DHF_t denote the flow of borrowings by the SLAs from the FHLB during month t. Various lags and moving averages of DSF and DHF were tried in the work below, and the best results were achieved by using the six-month moving average of DSF lagged one month (denoted as $DSF6_{t-1}$) and the three-month moving average of DHF lagged two months (denoted as $DHF3_{t-2}$). The results were not very sensitive, however, to slightly different specifications. The six-month moving average of DSF has the advantage of eliminating the monthly fluctuations in the series due to the quarterly interest payments by the SLAs and MSBs and the switching of funds at the beginning of each quarter. The current and various lagged values of the mortgage rate were also tried in the supply equation, and the one-month lagged value gave the best results. Seasonal factors were assumed to enter the supply equation in the same way in which they entered the demand equation. The supply of new mortgage funds is thus taken to be

$$MORT_t^S = \sum_{I=1}^{11} d'_I DI_t + d'_{12} W_t + c_1 DSF6_{t-1} + c_2 DHF3_{t-2} + c_3 RM_{t-1} + \eta_t^S. \tag{8.12}$$

The equivalent supply of housing starts from the financial sector was defined above to be $MORT_t^S/(a_0 + a_1 t)$. Let HS_t^{FS} denote this equivalent supply. Then $MORT_t^S = (a_0 + a_1 t)HS_t^{FS}$. As a further simplifying assumption, $t \cdot HS_t^{FS}$ will be approximated by $t + HS_t^{FS} + c_0$, where c_0 is a constant. This then implies that

$$HS_t^{FS} = \frac{1}{a_0 + a_1}(-a_1 c_0 - a_1 t + MORT_t^S).$$

Using equation (8.12) and ignoring the $1/(a_0 + a_1)$ multiplier, the equation determining HS_t^{FS} can thus be written

$$HS_t^{FS} = -a_1 c_0 - a_1 t + \sum_{I=1}^{11} d'_I DI_t + d'_{12} W_t + c_1 DSF6_{t-1} + c_2 DHF3_{t-2} + c_3 RM_{t-1} + \eta_t^S. \tag{8.13}$$

In other words, equation (8.12) explaining the supply of mortgage funds can be transformed into an equation explaining the equivalent supply of housing starts from the financial sector. The latter differs from equation (8.12) only in that a constant term and a time trend have been added to the equation. The time trend is designed to pick up any trend in the mortgage-fund–housing-starts ratio.

Equations (8.11) and (8.13) thus determine the demand and supply of housing starts respectively, and the model is closed by equation (8.7), which from the above assumption about home builders can be written

$$HS_t = \min\{HS_t^D, HS_t^{FS}\}. \tag{8.14}$$

The technique that was used to estimate equations (8.11) and (8.13) will now be discussed.

8.3 The Estimation Technique[3]

In Fair and Jaffee [20] four techniques for estimating disequilibrium markets were developed. Three of the techniques were designed to separate the sample period into demand and supply regimes so that each schedule could be fitted

[3] Some of the discussion in this section follows closely the discussion in [20], Section II.

against the observed quantity for the sample points falling within its regime. The fourth technique was designed to adjust the observed quantity for the effects of rationing so that both schedules could be estimated over the entire sample period using the adjusted quantity. The fourth technique has been used in this study, and it will be briefly outlined below. All four of the techniques developed in [20] were used to estimate the present model, and two of the four techniques gave good results. These results are presented and compared in [20], Section III. The fourth technique was chosen to be used in this study because it appeared to be somewhat more suited for forecasting purposes.

The technique used here is based on the following assumption about how prices (or, in this case, interest rates) are determined:

$$\Delta RM_t = q(HS_t^D - HS_t^{FS}), \qquad 0 \leq q \leq \infty. \tag{8.15}$$

Equation (8.15) states that the change in the mortgage rate is directly proportional to the amount of excess demand in the market. q equal to zero is the polar case of no adjustment, and q equal to ∞ is the polar case of perfect adjustment. Equation (8.15) is consistent with many theories of dynamic price setting behavior.

Solving equation (8.15) for excess demand yields:

$$HS_t^D - HS_t^{FS} = \frac{1}{q}\,\Delta RM. \tag{8.16}$$

If q can be estimated, then the actual amount of excess demand or supply can be determined directly from the change in the mortgage rate, and thus both the demand and supply schedules can be estimated over the entire sample period. The procedure described below simultaneously estimates q and the parameters of the two schedules.

First consider a period of rising rates. From equation (8.16) it is known that this will be a period of excess demand; and thus, from equation (8.14), the observed quantity will equal the supply. Consequently, the supply function can be directly estimated using the observed quantity as the dependent variable:

$$HS_t = HS_t^{FS}, \qquad \Delta RM_t \geq 0, \tag{8.17}$$

where HS_t^{FS} is given in (8.13). Furthermore, because the supply equals the observed quantity, equation (8.16) can be rewritten as

$$HS_t = HS_t^D - \frac{1}{q}\,\Delta RM_t, \qquad \Delta RM_t \geq 0, \tag{8.18}$$

where HS_t^D is given in (8.11). Thus the parameters of the demand function can also be estimated, using the observed quantity as the dependent variable, as long as the change in the mortgage rate is included in the equation as an implicit adjustment for the amount of rationing.

In periods of falling rates essentially the same principles apply. The supply and demand functions will then be estimated as, respectively:

$$HS_t = HS_t^{FS} - \frac{1}{q} |\Delta RM_t|, \qquad \Delta RM_t \leq 0, \tag{8.19}$$

and

$$HS_t = HS_t^D, \qquad \Delta RM_t \leq 0. \tag{8.20}$$

Indeed, the system of equations (8.17) to (8.20) can be reduced to a single demand equation and a single supply equation, each to be estimated over the entire sample period, by making the appropriate adjustment for the change in the mortgage rate:

$$HS_t = HS_t^D - \frac{1}{q} /\Delta RM_t/, \tag{8.21}$$

where

$$/\Delta RM_t/ = \begin{cases} \Delta RM_t & \text{if} \quad \Delta RM_t \geq 0 \\ 0 & \text{otherwise} \end{cases},$$

and

$$HS_t = HS_t^{FS} - \frac{1}{q} \backslash \Delta RM_t \backslash, \tag{8.22}$$

where

$$\backslash \Delta RM_t \backslash = \begin{cases} -\Delta RM_t & \text{if} \quad \Delta RM_t \leq 0 \\ 0 & \text{otherwise} \end{cases}.$$

It is apparent that equation (8.21) is equivalent to the two demand equations (8.18) and (8.20) and that equation (8.22) is equivalent to the two supply equations (8.17) and (8.19).

Equations (8.21) and (8.22) can thus be estimated directly, given the specifications of HS_t^D and HS_t^{FS} in (8.11) and (8.13) respectively, but two problems occur in the estimation. One problem is that the same coefficient $1/q$ appears in both equations. The second problem is the likelihood of simultaneous equation bias due to the endogeneity of $/\Delta RM_t/$ and $\backslash \Delta RM_t \backslash$. The introduction of equation (8.15) above makes RM_t an endogenous variable, and even though RM enters with a lag in (8.11) and (8.13), RM_t still enters in equations (8.21) and (8.22) through the $/\Delta RM_t/$ and $\backslash \Delta RM_t \backslash$ variables.

These two problems are heightened in the present case by the fact that the error terms ε_t^D and η_t^D, which enter equations (8.21) and (8.22) respectively, are assumed to be serially correlated.

Ignoring the fact that $1/q$ appears in both equations, the problem of simultaneous equation bias can be handled in the manner described by Fair and Jaffee [20]. Essentially the two-stage least squares technique can be used, but the step function characteristic of $/\Delta RM_t/$ and $\backslash\Delta RM_t\backslash$ makes the application of the technique somewhat more complicated than usual. In addition, if the error terms are serially correlated, the technique described in Chapter 2 (and in more detail in Fair [17]) must be used in place of the standard two-stage least squares technique. Ignoring the problem of simultaneous equation bias, the constraint across equations can be taken into account by using the technique developed in Fair [16]. This technique is designed for the estimation of models with restrictions across equations and serially correlated errors. In Fair and Jaffee [20], both of these techniques were used to estimate the present model, and both yielded reasonable results. Since techniques are not yet available for dealing with simultaneous equation bias and restrictions across equations at the same time, it is not clear theoretically which technique should be used. One sacrifices efficiency to gain consistency, while the other gains efficiency at a cost of consistency. The decision was made in this study to *ignore possible simultaneous equation bias and use the second technique to* account for the restriction across the two equations. This technique is somewhat easier to use than the other one, and this is the main reason for its use here.

It should be pointed out that the technique used here is based on the assumption that the error terms in the two equations (i.e., ε_t^D and η_t^S in (8.11) and (8.13) above) are each first order serially correlated, but are uncorrelated with one another. While it may not be too unrealistic to assume that the demand and supply error terms are uncorrelated, it may be unrealistic to assume that the error terms in equations (8.21) and (8.22) are uncorrelated. This is because HS_t may be measured with error. If HS_t is measured with error, this same error will be included in both (8.21) and (8.22), and thus the error terms in the two equations will be correlated. To the extent that this is true, the technique used here loses efficiency by not taking the correlation into account.

8.4 The Data

The data that have been used to estimate the demand and supply equations are presented in Table 8–1. All of the variables listed in the table are seasonally

Table 8–1. List and Description of the Variables Used in the Monthly Housing Starts Sector.

HS_t	= Private Nonfarm Housing Starts in thousands of units.
RM_t	= FHA Mortgage Rate series on new homes in units of 100 (beginning-of-month data).
$DSLA_t$	= Savings Capital (Deposits) of Savings and Loan Associations in millions of dollars.
$DMSB_t$	= Deposits of Mutual Savings Banks in millions of dollars.
DSF_t	$= (DSLA_t + DMSB_t) - (DSLA_{t-1} + DMSB_{t-1})$.
$DSF6_t$	= Six-month moving average of DSF.
$DHLB_t$	= Advances of the Federal Home Loan Bank to Savings and Loan Associations in million of dollars.
DHF_t	$= DHLB_t - DHLB_{t-1}$.
$DHF3_t$	= Three-month moving avaerage of DHF.
W_t	= Number of working days in month t.
DI_t	= Dummy variable I for month t, $I = 1, \ldots, 11$.

unadjusted. Data on HS_t are currently published in *Economic Indicators*,[4] and data on the three deposit variables and the mortgage rate are currently published in the *Federal Reserve Bulletin*. Data on the RM_t series were not directly available for January 1959 through April 1960, and the figures used here were constructed from an FHA series on the average of new and existing conventional mortgage rates. The data on RM_t and W_t are presented in Appendix A for the January 1959 to December 1969 period. The other data used in this chapter are easily obtainable from *Economic Indicators* or the *Federal Reserve Bulletin*.

8.5 The Results

Equations (8.21) and (8.22) were estimated by the above technique for the June 1959 to December 1969 period, with the following results:[5]

[4] Actually, the HS_t series was discontinued in December 1969. Beginning in 1970 the breakdown of private housing starts into farm and nonfarm was no longer made. The number of nonfarm housing starts was always a small fraction of the total number of housing starts, and the decision was made by the Department of Commerce to discontinue the breakdown into farm and nonfarm. This change does not affect the work in this study, but for future purposes the published figures on total housing starts will have to be adjusted downward slightly.

[5] The steel and automobile strikes appeared to have little effect on the level of housing starts, and so no observations were omitted from the period of estimation for the housing starts equations because of the strikes.

$$HS_t = \sum_{I=1}^{11} \hat{d}_I DI_t + \underset{(4.63)}{2.70}\, W_t + \underset{(2.46)}{112.95} - \underset{(2.27)}{.0709} \sum_{i=1}^{t-1} HS_i + \underset{(2.31)}{8.48}\, t$$

$$- \underset{(1.54)}{.127}\, RM_{t-2} - \underset{(2.81)}{.412}\, |\Delta RM_t| \qquad (8.23)$$

$$\hat{\rho} = \underset{(17.54)}{.841}$$

$$SE = 8.98$$

$$R\Delta^2 = .790$$

127 observ.

$$HS_t = \sum_{I=1}^{11} \hat{d}_I DI_t + \underset{(4.42)}{2.84}\, W_t - \underset{(1.75)}{49.22} - \underset{(2.63)}{.164}\, t + \underset{(8.07)}{.0541}\, DSF6_{t-1}$$

$$+ \underset{(5.27)}{.0497} DHF3_{t-2} + \underset{(2.67)}{.100}\, RM_{t-1} - \underset{(2.81)}{.412}\, |\Delta RM_t| \qquad (8.24)$$

$$\hat{\rho} = \underset{(6.64)}{.507}$$

$$SE = 8.30$$

$$R\Delta^2 = .822$$

127 observ.

$\hat{d}_1 = -34.44$ (12.52)	$\hat{d}_6 = 19.84$ (7.22)	$\hat{d}'_1 = -34.38$ (14.21)	$\hat{d}'_6 = 20.69$ (8.54)
$\hat{d}_2 = -33.72$ (11.46)	$\hat{d}_7 = 15.16$ (5.56)	$\hat{d}'_2 = -38.85$ (14.36)	$\hat{d}'_7 = 12.03$ (5.14)
$\hat{d}_3 = -9.67$ (2.87)	$\hat{d}_8 = 11.97$ (4.27)	$\hat{d}'_3 = -7.33$ (2.83)	$\hat{d}'_8 = 8.46$ (3.24)
$\hat{d}_4 = 18.62$ (5.47)	$\hat{d}_9 = 8.55$ (2.91)	$\hat{d}'_4 = 20.97$ (7.88)	$d'_9 = 6.57$ (2.57)
$\hat{d}_5 = 23.72$ (7.76)	$\hat{d}_{10} = 11.61$ (3.85)	$\hat{d}'_5 = 36.68$ (11.20)	$\hat{d}'_{10} = 10.01$ (3.83)
	$\hat{d}_{11} = -4.88$ (1.53)		$\hat{d}'_{11} = -7.74$ (3.16)

$\hat{\rho}$ in equations (8.23) and (8.24) denotes the estimate of the first order serial correlation coefficient. The R-squared is again the R-squared taking the dependent variable in first differenced form and is a measure of the percent of the variance of the change in HS_t explained by the equation. Note that because of the constraint that has been imposed on the model, the estimate of the coefficient of $/\Delta RM_t/$ in (8.23) is the same as the estimate of the coefficient of $\backslash\Delta RM_t\backslash$ in (8.24).

The dummy variables are in general highly significant in equations (8.23) and (8.24), which indicates the pronounced seasonality in the series. The working-day variable, W_t, is also significant in the equations, and thus the number of working days in a month does appear to influence the number of housing starts for that month. All of the other coefficient estimates in the two equations are of the expected sign, and all but the estimate of the coefficient of RM_{t-2} in (8.23) and the estimate of the constant term in (8.24) are significant. The time trend has a positive effect in the demand equation (8.23) and a negative effect in the supply equation (8.24), and the mortgage rate (RM_{t-2} or RM_{t-1}) has a negative effect in the demand equation and a positive effect in the supply equation. The time trend is expected to have a positive effect in the demand equation, since it is mainly proxying for population growth and trend income. The deposit flow variables are highly significant in the supply equation, and the housing stock variable is moderately significant in the demand equation. The fact that the time trend and the mortgage rate have opposite effects in the two equations (using the same dependent variable) certainly supports the hypothesis that (8.23) represents a demand equation and (8.24) a supply equation.

The estimate of the coefficients of $/\Delta RM_t/$ and $\backslash\Delta RM_t\backslash$ in (8.23) and (8.24) is of the expected negative sign and is significant. The significance of the estimate indicates that the housing market is not always in equilibrium and that rationing does occur. When equations (8.23) and (8.24) were estimated separately without imposing the constraint (by the standard Cochrane–Orcutt technique), the estimate of the coefficient of $/\Delta RM_t/$ in (8.23) was $-.408$ and the estimate of the coefficient of $\backslash\Delta RM_t\backslash$ in (8.24) was $-.438$. These compare with the restricted estimate of $-.412$. It is remarkable that the unconstrained estimates are so similar, which perhaps provides further support to the view that rationing does occur in the housing market.

The estimate of the serial correlation coefficient is larger in the demand equation (.841) than it is in the supply equation (.507), and the fit of the demand equation is somewhat worse than that of the supply equation (SE = 8.98 vs. 8.30).

A number of other variables were tried in the two equations, especially in equation (8.24); and some of these results should be mentioned. First, different lags of the mortage rate were tried in the two equations, and while RM_{t-2} and RM_{t-1} gave the best results in (8.23) and (8.24) respectively, the results were not substantially changed when slightly different lags were used. Theoretically, of course, it is not the absolute size of the mortagage rate that should matter, but the size of the mortgage rate relative to rates on alternative assets. A number of yield differential variables were tried in the equations, but with no success. While theoretically not very satisfying, it definitely appeared to be the absolute level of rates that mattered and not rate differences.

As mentioned above, different lags of the deposit flow variables in (8.24) were tried, and the ones presented in (8.24) gave the best results. Deposit flows into Life Insurance Companies and Commercial Banks were also tried in (8.24), but these flows added almost no explanatory power to the equation. Deposit and mortgage *stock* variables of the SLAs and MSBs were also tried in (8.24), and again with no real success. The flow variables always dominated the stock variables, which probably indicates that the adjustment of SLAs and MSBs to changing deposit conditions is fairly rapid. The flow variables of the SLAs and MSBs were also tried separately in (8.24), and the coefficient estimates were close enough so that it was decided to consider only the sum of two flow variables. Notice also that in (8.24) the coefficient estimate of DHF_{t-2} is nearly the same as the coefficient estimate of $DSF6_{t-1}$. The lag seemed to be slightly different for the DHF3 variable than for the DSF6 variable, however, and it was decided to treat these two variables separately.

Finally, the mortgage holdings of the Federal National Mortgage Association (FNMA) was tried as an explanatory variable in equation (8.24), but with no success.[6] Both stock and flow variables were tried and various moving averages and lags were tried, and none of these variables were significant. Most of the time the estimates were even of the wrong sign. The results in this study thus indicate that for policy purposes, the Federal Home Loan Bank lending activity (as reflected through $DHF3_{t-2}$ in (8.24)) has much more of an effect on the level of housing starts than does the activity of FNMA.[7] These results are, of course, not conclusive, since the level of aggregation is so high, but they do seem to indicate the importance of the FHLB relative to FNMA. It should be noted, however, that not even the FHLB will have an effect on housing starts if demand and not supply is the constraint.

8.6 The Use of the Housing Starts Equation for Forecasting Purposes

There are two basic ways in which equations (8.23) and (8.24) can be used for forecasting purposes. One way is to treat ΔRM_t as exogenous. Assuming

[6] In 1968 FNMA was split into two groups (the new FNMA and the Government National Mortgage Association), but in this study the two groups were treated as one.

[7] Jaffee [28] in a detailed study of the mortgage market has found that the activity of FNMA has little effect on the total stock of mortgages, which is consistent with the conclusions reached in this study.

ΔRM_t to be exogenous, let $\overline{HS}_t$ denote the predicted value of HS_t from equation (8.23), let $\widetilde{HS}_t$ denote the predicted value of HS_t from equation (8.24), and let $\widehat{HS}_t$ equal a weighted average of the two predicted values: $\widehat{HS}_t = \lambda\overline{HS}_t + (1 - \lambda)\widetilde{HS}_t$. It is easy to show that if the error terms in equations (8.23) and (8.24) are independent and if the desire is to choose λ so as to minimize

$$\sum_{t=1}^{T} (HS_t - \widehat{HS}_t)^2,$$

then the optimum value of λ is $\sigma_1^2/(\sigma_1^2 + \sigma_2^2)$, where σ_1^2 is the variance of the error term in equation (8.24), σ_2^2 is the variance of the error term in equation (8.23), and T is the number of observations. From estimates of σ_1^2 and σ_2^2, therefore, an estimate of λ can be used for forecasting purposes. In the present case the estimate of λ is $(8.30)^2/[(8.30)^2 + (8.98)^2] = .46$.[8] In other words, the predictions from equation (8.23) are weighted slightly less than those from (8.24), since the estimate of the variance of the error term is slightly larger in (8.23).

The other way in which (8.23) and (8.24) can be used for forecasting purposes is to treat ΔRM_t as endogenous. Let $\widehat{HS}_t^D$ denote the predicted value of demand, and let $\widehat{HS}_t^{FS}$ denote the predicted value of supply. $\widehat{HS}_t^D$ is obtained from (8.23) by ignoring the $/\Delta RM_t/$ term, and $\widehat{HS}_t^{FS}$ is obtained from (8.24) by ignoring the $\backslash\Delta RM_t\backslash$ term. [See (8.21) and (8.22).] Then given $\widehat{HS}_t^D$ and $\widehat{HS}_t^{FS}$, the predicted value of ΔRM_t (denoted as $\Delta\widehat{RM}_t$) can be obtained from equation (8.15), using as the estimate of q the reciprocal of the estimate of the coefficient of $/\Delta RM_t/$ and $\backslash\Delta RM_t\backslash$ in (8.23) and (8.24). $\Delta\widehat{RM}_t$ can be used to compute $/\Delta\widehat{RM}_t/$ and $\backslash\Delta\widehat{RM}_t\backslash$, and the predicted value of the actual number of housing starts, $\widehat{HS}_t$, can then be computed as

$$\widehat{HS}_t = \widehat{HS}_t^D - .412/\Delta\widehat{RM}_t/.$$

From equations (8.15), (8.21), and (8.22), it can be seen that the latter expression is the same as $\widehat{HS}_t^{FS} - .412\backslash\Delta\widehat{RM}_t\backslash$. Since RM also enters equations (8.23) and (8.24) with a lag (as RM_{t-1} and RM_{t-2}), in a dynamic simulation or forecast the values for $\widehat{RM}_{t-1}$ and $\widehat{RM}_{t-2}$ can be taken from the $\Delta\widehat{RM}_t$ series.

Treating ΔRM_t as endogenous thus yields one predicted value of HS_t, whereas treating ΔRM_t as exogenous yields two. There are, in other words,

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[8] The question of degrees of freedom has been ignored in this discussion. The estimates of the standard errors in (8.23) and (8.24) have been adjusted for degrees of freedom, whereas the variances that result from the above minimization are not so adjusted. Since the number of variables in equation (8.23) is only one less than the number in (8.24), however, the difference between adjusting or not adjusting for degrees of freedom is trivial.

two independent pieces of information in the system of equations (8.15), (8.23), and (8.24). The decision was made in this study to treat ΔRM_t as exogenous and generate the two predictions of HS_t. Some initial experimentation was done treating ΔRM_t as endogenous, and while the static simulation predictions of ΔRM_t from equation (8.15) were fairly good, the equation was sensitive to dynamic error accumulation and to errors made in forecasting the exogeneous variables. The results seemed to indicate that ΔRM_t could be more accurately forecast exogenously than by the use of equation (8.15).

Given that ΔRM_t is to be taken as exogenous, the question arises as to how the two predictions from (8.23) and (8.24) are to be weighted. The derivation at the beginning of the section suggested that the predictions should be weighted by the estimates of the variances of the error terms in the two equations. The derivation was based on the assumption that the errors in the two equations are uncorrelated. To the extent that the errors are positively correlated, it can be seen that the above minimization approach implies that even more weight should be attached to the equation with the smaller variance. In the limit, if the errors were perfectly correlated, it can be shown that all of the weight should be given to the equation with the smaller variance. The error terms in the two equations are in fact positively correlated (as a regression of one set of error terms on the other revealed), which is probably due in part to errors of measurement in the HS_t series. In spite of this, in the work below the predictions from the two equations have been weighted equally: equation (8.24) with the smaller variance has not been weighted more. For actual forecasting purposes, the better fit of equation (8.24) is somewhat illusory, since the equation includes the two important variables, $DSF6_{t-1}$ and $DHF3_{t-2}$, which must be forecast exogenously. In equation (8.23) the only exogenous variable that is not trivial to forecast is the mortgage rate. On these grounds, then, equation (8.23) should be given more weight, and in the final analysis the simple compromise of treating both equations equally was made.

9 Employment and the Labor Force

9.1 Introduction

In this chapter the employment and labor force sector will be discussed. The employment part of the sector is based on the work in Fair [19], where the short-run demand for workers and for hours paid-for per worker was examined in considerable detail. The labor force part of the sector is less sophisticated and consists essentially of two rather simple labor force participation equations. In Section 9.2 the employment equation will be developed and estimated, and in Section 9.3 the labor force equations will be discussed. The chapter concludes in Section 9.4 with a summary of the sector and with a discussion of how the sector is treated within the context of the overall model. Much of the discussions in Sections 9.2 and 9.3 follows closely the discussion in Fair [18].

In order of causality in the model, the price sector should actually be discussed before the employment and labor force sector, since real output feeds into the employment and labor force sector from the price sector. The price sector, however, uses the labor force equations (though not the labor force predictions) in the development of a potential GNP series, and it is thus more convenient to discuss the employment and labor force sector first.

9.2 The Short-Run Demand for Employment

In macroeconomic models the link between output changes and employment changes is generally provided either through an aggregate production function or an aggregate employment demand function. If an employment demand function is used, it is frequently derived from a production function. It was argued rather extensively in Fair [19] that any attempt to estimate the parameters of a short-run production function in the standard way is doomed to failure, because the true labor inputs are not observed. A critical distinction was made in [19] between the (observed) number of hours paid-for per worker and the (unobserved) number of hours actually worked per worker, and it was argued that the latter is not likely to be equal to the former except during peak output periods. Using this distinction, a model of short-run employment demand was developed in [19] and was estimated for a number of three-digit manufacturing industries. The concept of "excess labor" played an important role in the model, and the estimated amount of excess labor on hand for an industry appeared to be a significant determinant of the change in employment for that industry. The present study extends the model developed in [19] to the total private nonfarm sector. It will be seen that the estimated amount of excess labor on hand in the private nonfarm sector does appear to be a significant determinant of the change in employment in the sector. The following is a brief outline of the model.

The Concept of Excess Labor

Let M_t denote the number of workers employed during period t, HP_t the average number of hours paid-for per worker during period t, H_t the average number of hours actually worked per worker during period t, and H_t^* the standard number of hours of work per worker during period t. If HP_t is greater than H_t, then firms are paying workers for more hours than they are actually working, i.e., firms are paying for "nonproductive" hours. (HP_t can never be smaller than H_t, since hours worked must be paid for.) If output and the short-run production function are taken to be exogeneous, then the two variables at the firm's command in the short run are M_t and HP_t.[1] If the total number of man hours paid-for, $M_t HP_t$, is greater than total number of man hours worked, $M_t H_t$, the firm can decrease either M_t or HP_t or both.

In the present model the desired distribution of $M_t HP_t$ between M_t and HP_t is assumed to be a function of H_t^*. H_t^* is the dividing line between standard hours of work and more costly overtime hours: if HP_t is greater than H_t^*, then an overtime premium has to be paid on the hours above H_t^*. It is thus assumed that the long-run equilibrium number of hours paid-for per worker is H_t^*. With this in mind, the measure of excess labor is taken to be $\log H_t^* - \log H_t$, which is the (logarithmic) difference between the standard number of hours of work per worker and the actual number of hours worked per worker.[2] If H_t is less than H_t^*, there is considered to be a positive amount of excess labor on hand (i.e., too few hours worked per worker and thus too

[1] From the short-run production function below, once output and M_t are determined, H_t is automatically determined.

[2] For reasons that will be clearer below, the functional form of the model is taken to be the log-linear form. In order to ease matters of exposition and where no ambiguity is involved, in what follows the difference of the logs of two variables (e.g., $\log H_t^* - \log H_t$) will be referred to merely as the difference of the variables.

many workers on hand), and if H_t is greater than H_t^*, there is considered to be a negative amount of excess labor on hand (i.e., too many hours worked per worker and thus too few workers on hand).[3] How the amount of excess labor on hand is assumed to affect changes in employment will be discussed below.

The Short-Run Production Function

The production function inputs are taken to be the number of man hours worked and the number of machine hours used. The short-run production function is assumed to be characterized by (1) no short-run substitution possibilities between workers and machines and (2) constant short-run returns to scale both with respect to changes in the number of workers and machines used and with respect to changes in the number of hours worked per worker and machine per period. Let Y_t denote the amount of output produced during period t, let M_t continue to denote the number of workers employed during period t, and let K_t denote the number of machines used during period t. Under the assumption that there are no completely idle workers or machines (which will be made here), assumption (1) implies that the number of hours worked per worker, H_t, is equal to the number of hours worked per machine. This is discussed in more detail in Fair [19], Chapter 3, but basically all it says is that if a fixed number of workers is required per machine, then it is not possible to have workers and machines working a different number of hours.

Assumptions (1) and (2) imply that the short-run production function is

$$Y_t = \min\{\alpha_t M_t H_t, \beta_t K_t H_t\}, \tag{9.1}$$

where α_t and β_t are coefficients that may be changing through time as a result of technical progress. The assumption that there are no completely idle workers or machines implies that $\alpha_t M_t H_t$ equals $\beta_t K_t H_t$ in (9.1), so that (9.1) implies

$$Y_t = \alpha_t M_t H_t. \tag{9.2}$$

Equation (9.2) has been taken to be the basic production function in this study.[4]

[3] In some industries a certain amount of overtime work has become standard practice—workers expect it and firms are reluctant not to grant it—and for these industries H_t^* should be considered to be the standard number of hours of work per worker plus this standard or "accepted" number of overtime hours of work per worker. In other words, H_t^* should be considered to be the *desired* number of hours paid-for and worked per worker.

[4] See Fair [19], Chapter 3, for a more complete discussion of the derivation of this production function.

The Measurement of Excess Labor in the Private Nonfarm Sector

In [19] it was argued that when attempting to estimate the parameters of a production function, seasonally unadjusted data should be used. A production function is a technical relationship between certain physical inputs and a physical output, not a relationship between seasonally adjusted inputs and a seasonally adjusted output. Unfortunately perhaps, the world of empirical macroeconomics is largely a seasonally adjusted world, and much of the national income accounts data are not even published on a seasonally unadjusted basis. Consequently, for the work in this study seasonally adjusted data have been used. Because of this and because of the highly aggregated nature of the data anyway, much less reliance can be put on the conclusions reached in this study than on those reached in the study of three-digit industries in [19]. The present study is merely an attempt to use some of the ideas and conclusions in [19] to develop an aggregate employment equation that can be used for forecasting purposes. It should not be considered to be an attempt to test various hypotheses about short-run employment demand.

The data on Y_t, M_t, and HP_t that have been used to estimate the employment equation below are data for the private nonfarm sector. There appears to be little systematic short-run relationship between output and employment in the agricultural and government sectors: an attempt to explain agricultural and government employment in the same way that private nonfarm employment was explained did not meet with much success. The employment data for the agricultural sector are not very good, however, and the poor results for this sector may have been due in large part to measurement errors.[5] Whatever the reason for the poor results, the decision was made to treat both agricultural and government employment as exogenous in the model. The ability to forecast these variables exogenously will be examined in Chapter 13.

The data on Y_t, M_t, and HP_t are described in Table 9–1. The data on private nonfarm output, Y_t, are national income accounts data and are currently published in the *Survey of Current Business*. The data on private nonfarm employment, M_t, and on hours paid-for per private nonfarm worker, HP_t, are compiled by the Bureau of Labor Statistics (BLS). The data on M_t and HP_t used in this study were obtained directly from the BLS, but some of the data are currently published in index number form in the *Monthly Labor Review*, Table 32. The data on M_t and HP_t are designed by the BLS

[5] See [38], pp. 123–129 for a discussion of the lack of quality of much of the agricultural data.

Table 9–1. List and Description of the Variables Used in the Employment and Labor Force Sector.

For the Employment Equation

M_t = Private Nonfarm Employment in thousands of workers, SA (primarily establishment data).

HP_t = Hours Paid-for per Private Nonfarm Worker in hours per week per worker, SA.

Y_t = Private Nonfarm Output in billions of 1958 dollars, SA, annual rates.

For the Labor Force Equations

MA_t = Agricultural Employment in thousands of workers, SA (primarily household survey data).

MCG_t = Civilian Government Employment in thousands of workers, SA (primarily establishment data).

E_t = Total Civilian Employment in thousands of workers, SA (household survey data).

D_t = Difference between the establishment employment data and the household-survey employment data in thousands of workers, SA ($= M_t + MA_t + MCG_t - E_t$).

AF_t = Level of the Armed Forces in thousands.

LF_{1t} = Level of the Primary Labor Force (males 25–54) in thousands, SA (household survey data).

LF_{2t} = Level of the Secondary Labor Force (all others over 16) in thousands, SA (household survey data).

P_{1t} = Noninstitutional Population of males 25–54 in thousands.

P_{2t} = Noninstitutional Population of all others over 16 in thousands.

UR_t = The Civilian Unemployment Rate, SA (household survey data) ($= 1 - E_t/[LF_{1t} + LF_{2t} - AF_t]$).

Note: SA = Seasonally Adjusted.

to cover the same sector of the economy as the sector covered by the national income accounts data on private nonfarm output. Note that it is hours paid-for per worker that are observed (HP_t) and not necessarily hours actually worked per worker (H_t). The data on M_t and HP_t that have been used in this study are presented in Appendix A. The data on Y_t can be easily obtained from the *Survey of Current Business*.

Using the data on Y_t, M_t, and HP_t, excess labor in the private nonfarm sector is measured as follows. In Figure 9–1 output per paid-for man hour, $Y_t/M_t HP_t$, is plotted for the 471–694 period. The dotted lines in the figure are peak-to-peak interpolation lines of the series. The assumption is made that at each of the interpolation peaks $Y_t/M_t HP_t$ equals $Y_t/M_t H_t$, i.e., that output per paid-for man hour equals output per worked man hour. From equation (9.2) this provides an estimate of α_t at each of the peaks. The further assumption is then made that α_t moves smoothly through time along the interpolation lines from peak to peak. This assumption provides estimates of α_t for each quarter of the sample period, which from (9.2) and from the data on Y_t allows an estimate of man-hour requirements, $M_t H_t$, to be made for

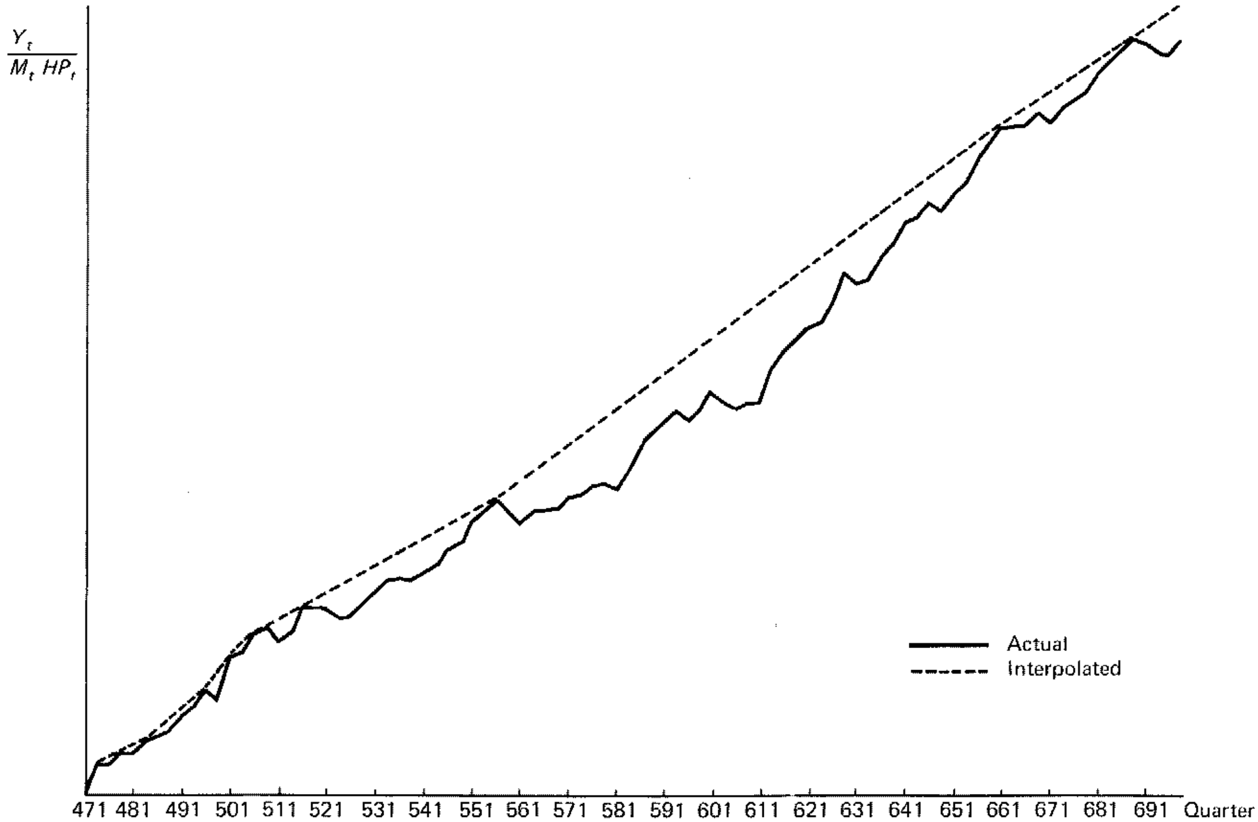

Figure 9.1. Output Per Paid-for Man Hour

each quarter.[6] For any quarter, $M_t H_t$ is the estimated number of man hours required to produce Y_t. If $M_t H_t$ is divided by H_t^*, the standard (or desired) number of hours of work per worker, the result, denoted as M_t^d, can be considered to be the desired number of workers employed for quarter t:

$$M_t^d = \frac{M_t H_t}{H_t^*}. \tag{9.3}$$

M_t^d is the desired number of workers employed in the sense that if man-hour requirements were to remain at the level $M_t H_t$, M_t^d can be considered to be the number of workers firms would want to employ in the long run. In the long run each worker would then be working the desired number of hours.

The amount of (positive or negative) excess labor on hand is then taken to be $\log M_t - \log M_t^d$, which is the (logarithmic) difference between the actual number of workers employed and the desired number. It is easy to show that this measure of excess labor is the same as $\log H_t^* - \log H_t$, which is the measure defined in Section 9.2:

$$\begin{aligned} \log M_t - \log M_t^d &= \log M_t - \log M_t H_t + \log H_t^* \qquad \text{[using (9.3)]} \\ &= \log M_t - \log M_t - \log H_t + \log H_t^* \\ &= \log H_t^* - \log H_t. \end{aligned} \tag{9.4}$$

In other words, the amount of excess labor on hand can be looked upon either as the difference between the number of workers employed and the desired number employed or as the difference between the standard number of hours of work per worker and the actual number of hours worked per worker.

Except for the measurement of H_t^*, the measurement of excess labor on hand in the private nonfarm sector is complete. The production function parameter α_t has been estimated from peak-to-peak interpolations of the output per paid-for man-hour series in Figure 9–1, and from the estimates of α_t and the data on Y_t, measurements of man-hour requirements have been made using the production function (9.2). Using (9.3), man-hour requirements can then be divided by some measure of the standard number of hours worked per worker to yield a series on the desired number of workers employed. The assumption that has been made about the standard number of hours of work per worker will be discussed in the next section.

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[6] The 661–684 line was extrapolated to get the 691, 692, 693, and 694 values for α_t. The choice of the peaks in Figure 9–1 is, of course, somewhat arbitrary, although the results were not very sensitive to the choice of slightly different peaks. The 601 and 624 "peaks" were not used as interpolation peaks because demand was still relatively weak during these periods and it seemed likely that output per paid-for man hour was still below output per worked man hour during 601 and 624.

In [19], using monthly data at the three-digit industry level, the change in the number of workers employed was seen to be a function of the amount of excess labor on hand and of expected future changes in output of up to six months in advance. Past changes in output were also seen to be significant for a few industries. It was argued in [19] (pp. 51–52), that the past change-in-output variables may help depict the reaction of firms to the amount of excess labor on hand. With respect to future output expectations, it is unlikely that the influence of output expectations more than one quarter ahead can be picked up with the highly aggregative data used in this study. The basic equation explaining employment demand is thus taken to be:

$$\log M_t - \log M_{t-1} = a_1(\log M_{t-1} - \log M^d_{t-1}) + b_0(\log Y_{t-1} - \log Y_{t-2}) + b_1(\log Y^e_t - \log Y_{t-1}). \tag{9.5}$$

Y^e_t is the expected amount of output produced during quarter t. Equation (9.5) states that the change in the number of workers employed during quarter t is a function of the amount of excess labor on hand in quarter $t-1$, of the change in output during quarter $t-1$, and of the expected change in output for quarter t. a_1 is expected to be negative and b_0 and b_1 to be positive. A more complete discussion of the theoretical model upon which equation (9.5) is based is presented in Chapter 3 of [19].

Since M_t is actually the average number of workers employed during quarter t and Y_t the average rate of output during quarter t and since employment decisions are likely to be made on less than a quarterly basis, it will be assumed here that $Y^e_t = Y_t$. In other words, it is assumed that output expectations are perfect for the current quarter.

One more assumption is necessary before equation (9.5) can be estimated. This is the assumption regarding the standard number of hours of work per worker, H^*. It is assumed that H^* is either a constant or a slowly trending variable, and specifically that

$$H^*_{t-1} = \bar{H}e^{qt}, \tag{9.6}$$

where $\bar{H}$ and q are constants. Using this assumption and the definition of M^d_t in (9.3), the excess labor variable in equation (9.5) can then be written

$$\log M_{t-1} - \log M^d_{t-1} = \log M_{t-1} - \log M_{t-1}H_{t-1} + \log \bar{H} + qt. \tag{9.7}$$

Using (9.7) and the assumption about Y_t^e made above, equation (9.5) becomes

$$\log M_t - \log M_{t-1} = a_1 \log \bar{H} + a_1 qt + a_1(\log M_{t-1} - \log M_{t-1}H_{t-1}) + b_0(\log Y_{t-1} - \log Y_{t-1}) + b_1(\log Y_t - \log Y_{t-1}). \tag{9.5'}$$

Equation (9.5′) is now in a form that can be estimated. Data on output and employment are available directly, and data on man-hour requirements, $M_{t-1}H_{t-1}$, were constructed in the manner described in the previous section.[7]

There are perhaps two main differences between equation (9.5) and previous aggregate employment equations. One, of course, is the inclusion of the excess labor variable. This variable is designed to measure the reaction of firms to the amount of too little or too much labor on hand. The second difference is that equation (9.5) does not directly include a capital stock variable. It is instead assumed that there are no short-run substitution possibilities between workers and machines and that the long-run effects of the growth of technical progress on employment (as embodied in, say, new capital stock) are reflected in the movement through time of α_t in (9.2). If α_t is increasing through time, then, other things being equal, M_t^d in (9.3) will be falling, since man-hour requirements, $M_t H_t$, will be falling. The amount of excess labor on hand will thus be increasing. The effects of the growth of technology on employment decisions are thus taken care of by the reaction of firms to the amount of excess labor on hand.

The Results

Equation (9.5′) was estimated for the 561–694 period under the assumption of first order serial correlation of the error terms. Since output is taken to be exogenous in the employment and labor force sectors, the two-stage least squares technique described in Chapter 2 did not have to be used to estimate the equation, and the equation was estimated using the simple Cochrane–Orcutt technique. As was done in the money GNP sector, observations for 593, 594, 601, 644, 651, and 652 were omitted from the sample period because

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[7] Note that the $\log M_{t-1} - \log M_{t-1}H_{t-1}$ term in (9.5)′ is equal to $-\log H_{t-1}$. Equation (9.5′) is written the way it is to emphasize that man-hour requirements, $M_{t-1}H_{t-1}$, were estimated directly from the above production function.

of strikes. The results were:

$$\log M_t - \log M_{t-1} = \underset{(3.44)}{-.514} + \underset{(1.57)}{.0000643t} - \underset{(3.41)}{.140}(\log M_{t-1} - \log M_{t-1}H_{t-1})$$
$$+ \underset{(2.34)}{.121}(\log Y_{t-1} - \log Y_{t-2}) + \underset{(6.43)}{.298}(\log Y_t - \log Y_{t-1})$$
$$\hat{\rho} = \underset{(2.52)}{.336} \qquad (9.8)$$
$$SE = .00310$$
$$R^2 = .778$$
50 observ.

As in previous chapters, the numbers in parentheses are t-statistics (in absolute values) and $\hat{\rho}$ is the estimate of the serial correlation coefficient. Since the dependent variable is already in first differenced form, the R-squared was computed taking the dependent variable to be in this form rather than in second differenced form.

All of the estimates in (9.8) are of the expected sign, and all but the estimate of the coefficient of the time trend are significant. The estimate of the coefficient of the excess labor variable is $-.140$, which implies that, other things being equal, 14 percent of the amount of excess labor on hand is removed each quarter. The past output change variable, however, is also picking up some of the effect of the reaction of firms to the amount of excess labor on hand. The estimate of the serial correlation coefficient is rather small at .336, but it is large enough to indicate that there is at least some degree of serial correlation present. This contrasts with the three-digit industry results in [19], which gave very little evidence of serial correlation.

Other equations similar to (9.8) were also estimated. The two-quarter-lagged change in output, $\log Y_{t-2} - \log Y_{t-3}$, was added to the equation, and it was not significant. In an effort to test for the effect of future output expectations on the change in employment, $\log Y_{t+1} - \log Y_t$ was added to (9.8) (under the hypothesis ot perfect expectations), and it likewise was not significant.[8] As expected, the aggregate data here do not appear to be capable of picking up any effect of future output expectations on current employment changes. Equation (9.8) was also estimated with $\log M_{t-1}$ replacing the excess labor variable, $\log M_{t-1} - \log M_{t-1}H_{t-1}$, to see if the excess labor variable is perhaps significant in (9.8) merely because it is of the nature of a lagged dependent variable.[9] The results were quite poor and $\log M_{t-1}$

[8] The equation included only 49 observations, since the 694 observation had to be dropped to allow for the last observation for Y_{t+1}.

[9] See the more complete discussion of this in [19], pp. 72–76.

was not significant by itself. The equation,

$$\log M_t - \log M_{t-1} = a_0 + a_1 t + a_2 \log M_{t-1} + a_3 \log Y_t + a_4 \log Y_{t-1},$$

which is common to many of the previous studies of short-run employment demand, was also estimated, and the results again were worse than those in (9.8).[10] Equation (9.8) was thus chosen as the basic equation determining the change in the number of private nonfarm workers employed.

Before concluding this section, the estimates of the amount of excess labor on hand will be examined in a little more detail. Note that from equation (9.8), estimates of q and $\bar{H}$ are available. (See equation (9.5′).) This means that a series on H_t^* can be constructed from equation (9.6). Using this series and the series on man-hour requirements, $M_t H_t$, constructed above, a series on the desired number of workers employed, M_t^d, can be constructed from equation (9.3). These calculations were made, and in Table 9–2 the actual series on M_t, the constructed series on M_t^d, and the difference in these series, $M_t - M_t^d$, are presented for the 561–694 period. The value of $M_t - M_t^d$ in Table 9–2 for any one quarter indicates what the excess labor situation was like for that quarter. In the last quarter of 1969, for example, there were 922,000 too many workers employed for the amount of output produced. This compares with a range of 2,240,000 too few workers in 661 to 2,722,000 too many workers in 611.

It should finally be noted that the employment model described above provides an explanation of why in the short run "productivity" falls when output falls and rises when output rises. The coefficient of $\log Y_t - \log Y_{t-1}$ in equation (9.8) is less than one (.298 to be exact), and thus when output changes by a certain percentage, employment changes by less than this percentage. Employment is then gradually changed over time to its desired level by the reaction of firms to the amount of excess labor on hand (and to the past change in output). Output per worker will thus be positively correlated with output in the short run. Also, from the results in [18] and [19] it can be seen that the number of hours paid-for per worker (HP_t) changes by a smaller percentage than output does in the short run, and indeed that total man hours paid-for ($M_t HP_t$) changes by a smaller percentage than output does. This means that output per paid-for man hour ($Y_t/M_t HP_t$) will also be positively correlated with output in the short run. Therefore, whether productivity is defined as output per worker or output per paid-for man hour, it follows that productivity and output will be positively correlated in the

[10] The fit was slightly worse: $R^2 = .758$ vs. .778 in (9.8), and serial correlation was much more pronounced: $\hat{r} = .610$ vs. .336 in (9.8). Also, as argued in [19], the equation just estimated has little theoretical justification, especially if it is taken as an equation from which a production function parameter can be derived.

short run. Only gradually will employment and hours paid-for per worker adjust to their desired levels. The process by which this adjustment takes place is described in more detail in Chapter 8 [19].

Table 9–2. Estimated Values for M_t^d.

Quarter	M_t	M_t^d	$M_t - M_t^d$	Quarter	M_t	M_t^d	$M_t - M_t^d$
561	54850	55417	−567	631	57461	57277	184
562	55087	55503	−416	632	57763	57444	319
563	54892	54886	6	633	58175	58186	−11
564	55133	55161	−28	634	58294	58717	−423
571	55340	55276	64	641	58738	59480	−742
572	55514	54899	615	642	59196	59951	−755
573	55437	54862	575	643	59499	60417	−918
574	54872	53510	1362	644	59934	60329	−395
581	53811	51571	2240	651	60464	61370	−906
582	53198	51571	1627	652	61011	61961	−950
583	53543	52659	884	653	61608	62993	−1385
584	54034	53692	342	654	62339	64187	−1848
591	54533	54256	277	661	62923	65163	−2240
592	55427	55493	−66	662	63526	65448	−1922
593	55421	54530	891	663	64182	65617	−1435
594	55607	54711	896	664	64472	65963	−1491
601	56250	55701	549	671	64730	65238	−508
602	56410	55028	1382	672	64762	65197	−435
603	56170	54326	1844	673	64948	65607	−659
604	55892	53556	2336	674	65401	65882	−481
611	55773	53051	2722	681	65835	66503	−668
612	55652	54009	1643	682	66368	67508	−1140
613	55929	54754	1175	683	66621	67813	−1192
614	56517	55554	963	684	67020	68125	−1105
621	56964	56108	856	691	67753	68147	−394
622	57361	56668	693	692	68192	68137	55
623	57384	57160	224	693	68526	68128	398
624	57200	57451	−251	694	68736	67814	922

Note: Figures are in thousands of workers.

9.3 The Labor Force and the Unemployment Rate

The purpose of the labor force equations is to allow predictions of the unemployment rate to be made, given predictions of private nonfarm employment (M_t) from the employment equation. There are three problems involved in going from predictions of M_t to predictions of the unemployment rate. First, M_t excludes agricultural and government workers. Secondly, M_t is based primarily on establishment data, and not on the household survey data, which are used to estimate the size of the labor force and the unemployment rate. A link thus has to be found between the establishment-based data and the household survey data. Finally, predictions of the labor force need to be made in order to allow predictions of the unemployment rate to be made.

With respect to the first problem, as mentioned above, agricultural employment and government employment are taken to be exogenous in the model. MA_t will be used to denote the number of agricultural workers employed, MCG_t the number of civilian government workers employed, and AF_t the number of people in the armed forces. The data on these three variables are described in Table 9–1. Data on AF_t can be obtained from data published currently in *Economic Indicators* by subtracting the figures on the civilian labor force from the figures on the total labor force. The data on MA_t and MCG_t, on the other hand, were obtained directly from the BLS. The data differ slightly from the data on agricultural and government workers that are currently published in *Economic Indicators*. Data on MCG_t, for example, exclude government enterprise workers, whereas the data on government workers in *Economic Indicators* include enterprise workers. For the BLS data used in this study, government enterprise workers are included in M_t, since government enterprise output is counted as private output. Likewise, there are a few discrepancies between the MA_t series and the agricultural employment series published in *Economic Indicators* because of the need by the BLS to match the agricultural employment series to the corresponding agricultural output series in the national income accounts.

With respect to the problem of establishment data versus household survey data, let E_t denote the total number of civilian workers employed according to the household survey. The data on E_t are described in Table 9–1 and are currently published in *Economic Indicators*. The difference D_t is then defined to be

$$D_t = M_t + MA_t + MCG_t - E_t. \quad (9.9)$$

D_t is positive and appears to consist in large part of people who hold more than one job. (The establishment series are on a job number basis and the household survey series are on a person employed basis.)

Given that D_t is composed primarily of people who hold more than one job, one would expect that it would respond to labor market conditions, and this appeared to be true from the results achieved here. D_t was taken to be a function of a time trend and M_t, and the following equation was estimated for the 561–694 period (excluding the strike observations 593, 594, 601, 644, 651, and 652) under the assumption of first order serial correlation of the error terms:

$$\begin{aligned} D_t &= -13014 - 71.10t + .358M_t \\ &\quad\;\; (8.23) \qquad (6.15) \quad\; (9.39) \\ \hat{r} &= .600 \\ &\quad (5.30) \\ \text{SE} &= 181.4 \\ R\Delta^2 &= .460 \\ &\qquad\qquad 50 \text{ observ.} \end{aligned} \tag{9.10}$$

What equation (9.10) says is that, other things being equal, a change in M_t of say, 1000, leads to a change in E_t of only 642. The difference of 358 is taken up either by moonlighters or by other discrepancies between the establishment data and household survey data.

A number of equations similar to (9.10) were also estimated. Black and Russell [2], for example, have estimated an equation similar to (9.10), with the unemployment rate used in place of M_t. This equation was also estimated for the work here, but it led to poorer results than those in (9.10). Slightly less than 50 percent of the variance of the change in D_t has been explained by equation (9.10) and the estimate of the serial correlation is fairly high, but none of the other equations estimated were an improvement over (9.10) and so (9.10) was chosen as the basic equation determining D_t.

Once M_t is determined, D_t can be determined by equation (9.10), and then taking MA_t and MCG_t as exogenous in equation (9.9), E_t can be determined. Since E_t is used in calculating the unemployment rate, this leaves only the labor force to be determined in order to determine the unemployment rate. There are many special factors that are likely to affect labor force participation rates—some of which have been described by Mincer [37]—and only limited success has so far been achieved in explaining participation rates over time. In this study no attempt has been made to develop an elaborate and refined set of participation rate equations. The labor force has been disaggregated only into primary (males 25–54) and secondary (all others over 16) workers, and the specification of the equations has remained simple. The purpose of the work here is merely to see how useful simple participation rate equations can be in forecasting the unemployment rate.

The labor force participation rate of primary workers does not appear to be sensitive to labor market conditions. None of the variables depicting labor market conditions were significant in the participation rate equations estimated here. In the final equation, therefore, the participation rate of primary workers was taken to be a simple function of time. The equation was estimated for the 561–694 period (excluding the six strike observations) under the assumption of first order serial correlation of the error terms. The results were:

$$\frac{LF_{1t}}{P_{1t}} = \underset{(658.38)}{.981} \quad - \underset{(8.57)}{.000190t}$$

$$\hat{\rho} = \underset{(1.94)}{.265}$$

$$SE = .00193$$

$$R\Delta^2 = .447$$

$$50 \text{ observ.} \qquad (9.11)$$

LF_{1t} denotes the primary (males 25–54) labor force, and P_{1t} denotes the noninstitutional population of males 25–54. Both variables include people in the armed forces. The data on LF_{1t} and P_{1t} are described in Table 9–1. The data are household survey data and were obtained directly from the BLS. P_{1t} is taken to be exogenous in the model. (The ability to forecast P_{1t} exogenously will be discussed in Chapter 13.) Note that less than half the variance of the change in the participation rate has been explained in equation (9.11). The variance of LF_{1t}/P_{1t} is small enough, however, so that the LF_{1t} series does not pose serious difficulties for short-run forecasting purposes.

The participation rate of secondary workers does appear to be sensitive to labor market conditions, but apparently in no simple way. The coefficients of the equations that were estimated in this study were quite sensitive to the choice of the period of estimation, and in particular the large increase in the participation rate from 1965 through 1969 did not appear to be consistent with past behavior. In the final equation chosen, the participation rate of secondary workers was taken to be a function of time and of the ratio of total employment (including armed forces) to total population 16 and over. The equation was estimated for the 561–694 period (excluding the six strike observations) under the assumption of first order serial correlation of the error terms. The results were:

$$\frac{LF_{2t}}{P_{2t}} = \underset{(2.69)}{.180} + \underset{(4.97)}{.000523t} + \underset{(3.67)}{.447} \frac{\widehat{E_t + AF_t}}{P_{1t} + P_{2t}}$$

$$\hat{\rho} = \underset{(9.32)}{.797}$$

$$SE = .00228$$

$$R\Delta^2 = .373$$

$$50 \text{ observ.} \qquad (9.12)$$

$$\left[1, t, \frac{LF_{2t-1}}{P_{2t-1}}, \frac{E_{t-1}+AF_{t-1}}{P_{1t-1}+P_{2t-1}}, \frac{AF_t}{P_{1t}+P_{2t}}, \frac{M_t}{P_{1t}+P_{2t}}, \frac{M_{t-1}}{P_{1t-1}+P_{2t-1}}, \frac{MCG_t}{P_{1t}+P_{2t}}, \frac{MA_{t-1}+MCG_{t-1}}{P_{1t-1}+P_{2t-1}}\right].$$

LF_{2t} denotes the secondary labor force (including armed forces) and P_{2t} denotes the noninstitutional population (including armed forces) of everyone over 16 except males 25–54. Data on LF_{2t} and P_{2t} are described in Table 9–1. Again, the data are household survey data and were obtained directly from the BLS. Like P_{1t}, P_{2t} is taken to be exogenous in the model.

Equation (9.12) is similar to equations estimated by Tella [42], [43], although here the employment population ratio is taken to include all workers and other individuals over 16 and not just secondary workers and other secondary individuals. Other kinds of participation equations for secondary workers were also estimated, but equation (9.12) appeared to give the best results.

There is one obvious statistical problem in estimating an equation like (9.12), which is due to the fact that LF_{2t} and total civilian employment, E_t, are computed from the same household survey. The household survey is far from being error free, and errors of measurement in the survey are likely to show up in a similar manner in both LF_{2t} and E_t. The coefficient estimate of $(E_t + AF_t)/(P_{1t} + P_{2t})$ in an equation like (9.12) will thus be biased upward unless account is taken of the errors of measurement problem. Because of this problem, equation (9.12) was estimated by the instrumental variable or two-stage least squares technique described in Chapter 2. The normal two-stage least squares technique could not be used because of the assumption of serial correlation of the error terms.

The instruments that were used for $(E_t + AF_t)/(P_{1t} + P_{2t})$ in (9.12) are listed in brackets after the equation. As discussed in Chapter 2, the first four instruments listed are necessary in order to insure consistent estimates. The other instruments are based on equations (9.9) and (9.10). Write equation (9.10) as

$$D_t = a_0 + a_1 t + a_2 M_t + u_t, \tag{9.10'}$$

where $u_t = r_0 u_{t-1} + e_t$. (The error term e_t is assumed to have mean zero and constant variance and to be uncorrelated with M_t and with its own past values.) Combining equations (9.9) and (9.10′) and solving for E_t yields

$$\begin{aligned} E_t = & -a_0(1 + r_0) + r_0 a_1 - a_1(1 + r_0)t + (1 - a_2)M_t + MA_t \\ & + MCG_t - r_0 E_{t-1} \\ & + r_0(1 - a_2)M_{t-1} + r_0 MA_{t-1} + r_0 MCG_{t-1} - e_t. \end{aligned} \tag{9.13}$$

Since M_t, M_{t-1}, MCG_t, and MCG_{t-1} in equation (9.13) are not computed from the household survey, they are not likely to be correlated with the measurement error in E_t and thus are good instruments to use. In addition, if the measurement errors themselves are serially uncorrelated (which is assumed here), then even though MA is computed from the household survey, MA_{t-1} in equation (9.13) will not be correlated with the measurement error in E_t and thus can be used as an instrument.

When an equation like (9.13) was estimated by the simple Cochrane–Orcutt technique for the same sample period, the coefficient estimate of $(E_t + AF_t)/(P_{1t} + P_{2t})$ was .608—versus .447 in (9.12)—which seems to indicate that, unless corrected, the measurement error bias is quite large in equations like (9.12).

It will be seen in Chapters 11–13 that equation (9.12) does not give particularly good results. The labor force participation of secondary workers grew quite rapidly during the 1965–1969 period—more rapidly than would seem warranted from the growth in the employment–population ratio—and equation (9.12) is not capable of accounting for all of this growth. The within-sample forecasts are reasonable, since the time trend in the equation can pick up most of the unexplained growth, but the outside-sample forecasts are much worse. As will be examined in Chapter 12, the coefficient estimates in (9.12) are not very stable over time, and the equation does a poor job of extrapolating into a period unless it has been estimated through that period. Mincer [37] makes a very compelling argument that many special factors (such as laws relating to Social Security retirement premiums and minimum wages) are likely to influence participation rates, and in a more complete study these factors should be taken into account. Also, the participation rates of much more disaggregated groups should be analyzed. It is beyond the scope of this study to attempt to do this, and to the extent that the labor force participation of secondary workers continues to change in ways not related to the employment–population ratio, equation (9.12) will continue to be one of the weaker equations of the model.

The employment and labor force sector is now complete. Having determined E_t in the manner described above, and taking P_{1t}, P_{2t}, and AF_t to be exogenous, LF_{1t} and LF_{2t} can be determined from equations (9.11) and (9.12). By definition, the civilian labor force is equal to $LF_{1t} + LF_{2t} - AF_t$, and so the civilian unemployment rate can be determined as:

$$UR_t = 1 - \frac{E_t}{LF_{1t} + LF_{2t} - AF_t}. \tag{9.14}$$

All of the data that have been collected for the work in this section are presented in Appendix A. These include data on MA_t, MCG_t, E_t, AF_t,

LF_{1t}, LF_{2t}, P_{1t}, and P_{2t}. The data are quarterly averages of monthly data. Except for AF_t, P_{1t}, and P_{2t}, the data are seasonally adjusted.

9.4 Summary

All of the variables that are used in the employment and labor force sector are listed in Table 9–1. The sector consists essentially of one production function, four behavioral equations, and two identities; and it will be convenient to list these equations in order of their causality in the sector.

$$\text{(i)} \qquad M_t H_t = \frac{1}{\alpha_t} Y_t \tag{9.2}$$

$$\begin{aligned}\text{(ii)} \quad \log M_t - \log M_{t-1} = {} & -.514 + .0000643t \\ & - .140(\log M_{t-1} - \log M_{t-1}H_{t-1}) \\ & + .121(\log Y_{t-1} - \log Y_{t-2}) \\ & + .298(\log Y_t - \log Y_{t-1}), \qquad \hat{r} = .336.\end{aligned} \tag{9.8}$$

$$\text{(iii)} \qquad D_t = -13014 - 71.10t + .358M_t, \quad \hat{r} = .600. \tag{9.10}$$

$$\text{(iv)} \qquad E_t = M_t + MA_t + MCG_t - D_t. \tag{9.9}$$

$$\text{(v)} \qquad \frac{LF_{1t}}{P_{1t}} = .981 - .000190t, \qquad \hat{r} = .265. \tag{9.11}$$

$$\text{(vi)} \qquad \frac{LF_{2t}}{P_{2t}} = .180 + .000523t + .447 \frac{E_t + AF_t}{P_{1t} + P_{2t}}, \qquad \hat{r} = .797. \tag{9.12}$$

$$\text{(vii)} \qquad UR_t = 1 - \frac{E_t}{LF_{1t} + LF_{2t} - AF_t}. \tag{9.14}$$

Private nonfarm output, Y_t, is fed into the employment and labor force sector from the price sector, and then the unemployment rate is determined as follows. First, man-hour requirements are determined from (i), α_t having been estimated in the manner described in Section 9.2. Then, using the man-hour requirement estimates, private nonfarm employment is determined from (ii). The difference between the establishment and household survey data is then determined from (iii), which allows total civilian employment to be determined from the definition (iv). The labor force is then determined from (v) and (vi), and finally the unemployment rate is determined from the definition (vii). Aside from Y_t, the exogenous variables in the section are MA_t, MCG_t, P_{1t}, P_{2t}, and AF_t.

With respect to predictions of the unemployment rate, there is some error cancellation in the model that is worth noting. Positive errors in predicting M_t, for example, will lead, other things being equal, to positive errors in predicting D_t in (iii), which will in turn lead to smaller positive errors in predicting E_t. Likewise, errors in predicting E_t will lead, other things being equal, to errors in the same direction in predicting LF_{2t} in (vi), which in turn lead to smaller errors in predicting the unemployment rate.

The accuracy of the sector as a whole will be examined in Chapters 11–13 within the context of the overall model. The accuracy is also examined in Fair [18], where the actual values of output are used rather than the predicted values from the price sector.

10 Prices

10.1 Introduction

In this chapter the price equation of the model will be discussed. The price equation provides the link between predictions of money GNP and predictions of real GNP. There is no feedback in the model from the price sector to the money GNP sector, and the causality runs from predictions of money GNP, to predictions of the price deflator, to predictions of real GNP. Real GNP is determined simply as money GNP divided by the price deflator. Real GNP is thus the "residual" in the model: it is determined from a simple definition once money GNP and the price level have been determined.

In most macroeconomic models prices are determined in a wage–price sector by various cost and excess demand variables. Unfortunately, in many of these models the wage–price sector has tended to be a large source of error.[1] Because of the simultaneous and lagged relationships between wages and prices, the wage–price sector is difficult to specify and estimate with precision, and in simulation the possibilities for error compounding in the sector are generally quite large. In the present model the whole wage–price nexus has been avoided, and prices have been assumed to be determined simply by current and past demand pressures. The price equation of the model can thus be considered to be a reduced form equation of a more general wage–price model. The equation is also similar to simple Phillips curve equations, where wage changes (or price changes) are taken to be a function of excess supply (as approximated by the unemployment rate) in the labor market.

Potential output plays an important role in the price sector, and the concept and measurement of potential output will be discussed in Section 10.2. The theory upon which the price equation is based will then be discussed in Section 10.3 and the results of estimating the equation will be presented. The chapter concludes in Section 10.4 with a discussion of how real GNP is computed. Some of the discussion in Sections 10.2 and 10.3 follows closely the discussion in Sections I and II of Fair [15]. Also, the development of a potential output series in Section 10.2 relies heavily on the work in the previous chapter.

[1] See, for example, Fromm and Taubman [24], p. 11, for a discussion of the difficulties encountered by the Brookings model in this area.

10.2 The Concept and Measurement of Potential Output

In Chapter 9 the production function (9.2) was derived under the assumption of no short-run substitution possibilities between workers and machines and constant short-run returns to scale. The production function is rewritten here for convenience:

$$Y_t = \alpha_t M_t H_t . \tag{9.2}$$

Y_t denotes private nonfarm output, M_t denotes private nonfarm employment, and H_t denotes the number of hours actually worked per private nonfarm worker. The production function parameter α_t was estimated in the manner described in Section 9.2.

"Potential nonfarm output" is defined in this study to be that level of output which results from equation (9.2) when the potential values of M_t and H_t are used in the equation. The potential values of M_t and H_t are defined to be the values that would occur at a 4 percent unemployment rate. "Potential output" is thus not meant to connote "maximum output." Output greater than potential could always be produced by using greater than potential values of M_t and H_t. "Potential output" is rather meant to refer to that level of output that is capable of being produced by working people at rates that have been observed to occur during periods when the unemployment rate was 4 percent.

In order to use equation (9.2) to develop a potential nonfarm output series, a potential nonfarm man-hours series has to be derived. In addition, since a potential GNP series is needed for the work below, series on potential government output and potential agricultural output have to be derived. It will be seen below that series on potential government employment and potential agricultural employment also have to be derived. In the following discussion, the potential output and employment series for the government and agricultural sectors will be derived first. Then a series on the potential number of private nonfarm workers employed will be derived, followed by the derivation of a series on the potential number of hours worked per private nonfarm worker. These latter two series then allow a series on potential private nonfarm output to be derived using the production function (9.2). The potential GNP series is then taken to be the sum of the three potential output series.

The variables that are used in the price sector are listed in Table 10–1. Many of the variables are the same as those used in the employment and labor force sector. The new variables that have been added are real agricultural output, YA_t; real government output, YG_t; government output in

Table 10–1. List and Description of the Variables Used in the Price Sector.

For the Potential GNP Calculations	
AF_t	= Level of the Armed Forces in thousands
P_{1t}	= Noninstitutional Population of males 25–54 in thousands
P_{2t}	= Noninstitutional Population of all others over 16 in thousands
MCG_t	= Civilian Government Employment in thousands of workers, SA
YG_t	= Government Output in billions of 1958 dollars, SA, annual rates
LF_{1t}^*	= Potential Level of the Primary Labor Force (males 25–54) in thousands, SA
LF_{2t}^*	= Potential Level of the Secondary Labor Force (all others over 16) in thousands, SA
E_t^*	= Potential Level of Total Civilian Employment in thousands of workers, SA
MA_t^*	= Potential Level of Agricultural Employment in thousands of workers, SA
M_t^*	= Potential Level of Private Nonfarm Employment in thousands of workers, SA
H_t^*	= Potential Number of Hours Worked per Private Nonfarm Worker in hours per week per worker, SA
Y_t^*	= Potential Private Nonfarm Output in billions of 1958 dollars, SA, annual rates
YA_t^*	= Potential Agricultural Output in billions of 1958 dollars, SA, annual rates
$GNPR_t^*$	= Potential GNP in billions of 1958 dollars, SA, annual rates
Other Variables Used in the Price Sector	
PD_t	= Private Output Deflator in units of 100, SA
GNP_t	= GNP in billions of current dollars, SA, annual rates
$GNPR_t$	= GNP in billions of 1958 dollars, SA, annual rates
GG_t	= Government Output in billions of current dollars, SA, annual rates
YA_t	= Agricultural Output in billions of 1958 dollars, SA, annual rates

Note: SA = Seasonally Adjusted

money terms, GG_t; real GNP, $GNPR_t$; and the private output deflator, PD_t. The data on these variables are described in Table 10–1. The data on the five new variables are national income accounts data and are currently published in the *Survey of Current Business*. The asterisk after a variable in the table denotes the potential value of the variable.

Potential Output and Employment in the Government and Agricultural Sectors

The potential values for government output, YG_t, and government employment (both civilian, MCG_t, and noncivilian, AF_t) have been taken to be equal to the actual values of these variables.

With respect to the agricultural sector, potential agricultural output and the potential number of agricultural workers employed were derived in the following manner. Agricultural output, YA_t, was first plotted for the 471–694 period, and the series was interpolated peak to peak. The interpolated series was then taken as the potential agricultural output series (denoted as YA_t^*). Agricultural output per worker, YA_t/MA_t, was next plotted for the 471–694 period, and a peak-to-peak interpolation of this series was made (denoted as PA_t^*). Finally, YA_t^* was divided by PA_t^* to yield a series on the potential number of agricultural workers employed (denoted as MA_t^*). Fortunately, the agricultural sector is small enough relative to the total economy so that the measurement of total potential output is not very sensitive to how the agricultural sector is treated. The treatment in this study has the advantage of smoothing out the erratic fluctuations that occur in the YA_t and MA_t series, many of which are undoubtedly due to measurement error.[2]

Potential Employment in the Private Nonfarm Sector

The derivation of the series on the potential number of private nonfarm workers employed (to be denoted as M_t^*) is based on equations (9.9), (9.10), (9.11), and (9.12) in Chapter 9. Equations (9.11) and (9.12) are the two labor force participation equations; equation (9.9) defines D_t, the difference between the establishment data and the household survey data; and equation (9.10) explains D_t as a function of a time trend and M_t. For convenience, the two labor force participation equations are repeated here:

$$\frac{LF_{1t}}{P_{1t}} = .981 - .000190t, \tag{9.11}$$

$$\frac{LF_{2t}}{P_{2t}} = .180 + .000523t + .447\frac{E_t + AF_t}{P_{1t} + P_{2t}}. \tag{9.12}$$

Also, equations (9.9) and (9.10) can be solved to eliminate D_t and to write M_t as a function of E_t, MA_t, and MCG_t. This solution is:

$$M_t = \frac{1}{1 - .358}(E_t - MA_t - MCG_t - 13014 - 71.10t). \tag{10.1}$$

Using equations (9.11), (9.12), and (10.1), the M_t^* series was derived in the following manner. In equation (9.12), $(E_t + AF_t)/(P_{1t} + P_{2t})$ was set equal to .586 for all values of t. The number .586 is the approximate value that the employment-population ratio reached when the unemployment rate was 4 percent. Using this value and taking P_{2t} to be exogenous, the potential labor force of secondary workers (denoted as LF_{2t}^*) was calculated from

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[2] See footnote 5 and related discussion in Chapter 9.

equation (9.12). The potential labor force of primary workers (denoted as LF^*_{1t}) was calculated directly from equation (9.11), taking P_{1t} to be exogenous. The potential civilian labor force was then calculated as $LF^*_{1t} + LF^*_{2t} - AF_t$ (AF_t being treated as exogenous). Potential civilian (household survey) employment (denoted as E^*_t) was next calculated as .96 ($LF^*_{1t} + LF^*_{2t} - AF_t$), where .96 is the employment rate corresponding to a 4 percent unemployment rate. Given E^*_t and given the series on potential agricultural employment, MA^*_t, computed above, the series on potential private nonfarm employment, M^*_t, was computed from equation (10.1) (MCG_t being treated as exogenous).

It should be stressed that while the derivation of M^*_t is based on equations (9.11), (9.12), and (10.1), it is not based on the *predictions* of LF_{1t}, LF_{2t}, D_t, E_t, and M_t from the employment and labor force sector. The coefficient estimates of the equations have merely been used in the derivations, along with the data on the exogenous variables, P_{1t}, P_{2t}, AF_t, and MCG_t. It should also be noted that the estimates of the serial correlation coefficients of the equations have not been used in the derivations.

The Potential Number of Hours Worked per Private Nonfarm Worker

The potential number of hours worked per private nonfarm worker will be denoted as H^*_t. In the previous chapter H^*_t was used to denote the standard or desired number of hours of work per worker. Given the assumption made about the standard number of hours of work in equation (9.6) and given the coefficient estimates in equation (9.8), a series on the standard number of hours of work can be constructed. This was done for the estimates of M^d_t presented in Table 9–2. For the work in this chapter the potential number of hours of work per worker could be taken to be the same as the standard number. In fact, a slightly different approach was followed here. The number of hours paid-for per worker, HP_t, was regressed on a constant and time for the 471–694 period and the predicted values from this equation were taken as the values for H^*_t. The equation was

$$\underset{}{HP_t} = \underset{(855.87)}{41.05} - \underset{(35.77)}{.032t}, \qquad SE = .23. \tag{10.2}$$

The estimation of the production parameter α_t in Chapter 9 was based on the assumption that hours paid-for per worker are greater than hours worked per worker except during peak output periods, and thus it does not seem unreasonable to take the potential number of hours worked per worker to be equal to the trend number of hours paid-for per worker. The values of

H_t^* achieved in this way are actually quite similar in concept to values that would have been achieved had H_t^* been taken to be equal to the constructed standard number of hours of work per worker, and the results below would have been quite similar regardless of which series had been used. The approach followed in this chapter is slightly more straightforward, and this is the reason for its use here.

Consistent with the derivation of M_t^* above, one also might use an interpolation of the hours paid-for per worker series as the series for H_t^*, where the benchmark quarters were chosen as those quarters in which the unemployment rate was approximately 4 percent. However, the value of hours paid-for during quarters in which the unemployment rate was approximately 4 percent showed no apparent consistency—the value was sometimes below trend and sometimes above trend—and this idea was therefore dropped from further consideration.

Potential Nonfarm Output and Potential Real GNP

The estimates of M_t^* and H_t^* constructed above can be multiplied together to yield a series on potential private nonfarm man hours, $M_t^* H_t^*$. Using the production function (9.2) and the estimates of α_t from Chapter 9, a series on potential private nonfarm output (denoted as Y_t^*) can then be constructed. Finally, potential real GNP (denoted as $GNPR_t^*$) can be calculated as the sum of potential private nonfarm output, potential agricultural output, and government output:

$$GNPR_t^* = Y_t^* + YA_t^* + YG_t. \tag{10.3}$$

In Table 10–2 the actual values of real GNP (denoted as $GNPR_t$), the values of $GNPR_t^*$, and the percentage changes in $GNPR_t^*$ (at annual rates) are presented quarterly for the 541–694 period.[3] Note that $GNPR_t^*$ grew less than average during late 1965 and 1966. This was due primarily to the Vietnam troop buildup during this period. As measured by the national income accounts, average output per government worker is less than average output per private worker, so that the movement of workers from private to government work (as when the level of the armed forces is increased) has a negative effect on total potential output. In general, the $GNPR_t^*$ series in Table 10–2

[3] The potential GNP numbers in Table 10–2 differ slightly from the numbers presented in Table 1 of Fair [15] because of different periods of estimation used to estimate the D_t, LF_{1t}/P_{1t}, and LF_{2t}/P_{2t} equations.

Table 10–2. Estimates of Potential Real GNP (billions of 1958 dollars).

Quarter	$GNPR_t$	$GNPR_t^*$	$\frac{4\Delta GNPR_t^*}{GNPR_{t-1}^*}$	Quarter	$GNPR_t$	$GNPR_t^*$	$\frac{4\Delta GNPR_t^*}{GNPR_{t-1}^*}$
541	402.9	427.1	.037	621	519.5	468.3	.026
542	402.1	430.7	.033	622	527.7	573.3	.035
543	407.2	433.9	.030	623	533.4	579.5	.043
544	415.7	437.6	.034	624	538.3	585.9	.045
551	428.0	441.7	.037	631	541.2	592.9	.047
552	435.4	445.7	.037	632	546.0	599.1	.042
553	442.1	450.1	.039	633	554.7	604.6	.037
554	446.4	454.0	.035	634	562.1	609.3	.031
561	443.6	457.5	.031	641	571.1	615.6	.041
562	445.6	461.1	.031	642	578.6	621.2	.037
563	444.5	465.4	.037	643	585.8	627.3	.039
564	450.3	469.0	.031	644	588.5	632.4	.032
571	453.4	472.5	.030	651	601.6	638.2	.037
572	453.2	476.6	.034	652	610.4	643.9	.036
573	455.2	481.5	.041	653	622.5	648.4	.028
574	448.2	486.7	.043	654	636.6	653.0	.028
581	437.5	491.2	.037	661	649.1	656.3	.020
582	439.5	495.3	.033	662	655.0	659.7	.021
583	450.7	499.3	.032	663	660.2	663.9	.026
584	461.6	504.3	.040	664	668.1	667.7	.023
591	468.6	508.5	.033	671	666.5	673.0	.032
592	479.9	513.6	.040	672	670.5	678.5	.032
593	475.0	518.5	.038	673	678.0	686.1	.045
594	480.4	522.5	.031	674	683.5	692.2	.036
601	490.2	530.7	.063	681	693.3	698.0	.033
602	489.7	535.5	.036	682	705.8	703.7	.032
603	487.3	540.1	.034	683	712.8	710.1	.037
604	483.7	545.6	.041	684	718.5	716.6	.036
611	482.6	551.2	.041	691	723.1	723.6	.039
612	492.8	556.3	.037	692	726.7	729.9	.035
613	501.5	561.2	.035	693	730.6	737.6	.042
614	511.7	564.6	.024	694	729.8	744.5	.038

is fairly smooth, but it is by no means as smooth as a simple trend measure like that of the Council of Economic Advisers.

The measurement of potential output in this chapter differs from that of Black and Russell [2] in two basic respects. First, the man-hours series used in this study covers only the private nonfarm sector, whereas Black and Russell derive a series for the total economy including the armed forces. The private nonfarm man-hours and output series are of greater reliability than the series for the total economy, and this is the reason why only the private nonfarm data were used to derive the above estimates of potential productivity. The second way the measurement of potential output in this study differs from that of Black and Russell is that the above estimates of potential productivity are based on the idea that the number of hours paid-for per worker does not equal the number of hours actually worked per worker except during peak output periods. Black and Russell do not distinguish between these two concepts and attempt to estimate the parameters of their production function directly. The defense of the idea that hours paid-for do not equal hours worked is made in Fair [19] and will not be repeated here.

10.3 The Price Equation

The Theory

The theory behind the specification of the price equation is simple. Aggregate price changes are assumed to be a function of current and past demand pressures. Current demand pressures have an obvious effect on current prices. If current demand is strong relative to the available supply, prices are likely to be bid (or set) higher, and if current demand is weak relative to the available supply, prices are likely to be bid (or set) lower.

There are two ways in which past demand pressures can affect current prices. One way is through the lagged response of individuals or firms to various economic stimuli. It may take a few quarters for some individuals or firms to change their prices as a result of changing demand conditions. This may, of course, not be irrational behavior, since people may want to determine whether a changed demand situation is likely to be temporary or permanent before responding to it. The other way in which past demand pressures can affect current prices is through input prices. If, for example, past demand pressures have caused past input prices to rise, this should lead to higher current output prices, as higher production costs are passed on to the customer. The lag in this case is the time taken for higher input prices to lead to higher costs of production[4] and for higher costs of production to lead to higher output prices. It may also take time for input prices to respond to demand pressures, which will further lengthen the lag between demand pressures and output prices.

Note that nothing specifically has been said about wage rates. Labor is treated like any other input—demand pressures are assumed to lead (usually with a lag) to higher wage rates, which then lead (perhaps with a lag) to higher output prices. The present approach avoids the problem of having to determine unit labor costs or wage rates before prices can be determined.

The first question which arises in specifying the price equation is what measure of demand pressure should be used. Two measures, denoted as

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[4] Since firms stockpile various inputs, this lag is not necessarily zero.

$GAP1_t$ and $GAP2_t$ respectively, were considered in the work in [15]:

$$GAP1_t = GNPR_t^* - GNPR_t, \tag{10.4}$$

$$GAP2_t = GNPR_t^* - GNPR_{t-1} - (GNP_t - GNP_{t-1}). \tag{10.5}$$

$GAP1_t$ as defined by (10.4) is the difference between potential and actual real GNP and is a commonly used measure of demand pressure. $GNPR_t^* - GNPR_{t-1}$ in (10.5) is the change in real GNP during period t that would be necessary to make $GNPR_t$ equal to $GNPR_t^*$ (to be referred to as the "potential real change in GNP"), and $GNP_t - GNP_{t-1}$ is the actual change in money GNP during period t. $GAP2_t$ as defined by (10.5) is thus the difference between the potential real change in GNP and the actual money change. $GAP2_t$ can also be considered to be a measure of demand pressure. If, for example, the potential real change in GNP is quite large, then the money change can be quite large and still lead to little pressure on available supply, but if the potential real change is small, then even a relatively small money change will lead to pressures on supply.

The results of using both GAP1 and GAP2 as the excess demand variable for the price equation are presented and discussed in Fair [15]. It turned out that the use of GAP2 led to somewhat better results, although both sets of results were reasonable. Since money GNP is determined before prices in the present model, GAP2, which includes current money GNP but not current real GNP in its definition, is the logical variable to use in the model. GAP2 has thus been used in the work below.

The Equation

The price deflator that is explained in the model is the private output deflator (denoted as PD_t), rather than the GNP deflator. Because of the way the government sector is treated in the national income accounts, the GNP deflator is influenced rather significantly by government pay increases, such as those that occurred in 683 and 693, and PD_t is likely to be a better measure of the aggregate price level.[5]

[5] The fact that the private output deflator is used as the price variable might imply that the demand pressure variable should be net of government output. Note from equation (10.4) that $GAP1_t$ is net of government output, since government output is included in both $GNPR_t^*$ and $GNPR_t$. It can be seen from equation (10.5), however, that $GAP2_t$ is not net of government output. When, for example, a government pay increase occurs, government output in money terms is increased by this amount (and thus GNP_t is increased), but government output in real terms is not affected (and thus $GNPR_t^*$ is not affected). A government pay increase thus has a negative effect on $GAP2_t$. For the work below, government output was not netted from $GAP2_t$, since it seemed reasonable to suppose that government pay increases and the like have a positive effect on the excess demand status of the private output market. In practice, however, using $GAP2_t$ net of government output produced results almost identical to those reported below using $GAP2_t$ directly.

In Table 10–3 values of PD_t, PD_{t-1}, and $GAP2_t$ are presented quarterly for the 561–694 period. Notice that $GAP2_t$ was quite large during the early 60s when there was little increase in the aggregate price level, and that it was much smaller (and in fact negative) during the late 60s when the price level was increasing quite rapidly. (Low values of $GAP2_t$ correspond to periods of high demand pressure.)

Table 10–3. Values of PD_t, $PD_t - PD_{t-1}$, and $GAP2_t$.

Quarter	PD_t	$PD_t - PD_{t-1}$	$GAP2_t$	Quarter	PD_t	$PD_t - PD_{t-1}$	$GAP2_t$
561	93.15	.94	9.3	631	105.38	.30	49.2
562	93.97	.82	11.9	632	105.70	.31	51.1
563	95.14	1.17	15.4	633	105.88	.18	48.1
564	95.89	.75	15.6	634	106.23	.34	43.5
571	96.87	.98	14.8	641	106.47	.24	41.6
572	97.52	.65	20.2	642	106.82	.35	39.8
573	98.45	.93	21.9	643	107.21	.40	37.8
574	98.82	.37	36.3	644	107.70	.49	40.4
581	99.52	.70	49.8	651	108.24	.54	32.0
582	99.77	.25	54.2	652	108.77	.52	29.4
583	100.07	.30	46.7	653	108.96	.19	22.6
584	100.48	.40	40.6	654	109.30	.35	11.6
591	100.99	.51	37.3	661	110.08	.78	.2
592	101.23	.25	32.1	662	111.15	1.07	−3.2
593	101.64	.41	41.5	663	112.03	.88	−3.7
594	101.78	.14	41.0	664	112.91	.88	−7.3
601	102.24	.46	37.8	671	113.52	.60	1.4
602	102.67	.43	43.6	672	114.09	.58	2.7
603	102.84	.17	50.9	673	115.21	1.12	−1.3
604	103.34	.50	59.2	674	116.26	1.05	−1.5
611	103.58	.24	67.2	681	117.24	.98	−4.7
612	103.61	.03	62.4	682	118.39	1.15	−13.0
613	103.59	−.02	59.1	683	119.41	1.03	−13.4
614	104.10	.51	49.6	684	120.61	1.20	−12.3
621	104.44	.34	46.5	691	122.02	1.41	−11.1
622	104.58	.14	44.4	692	123.57	1.55	−9.3
623	104.79	.22	44.6	693	124.98	1.41	−7.1
624	105.09	.30	44.9	694	126.34	1.36	4.5

The basic equation explaining the change in the deflator has been taken to be

$$PD_t - PD_{t-1} = a_0 + a_1\left(\frac{1}{a_2 + \frac{1}{8}\sum_{i=1}^{8} GAP2_{t-i+1}}\right) + e_t, \qquad (10.6)$$

where e_t is the error term.

$$\frac{1}{8}\sum_{i=1}^{8} GAP2_{t-i+1}$$

is the simple eight-quarter moving average of GAP2. Equation (10.6) is consistent with the theory expounded above. The current change in the price level is taken to be a function of current and past demand pressures as measured by the eight-quarter moving average of GAP2. A nonlinear functional form has been chosen, the functional form being similar to that used in studies of the Phillips curve, where the reciprocal of the unemployment rate is most often used as the explanatory variable.

Equation (10.6) is nonlinear in a_2 and must be estimated by a nonlinear technique. In studies of the Phillips curve, where the reciprocal of the unemployment rate is most often taken to be the explanatory variable, a coefficient like a_2 in (10.6) does not arise, since it is assumed that as the unemployment rate (excess supply) approaches zero, the change in wages (or prices) approaches infinity. In the present case, no such assumption can be made. GAP2 is a simple and highly aggregative measure of demand pressure, and there is no reason why zero values of GAP2 should correspond to infinite changes in PD_t. Indeed, GAP2 has actually been negative during part of the sample period, as can be seen from Table 10–3. Remember that potential GNP is not meant to refer to maximum GNP, but to that GNP level that is capable of being produced when the unemployment rate is 4 percent. Including a_2 in equation (10.6) allows the equation to *estimate* the value of the moving average variable that would correspond to an infinite rate of change of prices. Another way of looking at this is that including a_2 in equation (10.6) allows the excess demand variable in the equation to differ from the "true" measure of excess demand ("true" meaning that zero values of this variable correspond to infinite price changes) by some constant amount and still not bias the estimates of a_0 and a_1. The error will merely be absorbed in the estimate of a_2.

The Results

Equation (10.6) was estimated for the 561–694 period (excluding the six strike observations, 593, 594, 601, 644, 651, and 652) using a standard iterative technique. The equation to be estimated is first linearized by means of a Taylor series expansion around an initial set of parameter values. Using the linear equation, the difference between the true value and the initial value of each of the parameters is then estimated by ordinary least squares. The procedure is repeated until the estimated difference for each of the parameters is within some prescribed tolerance level. Convergence is not garanteed using this technique, but for the work in this chapter achieving convergence was no problem.

The results were[6]

$$PD_t - PD_{t-1} = \underset{(1.44)}{-1.037} + \underset{(1.19)}{165.76}\left(\frac{1}{\underset{(2.00)}{78.36} + \frac{1}{8}\sum_{i=1}^{8} GAP2_{t-i+1}}\right) \tag{10.7}$$

$$DW = 1.78$$
$$R^2 = .810$$
$$SE = .183$$
50 observ.

The three coefficient estimates in (10.7) are fairly collinear, and thus the t-statistics in (10.7) are low. When, for example, the value of a_2 in (10.7) was set equal to 78.36 (the estimated value) and the equation estimated by ordinary least squares, the resulting t-statistics for a_0 and a_1 were 8.69 and 14.32 respectively. The fit of equation (10.7) is quite good, with a standard error of only .183. The R-squared presented in (10.7) is the R-squared taking the dependent variable to be $PD_t - PD_{t-1}$, rather than the change in this difference. The equation explains 81 percent of the variance of the change in PD_t. As judged by the Durbin–Watson statistic, there is little evidence of serial correlation in the equation.

Other equations besides (10.7) were estimated, many of which are discussed in Fair [15], but (10.7) appeared to give the best results. Other moving averages of GAP2 were tried, for example, as well as various declining weighted averages. The use of moving averages of less than seven or eight quarters and the use of declining weighted averages lessened the ability of the equation to explain the inflation in 1969. As can be seen from Table 10–3, GAP2 was negative and large throughout 1968; and only using, for example, a four-quarter moving average did not appear to be enough to capture the demand pressure that built up during 1968 and that presumably led to the large price increases in 1969. Going from a four-quarter to an eight-quarter moving average substantially improved the ability of the equation to explain the inflation in 1969.

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[6] These results differ slightly from the results presented in Table 3 of Fair [15] because of different periods of estimation used. The six strike observations were not omitted for the work in [15].

The Council of Economic Advisers trend measure of potential GNP was also tried in place of the measure constructed above, and the results were not as good. Poorer results were also obtained using a linear version of equation (10.6). The nonlinear version appeared to be necessary in order to explain the inflation in 1969. It is true, however, that even the nonlinear version underpredicted the rate of inflation in 1969 unless the equation was estimated through 1969. This is, of course, not necessarily unexpected, since one generally cannot expect an equation to extrapolate well into a period where the values of the dependent and independent variables are considerably different from what they were during the period of estimation. It can be seen from Table 10–3 that the price changes were larger and the values of the eight-quarter moving average of GAP2 smaller in 1969 than at any other time during the sample period. It is thus to some extent too early to tell how useful the price equation will be for future forecasting purposes, but it is true for the work in this study that the outside-sample forecasts in Chapter 12 underpredict the rate of inflation in 1969. This is discussed in more detail in Chapter 12 below and in Fair [15].

10.4 Predictions of Real GNP

Given values of money GNP and of PD_t, real GNP can be computed as follows. Real private output can first be computed as

$$100 \frac{GNP_t - GG_t}{PD_t},$$

where GG_t is government output in money terms. Real GNP is then merely the sum of real private output and real government output:

$$GNPR_t = 100 \frac{GNP_t - GG_t}{PD_t} + YG_t, \tag{10.8}$$

where YG_t is government output in real terms. As mentioned above, YG_t is taken to be exogenous in the model. Likewise, government output in money terms, GG_t, will be taken to be exogenous as well.

The causality in the model thus runs from predictions of GNP_t in the money GNP sector, to prediction of $GAP2_t$ in equation (10.5), to predictions PD_t in (10.7), to predictions of $GNPR_t$ in (10.8). In computing $GAP2_t$, $GNPR_t^*$ is taken to be exogenous, since it is merely a function of the exogenous variables, P_{1t}, P_{2t}, AF_t, MA_t^*, YA_t^*, MCG_t, and YG_t. Note also that $GNPR_{t-1}$ enters in the computation of $GAP2_t$. This poses no problems, however, since the value of GNPR from the previous iteration can be used.

Real GNP is by definition equal to real agricultural output plus real government output plus real private nonfarm output. The latter was denoted as Y_t in Chapter 9 and was taken to be exogenous in the employment and labor force sector. Taking real agricultural output (YA_t) to be exogenous, Y_t can be computed as:

$$Y_t = GNPR_t - YA_t - YG_t, \tag{10.9}$$

where GNPR_t is computed as above and where YG_t is exogenous. Using equation (10.9), therefore, Y_t can be computed in the price sector and fed into the employment and labor force sector.

11 Tests of Different Versions of the Model and the Properties of the Final Version

11.1 Introduction

In this chapter the phrase "version of the model" is used to refer to a particular set of estimated equations. The word "model" is used rather loosely to refer to the set of all of the versions considered. One of the advantages of a small-scale model such as the present one is that different versions of it can be readily tested, and in this chapter the results of testing the different versions of the model will be discussed.

The procedure that has been used to test each version will be discussed in Section 11.2, and the error measures that have been used will be discussed in Section 11.3. The results of testing the different versions will then be examined in Section 11.4, and the final version will be presented in tabular form in Section 11.5. Finally, the properties of the final version of the model will be examined in detail in Section 11.6.

11.2 The Procedure Used to Test Each Version

Using the matrix notation in Chapter 2, the money GNP sector of the model can be written as:

$$AY + BX = U, \tag{11.1}$$

$$U = RU_{-1} + E. \tag{11.2}$$

Y is the matrix of endogenous variables, X is the matrix of predetermined variables, U and E are matrices of error terms, and A, B, and R are coefficient matrices. Since there are eight endogenous variables in the money GNP sector, (11.1) consists of eight equations, one of which is the income identity. The reduced form for each of the eight endogenous variables can be derived from (11.1) and (11.2). Since U_{-1} equals $AY_{-1} + BX_{-1}$,

$$AY + BX = RAY_{-1} + RBX_{-1} + E, \tag{11.3}$$

or

$$Y = -A^{-1}BX + A^{-1}RAY_{-1} + A^{-1}RBX_{-1} + A^{-1}E. \tag{11.4}$$

(11.4) consists of eight equations, each equation being the reduced form equation for one of the endogenous variables. The expression for Y in (11.4) is the same as the expression (2.10) in Chapter 2.

From the results in Chapters 3–7, estimates of the coefficients in A, B, and R are available. Many of the coefficients are, of course, known a priori to be zero, one, or minus one. Using the estimates of A, B, and R; assuming E to be zero; and given values for the predetermined variables, X, for the lagged endogenous variables, Y_{-1}, and for the lagged predetermined variables, X_{-1}, predictions of each of the endogenous variables can be made from (11.4). It should be remembered that some lagged endogenous variables are included among the predetermined variables in X. This means that these variables are included in both X and Y_{-1}. For example, CS_{t-1} is included in both X and Y_{-1} (since CS_{t-1} is an explanatory variable in the equation explaining CS_t), whereas IP_{t-1} is included only in Y_{-1} (IP_{t-1} enters the reduced form (11.4) only because of the serial correlation in the equation explaining IP_t).

Different versions of the model correspond to different estimates of A, B, and R, as well as perhaps to different predetermined variables in X. The question arises as to how the different versions of the model should be tested. One obvious test of the accuracy of each version is to derive within the sample period the reduced form predictions for each endogenous variable and to compare these predictions with the actual values. These reduced form predictions are similar to one-period forecasts of the endogenous variables, since the actual values of the lagged endogenous variables are assumed to be known for each prediction.

Howrey and Kelejian [27] have shown that for purposes of validating an econometric model no additional information beyond that already contained in the reduced form results can be gained by simulating the model within the sample period and comparing the simulated values with the actual values. "Simulation" here refers to the procedure of generating predictions from equations like (11.4) using generated values of the lagged endogenous variables as opposed to the actual values. "Validation" refers to the procedure of testing the hypothesis that the model is a true representation of the structure it is designed to explain. While Howrey and Kelejian's conclusion holds for purposes of validation, it does not apply to the testing procedure that is of concern here. The question that arises here is not which version of the model is the best representation of the structure of the economy, but rather which version generates the best forecasts; and for purposes of answering this question simulation results are likely to be of help. For multiperiod forecasting purposes, error accumulation is important, and simulating the different versions of the model for the length of the forecast period should indicate the degree to which each of the versions is sensitive to this accumulation—something that the reduced form results could not indicate.

This question of whether the model should be simulated is related to the discussion in Chapter 2 about what kind of techniques should be used when estimating forecasting models. As Klein and others have pointed out, the classical techniques such as ordinary least squares or two-stage least squares are based on the assumption that the actual values of the lagged endogenous variables are known, which is contrary to the situation that exists in multiperiod forecasting. Since, as pointed out in Chapter 2, the estimating techniques that might be used for forecasting models are complicated to use and not as yet well understood, the technique that was used in this study is based on the classical assumption of known values of the lagged endogenous variables. Notice, however, that if simulation results are used in the choice of the final version of the model, the overall procedure of estimating and choosing the final version cannot be considered to rest completely on the assumption of known values of the lagged endogenous variables. Presumably those versions that are sensitive to error accumulation will be eliminated by the simulation tests. The procedure used here can thus perhaps be considered to be a first approximation to a more general procedure for estimating multiperiod forecasting models.

In addition to the reduced form (one-period) predictions, then, each of the versions of the model was simulated for five quarters at a time (with the base period being increased by one quarter after each five-quarter forecast), and the simulated values of the endogenous variables were compared with the actual values. (Five quarters was chosen, somewhat arbitrarily, as the length of the forecasting horizon.) For all of these simulations the actual values of the exogenous variables were used. The prediction period that was used for the simulations and for the reduced form predictions was from 602 through 694, excluding 644, 651, and 652. The last three quarters were excluded from the prediction period since they were omitted from the periods of estimation because of the automobile strike. The reason this shorter period was used instead of the period beginning in 561 was the unavailability of some of the data before 1959. The 602 quarter was chosen as the starting point because the observations for 593, 594, and 601 were omitted from the periods of estimation because of the steel strike. Using this prediction period, there were thus a total of 36 quarters for which one-quarter-ahead (reduced form) forecasts could be made, 34 quarters for which two-quarter-ahead forecasts could be made, 32 quarters for which three-quarter-ahead forecasts could be made, 30 quarters for which four-quarter-ahead forecasts could be made, and 28 quarters for which five-quarter-ahead forecasts could be made. All of the forecasts considered in this chapter were within-sample forecasts, i.e., all of the equations tested were estimated through 694.

So far in this chapter attention has been concentrated on the money GNP sector of the model. The money GNP sector is the only sector for which extensive simulation tests were made in order to choose the final equations of the sector. The equations in the monthly housing starts sector, the employment and labor force sector, and the price sector were chosen primarily by looking at the properties of the estimated equations. There is no simultaneity within or between these sectors, and so there is less of a need to examine the equations in simulation before making the final choices. Nevertheless, the entire model was simulated when the money GNP sector was being tested, and all of the equations were examined to make sure that none of them were giving unexpected results.

The simulations were performed as follows. The two monthly housing starts equations were first used to generate predictions of monthly housing starts. Lagged housing starts enter both equations through the serial correlation of the error terms; and in the demand equation, lagged housing starts also enter through the housing stock variable After the one-month-ahead prediction, generated values of lagged housing starts were used, rather than the actual values. The two housing starts equations were weighted equally, and the housing starts prediction for any one month was taken to be the average of the predictions from the two equations for that month. The generated values of lagged housing starts for use in both equations were taken from the average of the two predictions, and not from the separate predictions of the two equations.

The monthly housing starts predictions were used to construct predictions of quarterly (seasonally adjusted) housing starts to be used in the money GNP sector. The money GNP sector was then simulated in the manner described above, using the predicted values of the quarterly housing starts variable rather than the actual values. With respect to the generation of the values for the lagged endogenous variables, it should be noted that there are two-quarter-lagged values of some of the endogenous variables in the X_{-1} matrix in (11.4). For these cases the actual values of the variables were used for the two-quarter-ahead forecast, and only beginning with the three-quarter-ahead forecast were the generated values used. It should also be noted that lagged values of the quarterly housing starts variable are included in the X and X_{-1} matrices in (11.4). Again, the actual values of these variables were used until the appropriate time came to switch to using the predictions from the monthly housing starts sector.

The money GNP predictions were used in the price sector to generate predictions of the private output deflator and real GNP (government output being taken to be exogenous). Taking farm output to be exogenous, predictions of real private nonfarm output could then be made, and these predictions were used in the employment and labor force sector to generate predictions of man-hour requirements and then private nonfarm employment. The employment predictions were then used to generate predictions of the labor force, and from these predictions, predictions of the unemployment rate were made. In the price and employment and labor force sectors, lagged values of the endogenous variables were treated in the same way as described above for the money GNP sector. Lagged endogenous variables enter all of the equations in the employment and labor force sector, since all of the equations have been estimated under the assumption of first order serial correlation of the error terms.

The one problem that arose in simulating the model was how to treat the quarters, 684, 691, 692, and 693, which were affected by the dock strike. The dock strike had little effect on net exports and thus on GNP, but it had a pronounced effect on exports and imports individually. As mentioned in Chapter 2, the 684–693 quarters were omitted from the sample period for the import equation, and the export variable was not used as an instrument in estimating any of the equations. In simulating the model through the 684–693 period, the following procedure was followed with respect to exports and imports. The level of exports was 53.4 billion dollars in 683 and 57.8 billion dollars in 693 (at annual rates). The change from 683 to 693 was thus 4.4 billion dollars. An *adjusted* export series was constructed in which the level of exports was taken to change by 1.1 billion dollars in each of the four quarters, 684–693. This adjusted series was then used in place of the actual series for the simulations.

With respect to imports, the level of imports was 49.7 billion dollars in 683 and 55.2 billion dollars in 693, for a change of 5.5 billion dollars. An *adjusted* import series was thus constructed in which the level of imports was taken to change by 1.3 billion dollars in 684 and 1.4 billion dollars in each of the other three quarters, 691–693. The import equation was then allowed to simulate through the 684–693 period, with the only difference being that for the one-quarter-ahead forecast (for which the actual value of lagged imports is required), the "actual" value of lagged imports was taken to be the adjusted value.

The treatment of exports and imports in this way will have little effect on the predictions of GNP and its other components, which is consistent with the small effect that the dock strike had on actual GNP and its other components. Looking at this in another way, in an actual forecasting situation, assuming no knowledge of the dock strike, the import equation would have been used in the model in the normal way and exports would have been assumed to increase by about one billion dollars a quarter, which is consistent with the procedure that was followed for the simulations.

11.3 The Error Measures Used

There are a number of error measures that can be used when comparing the predicted values of the endogenous variables with their actual values. Two obvious ones are the mean absolute error and the root mean square error. Let y_{it} denote the actual value of variable y_i for period t and let y_{pit} denote the predicted value of variable y_i for period t. Then the mean absolute error for y_i is

$$\mathrm{MAE}_i = \frac{1}{T}\sum_{t=1}^{T} |y_{it} - y_{pit}|, \tag{11.5}$$

where T is the number of observations for the prediction period. The root mean square error for y_i is

$$\mathrm{RMSE}_i = \sqrt{\frac{1}{T}\sum_{t=1}^{T} (y_{it} - y_{pit})^2}. \tag{11.6}$$

For purposes of judging the accuracy of short-term forecasting models, how well the model forecasts changes in the endogenous variables may be of more importance than how well it forecasts levels. Errors made in terms of levels may tend to compound over time, whereas this is less likely to be true for errors in terms of changes. If, for example, a model substantially overpredicted the one-quarter-ahead change, but was quite accurate in forecasting the next four quarterly changes, the level error measures as in (11.5) and (11.6) would penalize the model for the two-, three-, four-, and five-quarter-ahead forecasts more heavily than would seem warranted by the nature of the error that was made. Equations (11.5) and (11.6) can be expressed in terms of changes rather than levels:

$$\mathrm{MAE}\Delta_i = \frac{1}{T}\sum_{t=1}^{T} |(y_{it} - y_{it-1}) - (y_{pit} - y_{pit-1})|, \tag{11.7}$$

$$\mathrm{RMSE}\Delta_i = \sqrt{\frac{1}{T}\sum_{t=1}^{T} [(y_{it} - y_{it-1}) - (y_{pit} - y_{pit-1})]^2}. \tag{11.8}$$

MAEΔ denotes the mean absolute error in terms of changes, and RMSEΔ denotes the root mean square error in terms of changes. For one-quarter-ahead forecasts, y_{it-1} and y_{pit-1} are the same (the actual values of the lagged endogenous variables are known), and thus for these forecasts, MAEΔ and RMSEΔ in (11.7) and (11.8) are the same as MAE and RMSE in (11.5) and (11.6) respectively.

Whether the MAE criterion, the RMSE criterion, or some other error criterion should be used depends on one's welfare or loss function. The mean absolute error is perhaps easiest to interpret, and it is the error measure that has been used here. The root mean square errors were also computed in this study, and in general they lead to the same conclusions as did the mean absolute errors.

In computing MAE and MAEΔ for imports, the 684–693 period was excluded, since the errors made during this period (either predicted minus actual imports or predicted minus adjusted imports) were in some sense artificial. For the error measures for the other variables, the 684–693 period was not excluded, and it should be noted that the "actual" GNP series that was used in computing the GNP error measures was the published series and not the series that could have been constructed using the adjusted export and import series.

11.4 The Results of Testing Each Version

The eight equations that were tested are presented in Table 11–1. There were two equations tested for durable consumption, two for nondurable consumption, two for inventory investment, and two for imports. The two durable consumption equations differ in that the second one was estimated over the shorter sample period and includes the Bureau of Census buying expectations variable, $ECAR_{t-2}$, in place of one of the lagged values of the Michigan Survey Research Center consumer sentiment variable, $MOOD_{t-2}$. The two nondurable consumption equations differ in that the first one was estimated over the shorter sample period. The two inventory investment equations differ in that the second one includes GNP_t as an explanatory variable rather than $CD_{t-1} + CN_{t-1}$. Finally, the two import equations differ in that the second one includes the lagged GNP variable.

Since there are two possible equation choices for four different endogenous variables, this means that there are $2^4 = 16$ different versions of the model to consider. Each of the 16 versions was simulated in the manner described above, and MAE and MAEΔ were calculated for each of the endogenous variables for the one-, two-, three-, four-, and five-quarter-ahead forecasts

Table 11–1. The Equations Tested in this Chapter. (The first equation for each variable is the one chosen for the final version of the model.)

Equation		$\hat{\rho}$	SE	$R\Delta^2$	No. of Observations
(3.1)	$CD_t = -25.43 + .103\widehat{GNP}_t + .110MOOD_{t-1} + .092MOOD_{t-2}$	.648	1.125	.554	50
	(4.22) (39.78) (1.88) (1.54)	(6.01)			
(3.2)	$CD_t = -32.09 + .105\widehat{GNP}_t + .164MOOD_{t-1} + .084ECAR_{t-2}$	.456	1.155	.527	36
	(4.38) (35.33) (2.35) (1.64)	(3.08)			
(3.7)	$CN_t = .081\widehat{GNP}_t + .646CN_{t-1} + .147MOOD_{t-2}$	−.381	1.383	.550	36
	(5.40) (9.30) (4.67)	(2.47)			
(3.8)	$CN_t = .034\widehat{GNP}_t + .866CN_{t-1} + .049MOOD_{t-2}$	−.320	1.436	.402	50
	(3.50) (19.71) (2.50)	(2.47)			
(6.15)	$V_t - V_{t-1} = -114.76 + .728(CD_{t-1} + CN_{t-1}) - .357V_{t-1}$				
	(4.09) (4.27) (3.94)				
	$+ .095(CD_{t-1} + CN_{t-1} - \widehat{CD}_t - \widehat{CN}_t)$	.791	2.540	.589	50
	(0.42)	(9.15)			
(6.18)	$V_t - V_{t-1} = -94.48 + .241\widehat{GNP}_t - .368V_{t-1}$				
	(5.66) (6.25) (5.88)				
	$- .568(\widehat{CD}_t + \widehat{CN}_t - CD_{t-1} - CN_{t-1})$	.882	1.927	.763	50
	(5.04)	(13.24)			
(7.3)	$IMP_t = .078\widehat{GNP}_t$	1.0	.637	.437	45
	(8.70)				
(7.1)	$IMP_t = .050\widehat{GNP}_t + .030GNP_{t-1}$	1.0	.608	.499	45
	(2.09) (1.31)				

over the relevant prediction periods.[1] These errors were then examined for the various versions, with special emphasis being placed on the errors made in forecasting total GNP and on the errors made in forecasting beyond one or two quarters. When comparing two different equations for the same endogenous variable, all of the other equations remaining the same, emphasis was also placed on the errors made in forecasting that particular variable.

The procedure of selecting the final version of the model was of necessity somewhat subjective, but the final choice was not too difficult. Almost all of the results were unambiguous in the sense that an equation that performed better than another when one set of the remaining equations was used also performed better when other sets were used. There appeared, in other words, to be little simultaneous interacting of errors. Also, a version that gave better one- and two-quarter-ahead forecasts than another also tended to give better three-, four-, and five-quarter-ahead forecasts. There was thus no dilemma involved in having to choose between one- and two-quarter-ahead forecasting accuracy and three-, four-, and five-quarter-ahead accuracy.

The major difficulty that arose in analyzing the test results was due to the fact that the above tests are biased in favor of the equations that were estimated using the period of estimation beginning in 602 instead of the longer period beginning in 561. Equations that were estimated using the shorter period would be expected to give better results when tested for the same period than equations that were estimated using the longer period but tested for the shorter period. If one felt that a structural change had taken place beginning about 1960, then he would be justified in using the shorter period of estimation exclusively; otherwise more efficient estimates can be achieved using the longer estimation period. When comparing two equations that were estimated using the different periods of estimation, the results that were achieved using the equation estimated for the shorter period were discounted to some extent.

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[1] As mentioned in Section 11.3, MAE and MAEΔ are the same for the one-quarter-ahead forecasts. For the two- through five-quarter-ahead forecasts, computing MAE is straightforward: the forecasted levels are merely compared with the actual levels. There may be some confusion in how MAEΔ was computed for the two- through five-quarter-ahead forecasts, however, and this is worth elaborating on. Let $y_{pit}^{(j)}$ denote the j-quarter-ahead forecast of y_i for quarter t (the forecast being made in quarter $t-j$), and let y_{it} continue to denote (as above) the actual value of y_i for quarter t. Then MAEΔ for the j-quarter-ahead forecast is

$$\frac{1}{T}\sum_{T=1}^{T} |(y_{it} - y_{it-1}) - (y_{pit}^{(j)} - y_{pit-1}^{(j-1)})|,$$

where $y_{pit-1}^{(j-1)}$ is the $(j-1)$-quarter-ahead forecast of y_i for quarter $t-1$. The forecasts $y_{pit}^{(j)}$ and $y_{pit-1}^{(j-1)}$ are made at the same time (in quarter $t-j$), and so the difference in these two forecasts is the j-quarter-ahead forecast of the *change* in y_i for quarter t.

Turning first to the nondurable consumption equations in Table 11–1, the choice between equation (3.7), which was estimated for the shorter sample period, and equation (3.8), which was estimated for the longer period, was fairly easy. The results using equation (3.7) were consistently better, many times by a fairly wide margin; and in particular the errors made by using equation (3.8) tended to compound much more.[2] Even considering the bias in favor of equation (3.7) because it was estimated for the shorter period, the results still seemed to indicate that equation (3.8) should not be accepted. In other words, the results seemed to indicate that there has been a shift in the relationship specified in the nondurable equation between 1956 and 1960. Equation (3.7) was thus chosen as the basic equation explaining the consumption of nondurables.

For durable consumption the choice was more difficult. Equation (3.2), which was estimated for the shorter sample period and which includes the consumer buying expectations variable of the Bureau of the Census, in general gave slightly better results in terms of the level errors and slightly poorer results in terms of the change errors than did equation (3.1). Considering the slight bias in favor of equation (3.2) because it was estimated for the shorter sample period, the results were quite close, and there was little to choose between the two equations. Either equation could have been included in the final version of the model. Equation (3.1) was chosen for the final version for two main reasons. First, it was based on more observations, which, other things being equal, is a desirable property to have. Secondly, using equation (3.1) in the final version meant the $ECAR_{t-2}$ did not have to be included among the final exogenous variables of the model, which meant that there was one less exogenous variable to forecast ahead of the overall forecast. Since the desire was to keep the model as simple as possible and since the *MOOD* series would have been used in the model even if equation (3.2) had been chosen, it seemed natural to choose equation (3.1) over (3.2) and lessen by one the number of exogenous variables in the model. This would not have been done had the use of equation (3.2) led to noticeably better results.

With respect to the import equations, equation (7.3), which does not include the lagged GNP variable, appeared to give slightly better results than did equation (7.1). In terms of the level errors the results were quite close, but in terms of the change errors the results achieved using equation

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[2] For example, the nondurable consumption mean absolute errors in terms of levels for the one- through five-quarter-ahead forecasts were 1.11, 1.34, 1.46, 1.41, and 1.37 billion dollars respectively when equation (3.7) was used (all other equations of the final version being used) and were 1.15, 1.49, 1.79, 1.74, and 1.75 billion dollars respectively when equation (3.8) was used (again, all other equations of the final version being used).

(7.3) were marginally better. Equation (7.3) was thus chosen as the equation determining the level of imports, but either equation would have been satisfactory for this purpose.

With respect to the inventory investment equation, the results were quite interesting. The choice was between equation (6.18), which includes GNP_t as an explanatory variable, and equation (6.15), which includes $CD_{t-1} + CN_{t-1}$ instead. Note in Table 11–1 that the fit of equation (6.18) is noticeably better than the fit of equation (6.15) (SE = 1.927 vs. 2.540). In order to examine in some detail the simulation results achieved using the two equations, the mean absolute errors for GNP and inventory investment are presented in Table 11–2 for the two equations. The other equations

Table 11–2. Comparison of Equations (6.15) and (6.18). (Errors presented for GNP_t and $V_t - V_{t-1}$ only.)

Length of Forecast	Variable	No. of Observations	MAE for (6.15)	MAE for (6.18)	MAEΔ for (6.15)	MAEΔ for (6.18)
One quarter ahead	GNP_t	36	2.34	2.63	same	
One quarter ahead	$V_t - V_{t-1}$	36	1.87	1.98		
Two quarters ahead	GNP_t	34	3.37	3.36	2.24	2.47
Two quarters ahead	$V_t - V_{t-1}$	34	2.63	2.46	2.78	2.81
Three quarters ahead	GNP_t	32	3.18	3.43	2.34	2.58
Three quarters ahead	$V_t - V_{t-1}$	32	2.61	2.32	3.04	3.12
Four quarters ahead	GNP_t	30	2.91	3.34	2.32	2.51
Four quarters ahead	$V_t - V_{t-1}$	30	2.47	2.20	3.17	3.12
Five quarters ahead	GNP_t	28	3.09	3.31	2.36	2.52
Five quarters ahead	$V_t - V_{t-1}$	28	2.20	1.86	3.21	3.23

that were used for the results presented in Table 11–2 are the equations that were included in the final version of the model, namely the equations listed first for each variable in Table 11–1.

Comparing the results in Table 11–2, the use of equation (6.15) clearly leads to better results in terms of forecasting GNP. For the one-quarter-ahead forecast, for example, the mean absolute error for GNP was 2.34 billion dollars using equation (6.15) versus 2.63 billion dollars using equation (6.18). Likewise, for the five-quarter-ahead forecast the error was 3.09 using equation (6.15) versus 3.31 using equation (6.18). Even though the fit of equation (6.18), which includes GNP_t as an explanatory variable, is considerably better than the fit of equation (6.15), the use of equation (6.18) led to poorer simulation results in terms of predicting GNP. In terms of predicting inventory investment, equation (6.18) performed slightly better with respect to predicting the level of inventory investment (aside from the one-quarter-ahead forecast) and about the same with respect to predicting the change in inventory investment. The use of equation (6.15) has thus resulted in slightly more error cancellation with respect to predicting GNP.

It is encouraging that equation (6.15), which is based on stronger theoretical grounds, performed so well in simulation. The better fit of equation (6.18) thus appears to be misleading, even though the two-stage least squares technique was used to estimate the equation. Equation (6.15) was thus chosen as the final equation determining inventory investment—a choice that may not have been made had not the model been simulated to determine the final equation.

This completes the discussion of the tests of the various versions. In practice many more versions than those described above were tested during the development of the model, but the choice appeared to narrow down to one of the above versions. In general, the kinds of tests described in this section appeared to be worth the costs involved in performing them. There were enough surprises—such as the better performance of equation (6.15) relative to equation (6.18)—to indicate that one should not attempt to choose equations without first testing them within the context of the overall model.

11.5 The Final Version of the Model

The variables that are used in the final version of the model are listed in Table 11–3 in alphabetical order by sector. The equations of the final version are listed in Table 11–4 by sector. There are fourteen behavioral equations in the model, one production function, and six identities. There are four basic exogenous variables in the monthly housing starts sector (not counting

Table 11–3. Variables of the Model in Alphabetical Order by Sector.

The Monthly Housing Starts Sector	
†$DHF3_t$	= Three-month moving average of the flow of advances from the Federal Home Loan Bank to Savings and Loan Associations in millions of dollars
†DI_t	= Dummy variable I for month t, $I = 1, 2, \ldots, 11$
†$DSF6_t$	= Six-month moving average of private deposit flows into Savings and Loan Associations and Mutual Savings Banks in millions of dollars
HS_t	= Private nonform housing starts in thousands of units
†RM_t	= FHA mortgage rate series on new homes in units of 100
†W_t	= Number of working days in month t
†$/\Delta RM_t/$	= [see equation (8.21)]
†$\backslash\Delta RM_t\backslash$	= [see equation (8.22)]

Table 11-3 (cont.)

The Money GNP Sector	
CD_t	= Consumption expenditures for durable goods, SAAR
CN_t	= Consumption expenditures for nondurable goods, SAAR
CS_t	= Consumption expenditures for services, SAAR
†EX_t	= Exports of goods and services, SAAR
†G_t	= Government expenditures plus farm residential fixed investment, SAAR
GNP_t	= Gross National Product, SAAR
HSQ_t	= Quarterly nonfarm housing starts, seasonally adjusted at quarterly rates in thousands of units
IH_t	= Nonfarm residential fixed investment, SAAR
IMP_t	= Imports of goods and services, SAAR
IP_t	= Nonresidential fixed investment, SAAR
†$MOOD_t$	= Michigan Survey Research Center index of consumer sentiment in units of 100
†$PE2_t$	= Two-quarter-ahead expectation of plant and equipment investment, SAAR
$V_t - V_{t-1}$	= Change in total business inventories, SAAR
The Price Sector and the Employment and Labor Force Sector	
†AF_t	= Level of the armed forces in thousands
D_t	= Difference between the establishment employment data and household survey employment data, seasonally adjusted in thousands of workers
E_t	= Total civilian employment, seasonally adjusted in thousands of workers
†GG_t	= Government output, SAAR
$GNPR_t$	= Gross National Product, seasonally adjusted at annual rates in billions of 1958 dollars
†$GNPR_t^*$	= Potential GNP, seasonally adjusted at annual rates in billions of 1958 dollars
LF_{1t}	= Level of the primary labor force (males 25–54), seasonally adjusted in thousands
LF_{2t}	= Level of the secondary labor force (all others over 16), seasonally adjusted in thousands
M_t	= Private nonfarm employment, seasonally adjusted in thousands of workers
†MA_t	= Agricultural employment, seasonally adjusted in thousands of workers
†MCG_t	= Civilian government employment, seasonally adjusted in thousands of workers
$M_t H_t$	= Man-hour requirements in the private nonfarm sector, seasonally adjusted in thousands of man-hours per week
†P_{1t}	= Noninstitutional population of males 25–54 in thousands
†P_{2t}	= Noninstitutional population of all others over 16 in thousands
PD_t	= Private output deflator, seasonally adjusted in units of 100
UR_t	= Civilian unemployment rate, seasonally adjusted
Y_t	= Private nonfarm output, seasonally adjusted at annual rates in billions of 1958 dollars
†YA_t	= Agricultural output, seasonally adjusted at annual rates in billions of 1958 dollars
†YG_t	= Government output, seasonally adjusted at annual rates in billions of 1958 dollars

Notes: † Exogenous variable.
SAAR = Seasonally adjusted at annual rates in billions of current dollars.

the dummy variables), four exogenous variables in the money GNP sector (not counting the quarterly housing starts variable), and nine exogenous variables in the price and employment and labor force sectors.

The causality in the model has been described previously and will not be elaborated on here. It should be remembered that the quarterly housing starts variable, HSQ_t, is exogenous in the money GNP sector, but is endogenous in the overall model. Likewise, money GNP is exogenous in the price sector, but is endogenous in the overall model; and private nonfarm output is exogenous in the employment and labor force sector, but is endogenous in the overall model.

Two points about error cancellation in the model should be mentioned. The first point is that errors in one direction in predicting durable and nondurable consumption should lead to errors in the opposite direction in predicting inventory investment: as can be seen in equation (6.15) in Table 11–4, current inventory investment and current durable and nondurable consumption are inversely related. These offsetting errors will then lead to smaller errors in predicting total GNP. The second point about error cancellation relates to the employment and labor force sector and was touched on briefly in Chapter 9. As can be seen from equations (9.9) and (9.10), errors in predicting private nonfarm employment, M_t, will lead to errors in the same direction in predicting the D_t variable, which will in turn lead to smaller errors in predicting total civilian employment, E_t. Likewise, errors in predicting E_t lead in equation (9.12) to errors in the same direction in predicting the secondary labor force, LF_{2t}, which will in turn lead to smaller errors in equation (9.14) in predicting the unemployment rate.

11.6 The Properties of the Final Version

The Quarterly Results

It can be seen from the results for equation (6.15) in Table 11–2 that the simulation errors for GNP are quite small. The largest mean absolute error in terms of levels is 3.37 billion dollars (for the two-quarter-ahead forecast), and the largest mean absolute error in terms of changes is 2.36 billion dollars (for the five-quarter-ahead forecast). The results in Table 11–2 cannot be used to compare how the accuracy of the forecasts varies with the length of the forecast period because the results for each of the five quarterly forecasts are based on a different prediction period. In order to make this comparison, the mean absolute errors for the one-, two-, three-, and four-quarter-ahead forecasts were computed for the same prediction period (28 observations)

Table 11–4. Equations of the Model by Sector.

Equation		$\hat{r}$	SE	$R\Delta^2$	No. of observations
	The Monthly Housing Starts Sector				
(8.23)*	$HS_t = \sum_{I=1}^{11} \hat{d}_I DI_t + \underset{(4.63)}{2.70W_t} + \underset{(2.46)}{112.95} - \underset{(2.27)}{.0709} \sum_{i=1}^{t-1} HS_i + \underset{(2.31)}{8.48t}$ $- \underset{(1.45)}{.127RM_{t-2}} - \underset{(2.81)}{.412/\Delta RM_t/}$	.841 (17.54)	8.98	.790	127
(8.24)*	$HS_t = \sum_{I=1}^{11} \hat{d}_I' DI_t + \underset{(4.42)}{2.84W_t} - \underset{(1.75)}{49.22} - \underset{(2.63)}{.164t} + \underset{(8.07)}{.0541DSF6_{t-1}} + \underset{(5.27)}{.0497DHF3_{t-2}}$ $+ \underset{(2.67)}{.100RM_{t-1}} - \underset{(2.81)}{.412\backslash\Delta RM_t\backslash}$	.507 (6.64)	8.30	.822	127
	The Money GNP Sector				
(3.3)	$CD_t = -\underset{(4.22)}{25.43} + \underset{(39.78)}{.103\widehat{GNP}_t} + \underset{(1.88)}{.110MOOD_{t-1}} + \underset{(1.54)}{.092MOOD_{t-2}}$	.648 (6.01)	1.125	.554	50
(3.7)	$CN_t = \underset{(5.40)}{.081\widehat{GNP}_t} + \underset{(9.30)}{.646CN_{t-1}} + \underset{(4.67)}{.147MOOD_{t-2}}$	−.381 (2.47)	1.383	.550	36
(3.11)	$CS_t = \underset{(4.15)}{.022\widehat{GNP}_t} + \underset{(47.77)}{.945CS_{t-1}} - \underset{(7.37)}{.023MOOD_{t-2}}$	−.077 (0.55)	.431	.891	50
(4.4)	$IP_t = -\underset{(4.86)}{8.50} + \underset{(8.87)}{.063\widehat{GNP}_t} + \underset{(8.34)}{.687PE2_t}$	.689 (6.72)	1.011	.633	50
(5.5)	$IH_t = -\underset{(2.31)}{3.53} + \underset{(13.12)}{.016\widehat{GNP}_t} + \underset{(5.37)}{.0242HSQ_t} + \underset{(4.45)}{.0230HSQ_{t-1}} + \underset{(1.66)}{.0074HSQ_{t-2}}$	.449 (3.01)	.582	.792	36

Table 11–4 (contd.)

Equation		$\hat{r}$	SE	$R\Delta^2$	No. of Observations
	The Money GNP Sector				
(6.15)	$V_t - V_{t-1} = \underset{(4.09)}{-114.76} + \underset{(4.27)}{.728}(CD_{t-1} + CN_{t-1}) - \underset{(3.94)}{.357}V_{t-1}$				
	$+ \underset{(0.42)}{.095}(CD_{t-1} + CN_{t-1} - \widehat{CD}_t - \widehat{CN}_t)$	.791 (9.15)	2.540	.589	50
(7.3)	$IMP_t = \underset{(8.70)}{.078}\widehat{GNP}_t$	1.0	.637	.437	45
Income identity	$GNP_t = CD_t + CN_t + CS_t + IP_t + IH_t + V_t - V_{t-1} - IMP_t + EX_t + G_t$				
	The Price Sector				
(10.5)	$GAP2_t = GNPR_t^* - GNPR_{t-1} - (GNP_t - GNP_{t-1})$				
(10.7)‡	$PD_t - PD_{t-1} = \underset{(1.44)}{-1.037} + \underset{(1.19)}{165.76} \dfrac{1}{\underset{(2.00)}{78.36} + \frac{1}{8}\sum_{i=1}^{8} GAP2_{t-i+1}}$	0	.183	.810	50
(10.8)	$GNPR_t = 100\,\dfrac{GNP_t - GG_t}{PD_t} + YG_t$				
(10.9)	$Y_t = GNPR_t - YA_t - YG_t$				

(9.2)	$M_tH_t = \frac{1}{\alpha_t} Y_t$				
(9.8)‡	$\log M_t - \log M_{t-1} = \underset{(3.44)}{-.514} + \underset{(1.57)}{.0000643t} - \underset{(3.41)}{.140}(\log M_{t-1} - \log M_{t-1}H_{t-1})$ $+ \underset{(2.34)}{.121}(\log Y_{t-1} - \log Y_{t-2}) + \underset{(6.43)}{.298}(\log Y_t - \log Y_{t-1})$	.336 (2.52)	.00310	.778	50
(9.10)	$D_t = \underset{(8.23)}{13014} - \underset{(6.15)}{71.10t} + \underset{(9.39)}{.358M_t}$	.600 (5.30)	181.4	.460	50
(9.9)	$E_t = M_t + MA_t + MCG_t - D_t$				
(9.11)	$\frac{LF_{1t}}{P_{1t}} = \underset{(652.38)}{.981} - \underset{(8.57)}{.000190t}$	.265 (1.94)	.00193	.447	50
(9.12)	$\frac{LF_{2t}}{P_{2t}} = \underset{(2.69)}{.180} + \underset{(4.97)}{.000523t} + \underset{(3.67)}{.447} \widehat{\frac{E_t + AF_t}{P_{1t} + P_{2t}}}$	.797 (9.32)	.00228	.373	50
(9.14)	$UR_t = 1 - \frac{E_t}{LF_{1t} + LF_{2t} - AF_t}$				

* $\hat{d}_I$ and $\hat{d}_I'$ values are presented in Chapter 8.

‡ The *R*-squared is computed taking the dependent variable to be in the form listed on the left-hand side of the equation rather than in the change in this form.

as was used for the five-quarter-ahead forecasts. The results for 15 of the endogenous variables of the model are presented in Table 11–5. All of the quarterly endogenous variables that are explained by behavioral (stochastic) equations have been included in the table, as well as three of the endogenous variables that are explained by identities: money GNP, real GNP, and the unemployment rate.

From the results in Table 11–5 it can be seen that there is a tendency for

Table 11–5. Errors for the Final Version of the Model Computed for the Same Prediction Period.

	Variable	Length of Forecast: One Quarter Ahead	Two Quarters Ahead	Three Quarters Ahead	Four Quarters Ahead	Five Quarters Ahead	No. of Observations
MAE							
	GNP_t	1.99	2.53	2.16	2.33	3.09	28
	CD_t	.83	1.01	1.11	1.22	1.25	28
	CN_t	1.14	1.24	1.38	1.37	1.37	28
	CS_t	.31	.45	.57	.71	.79	28
	IP_t	.84	.93	.98	1.11	1.17	28
	IH_t	.53	.73	.85	.87	.87	28
	$V_t - V_{t-1}$	1.85	2.39	2.21	2.20	2.20	28
	IMP_t	.55	.77	1.06	1.21	1.25	24
	PD_t	.12	.20	.26	.30	.31	28
	$GNPR_t$	1.92	2.46	2.43	2.36	2.43	28
	M_t	130	241	321	378	372	28
	D_t	175	210	217	239	241	28
	LF_{1t}	48	52	52	52	52	28
	LF_{2t}	196	280	294	323	336	28
	UR_t	.0017	.0023	.0031	.0035	.0040	28
MAEΔ							
	GNP_t	1.99	1.94	2.34	2.35	2.36	28
	CD_t	.83	.93	.95	.92	.98	28
	CN_t	1.14	1.19	1.20	1.25	1.29	28
	CS_t	.31	.32	.32	.31	.31	28
	IP_t	.84	.83	.89	.85	.89	28
	IH_t	.53	.63	.68	.67	.69	28
	$V_t - V_{t-1}$	1.85	2.85	3.13	3.21	3.21	28
	IMP_t	.55	.50	.49	.48	.48	24
	PD_t	.12	.12	.12	.12	.13	28
	$GNPR_t$	1.92	1.86	2.12	2.07	2.12	28
	M_t	130	179	141	146	160	28
	D_t	175	182	184	181	186	28
	LF_{1t}	48	53	54	55	55	28
	LF_{2t}	196	199	197	195	198	28
	UR_t	.0017	.0015	.0014	.0014	.0015	28

the errors in terms of levels to compound as the forecast horizon lengthens. For money GNP and real GNP there is only a very slight tendency, but for the price, employment, and labor force variables there is more of a tendency. For the unemployment rate, for example, MAE increases from .0017 for the one-quarter-ahead forecast to .0040 for the five-quarter-ahead forecast. For the errors in terms of changes, on the other hand, there is very little evidence of error compounding. The errors in terms of changes are also in general smaller than the corresponding errors in terms of levels. The one major exception is the inventory investment variable. Notice also that the sum of the errors made in predicting the components of GNP_t is always greater than the actual error in predicting GNP_t, which implies that there is a good deal of error cancellation among the various components.

In order to examine the simulation results in more detail, the quarter-by-quarter results are presented in Table 11–6 for eleven variables. The variables include GNP_t, total consumption expenditures $CD_t + CN_t + CS_t$, plant and equipment investment IP_t, housing investment IH_t, inventory investment $V_t - V_{t-1}$, imports IMP_t, the private output deflator PD_t, real gross national product $GNPR_t$, private nonfarm employment M_t, the total labor force $LF_{1t} + LF_{2t}$, and the unemployment rate UR_t. In the table, for each quarter, the first line gives the actual change in each of the variables for that quarter, and the next five lines give respectively the one-, two-, three-, four-, and five-quarter-ahead forecast of the change in each of the variables for that quarter.[3] For 694, for example, the actual change in money GNP was 9.40 billion dollars, the one-quarter-ahead forecast (starting from 693) was 6.74, the two-quarter-ahead forecast (starting from 692) was 9.73, the three-quarter-ahead forecast (starting from 691) was 9.06, the four-quarter-ahead forecast (starting from 684) was 9.61, and finally the five-quarter-ahead forecast (starting from 683) was 9.40. For 602 and 653, the initial quarters after the strike periods, only one-quarter-ahead forecasts could, of course, be computed; for 603 and 654 only one- and two-quarter-ahead forecasts could be computed; and so on.

The results in Table 11–6 will not be discussed in detail, since they are rather self-explanatory, but a few of their more notable features will be mentioned. Looking at the money GNP forecasts first, there were four quarters (of the 36 quarters considered) in which errors larger than 5 billion dollars occurred: 611, 612, 654, and 671. The one- and two-quarter-ahead forecasts for 611 were about 5 billion dollars too high, and the forecasts for 612 were between about 4 and 9 billion dollars too low. In general, the slow growth of GNP during the 602–611 period was caught fairly well,

[3] Using the notation in footnote 1, the j-quarter-ahead forecast ($j = 2, 3, 4, 5$) of variable y_i for quarter t presented in Table 11–6 is $y_{pit}^{(j)} - y_{pit-1}^{(j-1)}$. The one-quarter-ahead forecast is $y_{pit}^{(j)} - y_{it-1}$.

Table 11–6. Actual and Forecasted Changes for Selected Variables of the Model. (Forecasts are within-sample forecasts and are based on actual values of the exogenous variables. Forecasts for UR_t are in terms of levels.)

Quarter	Length of Forecast	GNP_t	$CD_t+CN_t+CS_t$	IP_t	IH_t	V_t-V_{t-1}	IMP_t	PD_t	$GNPR_t$	M_t	$LF_{1t}+LF_{2t}$	UR_t
602		1.70	5.20	1.20	−1.60	−6.00	.20	.43	−.50	160	925	.0524
	1	5.15	5.09	1.68	−1.71	−2.61	.40	.37	3.14	239	201	.0485
603		−.50	−.40	−.60	−1.10	−.80	−.60	.17	−2.40	−240	198	.0556
	1	5.14	3.40	.55	−.86	.75	.40	.36	2.24	−101	177	.0532
	2	3.91	3.76	.40	−.71	−.93	.31	.37	1.00	131	365	.0471
604		−.90	1.80	.0	−.40	−5.50	−1.40	.50	−3.60	−278	352	.0626
	1	1.92	3.07	−.16	−.56	−2.08	.15	.33	−.15	−265	94	.0593
	2	3.26	2.29	−.33	−.03	−.33	.25	.35	1.06	−46	160	.0561
	3	2.17	2.11	−.45	.05	−1.28	.17	.36	−.05	−99	277	.0504
611		.30	.70	−2.40	.10	−1.10	.10	.24	−1.10	−119	285	.0678
	1	5.47	2.59	−1.05	−.23	1.58	.43	.30	3.65	−197	26	.0651
	2	5.42	2.37	−.94	.48	.93	.42	.30	3.55	−194	118	.0629
	3	2.99	2.23	−1.27	.50	−1.24	.23	.32	1.10	−135	138	.0596
	4	1.83	2.06	−1.38	.41	−2.12	.14	.34	−.06	−208	225	.0549
612		11.30	3.90	.0	.40	5.60	.20	.03	10.20	−121	−6	.0699
	1	6.64	2.61	−.03	.74	2.34	.52	.24	4.79	−114	−5	.0726
	2	7.08	3.58	−.32	1.08	1.69	.55	.26	5.15	−95	−6	.0696
	3	5.07	3.16	−.38	1.20	−.12	.40	.27	3.17	−73	44	.0678
	4	2.93	2.47	−.63	.58	−.86	.23	.29	1.00	−167	28	.0654
	5	2.23	2.26	−.70	.55	−1.30	.17	.30	.29	−236	94	.0616

613		9.30	4.40	1.50	.80	1.70	1.40	−.02	8.70	277	−85	.0676
	1	9.27	4.62	1.42	.61	1.13	.72	.23	7.57	182	147	.0682
	2	10.73	5.10	1.43	.83	1.90	.84	.22	9.02	93	180	.0710
	3	10.00	4.69	1.17	1.10	1.53	.78	.24	8.22	143	226	.0683
	4	7.62	4.02	1.07	.42	.41	.59	.24	5.91	57	235	.0674
	5	6.07	3.53	.89	.28	−.45	.47	.26	4.32	−53	216	.0657
614		13.50	6.40	1.10	.90	1.70	.40	.51	10.20	588	72	.0618
	1	12.36	5.68	1.85	1.19	.81	.96	.22	10.41	329	297	.0646
	2	12.88	6.03	1.90	1.03	1.01	1.00	.22	10.89	270	222	.0660
	3	14.37	6.01	1.94	.72	2.92	1.12	.20	12.36	341	244	.0678
	4	12.44	5.77	1.67	.48	1.59	.97	.22	10.40	321	279	.0657
	5	11.09	5.23	1.62	.42	.79	.87	.23	9.10	231	280	.0656
621		10.10	5.20	.90	.60	1.20	.60	.34	7.80	447	176	.0563
	1	10.90	5.60	1.47	.48	1.29	.85	.21	9.16	422	446	.0565
	2	11.47	6.28	1.25	.86	1.07	.90	.21	9.74	476	383	.0590
	3	12.10	6.26	1.31	.95	1.62	.94	.21	10.32	416	324	.0610
	4	12.53	6.43	1.30	.62	2.26	.98	.19	10.80	433	323	.0623
	5	11.45	6.04	1.13	.60	1.67	.89	.21	9.65	400	349	.0608
622		9.40	3.40	1.80	1.00	−.60	.60	.14	8.20	397	114	.0550
	1	11.90	6.76	1.24	.46	−.03	.93	.21	10.25	398	355	.0564
	2	11.81	6.86	1.07	.60	−.10	.92	.21	10.17	590	284	.0555
	3	12.30	6.75	.92	.23	1.05	.96	.21	10.65	481	211	.0585
	4	12.66	6.91	.96	.46	1.02	.99	.21	10.98	496	180	.0605
	5	13.20	7.02	.96	.45	1.49	1.03	.20	11.56	496	173	.0614
623		7.20	5.50	1.80	.60	−.90	.10	.21	5.70	23	305	.0555
	1	6.01	6.57	1.20	−.11	−1.27	.47	.21	4.58	271	381	.0553
	2	8.19	5.97	1.56	.32	.89	.64	.22	6.62	518	401	.0555
	3	8.20	5.98	1.45	.34	.98	.64	.22	6.61	434	331	.0552
	4	7.82	6.03	1.30	−.00	1.00	.61	.23	6.25	432	294	.0581
	5	8.08	6.11	1.33	.05	1.12	.63	.23	6.48	465	276	.0599

Table 11–6 (cont.)

Quarter	Length of Forecast	GNP_t	$CD_t + CN_t + CS_t$	IP_t	IH_t	$V_t - V_{t-1}$	IMP_t	PD_t	$GNPR_t$	M_t	$LF_{1t} + LF_{2t}$	UR_t
624		7.60	5.80	−.40	−.40	1.20	.30	.30	4.90	−184	−4	.0552
	1	7.62	5.88	.53	−.32	.52	.59	.23	5.23	193	335	.0575
	2	9.00	5.14	.78	.28	1.70	.70	.23	6.55	386	397	.0559
	3	7.33	4.70	.83	.47	.09	.57	.24	4.89	311	342	.0565
	4	7.13	4.70	.74	.39	.05	.56	.25	4.68	285	306	.0564
	5	7.10	4.66	.66	.36	.18	.55	.25	4.65	317	286	.0591
631		5.40	5.20	−.70	.50	−1.70	−.10	.30	2.90	261	377	.0579
	1	8.16	5.43	.55	.81	−.09	.64	.26	5.70	116	385	.0577
	2	7.93	5.04	.24	.36	.70	.62	.26	5.48	197	361	.0585
	3	7.51	5.03	.33	.70	−.16	.59	.26	5.10	211	364	.0566
	4	6.15	4.44	.35	.65	−1.01	.48	.27	3.73	125	311	.0575
	5	6.06	4.41	.29	.67	−1.04	.47	.28	3.61	119	290	.0575
632		6.80	3.80	1.50	.70	.10	.70	.31	4.80	302	458	.0570
	1	9.27	5.73	1.71	.32	.83	.72	.27	7.34	273	463	.0597
	2	7.98	5.92	1.30	.24	−.16	.62	.28	6.09	199	375	.0596
	3	7.73	5.94	1.08	.47	−.46	.60	.28	5.86	224	341	.0595
	4	7.40	5.64	1.14	.28	−.38	.58	.27	5.56	164	323	.0578
	5	6.39	5.21	1.15	.25	−1.02	.50	.29	4.53	103	282	.0588
633		10.50	6.30	1.50	.30	1.20	.70	.18	8.70	412	249	.0551
	1	9.46	5.89	1.83	.62	−.24	.74	.28	7.25	343	421	.0583
	2	9.54	5.30	1.82	.36	.70	.74	.29	7.29	464	430	.0591
	3	8.59	5.22	1.53	.03	.39	.67	.29	6.36	344	392	.0600
	4	8.74	5.16	1.40	.21	.55	.68	.29	6.51	311	351	.0594
	5	8.42	5.02	1.44	.17	.35	.66	.29	6.22	242	331	.0580

634		11.10	3.20	1.80	.90	2.10	.20	.35	7.40	119	322	.0558
	1	11.52	6.25	1.91	.79	.16	.90	.29	8.05	443	489	.0549
	2	11.12	5.69	1.76	.22	1.23	.87	.29	7.70	478	435	.0570
	3	10.06	5.58	1.68	.49	−.00	.78	.30	6.65	394	418	.0577
	4	9.51	5.52	1.49	.53	−.38	.74	.30	6.10	375	417	.0590
	5	9.42	5.50	1.39	.53	−.36	.74	.30	6.02	325	378	.0582
641		11.90	10.20	1.50	−.30	−3.30	.50	.24	9.00	444	288	.0547
	1	9.89	8.81	.62	−.01	−3.16	.77	.29	6.85	326	322	.0579
	2	12.08	7.28	.73	.20	.41	.94	.30	8.89	597	389	.0555
	3	11.74	7.30	.63	.06	.27	.92	.29	8.60	464	330	.0579
	4	11.58	7.09	.61	.47	−.09	.90	.30	8.40	439	328	.0585
	5	11.23	7.00	.48	.49	−.25	.88	.31	8.04	453	337	.0599
642		10.30	5.90	1.80	−.50	1.30	.70	.35	7.50	458	663	.0524
	1	14.42	7.31	2.20	.02	3.61	1.12	.31	11.55	604	426	.0536
	2	12.93	7.22	2.34	−.59	2.67	1.01	.30	10.20	528	431	.0568
	3	11.27	7.14	2.22	−.58	1.07	.88	.31	8.62	507	413	.0545
	4	11.96	7.14	2.20	−.22	1.47	.93	.30	9.31	484	388	.0566
	5	11.57	7.01	2.17	−.19	1.18	.90	.31	8.88	481	389	.0571
643		10.90	9.00	2.30	−.10	−1.30	.50	.40	7.20	303	−109	.0501
	1	10.60	8.00	1.78	−.05	.10	.83	.31	7.35	443	313	.0529
	2	9.53	7.31	1.66	−.53	.14	.74	.32	6.29	643	465	.0521
	3	10.12	7.34	1.86	−.34	.36	.79	.31	6.91	491	429	.0557
	4	9.70	6.79	1.83	−.40	.54	.76	.32	6.48	408	394	.0537
	5	9.96	6.87	1.80	−.35	.72	.78	.31	6.77	420	382	.0556
653		15.40	8.40	2.90	.30	.20	.30	.19	12.10	597	264	.0437
	1	11.17	6.89	.99	.15	.12	.87	.41	7.11	477	300	.0470
654		18.90	11.10	3.80	.20	.60	1.50	.34	14.10	731	358	.0411
	1	13.66	8.61	1.48	−.32	.25	1.07	.46	8.71	614	465	.0430
	2	13.16	8.23	1.96	−.32	−.38	1.03	.44	8.34	649	474	.0454

Table 11–6 (cont.)

Quarter	Length of Forecast	GNP_t	$CD_t + CN_t + CS_t$	IP_t	IH_t	$V_t - V_{t-1}$	IMP_t	PD_t	$GNPR_t$	M_t	$LF_{1t} + LF_{2t}$	UR_t
661		19.50	10.30	2.60	.0	1.60	1.50	.78	12.50	584	345	.0386
	1	18.86	8.66	2.55	.32	2.40	1.47	.54	13.21	827	559	.0380
	2	17.27	8.81	3.07	−.34	.67	1.35	.52	11.90	841	535	.0396
	3	17.41	8.69	3.43	−.42	.67	1.36	.49	12.17	659	490	.0426
662		13.80	4.10	1.50	−1.50	4.90	1.10	1.07	5.90	603	507	.0383
	1	14.94	7.60	1.61	−.42	1.52	1.17	.63	9.33	690	560	.0351
	2	13.66	8.40	1.53	−.51	−.61	1.07	.62	8.19	934	596	.0334
	3	15.50	8.44	2.08	−.16	.46	1.21	.59	10.08	741	532	.0359
	4	16.09	8.41	2.36	−.01	.69	1.25	.55	10.82	688	513	.0388
663		12.60	9.30	2.70	−1.20	−4.30	2.20	.88	5.20	656	576	.0377
	1	9.73	7.22	1.93	−.97	−5.80	.76	.71	3.59	432	479	.0364
	2	14.11	7.53	2.20	−1.03	−1.68	1.10	.73	7.39	808	549	.0322
	3	14.90	7.61	2.25	−1.40	−.59	1.16	.73	8.13	672	493	.0313
	4	16.90	8.08	2.67	−.64	−.10	1.32	.68	10.20	681	478	.0336
	5	17.31	8.11	2.86	−.61	.10	1.35	.63	10.86	677	469	.0362
664		14.80	3.40	1.20	−2.70	8.00	.60	.88	7.90	290	688	.0369
	1	10.00	5.74	1.36	−1.51	−.31	.78	.82	3.96	399	541	.0344
	2	10.29	6.57	1.56	−1.08	−1.65	.80	.81	4.30	514	558	.0332
	3	9.98	6.04	1.53	−1.40	−1.11	.78	.85	3.75	473	539	.0298
	4	10.48	6.39	1.57	−1.30	−1.05	.82	.85	4.20	430	505	.0290
	5	11.75	6.73	1.85	−1.20	−.41	.92	.80	5.66	486	503	.0309

671		3.50	6.60	−.90	−.60	−10.90	.50	.60	−1.60	258	358	.0376
	1	8.11	7.66	.19	.51	−9.72	.63	.93	.69	204	337	.0355
	2	12.45	6.34	.32	.26	−3.60	.97	.92	4.61	477	470	.0323
	3	15.06	6.96	.61	.13	−1.56	1.18	.91	6.98	402	458	.0320
	4	13.64	6.53	.51	−.37	−2.06	1.06	.97	5.35	345	438	.0293
	5	14.11	6.71	.54	−.37	−1.78	1.10	.98	5.75	325	414	.0284
672		9.30	8.60	−.30	1.60	−5.60	−.30	.57	4.00	32	171	.0386
	1	8.91	5.66	−.19	2.69	−3.15	.70	1.00	1.41	64	233	.0371
	2	9.29	6.49	−.41	2.55	−2.91	.73	1.02	1.59	185	319	.0360
	3	10.03	6.73	−.47	2.04	−1.80	.78	1.01	2.30	215	356	.0329
	4	11.19	7.36	−.31	1.53	−.81	.87	1.01	3.32	271	374	.0327
	5	10.38	6.96	−.36	1.40	−1.11	.81	1.09	2.11	223	360	.0305
673		16.90	6.00	.50	3.40	4.40	.60	1.12	7.50	186	752	.0386
	1	16.19	8.32	1.49	2.91	1.44	1.26	1.07	7.14	288	469	.0367
	2	12.98	9.21	1.24	2.67	−2.53	1.01	1.05	4.46	237	447	.0362
	3	11.97	8.82	1.01	2.31	−2.64	.93	1.08	3.40	172	435	.0360
	4	13.02	8.68	1.01	1.91	−.96	1.02	1.08	4.35	168	451	.0332
	5	14.11	9.17	1.13	1.88	−.37	1.10	1.08	5.23	243	474	.0327
674		15.70	6.90	1.50	2.40	1.70	2.10	1.05	5.50	453	571	.0392
	1	14.30	10.35	1.18	1.99	−3.60	1.12	1.12	3.94	277	386	.0380
	2	17.85	9.80	1.08	2.45	.51	1.39	1.12	6.95	398	479	.0353
	3	18.72	10.01	1.10	2.16	1.50	1.46	1.09	7.92	347	456	.0354
	4	16.90	9.76	.87	1.69	.50	1.32	1.12	6.17	276	431	.0358
	5	17.42	9.87	.86	1.65	1.00	1.36	1.12	6.61	273	441	.0331
681		19.20	18.10	4.10	−.30	−7.90	3.10	.98	9.80	434	106	.0369
	1	19.17	12.62	3.04	.70	−3.79	1.50	1.14	8.91	435	363	.0370
	2	24.20	11.24	3.43	1.48	2.04	1.89	1.14	13.16	564	418	.0356
	3	23.15	10.74	3.14	1.63	1.55	1.81	1.16	12.17	543	467	.0331
	4	23.06	11.06	3.12	1.12	1.66	1.80	1.11	12.38	519	453	.0335
	5	22.08	10.72	2.97	1.01	1.20	1.72	1.13	11.38	461	431	.0343

Table 11–6 (cont.)

Quarter	Length of Forecast	GNP_t	$CD_t+CN_t+CS_t$	IP_t	IH_t	V_t-V_{t-1}	IMP_t	PD_t	$GNPR_t$	M_t	$LF_{1t}+LF_{2t}$	UR_t
682		23.40	9.60	−2.70	1.70	8.30	1.40	1.15	12.50	533	508	.0360
	1	26.04	8.60	.92	1.22	9.43	2.03	1.18	14.54	682	437	.0333
	2	21.12	10.87	.94	.27	2.59	1.65	1.16	10.50	672	399	.0342
	3	20.84	11.02	.97	.33	2.03	1.63	1.18	10.14	633	414	.0334
	4	19.66	10.42	.75	.19	1.74	1.53	1.19	9.04	569	441	.0314
	5	19.94	10.57	.75	.10	1.97	1.56	1.13	9.66	549	430	.0320
683		17.70	14.60	1.70	−.30	−2.70	2.40	1.03	7.00	253	146	.0356
	1	18.60	10.51	3.31	.09	−.65	1.45	1.21	6.74	487	391	.0351
	2	17.32	11.42	2.15	.34	−2.03	1.35	1.23	5.58	644	433	.0320
	3	20.14	11.85	2.55	.27	.24	1.57	1.20	8.14	521	362	.0337
	4	20.16	11.45	2.59	−.12	1.02	1.57	1.22	7.99	513	378	.0332
	5	19.30	11.02	2.43	−.13	.68	1.51	1.24	7.18	458	398	.0317
684		16.10	5.80	3.40	2.00	3.30	1.30†	1.20	5.70	399	226	.0340
	1	18.83	8.50	1.69	.67	4.35	1.47	1.24	7.74	421	433	.0350
	2	14.89	9.36	.96	−.04	.67	1.16	1.23	4.55	521	394	.0339
	3	14.77	9.34	.21	−.02	1.29	1.15	1.24	4.34	366	375	.0319
	4	16.00	10.40	.45	.04	1.26	1.25	1.21	5.57	395	343	.0334
	5	15.80	10.32	.46	.01	1.14	1.23	1.24	5.20	411	361	.0331
691		16.20	11.30	3.80	1.40	−3.90	1.40†	1.40	4.60	733	959	.0336
	1	19.67	11.54	5.55	.17	−2.85	1.53	1.29	8.06	444	486	.0331
	2	18.23	10.20	6.04	.38	−1.57	1.42	1.31	6.78	517	433	.0334
	3	19.20	10.69	5.77	.31	−.67	1.50	1.28	7.73	417	376	.0327
	4	18.67	10.84	5.23	.46	−1.00	1.46	1.30	7.19	351	376	.0314
	5	19.99	11.43	5.42	.48	−.38	1.56	1.26	8.48	396	355	.0326

692		16.10	10.80	2.50	−.60	.30	1.40†	1.55	3.60	439	280	.0349
	1	18.86	10.37	1.58	−.17	2.85	1.47	1.34	6.95	444	342	.0322
	2	15.80	10.01	.92	−.16	2.36	1.23	1.36	4.35	479	476	.0319
	3	14.33	9.78	1.23	.28	.26	1.12	1.37	3.09	324	406	.0329
	4	15.49	10.46	1.07	.63	.63	1.21	1.34	4.21	306	379	.0323
	5	15.13	10.42	.70	.67	.62	1.18	1.35	3.82	265	382	.0313
693		18.00	7.00	3.30	−1.30	3.80	1.40†	1.41	3.90	334	688	.0363
	1	20.36	10.88	3.14	−1.02	2.56	1.59	1.36	6.05	288	331	.0369
	2	17.50	10.82	3.30	−1.22	.77	1.36	1.38	3.65	486	290	.0335
	3	17.14	10.95	2.95	−.71	.09	1.34	1.40	3.25	266	316	.0345
	4	17.30	10.61	3.24	−.10	−.29	1.35	1.41	3.33	220	283	.0357
	5	18.08	11.07	3.13	−.05	.14	1.41	1.37	4.16	212	264	.0351
694		9.40	9.60	1.40	.10	−3.00	.70	1.36	−.80	210	417	.0359
	1	6.74	8.74	−.55	−.72	−2.11	.53	1.32	−2.67	8	206	.0395
	2	9.73	7.88	−.26	−1.01	1.79	.76	1.35	−.49	233	313	.0377
	3	9.06	7.90	−.07	−1.20	1.05	.71	1.36	−1.11	101	264	.0356
	4	9.61	8.03	−.26	−.56	1.05	.75	1.39	−.81	104	314	.0369
	5	9.40	7.87	−.08	−.48	.73	.73	1.39	−1.01	96	296	.0380

† Adjusted value rather than the actual value.

although the upturn in 612 was missed. This latter error was due primarily to errors made in forecasting inventory investment. No large errors were made in forecasting GNP_t for the 613–643 period—even the moderate sluggishness in the 623–632 period was picked up—and the next error of larger than 5 billion dollars did not occur until 654. In 654 the change in GNP was underpredicted by about 5 billion dollars, on top of an underprediction of about 4 billion dollars in 653. In both of these quarters, consumption and plant and equipment investment were underpredicted. The next quarter in which large errors were made was 671, where errors between about 4.5 and 11.5 billion dollars were made. The small increase in GNP in 671 was not captured by the model, due primarily to a failure to forecast accurately the 10.90 billion dollar decrease in inventory investment in 671. The remaining 672–694 period was forecast fairly well, including the slowdown in 694. In particular, no significant slowdown in the last half of 1968 was forecast by the model, a slowdown many economists were expecting after the tax increase was passed in June 1968.

With respect to the forecast of GNP, then, there appear to be only two or three quarters in which the model gave misleading results. The model missed the upturn in 612, it underpredicted the increase in GNP in 654 by about 5 billion dollars, and it missed the slowdown in 671. The largest errors were made in 671. Inventory investment increased from 11.9 billion dollars in 663 to 19.9 billion dollars in 664 and then decreased to 9.0 billion dollars in 671. The model failed to forecast the 8.0 billion dollar increase in inventory investment in 664, but offsetting errors in the model (namely, in consumption) caused the overall GNP forecasts to be moderately good. The model then failed to forecast (aside from the one-quarter-ahead forecast) the 10.9 billion dollar decrease in inventory investment in 671. This time there were no offsetting errors, and thus large errors in forecasting the change in GNP were made.

With respect to the forecasts of the change in the price deflator, the largest errors occurred in 662, where the model underpredicted the rate of inflation, and in 672, where the model overpredicted the rate of inflation. The inflation in the last half of the 1960s was caught quite well, aside from a slight underprediction in 691 and 692. With respect to the unemployment rate, the forecasts in Table 11–6 are in terms of levels rather than changes, since the level of the unemployment rate is the most widely followed. There is a tendency for the errors in forecasting the unemployment rate to compound as the forecast horizon lengthens. This is definitely true for the 602–611 period, and also for the 664–674 period. In both periods the unemployment rate was more and more underpredicted as the forecast horizon lengthened. For the 602–611 period this was due primarily to the failure of the model to forecast the large increase in the labor force in 602. In general, however, the high unemployment rates in the early 1960s and the low rates in the late 1960s were caught moderately well.

The forecasts in Table 11–6 are not, of course, *ex ante* forecasts. They are within-sample forecasts and are based on the use of actual values for the exogenous variables. The results in Table 11–6 are thus better than are likely to be achieved in practice. In Chapter 12 outside-sample forecasts will be generated and compared with the within-sample forecasts in Table 11–6 to see how much accuracy is lost by having to make outside-sample forecasts. The sensitivity of the results to likely errors made in forecasting the exogenous variables will then be examined in Chapter 13. The forecasts in Chapter 13 are close to being forecasts that could have been generated *ex ante*.

What has been shown in this chapter, however, is that *ex post* the model is capable of tracking the economy quite well. This is contrary to the conclusion reached by Evans, Haitovsky, and Treyz [14] for the Wharton and OBE models. As mentioned in Chapter 1, Evans et al. found that even when within-sample forecasts were made and actual values of the exogenous variables were used, the forecasts generated by the Wharton and OBE models were not very good. The results achieved by Evans, et al. will be examined in more detail in Chapter 14, but it does appear from the results in this chapter that their pessimistic conclusion about econometric models may be related to the particular models they considered.

Results from the Monthly Housing Starts Equations

So far no explicit mention has been made of the accuracy of the monthly housing starts equations, but it is implicit in the results presented above for housing investment. Since the monthly housing starts forecasts are used to construct forecasts of the quarterly (seasonally adjusted) housing starts variable, HSQ_t, it is appropriate to examine the forecasts of HSQ_t. In Table 11–7 the mean absolute errors in terms of levels and changes are

Table 11–7. Errors in Forecasting HSQ_t. (Forecasts of HSQ_t are based on the forecasts from the monthly housing starts sector. The errors are computed for the same prediction period and are in thousand of units at annual rates.)

	Length of Forecast					
Error Measure	One Quarter Ahead	Two Quarters Ahead	Three Quarters Ahead	Four Quarters Ahead	Five Quarters Ahead	No. of Observations
MAE	56.4	66.2	68.2	68.4	68.4	28
MAEΔ	56.4	58.9	56.0	58.2	59.0	28

Table 11–8. Actual and Forecasted Levels of HSQ_t. (Forecasts are within-sample forecasts and are based on actual values of the exogenous variables. Figures are in thousands of units at annual rates.)

		Length of Forecast				
Quarter	Actual Value	One Quarter Ahead	Two Quarters Ahead	Three Quarters Ahead	Four Quarters Ahead	Five Quarters Ahead
602	1224	1212				
603	1203	1224	1243			
604	1134	1177	1265	1270		
611	1211	1208	1285	1308	1309	
612	1214	1323	1343	1353	1354	1354
613	1334	1314	1329	1334	1334	1330
614	1310	1412	1377	1376	1377	1373
621	1356	1387	1426	1418	1411	1410
622	1433	1413	1409	1412	1412	1407
623	1401	1375	1398	1396	1393	1395
624	1484	1413	1458	1465	1464	1458
631	1447	1514	1485	1498	1500	1499
632	1594	1494	1474	1472	1473	1473
633	1557	1530	1499	1492	1494	1494
634	1628	1597	1546	1542	1539	1543
641	1603	1514	1548	1536	1542	1540
642	1473	1480	1456	1462	1463	1468
643	1402	1490	1450	1447	1448	1451
644	1491	1408	1482	1470	1473	1473
651	1396	1453	1443	1459	1457	1463
652	1475	1391	1399	1400	1398	1399
653	1384	1389	1344	1345	1348	1341
654	1463	1353	1344	1335	1333	1337
661	1349	1397	1308	1305	1309	1306
662	1267	1311	1306	1295	1295	1300
663	1018	1115	1168	1166	1168	1168
664	883	998	1044	1057	1055	1063
671	1038	1095	1100	1108	1107	1105
672	1206	1266	1307	1305	1302	1298
673	1316	1331	1369	1378	1374	1369
674	1420	1456	1472	1480	1478	1473
681	1436	1410	1472	1476	1473	1468
682	1434	1443	1402	1411	1411	1407
683	1448	1414	1407	1397	1397	1396
684	1548	1452	1396	1394	1394	1390
691	1604	1478	1440	1426	1426	1429
692	1507	1513	1470	1467	1467	1467
693	1341	1361	1366	1359	1361	1365
694	1290	1381	1338	1339	1343	1348

presented for HSQ_t for the one-through five-quarter-ahead forecasts. The errors are in thousands of units *at annual rates* and have been computed for the 28 quarters for which five-quarter-ahead forecasts were made. The errors range from 56.0 to 68.4 thousand units and in general show little evidence of error compounding

In Table 11–8 the quarter-by-quarter forecasts of HSQ_t are presented for the 602–694 period. Since no strike observations were omitted from the sample period for the monthly housing starts equations, the results for the entire 602–694 period are presented in Table 11–8. The error measures presented in Table 11–7 thus correspond to a subset of the forecasts presented in Table 11–8. The results in Table 11–8 appear to be fairly good. The crunch in late 1966 and early 1967 was overpredicted, but not too badly. The slowdown in the last half of 1969 was also captured moderately well.

The Reduced Form Equation for GNP

The reduced form equation in (11.4) for GNP_t for the final version of the model is:

$$\begin{aligned} GNP_t = & -45.17 - .004GNP_{t-1} + 1.839CD_{t-1} + 1.402CN_{t-1} + 1.068CS_{t-1} \\ & - .802CD_{t-2} - .538CN_{t-2} + .090CS_{t-2} + .849IP_{t-1} + .553IH_{t-1} \\ & + .974(V_{t-1} - V_{t-2}) - .440V_{t-1} + .348V_{t-2} - 1.232IMP_{t-1} \\ & + .846PE2_t - .583PE2_{t-1} + .0298HSQ_t + .0150HSQ_{t-1} \\ & - .0036HSQ_{t-2} - .0041HSQ_{t-3} + .122MOOD_{t-1} \\ & + .231MOOD_{t-2} - .079MOOD_{t-3} + 1.232(G_t + EX_t). \end{aligned} \tag{11.9}$$

Some of the lagged endogenous variables in equation (11.9) are serving both in their capacity as predetermined variables—i.e., as those in X in (11.4)—and as lagged values of the endogenous variables—i.e., as those in Y_{-1} in (11.4). The short-run government multiplier for the model is 1.232, as can be seen from the coefficient of $G_t + EX_t$ in equation (11.9). According to this equation, an increase in exports or government spending of, say, one billion dollars will lead to a 1.232 billion dollar increase in GNP in the same quarter.

Care must be used in the interpretation of the short-run multiplier because of the expectational variables in the model. If, for example, government expenditure policy affects consumer sentiment or plant and equipment investment expectations, this will have an effect on GNP for quarters beyond $t + 1$ or $t + 2$, and these kinds of effects are not incorporated into the 1.232 multiplier.

12 The Stability of the Estimated Relationships and the Outside-Sample Forecasts

12.1 Introduction

In this chapter the stability of the estimated relationships of the model will be examined, and outside-sample forecasts will be generated. "Stability" is meant to refer to how much or little the coefficient estimates in an equation change as the sample period is lengthened. The less the coefficient estimates in an equation change as the sample is lengthened, the more stable the equation is considered to be. In the limit, for a perfectly stable model, the outside-sample forecasting results would be the same as the within-sample results, since the coefficient estimates would be the same in both cases. Otherwise, one would expect the outside-sample results to be somewhat poorer than the within-sample results.

Unless the estimated relationships in a model are reasonably stable over time, the model will be of limited use as a forecasting tool. The basic assumption of any forecasting model is that relationships that have been estimated for the past will continue to hold for the future. The advantage of a small scale model such as the present one is that the validity of this assumption can be tested by estimating each of the equations of the model over different sample periods and comparing the results. This will be done in Section 12.2. Having done this, the different sets of estimates can by used to generate forecasts beyond the sample period, and these forecasts can be compared with the within-sample forecasts of Chapter 11. This is the purpose of Section 12.3.

12.2 Stability Results

The Procedure

The validity of the stability assumption was examined in the following manner. Each of the twelve quarterly behavioral equations was estimated eighteen times, with the sample period first ending in 653, then in 654, and so on through 694. For each equation the beginning of the sample period was the same as before: 602 for the nondurable consumption and housing investment equations and 561 for the others. Also as before, the strike observations were omitted from all of the sample periods. The two monthly housing starts equations were also estimated eighteen times, with the first sample period ending in September 1965, and the successive sample periods being increased by three months each time. The coefficient estimates from these equations can then be examined for their stability over time, and from this examination a judgement can be made as to the probable usefulness of each of the equations for forecasting purposes.

In the rest of this section the results of estimating the equations over the different sample periods will be presented and discussed. All of the coefficient estimates are presented, since these are the estimates that have been used to generate the outside-sample forecasts below. It should be stressed that the following discussion of the stability of the estimates is quite informal and subjective. A much better idea of how "stable" the model is can be achieved by comparing the within-sample and outside-sample forecasting results, and this will be done in the next section. It should also be stressed that the different coefficient estimates achieved below by estimating the equations over the different sample periods are not statistically independent of one another, since the sample periods all overlap. The purpose of the following analysis is not to test in any rigorous way the hypothesis that coefficients of an equation are the same for different sample periods.

Consumption of Durables

In Table 12–1 the results of estimating equation (3.1) for the eighteen different sample periods are presented. The eighteenth equation estimate is the one that has already been presented in Chapter 3. For the first equation estimate in the table, the sample period ended in 653, and for the successive estimates after that, the end of the sample period was increased one quarter at a time. For this particular equation, the sample period began in 561, and the observations for 593, 594, 601, 644, 651, and 652 were omitted because of strikes.

From the results in Table 12–1, the stability of the durables equation appears to be fairly good. The only large change that occurred was in the estimate of the serial correlation coefficient, which was as high as .847 for the period ending in 661 and as low as .579 for the period ending in 681. The coefficient estimate of the GNP variable is remarkably stable for the different periods.

Consumption of Nondurables

In Table 12–2 the results of estimating equation (3.7) for the eighteen sample periods are presented. For this equation the sample period began in 602,

Table 12–1. Coefficient Estimates of Equation (3.1) for Eighteen Sample Periods. (Dependent variable is CD_t.)

		Coefficient Estimates for						
End of Sample Period	No. of Obser-vations	Con-stant	$\widehat{GNP}_t$	$MOOD_{t-1}$	$MOOD_{t-2}$	$\hat{r}$	SE	$R\Delta^2$
653	33	−30.51 (5.22)	.106 (10.71)	.106 (2.20)	.128 (2.73)	.839 (8.87)	.736	.744
654	34	−30.92 (5.63)	.107 (12.02)	.105 (2.23)	.128 (2.77)	.843 (9.15)	.724	.756
661	35	−31.26 (5.91)	.108 (13.30)	.104 (2.27)	.127 (2.82)	.847 (9.43)	.711	.765
662	36	−27.96 (4.63)	.093 (13.98)	.149 (2.51)	.134 (2.29)	.748 (6.77)	.928	.648
663	37	−26.71 (4.56)	.098 (19.01)	.119 (1.97)	.120 (1.98)	.684 (5.71)	.971	.625
664	38	−26.50 (4.64)	.099 (21.46)	.116 (2.00)	.118 (1.99)	.688 (5.84)	.957	.625
671	39	−27.65 (4.96)	.097 (23.18)	.124 (2.14)	.134 (2.30)	.672 (5.67)	.964	.637
672	40	−27.73 (4.83)	.100 (25.14)	.149 (2.51)	.094 (1.63)	.657 (5.51)	1.009	.624
673	41	−25.87 (4.66)	.097 (28.42)	.145 (2.33)	.094 (1.55)	.601 (4.82)	1.055	.581
674	42	−25.55 (4.64)	.097 (29.27)	.145 (2.35)	.093 (1.55)	.607 (4.95)	1.044	.585
681	43	−25.57 (4.59)	.099 (32.42)	.113 (1.81)	.112 (1.81)	.579 (4.66)	1.090	.587
682	44	−25.53 (4.55)	.100 (33.80)	1.17 (1.92)	.103 (1.74)	.595 (4.92)	1.080	.592
683	45	−25.69 (4.10)	.103 (30.55)	.089 (1.41)	.116 (1.87)	.655 (5.81)	1.134	.575
684	46	−25.70 (4.15)	.103 (32.53)	.089 (1.42)	.117 (1.92)	.653 (5.85)	1.121	.575
691	47	−25.84 (4.10)	.103 (32.60)	.085 (1.37)	.116 (1.92)	.676 (6.28)	1.116	.574
692	48	−26.39 (4.14)	.104 (32.51)	.091 (1.49)	.111 (1.85)	.697 (6.73)	1.110	.574
693	49	−25.93 (4.17)	.102 (37.44)	.115 (1.90)	.093 (1.55)	.648 (5.96)	1.136	.555
694	50	−25.43 (4.22)	.103 (39.78)	.110 (1.88)	.092 (1.54)	.648 (6.01)	1.125	.554

Table 12–2. Coefficient Estimates of Equation (3.7) for Eighteen Sample Periods. (Dependent variable is CN_t.)

End of Sample Period	No. of Observations	Coefficient Estimates for					
		$\widehat{GNP}_t$	CN_{t-1}	$MOOD_{t-2}$	$\hat{r}$	SE	$R\Delta^2$
653	19	.048	.810	.059	−.548	1.069	.536
		(2.73)	(8.38)	(0.87)	(2.86)		
654	20	.051	.808	.047	−.575	1.098	.603
		(2.87)	(8.26)	(0.69)	(3.15)		
661	21	.055	.793	.044	−.467	1.135	.607
		(2.87)	(7.39)	(0.59)	(2.42)		
662	22	.054	.806	.034	−.469	1.107	.623
		(2.91)	(8.04)	(0.51)	(2.49)		
663	23	.057	.782	.051	−.449	1.083	.626
		(3.50)	(9.13)	(0.96)	(2.41)		
664	24	.084	.625	.162	−.289	1.224	.550
		(4.70)	(7.06)	(3.24)	(1.48)		
671	25	.074	.681	.124	−.439	1.224	.552
		(4.93)	(9.45)	(3.30)	(2.44)		
672	26	.070	.703	.111	−.412	1.205	.552
		(5.10)	(11.10)	(3.60)	(2.31)		
673	27	.073	.686	.123	−.396	1.206	.536
		(5.32)	(11.02)	(4.34)	(2.24)		
674	28	.071	.690	.131	−.324	1.294	.553
		(4.60)	(9.85)	(4.15)	(1.82)		
681	29	.081	.651	.137	−.487	1.450	.568
		(5.45)	(9.53)	(4.31)	(3.00)		
682	30	.083	.641	.138	−.401	1.436	.559
		(5.39)	(8.99)	(4.18)	(2.40)		
683	31	.084	.641	.137	−.405	1.411	.578
		(5.52)	(9.16)	(4.26)	(2.46)		
684	32	.083	.639	.144	−.419	1.438	.553
		(5.46)	(9.07)	(4.48)	(2.61)		
691	33	.083	.639	.146	−.391	1.422	.559
		(5.42)	(9.02)	(4.53)	(2.44)		
692	34	.083	.639	.146	−.392	1.400	.562
		(5.50)	(9.17)	(4.62)	(2.48)		
693	35	.081	.646	.146	−.388	1.403	.547
		(5.37)	(9.23)	(4.59)	(2.49)		
694	36	.081	.646	.147	−.381	1.383	.550
		(5.40)	(9.30)	(4.67)	(2.47)		

so the first estimate was based on only 19 observations. As usual, the observations for 644, 651, and 652 were omitted from the sample periods because of the automobile strike.

The estimates in Table 12–2 are reasonably stable from 681 through 694, but less so from 653 to 681. The coefficient estimate of GNP went from .048 for the period ending in 653 to .081 for the period ending in 681 and then stabilized around .08; the coefficient estimate of CN_{t-1} went from .810 to .651 during this period and then stabilized around .64 or 65; the coefficient estimate of $MOOD_{t-2}$ went from .059 to .137 and then stabilized around .14 or .15; and the estimate of the serial correlation coefficient went from −.548 to −.487 and then stabilized around −.40 or −.39. The results are therefore only moderately good, but the fact that the estimates since 681 have been fairly stable is somewhat encouraging. Remember, however, that the reason the longer sample period was not used for the nondurable equation was because there appeared to be a shift in the aggregate relationship between 561 and 602. This, of course, further limits the confidence that one can place on the assumption that the relationship will be stable in the future.

Consumption of Services

In Table 12–3 the results of estimating equation (3.11) for the eighteen sample periods are presented. For this equation the longer period was used. From Table 12–3 there appears to be no serious instability in the services equation. The coefficient estimate of GNP_t has appeared to stabilize around .02, the coefficient estimate of CS_{t-1} around .94, the coefficient estimate of $MOOD_{t-2}$ around −.02, and the estimate of the serial correlation coefficient around −.07.

Plant and Equipment Investment

In Table 12–4 the results of estimating equation (4.4) for the eighteen sample periods are presented. The stability of the equation appears to be reasonable. The estimate of the coefficient of GNP_t has varied between .051 and .063, the estimate of the coefficient of $PE2_t$ between .687 and .841, and the estimate of the serial correlation coefficient between .600 and .757.

Equation (4.4) uses the two-quarter-ahead expectation variable. As discussed in Chapter 4, an equation, equation (4.7), was also estimated using the one-quarter-ahead expectation variable. Although equation (4.7) is not used for any of the work in this chapter, it will be used for some of the work in the next chapter, and so the stability of the equation was examined in the same way as the others. The eighteen estimates of equation (4.7) are presented in Table 12–5. A similar conclusion emerges from Table 12–5 as emerged from Table 12–4: the coefficient estimates appear to be reasonably stable. The coefficient estimate of GNP_t is the most stable, with a range of only .042 to .048.

Table 12–3. Coefficient Estimates of Equation (3.11) for Eighteen Sample Periods. (Dependent variable is CS_t.)

End of Sample Period	No. of Observations	Coefficient Estimates for $\widehat{GNP}_t$	CS_{t-1}	$MOOD_{t-2}$	$\hat{r}$	SE	$R\Delta^2$
653	33	.029	.920	−.028	−.184	.392	.614
		(3.75)	(35.59)	(3.45)	(1.07)		
654	34	.029	.921	−.028	−.189	.387	.657
		(4.11)	(38.87)	(3.88)	(1.12)		
661	35	.024	.935	−.023	−.158	.394	.663
		(3.74)	(41.70)	(3.55)	(.94)		
662	36	.019	.953	−.017	−.094	.410	.642
		(2.90)	(42.13)	(2.74)	(.57)		
663	37	.016	.962	−.014	−.057	.411	.658
		(2.61)	(44.07)	(2.50)	(.35)		
664	38	.014	.969	−.012	−.037	.413	.670
		(2.42)	(46.64)	(2.34)	(.23)		
671	39	.017	.959	−.015	−.080	.419	.723
		(3.11)	(48.46)	(3.43)	(.50)		
672	40	.017	.959	−.016	−.067	.414	.751
		(3.21)	(48.79)	(3.82)	(.42)		
673	41	.019	.955	−.019	−.061	.430	.777
		(3.38)	(46.75)	(4.50)	(.39)		
674	42	.019	.955	−.019	−.059	.425	.795
		(3.43)	(47.33)	(4.73)	(.38)		
681	43	.019	.953	−.020	−.061	.422	.816
		(3.57)	(47.77)	(5.16)	(.40)		
682	44	.020	.950	−.021	−.050	.419	.838
		(3.79)	(48.04)	(5.76)	(.33)		
683	45	.023	.940	−.024	−.011	.444	.850
		(4.03)	(43.46)	(6.39)	(.07)		
684	46	.022	.942	−.023	−.072	.446	.853
		(4.13)	(46.03)	(6.59)	(.49)		
691	47	.022	.944	−.022	−.068	.442	.864
		(4.02)	(46.12)	(6.72)	(.46)		
692	48	.022	.944	−.023	−.068	.437	.876
		(4.10)	(46.58)	(7.03)	(.47)		
693	49	.022	.944	−.022	−.070	.434	.882
		(4.13)	(46.94)	(7.12)	(.49)		
694	50	.022	.945	−.023	−.077	.431	.891
		(4.15)	(47.77)	(7.37)	(.55)		

Table 12–4. Coefficient Estimates of Equation (4.4) for Eighteen Sample Periods. (Dependent variable is IP_t.)

End of Sample Period	No. of Observations	Coefficient Estimates for Constant	$\widehat{GNP}_t$	$PE2_t$	$\hat{\rho}$	SE	$\bar{R}^2$
653	33	−10.47	.057	.816	.600	.721	.749
		(4.29)	(10.98)	(10.23)	(4.21)		
654	34	−13.29	.061	.841	.668	.745	.761
		(5.25)	(9.95)	(10.17)	(5.29)		
661	35	−11.53	.059	.828	.621	.757	.757
		(5.69)	(10.32)	(11.42)	(4.69)		
662	36	−10.72	.059	.803	.631	.756	.751
		(5.63)	(10.16)	(11.54)	(4.87)		
663	37	−10.62	.059	.789	.645	.743	763
		(5.80)	(10.17)	(11.97)	(5.14)		
664	38	−10.01	.062	.742	.691	.748	.753
		(5.01)	(9.52)	(10.78)	(5.90)		
671	39	−9.48	.063	.708	.729	.756	.751
		(4.30)	(8.86)	(9.70)	(6.66)		
672	40	−9.28	.062	.709	.733	.747	.753
		(4.34)	(9.02)	(9.77)	(6.81)		
673	41	−8.49	.062	.696	.757	.758	.739
		(3.72)	(8.46)	(9.12)	(7.41)		
674	42	−8.73	.062	.699	.747	.750	.740
		(4.23)	(9.07)	(9.46)	(7.29)		
681	43	−9.35	.062	.715	.725	.756	.759
		(5.02)	(9.41)	(9.92)	(6.90)		
682	44	−6.83	.052	.794	.667	.917	.679
		(3.79)	(7.51)	(10.01)	(5.93)		
683	45	−6.02	.051	.782	.721	.926	.667
		(2.91)	(6.74)	(9.07)	(6.97)		
684	46	−7.27	.054	.769	.637	.978	.642
		(4.43)	(8.14)	(9.63)	(5.61)		
691	47	−6.71	.056	.728	.650	.989	.650
		(3.90)	(8.17)	(9.20)	(6.05)		
692	48	−7.27	.058	.727	.643	.998	.643
		(4.53)	(8.60)	(9.30)	(5.80)		
693	49	−7.44	.058	.730	.643	.989	.656
		(4.81)	(8.68)	(9.47)	(5.88)		
694	50	−8.50	.063	.687	.689	1.011	.633
		(4.86)	(8.87)	(8.34)	(6.72)		

Table 12–5. Coefficient Estimates of Equation (4.7) for Eighteen Sample Periods. (Dependent variable is IP_t.)

End of Sample Period	No. of Observations	Coefficient Estimates for Constant	$\widehat{GNP}_t$	PEI_t	$\hat{r}$	SE	$R\Delta^2$
653	33	−8.64	.046	.927	.399	.647	.798
		(5.61)	(12.57)	(15.22)	(2.50)		
654	34	−9.16	.046	.941	.425	.640	.823
		(6.97)	(12.36)	(17.43)	(2.74)		
661	35	−9.17	.046	.940	.426	.630	.831
		(8.00)	(12.60)	(19.10)	(2.78)		
662	36	−8.39	.047	.914	.438	.644	.819
		(7.70)	(12.28)	(19.20)	(2.92)		
663	37	−8.40	.047	.913	.438	.634	.827
		(8.31)	(12.48)	(20.47)	(2.96)		
664	38	−8.17	.047	.903	.456	.630	.825
		(8.31)	(12.30)	(20.42)	(3.16)		
671	39	−7.70	.048	.880	.507	.649	.816
		(7.16)	(11.16)	(18.20)	(3.67)		
672	40	−7.57	.048	.875	.526	.642	.818
		(7.10)	(10.99)	(17.76)	(3.91)		
673	41	−6.94	.048	.856	.590	.671	.796
		(5.64)	(9.48)	(15.08)	(4.67)		
674	42	−7.17	.048	.860	.558	.667	.794
		(6.55)	(10.29)	(16.04)	(4.36)		
681	43	−7.42	.048	.863	.545	.664	.814
		(7.22)	(10.60)	(16.55)	(4.20)		
682	44	−5.95	.043	.897	.498	.839	.731
		(5.30)	(8.29)	(14.73)	(3.81)		
683	45	−5.65	.042	.899	.542	.834	.730
		(4.82)	(7.77)	(13.93)	(4.33)		
684	46	−5.58	.042	.899	.551	.825	.745
		(4.86)	(7.72)	(13.85)	(4.48)		
691	47	−5.14	.043	.879	.593	.834	.751
		(4.12)	(7.28)	(12.91)	(5.05)		
692	48	−5.43	.043	.882	.561	.833	.751
		(4.83)	(7.76)	(13.56)	(4.70)		
693	49	−6.11	.045	.876	.549	.877	.730
		(5.49)	(7.90)	(13.05)	(4.60)		
694	50	−6.36	.046	.874	.572	.873	.727
		(5.59)	(7.76)	(12.65)	(4.94)		

Housing Investment

In Table 12–6 the results of estimating equation (5.5) for the eighteen sample periods are presented. Due to lack of data on housing starts before 1959, the shorter period of estimation was used for this equation. The seasonal adjustment coefficients that were used for HSQ were calculated using data only through 652 to insure that information beyond the sample period was not used. As mentioned in Chapter 5, the seasonal adjustment coefficients were actually quite stable for changes in the sample period.

Aside from the estimates of the constant term and the serial correlation coefficient, the coefficient estimates in Table 12–6 are fairly stable. The first six estimates (through the sample period ending in 664) of the coefficient of HSQ_{t-1} are lower than the others, but after 664 the estimates appear to have stabilized. The estimate of the constant term has, in general, been decreasing over time, but the estimate has only been significant since 691. The estimate of the serial correlation coefficient has not been very stable and has ranged from a low of .132 to a high of .573. Given the nonstructural nature of equation (5.5), it it not too surprising that some of the coefficient estimates are unstable, but the overall results in Table 12–6 do not appear too unreasonable.

Inventory Investment

In Table 12–7 the results of estimating equation (6.15) for the eighteen samples periods are presented. The estimates have been fairly stable since 681, but less so before that. In particular, the estimate of the coefficient of $CD_{t-1} + CN_{t-1} - CD_t - CN_t$ (which is the same as the estimate of the coefficient of $-CD_t - CN_t$, since $CD_{t-1} + CN_{t-1}$ is included as a separate explanatory variable in the equation) was negative, with one exception, before 681. Also, the estimate of the coefficient of V_{t-1} was larger in absolute value, with one exception, before 681 than after. The estimates were changed a lot in 664, which was the quarter in which inventory investment was 19.9 billion dollars, and in 681, which was a quarter in which inventory investment was only 1.6 billion dollars. In general, however, the results in Table 12–7 appear to be reasonable, especially considering the highly volatile nature of the inventory investment series.

Imports

In Table 12–8 the results of estimating equation (7.3) for fourteen sample periods are presented. Since the observations for 653 were omitted from the

Table 12–6. Coefficient Estimates of Equation (5.5) for Eighteen Sample Periods. (Dependent variable is IH_t.)

End of Sample Period	No. of Observations		Coefficient Estimates for						
		Constant	$\widehat{GNP}_t$	HSQ_t	HSQ_{t-1}	HSQ_{t-2}	$\hat{r}$	SE	$R\Delta^2$
653	19	.37	.018	.0218	.0152	.0030	.280	.333	.830
		(.30)	(5.08)	(4.78)	(2.81)	(0.61)	(1.27)		
654	20	.87	.016	.0211	.0181	.0033	.233	.331	.820
		(.84)	(6.63)	(4.85)	(4.08)	(0.71)	(1.07)		
661	21	.93	.015	.0214	.0180	.0017	.226	.322	.819
		(.95)	(8.41)	(5.19)	(4.20)	(0.85)	(1.06)		
662	22	1.09	.013	.0235	.0206	.0016	.177	.352	.821
		(1.08)	(8.17)	(5.45)	(4.49)	(0.35)	(.84)		
663	23	1.16	.013	.0228	.0207	.0017	.160	.343	.840
		(1.20)	(9.30)	(6.06)	(4.57)	(0.38)	(.78)		
664	24	.90	.013	.0231	.0235	.0008	.132	.359	.880
		(.94)	(9.23)	(5.93)	(5.28)	(0.17)	(.65)		
671	25	.66	.011	.0192	.0262	.0052	.267	.372	.865
		(.57)	(8.68)	(5.62)	(6.79)	(1.26)	(1.39)		
672	26	.70	.011	.0183	.0258	.0072	.318	.368	.879
		(.57)	(9.10)	(5.81)	(7.02)	(2.32)	(1.71)		
673	27	.34	.012	.0197	.0270	.0040	.172	.419	.889
		(.30)	(11.33)	(5.64)	(5.93)	(1.16)	(.91)		
674	28	−2.77	.014	.0212	.0268	.0069	.573	.469	.874
		(1.38)	(7.41)	(5.31)	(6.46)	(1.77)	(3.70)		
681	29	−.38	.012	.0217	.0261	.0037	.245	.479	.863
		(.29)	(11.22)	(5.52)	(5.28)	(0.94)	(1.36)		
682	30	−1.27	.013	.0221	.0259	.0046	.258	.511	.847
		(.95)	(12.02)	(5.28)	(4.95)	(1.11)	(1.46)		
683	31	−1.26	.013	.0221	.0259	.0046	.256	.501	.848
		(1.01)	(13.09)	(5.40)	(5.05)	(1.14)	(1.48)		
684	32	−2.32	.014	.0240	.0248	.0053	.308	.539	.830
		(1.72)	(12.88)	(5.57)	(4.64)	(1.22)	(1.83)		
691	33	−3.34	.015	.0241	.0257	.0057	.430	.547	.823
		(2.24)	(11.81)	(5.47)	(5.08)	(1.30)	(2.74)		
692	34	−3.11	.015	.0245	.0254	.0053	.400	.539	.825
		(2.30)	(13.07)	(5.75)	(5.09)	(1.24)	(2.55)		
693	35	−3.18	.015	.0243	.0254	.0056	.407	.530	.833
		(2.40)	(13.83)	(5.94)	(5.19)	(1.38)	(2.64)		
694	36	−3.53	.016	.0242	.0230	.0074	.449	.582	.792
		(2.31)	(13.12)	(5.37)	(4.45)	(1.66)	(3.01)		

Table 12–7. Coefficient Estimates of Equation (6.15) for Eighteen Sample Periods. (Dependent variable is $V_t - V_{t-1}$.)

End of Sample Period	No. of Observations	Constant	Coefficient Estimates for $CD_{t-1} + CN_{t-1}$	V_{t-1}	$CD_{t-1} + CN_{t-1} - \widehat{CD}_t - \widehat{CN}_t$	$\hat{r}$	SE	$R\Delta^2$
653	33	−155.06	.986	−.542	−.387	.855	2.027	.527
		(4.53)	(4.72)	(4.49)	(1.61)	(9.45)		
654	34	−153.12	.974	−.533	−.361	.852	1.993	.527
		(4.63)	(4.78)	(4.42)	(1.50)	(9.48)		
661	35	−152.53	.971	−.533	−.362	.851	1.960	.532
		(4.87)	(4.97)	(4.50)	(1.52)	(9.57)		
662	36	−165.22	1.026	−.515	−.319	.868	2.171	.458
		(4.55)	(4.62)	(4.00)	(1.26)	(10.49)		
663	37	−160.54	.989	−.484	−.349	.872	2.159	.483
		(4.62)	(4.75)	(4.25)	(1.40)	(10.83)		
664	38	−126.89	.772	−.327	.042	.842	2.498	.410
		(3.43)	(3.44)	(2.73)	(.17)	(9.61)		
671	39	−159.13	.967	−.433	−.084	.869	2.511	.540
		(4.75)	(5.00)	(4.65)	(.34)	(10.96)		
672	40	−158.74	.976	−.454	−.113	.868	2.547	.542
		(4.82)	(5.05)	(4.83)	(.43)	(10.12)		
673	41	−163.24	.999	−.457	−.087	.859	2.522	.556
		(4.89)	(5.14)	(4.88)	(.34)	(10.74)		
674	42	−178.61	1.071	−.468	−.208	.890	2.610	.515
		(4.72)	(4.99)	(4.74)	(.76)	(12.68)		
681	43	−133.15	.829	−.385	.103	.778	2.627	.547
		(4.58)	(4.72)	(4.31)	(.49)	(8.11)		
682	44	−117.55	.737	−.345	.084	.743	2.629	.584
		(4.53)	(4.66)	(4.15)	(.40)	(7.36)		
683	45	−111.78	.704	−.332	.143	.742	2.606	.585
		(4.46)	(4.60)	(4.08)	(.72)	(7.42)		
684	46	−113.89	.719	−.344	.085	.757	2.612	.581
		(4.41)	(4.56)	(4.11)	(.43)	(7.86)		
691	47	−107.68	.682	−.327	.168	.760	2.569	.593
		(4.07)	(4.23)	(3.81)	(.81)	(8.01)		
692	48	−105.30	.670	−.326	.171	.777	2.570	.584
		(3.96)	(4.13)	(3.74)	(.82)	(8.55)		
693	49	−109.79	.697	−.339	.131	.777	2.552	.589
		(3.98)	(4.15)	(3.77)	(.59)	(8.65)		
694	50	−114.76	.728	−.357	.095	.791	2.540	.589
		(4.09)	(4.27)	(3.94)	(.42)	(9.15)		

Table 12–8. Coefficient Estimates of Equation (7.3) for Fourteen Sample Periods. (Dependent variable is IMP_t.)

End of Sample Period	No. of Observations	Coefficient Estimate for $\widehat{GNP}_t$	$\hat{r}$	SE	$R\Delta^2$
643	32	.051 (4.58)	1.0	.514	.268
654	33	.050 (4.65)	1.0	.515	.325
661	34	.054 (5.44)	1.0	.512	.378
662	35	.055 (5.86)	1.0	.507	.395
663	36	.063 (6.20)	1.0	.554	.390
664	37	.061 (6.28)	1.0	.549	.384
671	38	.061 (6.40)	1.0	.544	.380
672	39	.059 (6.09)	1.0	.555	.356
673	40	.057 (6.18)	1.0	.552	.347
674	41	.063 (6.79)	1.0	.573	.371
681	42	.075 (7.61)	1.0	.634	.403
682	43	.073 (8.00)	1.0	.628	.417
683	44	.078 (8.51)	1.0	.644	.437
694	45	.078 (8.70)	1.0	.637	.437

sample period for the import equation, the first estimate presented in Table 12–8 is for the period ending in 643. The second estimate is then for the period ending in 654. Observations for 684, 691, 692, and 693 were also omitted from the sample period for the import equation, and thus the penultimate estimate presented in the table is for the period ending in 683 and the last estimate is for the period ending in 694.

As can be seen from the results in Table 12–8, the estimate of the coefficient of GNP_t has been increasing through time—from .051 for the period ending in 643 to .078 for the period ending in 694. The estimate was changed a lot in 681, which corresponded to an increase in imports of 3.1 billion dollars. The overall results indicate that the import equation is not stable through time, but that the movement of the coefficient estimate over time is fairly smooth.

Employment

The results of estimating equation (9.8) for the eighteen sample periods are presented in Table 12–9. In order to estimate equation (9.8), estimates of the production function parameter α_t first have to be made. For the work in Chapter 9, α_t was estimated from peak-to-peak interpolations of the output per paid-for man-hour series in Figure 9-1. Two of the peaks that were used for this purpose were the peaks in 661 and 684, and so theoretically neither of these peak observations should be used for the estimates through 654. Likewise, the 684 peak observation should not be used for the estimates through 683. In practice, however, both of these peak observations were used for the estimates presented in Table 12–9. In particular, the estimates of α_t that were made in Chapter 9 were used for the work here. Since the slopes of the last two interpolation lines in Figure 9–1 are nearly the same, the results presented in Table 12–9 are nearly the same as the results that would have been achieved had the 684 peak observation not been used. Likewise, the results for 653 and 654 would have been only slightly different had the 661 peak observation not been used.

Aside from the estimate of the coefficient of the time trend in Table 12–9, the estimates of the employment equation are quite stable. The estimate of the coefficient of the time trend has, in general, been increasing over time, but it has always been small and not significant. The employment equation appears to pose no serious stability problems.

The D_t Equation

The results of estimating equation (9.10) for the eighteen sample periods are presented in Table 12–10. Equation (9.10) is the equation explaining the difference between the establishment employment data and the household survey employment data. Aside from the estimates for the first three periods, the estimates in Table 12–10 are quite stable. During the first three periods, the estimates increased slightly in absolute value.

Table 12–9. Coefficient Estimates of Equation (9.8) for Eighteen Sample Periods. (Dependent variable is $\log M_t - \log M_{t-1}$.)

End of Sample Period	No. of Observations	Constant	Coefficient Estimates for: t	$\log M_{t-1} - \log M_{t-1}H_{t-1}$	$\log Y_t - \log Y_{t-1}$	$\log Y_{t-1} - \log Y_{t-2}$	$\hat{r}$	SE	R^2
653	33	−.550	.0000099	−.151	.337	.134	.303	.00344	.805
		(2.94)	(.11)	(2.94)	(6.11)	(2.17)	(1.83)		
654	34	−.535	.0000024	−.147	.335	.136	.301	.00339	.813
		(3.02)	(.03)	(3.02)	(6.21)	(2.23)	(1.84)		
661	35	−.493	−.0000180	−.136	.334	.139	.297	.00337	.813
		(2.91)	(.24)	(2.91)	(6.22)	(2.31)	(1.84)		
662	36	−.511	−.0000075	−.141	.332	.137	.291	.00333	.816
		(3.21)	(.11)	(3.21)	(6.29)	(2.32)	(1.83)		
663	37	−.562	.0000182	−.154	.330	.120	.325	.00333	.814
		(3.46)	(.26)	(3.44)	(6.24)	(2.07)	(2.09)		
664	38	−.529	.0000004	−.145	.330	.133	.278	.00332	.810
		(3.51)	(.01)	(3.49)	(6.28)	(2.33)	(1.78)		
671	39	−.534	.0000189	−.147	.317	.132	.270	.00331	.805
		(3.59)	(.32)	(3.57)	(6.28)	(2.33)	(1.75)		
672	40	−.529	.0000150	−.145	.317	.137	.262	.00327	.806
		(3.67)	(.28)	(3.65)	(6.37)	(2.54)	(1.71)		

673	41	−.530	.0000107	−.146	.317	.138	.262	.00322	.805
		(3.73)	(.21)	(3.71)	(6.45)	(2.60)	(1.74)		
674	42	−.525	.0000215	−.144	.315	.140	.253	.00321	.803
		(3.75)	(.44)	(3.72)	(6.44)	(2.64)	(1.69)		
681	43	−.525	.0000231	−.144	.315	.139	.255	.00317	.804
		(3.79)	(.49)	(3.76)	(6.53)	(2.67)	(1.73)		
682	44	−.525	.0000208	−.144	.314	.139	.254	.00313	.806
		(3.84)	(.46)	(3.82)	(6.61)	(2.71)	(1.74)		
683	45	−.529	.0000110	−.145	.319	.134	.260	.00312	.802
		(3.85)	(.25)	(3.83)	(6.79)	(2.62)	(1.81)		
684	46	−.529	.0000160	−.145	.319	.132	.251	.00309	.801
		(3.95)	(.39)	(3.92)	(6.85)	(2.64)	(1.76)		
691	47	−.534	.0000396	−.146	.309	.128	.269	.00322	.784
		(3.73)	(.93)	(3.70)	(6.39)	(2.44)	(1.91)		
692	48	−.537	.0000489	−.147	.306	.123	.309	.00320	.782
		(3.58)	(1.14)	(3.55)	(6.39)	(2.35)	(2.25)		
693	49	−.529	.0000564	−.145	.303	.121	.325	.00318	.781
		(3.51)	(1.34)	(3.48)	(6.41)	(2.33)	(2.41)		
694	50	−.514	.0000643	−.140	.298	.121	.336	.00316	.778
		(3.44)	(1.57)	(3.41)	(6.43)	(2.34)	(2.52)		

Table 12–10. Coefficient Estimates of Equation (9.10) for Eighteen Sample Periods. (Dependent variable is D_t.)

End of Sample Period	No. of Obser-vations	Coefficient Estimates for Constant	t	M_t	$\hat{r}$	SE	$R\Delta^2$
653	33	−10086	−65.18	.300	.491	167.8	.539
		(4.01)	(6.70)	(5.73)	(3.24)		
654	34	−11095	−67.13	.319	.505	166.8	.555
		(4.95)	(7.03)	(6.75)	(3.42)		
661	35	−12156	−69.40	.341	.536	166.6	.559
		(5.74)	(7.02)	(7.51)	(3.76)		
662	36	−13747	−73.12	.373	.594	169.7	.557
		(6.41)	(6.61)	(7.97)	(4.43)		
663	37	−14408	−74.87	.386	.625	168.1	.560
		(6.97)	(6.44)	(8.43)	(4.88)		
664	38	−14096	−74.19	.380	.609	166.1	.561
		(7.37)	(6.70)	(8.88)	(4.73)		
671	39	−14497	−74.88	.388	.620	165.1	.557
		(7.74)	(6.65)	(9.10)	(4.93)		
672	40	−14713	−75.03	.392	.631	163.5	.553
		(7.90)	(6.56)	(9.24)	(5.14)		
673	41	−14118	−74.19	.380	.594	166.5	.548
		(8.14)	(6.98)	(9.61)	(4.73)		
674	42	−14072	−74.12	.379	.595	164.3	.550
		(8.41)	(7.06)	(9.87)	(4.80)		
681	43	−14466	−74.79	.387	.587	164.9	.554
		(8.87)	(7.16)	(10.26)	(4.76)		
682	44	−14384	−74.52	.385	.584	162.9	.554
		(9.30)	(7.37)	(10.71)	(4.77)		
683	45	−14482	−74.70	.387	.586	161.2	.553
		(9.58)	(7.43)	(10.95)	(4.86)		
684	46	−14534	−74.83	.388	.588	159.3	.553
		(9.87)	(7.51)	(11.21)	(4.93)		
691	47	−13820	−72.35	.373	.567	163.9	.521
		(9.76)	(7.40)	(11.14)	(4.72)		
692	48	−14157	−73.16	.380	.539	164.7	.531
		(10.71)	(7.92)	(12.08)	(4.43)		
693	49	−13510	−71.27	.367	.519	173.8	.501
		(10.25)	(7.65)	(11.65)	(4.25)		
694	50	−13014	−71.10	.358	.600	181.4	.460
		(8.23)	(6.15)	(9.39)	(5.30)		

The Primary Labor Force

The results of estimating equation (9.11) for the eighteen sample periods are presented in Table 12–11. The labor force participation of primary workers is explained merely by a constant and a time trend, and thus the results in Table 12–11 are not very interesting. The estimate of the coefficient of the time trend is fairly stable, although it has been increasing slightly in absolute value in the last three quarters.

The Secondary Labor Force

The results of estimating equation (9.12) for the eighteen sample periods are presented in Table 12-12. The estimate of the coefficient of the time trend has been increasing over time—from .000120 for the period ending in 653 to .000523 for the period ending in 694—and the estimate of the serial correlation coefficient has been increasing over time—from .398 for the period ending in 653 to .797 for the period ending in 694. The estimate of the coefficient of the $(E_t + AF_t)/(P_{1t} + P_{2t})$ rose from .241 in 653 to .425 in 664 and stabilized after that.

The labor force participation of secondary workers has risen very sharply since 1965, and equation (9.12) does not appear to be capable of accounting for this rise in any satisfactory way. Even after 664, when the coefficient estimate of $(E_t + AF_t)/(P_{1t} + P_{2t})$ stabilized, the coefficient estimate of the time trend continued to rise. There are obviously factors affecting the labor force participation of secondary workers that have been excluded from equation (9.12), and these factors appear to have been quite important in the last few years. The rise in the labor force participation of secondary workers cannot be explained merely by the rise in the employment–population ratio.

It will be seen below that the use of the results in Table 12–12 has caused the model to consistently underpredict the growth of the labor force and thus underpredict the unemployment rate. This is one of the more serious problems in the model, but given the purpose of the present study, it is not clear that much can be done about it. As mentioned in Chapter 9, the factors that are likely to influence the labor force participation of secondary workers have been discussed by Mincer [37], but these factors would be difficult to incorporate into a short-run forecasting model. Also, the disaggregation that should be made in any detailed study of labor force participation rates is beyond the scope of the present study. Consequently, equation (9.12) has been chosen to be used in the model, but unless the equation is more stable in the future than it has been in the past, it will continue to be one of the weaker equations of the model.

Table 12–11. Coefficient Estimates of Equation (9.11) for Eighteen Sample Periods. (Dependent variable is LF_{1t}/P_{1t}.)

End of Sample Period	No. of Observations	Coefficient Estimates for Constant	t	$\hat{r}$	SE	$\bar{R}^2$
653	33	.980	−.000177	.180	.00201	.540
		(450.34)	(4.50)	(1.05)		
654	34	.980	−.000177	.180	.00197	.540
		(476.52)	(4.88)	(1.07)		
661	35	.980	−.000171	.179	.00195	.539
		(500.01)	(5.02)	(1.08)		
662	36	.980	−.000169	.180	.00192	.539
		(524.29)	(5.25)	(1.10)		
663	37	.980	−.000172	.180	.00190	.538
		(549.77)	(5.68)	(1.11)		
664	38	.980	−.000164	.173	.00189	.538
		(571.33)	(5.70)	(1.08)		
671	39	.979	−.000150	.194	.00195	.509
		(556.45)	(5.11)	(1.24)		
672	40	.979	−.000150	.193	.00192	.520
		(580.40)	(5.40)	(1.25)		
673	41	.979	−.000154	.191	.00191	.519
		(603.18)	(5.83)	(1.25)		
674	42	.979	−.000158	.195	.00189	.516
		(621.50)	(6.19)	(1.29)		
681	43	.979	−.000154	.191	.00187	.520
		(645.63)	(6.37)	(1.27)		
682	44	.980	−.000158	.188	.00186	.519
		(667.98)	(6.84)	(1.27)		
683	45	.980	−.000163	.196	.00185	.511
		(678.89)	(7.23)	(1.34)		
684	46	.980	−.000169	.210	.00185	.500
		(681.18)	(7.57)	(1.46)		
691	47	.980	−.000166	.201	.00184	.511
		(708.27)	(7.83)	(1.41)		
692	48	.980	−.000175	.196	.00188	.495
		(711.29)	(8.37)	(1.38)		
693	49	.981	−.000181	.226	.00189	.478
		(693.30)	(8.53)	(1.63)		
694	50	.981	−.000190	.265	.00193	.447
		(658.38)	(8.57)	(1.94)		

Table 12–12. Coefficient Estimates of Equation (9.12) for Eighteen Sample Periods. (Dependent variable is LF_{2t}/P_{2t}.)

End of Sample Period	No. of Observations	Coefficient Estimates for Constant	t	$\widehat{(E_t + AF_t)/(P_{1t} + P_{2t})}$	$\hat{r}$	SE	$R\Delta^2$
653	33	.319	.000120	.241	.398	00219	.495
		(5.44)	(1.60)	(2.41)	(2.49)		
654	34	.295	.000155	.279	.425	.00218	.489
		(5.32)	(2.27)	(2.99)	(2.74)		
661	35	.282	.000174	.301	.440	.00215	.485
		(5.42)	(2.80)	(3.41)	(2.90)		
662	36	.259	.000209	.338	.465	.00217	.473
		(5.12)	(3.51)	(3.92)	(3.15)		
663	37	.229	.000252	.387	.510	.00222	.452
		(4.43)	(4.10)	(4.37)	(3.60)		
664	38	.206	.000290	.425	.562	.00225	.435
		(3.88)	(4.44)	(4.63)	(4.19)		
671	39	.200	.000307	.433	.590	.00224	.427
		(3.76)	(4.65)	(4.68)	(4.57)		
672	40	.197	.000323	.437	.613	.00222	.419
		(3.63)	(4.84)	(4.61)	(4.91)		
673	41	.189	.000364	.446	.661	.00229	.398
		(3.22)	(4.84)	(4.33)	(5.63)		
674	42	.196	.000407	.430	.719	.00232	.373
		(3.03)	(4.53)	(3.75)	(6.70)		
681	43	.194	.000393	.436	.700	.00229	.388
		(3.15)	(4.83)	(4.00)	(6.43)		
682	44	.186	.000415	.447	.716	.00229	.384
		(3.01)	(4.94)	(4.08)	(6.80)		
683	45	.186	.000414	.447	.714	.00226	.391
		(3.07)	(5.13)	(4.13)	(6.85)		
684	46	.187	.000412	.446	.713	.00224	.393
		(3.15)	(5.30)	(4.20)	(6.90)		
691	47	.166	.000430	.480	.712	.00225	.413
		(2.90)	(5.53)	(4.66)	(6.95)		
692	48	.167	.000450	.478	.732	.00225	.402
		(2.81)	(5.55)	(4.48)	(7.44)		
693	49	.169	.000488	.471	.767	.00228	.386
		(2.65)	(5.21)	(4.09)	(8.36)		
694	50	.180	.000523	.447	.797	.00228	.373
		(2.69)	(4.97)	(3.67)	(9.32)		

Prices

The results of estimating the price equation for the eighteen sample periods are presented in Table 12–13. It was mentioned in Chapter 10, and is discussed in more detail in Fair [15], that only since about 1968 or 1969 has the nonlinearity in the price relationship become apparent. Before 1968 or 1969 there was little evidence of anything but a linear relationship. Indeed, for most of the sample periods ending before 1969 it was not possible to get the coefficient estimates of equation (10.7) to converge. Consequently, for the work here the linear version of equation (10.7) was used for the estimates through 684, and only for the last four sample periods (ending in 691, 692, 693, and 694 respectively) was the nonlinear version used.

In order to estimate the price equation, estimates of potential GNP have to be made. As discussed in Chapter 10, the estimates of potential GNP are based on (1) the estimate of the production function parameter α_t from Chapter 9; (2) the peak-to-peak interpolations of the agricultural output series, YA_t, and the agricultural "productivity" series, YA_t/MA_t; (3) the coefficient estimates of the two labor force participation equations and of the D_t equation; and (4) the coefficient estimates of the HP_t regression in (10.2). In computing the estimates of potential GNP for the work in this chapter, the estimates of α_t from Chapter 9 were used, as well as peak-to-peak interpolations of the two agricultural series from Chapter 10. As discussed above for the employment equation, the results would have been only slightly changed if the 661 and 684 peaks had not been used in the estimation of α_t. Likewise, the results would have been only slightly changed had the interpolations of the two agricultural series been based only on information before 653. The estimates of the HP_t regression in (10.2) were also used for work here, since there would have been very little difference in results had only information before 653 been used to estimate (10.2). With respect to the coefficient estimates of the labor force participation equations and of the D_t equation, the estimates of potential GNP in this chapter were based only on the coefficient estimates that would have been available at the time the price equation would have been estimated. Each of the estimates in Table 12–13 is thus based on a slightly different potential GNP series. Again, however, it makes little difference which set of coefficient estimates is used to estimate the potential GNP series. Different sets of coefficient estimates primarily influence the overall level of the potential GNP series and have little influence on the change in the series. Since any "errors" made in estimating the level of potential GNP are absorbed in the estimate of the constant term in the price equation, it makes little difference which set of coefficient estimates is used.

Table 12–13. Coefficient Estimates of the Price Equation for Eighteen Sample Periods. (Dependent variable is $PD_t - PD_{t-1}$.)

End of Sample Period	No. of Obser-vations	Linear Version Coefficient Estimates for Constant	$\frac{1}{8}\sum_{i=1}^{8} GAP2_{t-i+1}$	Nonlinear Version Equation (10.7) $\hat{a}_0$	$\hat{a}_1$	$\hat{a}_2$	SE	R^2	DW
653	33	1.044 (10.45)	−.0189 (6.51)				.191	.577	2.15
654	34	1.002 (10.22)	−.0174 (6.23)				.194	.548	1.88
661	35	1.018 (11.21)	−.0174 (6.82)				.187	.585	2.05
662	36	1.076 (12.57)	−.0180 (7.77)				.183	.640	2.08
663	37	1.087 (13.60)	−.0176 (8.35)				.179	.666	2.17
664	38	1.073 (14.52)	−.0171 (8.74)				.177	.680	2.14
671	39	.969 (14.03)	−.0154 (7.86)				.189	.625	1.88
672	40	.959 (13.43)	−.0140 (7.40)				.196	.590	1.68
673	41	.975 (14.89)	−.0145 (8.19)				.193	.632	1.86
674	42	.978 (16.25)	−.0146 (8.86)				.189	.662	1.89
681	43	.977 (17.24)	−.0144 (9.28)				.187	.677	1.89
682	44	.991 (18.55)	−.0147 (9.96)				.185	.703	1.90
683	45	.987 (19.65)	−.0146 (10.41)				.183	.716	1.91
684	46	.966 (20.97)	−.0148 (11.06)				.182	.735	1.91
691	47			−3.648 (.61)	1179.9 (.36)	251.9 (.65)	.185	.757	1.85
692	48			−1.527 (1.13)	286.5 (.80)	109.8 (1.37)	.187	.778	1.76
693	49			−1.128 (1.35)	186.0 (1.07)	83.8 (1.80)	.185	.797	1.78
694	50			−1.037 (1.44)	165.8 (1.19)	78.4 (2.00)	.183	.810	1.78

The estimates of the linear version of the price equation are fairly stable in Table 12–13, although the estimate of the coefficient of the demand pressure variable is larger in absolute value for the periods before 671 than it is for the periods after. As for the nonlinear estimates, it is difficult to tell how stable or unstable they are because of the multicollinearity among the estimates, but the last three sets of estimates appear to be reasonably stable.

It is true, as is examined in Fair [15], that the price equation consistently underpredicts the inflation in 1969 unless it is estimated through 1969. As discussed in Chapter 10, however, this is not necessarily unexpected, since one generally cannot expect an equation to extrapolate well into a period where the values of the dependent and independent variables are considerably different from what they were during the period of estimation. It thus may be too early to tell how stable the nonlinear version of the price equation is. It is true for the work below, however, that the use of the estimates in Table 12–13 to generate outside-sample forecasts results in an underprediction of the rate of inflation in 1969.

Monthly Housing Starts

The results of estimating the demand equation (8.23) for the eighteen sample periods are presented in Table 12–14 and the results of estimating the supply equation (8.24) in Table 12–15. To conserve space, the estimates of the coefficients of the seasonal dummy variables and the working-day variable have not been presented in the tables: the estimates were fairly stable over the different sample periods.

The 1965–1969 period was a difficult period in which to explain housing starts, since it included the crunch in 1966 and the very high interest rates in 1968 and 1969. The results in Table 12–14 and 12–15 reflect the difficulty. Looking at the demand equation in Table 12–14 first, only the estimate of the coefficient of $/\Delta RM_t/$ is at all stable. The estimates of the coefficients of the housing stock variable and the time trend and the estimate of the serial correlation coefficient have all been increasing in absolute value over time, and the estimate of RM_{t-2} has been decreasing in absolute value. Except for a slight drop in early 1967, the mortgage rate has essentially been rising throughout the entire 1965–1969 period, and as the rate has been rising, the estimated negative effect it has on housing demand has been falling.

For the supply equation the results are somewhat better, as can be seen in Table 12–15, although the estimate of the constant term and the estimate of the coefficient of RM_{t-1} have not been stable. The estimate of the coefficient of RM_{t-1} was negative for the periods ending before March 1968

Table 12–14. Coefficient Estimates of Equation (8.23) for Eighteen Sample Periods. (Dependent variable is HS_t.)

End of Sample Period	No. of Observations	Constant	Coefficient Estimates for $\sum_{i=1}^{t-1} HS_i$	t	RM_{t-2}	$/\Delta RM_t/$	$\hat{r}$	SE	$R\Delta^2$
Sept. 1965	76	487.04	−.0023	.11	−.725	−.619	.436 (4.23)	8.44	.836
Dec. 1965	79	477.82	−.0018	.08	−.714	−.548	.435 (4.29)	8.28	.838
March 1966	82	444.72	−.0029	.24	−.662	−.423	.413 (4.10)	8.30	.842
June 1966	85	456.89	−.0025	.19	−.680	−.411	.408 (4.11)	8.25	.841
Sept. 1966	88	446.99	−.0037	.34	−.663	−.371	.405 (4.15)	8.12	.842
Dec. 1966	91	396.82	−.0076	.84	−.593	−.462	.407 (4.25)	8.40	.826
March 1967	94	349.05	−.0145	1.69	−.518	−.485	.486 (5.39)	8.45	.822
June 1967	97	340.90	−.0187	2.20	−.505	−.448	.505 (5.76)	8.32	.826
Sept. 1967	100	328.88	−.0300	3.56	−.480	−.391	.557 (6.70)	8.51	.811
Dec. 1967	103	308.88	−.0374	4.46	−.453	−.424	.620 (8.03)	8.55	.813
March 1968	106	281.06	−.0459	5.49	−.402	−.478	.684 (9.65)	8.74	.808
June 1968	109	252.85	−.0525	6.28	−.356	−.334	.714 (10.65)	9.05	.797
Sept. 1968	112	180.17	−.0584	6.99	−.236	−.426	.785 (13.41)	9.11	.787
Dec. 1968	115	164.30	−.0637	7.62	−.207	−.388	.808 (14.69)	9.13	.786
March 1969	118	134.85	−.0740	8.86	−.163	−.411	.846 (17.24)	9.18	.787
June 1969	121	126.44	−.0738	8.83	−.150	−.392	.850 (17.71)	9.06	.791
Sept. 1969	124	101.14 (1.98)	−.0703 (2.16)	8.40 (2.21)	−.107 (1.16)	−.430 (2.92)	.848 (17.82)	9.03	.789
Dec. 1969	127	112.95 (2.46)	−.0709 (2.27)	8.48 (2.31)	−.127 (1.54)	−.412 (2.81)	.841 (17.54)	8.98	.790

Note: t-statistics are not presented for most of the estimates because of the inability to invert the appropriate matrix.

Table 12–15. Coefficient Estimates of Equation (8.24) for Eighteen Sample Periods. (Dependent variable is HS_t.)

End of Sample Period	No. of Observations	Constant	t	$DHF3_{t-2}$	$DSF6_{t-1}$	RM_{t-1}	$\|\Delta RM_t\|$	$\hat{\rho}$	SE	$\bar{R}^2$
Sept. 1965	76	12.85	−.189	.0600	.0463	0	−.619	.395 (3.75)	8.88	.819
Dec. 1965	79	17.43	−.053	.0417	.0365	0	−.548	.455 (4.54)	8.85	.815
March 1966	82	15.93	−.072	.0473	.0379	0	−.423	.444 (4.49)	8.69	.827
June 1966	85	11.79	−.139	.0398	.0468	0	−.411	.460 (4.78)	8.64	.826
Sept. 1966	88	7.77	−.146	.0337	.0483	0	−.371	.479 (5.11)	8.52	.826
Dec. 1966	91	4.26	−.147	.0318	.0491	0	−.462	.466 (5.02)	8.51	.821
March 1967	94	5.03	−.145	.0332	.0485	0	−.485	.467 (5.12)	8.39	.825
June 1967	97	6.95	−.163	.0432	.0475	0	−.448	.470 (5.24)	8.28	.827
Sept. 1967	100	11.63	−.162	.0434	.0475	0	−.391	.459 (5.17)	8.23	.823
Dec. 1967	103	9.11	−.164	.0432	.0477	0	−.424	.452 (5.15)	8.14	.830
March 1968	106	.39	−.149	.0488	.0487	.019	−.478	.463 (5.37)	8.21	.832
June 1968	109	−9.83	−.149	.0499	.0500	.035	−.334	.452 (5.30)	8.38	.828
Sept. 1968	112	−44.45	−.164	.0538	.0529	.089	−.426	.470 (5.64)	8.39	.821
Dec. 1968	115	−65.79	−.172	.0556	.0552	.125	−.388	.505 (6.28)	8.41	.820
March 1969	118	−74.41	−.176	.0567	.0560	.136	−.441	.506 (6.38)	8.35	.826
June 1969	121	−60.75	−.166	.0536	.0545	.117	−.392	.511 (6.55)	8.26	.828
Sept. 1969	124	−54.79 (1.88)	−.168 (2.69)	.0529 (5.39)	.0541 (8.04)	.111 (2.85)	−.430 (2.92)	.508 (6.57)	8.32	.822
Dec. 1969	127	−49.22 (1.75)	−.164 (2.63)	.0497 (5.27)	.0541 (8.07)	.100 (2.67)	−.412 (2.81)	.507 (6.64)	8.30	.822

Note: t-statistics are not presented for most of the estimates because of the inability to invert the appropriate matrix.

(although less negative than the corresponding estimate of the coefficient of RM_{t-2} in the demand equation), and for the results presented in Table 12–15 the coefficient was constrained to be zero for these periods. The data before 1968 did not appear to be capable of picking up separate demand and supply effects from the mortage rate. The estimates of the coefficients of the two deposit flow variables have been fairly stable, although they were generally smaller before 1968 than afterwards.

The results in the two tables are thus not too encouraging. Perhaps the most encouraging result is that the estimates have been fairly stable in 1969. The mortgage rate did rise during the 1966–1969 period to levels much higher than ever before observed, however; and on this ground one would not expect the housing starts equations to have performed too well during this period. Whether the equations will prove to be more stable in the future is perhaps still uncertain. The estimates in Tables 12–14 and 12–15 have been used in the work below, and from the results it will be possible to tell how sensitive the forecasting accuracy of the model is to the use of these somewhat unstable estimates.

Conclusion

The question under consideration in this chapter is whether the estimated relationships in the model are stable enough in the short run to allow accurate forecasts to be made. The one conclusion that is evident from the results that have just been presented is that the estimated relationships are not stable enough to lead to the conclusion that the outside-sample forecasts are as accurate as the within-sample forecasts. Just how much accuracy is lost by having to make outside-sample forecasts will be examined in the next section. In general, however, the above results appear to be moderately good. The most unstable equations are the inventory investment equation, the labor force participation equation for secondary workers, the price equation, and the two housing starts equations. The other equations are generally fairly stable.

12.3 Results of Forecasting Outside of the Sample Period

The Quarterly Results

Using the estimates of the model that have just been presented, one-, two-, three-, four-, and five-quarter-ahead forecasts were generated beyond the sample period. For the first set of forecasts, for example, the estimates through

653 were used to forecast 654, 661, 662, 663, and 664. Then for the second set of forecasts, the estimates through 654 were used to forecast 661, 662, 663, 664, and 671; and so on for the seventeen different sets of estimates. The eighteenth set of estimates presented above was not used, since no forecasts were made beyond 694. The eighteenth set of estimates was the one used for the within-sample forecasts in Chapter 11. The outside-sample forecasts can be compared with the within-sample forecasts of Chapter 11 to see how much accuracy has been lost by having to forecast beyond the sample period.

Aside from using different coefficient estimates, the outside-sample forecasts were generated in the same way as the within-sample forecasts in Chapter 11. With respect to the coefficient estimates, only the estimates of the production function parameter α_t in Chapter 9, the interpolations of the two agricultural series in Chapter 10, and the estimates of the HP_t equation in (10.2) remained the same for the outside-sample forecasts. For each set of forecasts, potential GNP was calculated using only the coefficient estimates of the labor force participation equations and the D_t equation that would have been available at the time the forecasts would have been made. As discussed above, this same procedure was followed for the estimates of the price equation in Table 12–13.

In Table 12–16 the mean absolute errors (both in terms of levels and changes) for the within-sample forecasts of Chapter 11 and the outside-sample forecasts of this chapter are presented for 15 endogenous variables. The endogenous variables are the same as those considered previously in Table 11–5. The prediction period was from 654 through 694, so there were 17 one-quarter-ahead forecasts that were generated, 16 two-quarter-ahead forecasts, 15 three-quarter-ahead forecasts, 14 four-quarter-ahead forecasts, and 13 five-quarter-ahead forecasts. The mean absolute errors in Table 12–16 for the within-sample forecasts differ from those in Table 11–5 because of the different prediction periods that were used to compute the error measures. Also, the results in Table 12–16 should not be used to compare the one-quarter-ahead forecasts with the two-quarter-ahead forecasts, and so on, since the prediction periods differ. The results in Table 12–16 are meant to be used only for comparing the within-sample and outside-sample forecasts. At the bottom of Table 12–16 the error measures that have been computed for GNP_t for the eight quarters of 1968 and 1969 are presented.

Comparing the one-quarter-ahead forecasts in Table 12–16, the results are fairly close, with the difference between the mean absolute errors of the GNP forecast being only .16 billion dollars. For the two-quarter-ahead forecast of GNP the difference is .56 for the error in terms of levels and .76 for the error in terms of changes; for the three-quarter-ahead forecast the difference is 1.38 in terms of levels and .16 in terms of changes; for the four-quarter-ahead forecast the difference is 1.94 in terms of levels and .09 in terms of changes; and for the five-quarter-ahead forecast the difference is 3.19 in terms of levels and .25 in terms of changes. For the three-, four-, and five-quarter-ahead forecasts there is thus a tendency for the outside-sample forecasts to be much worse (relative to the within-sample forecasts) for the predictions in terms of levels than for the predictions in terms of changes. This conclusion also holds in general for the other endogenous variables of the model.

For all of the variables except the price deflator the errors in terms of changes for the outside-sample forecasts are quite close to the errors in terms of changes for the within-sample forecasts. In terms of forecasting the change in the variables, little accuracy appears to have been lost in making outside-sample forecasts. It was mentioned in Chapter 11 that in judging the accuracy of the forecasts the mean absolute error in terms of changes is probably a more useful measure than the error in terms of levels, and it is encouraging that for this error measure the outside-sample forecast errors in Table 12–16 are so close to the within-sample errors.

It should be noted from the results presented at the bottom of Table 12–16 that for the 1968–1969 period the within-sample and outside-sample results are quite close using either error measure. For this period little accuracy appears to have been lost in making outside-sample forecasts, either in terms of forecasting changes or in terms of forecasting levels.

In order to compare the accuracy of the outside-sample forecasts to changes in the forecast horizon, the mean absolute errors for the one-through four-quarter-ahead forecasts were computed for the same prediction period that was used for the five-quarter-ahead forecasts (664–694, 13 observations). The results are presented in Table 12–17. Also, the outside-sample results for the 1968–1969 period presented at the bottom of Table 12–16 are presented again at the bottom of Table 12–17.

There is definitely a tendency for the errors in terms of levels in Table 12–17 to compound as the forecast horizon lengthens. The MAE for GNP, for example, increases from 2.50 billion dollars for the one-quarter-ahead forecast to 6.98 billion dollars for the five-quarter-ahead forecast. Again, this is not true for the 1968–1969 period, however, where the MAE for GNP only increases from 2.61 to 2.88 billion dollars. Also, there is little tendency for the errors in terms of changes to compound as the forecast horizons lengthen. Indeed, for some of the variables the errors actually drop slightly as the horizon lengthens. Only for the price deflator is there much evidence that the errors in terms of changes are compounding. The worst results in Table 12–17 are those for the secondary labor force (LF_{2t}). The MAE for

Table 12–16. Comparisons of the Within-Sample and Outside-Sample Forecasts.

Variable	One quarter ahead (17 observations) Within-Sample	One quarter ahead (17 observations) Outside-Sample	Two quarters ahead (16 observations) Within-Sample	Two quarters ahead (16 observations) Outside-Sample	Three quarters ahead (15 observations) Within-Sample	Three quarters ahead (15 observations) Outside-Sample	Four quarters ahead (14 observations) Within-Sample	Four quarters ahead (14 observations) Outside-Sample	Five quarters ahead (13 observations) Within-Sample	Five quarters ahead (13 observations) Outside-Sample
MAE										
GNP_t	2.31	2.47	3.38	3.94	2.50	3.88	2.73	4.67	3.79	6.98
CD_t	1.33	1.46	1.43	1.90	1.29	1.77	1.31	2.41	1.35	2.62
CN_t	1.29	1.62	1.42	2.15	1.46	2.48	1.35	1.77	1.25	3.39
CS_t	.37	.43	.51	.75	.70	1.13	.80	1.59	.85	1.98
IP_t	1.10	1.36	1.15	1.54	1.19	1.75	1.38	2.17	1.47	2.50
IH_t	.73	.82	1.14	1.62	1.27	2.36	1.36	3.05	1.39	3.86
$V_t - V_{t-1}$	2.37	3.13	3.16	3.78	3.18	3.92	2.95	3.64	2.86	3.66
IMP_t	.64	.73	.91	1.20	1.14	1.66	1.06	1.78	.89	1.61
PD_t	.16	.17	.29	.30	.40	.45	.45	.67	.45	.89
$GNPR_t$	2.23	2.61	3.10	4.11	2.59	4.05	2.60	4.06	2.63	5.14
M_t	123	136	201	184	259	253	325	298	345	374
D_t	157	188	162	228	143	204	157	256	139	245
LF_{1t}	46	52	53	61	54	63	55	65	59	73
LF_{2t}	193	283	269	438	260	588	268	735	262	847
UR_t	.0016	.0031	.0028	.0055	.0033	.0071	.0037	.0083	.0042	.0094

MAEΔ										
GNP_t			2.22	2.98	3.02	3.18	2.84	2.93	2.49	2.74
CD_t			1.50	1.51	1.58	1.57	1.29	1.37	1.34	1.45
CN_t			1.32	1.47	1.36	1.45	1.48	1.66	1.62	1.89
CS_t			.39	.46	.38	.49	.36	.47	.37	.48
IP_t	s		1.03	1.25	1.18	1.32	1.13	1.32	1.29	1.39
IH_t	a		.89	1.01	1.01	1.13	.97	1.11	1.02	1.27
$V_t - V_{t-1}$	m		4.25	4.39	4.62	4.83	4.76	4.87	4.59	4.66
IMP_t	e		.56	.66	.59	.71	.64	.80	.64	.72
PD_t			.16	.18	.15	.20	.13	.24	.15	.29
$GNPR_t$			2.08	2.86	2.66	2.47	2.22	2.31	1.89	1.92
M_t			166	102	127	120	129	154	131	161
D_t			152	171	169	175	156	170	175	175
LF_{1t}			50	51	52	53	55	56	56	57
LF_{2t}			194	233	195	241	209	236	215	230
UR_t			.0015	.0026	.0013	.0020	.0010	.0015	.0010	.0014

1968–1969 Period Only (8 observations)

MAE for *GNP*	2.19	2.61	2.67	3.20	2.17	2.71	2.25	2.12	2.73	2.88
MAEΔ for GNP_t	2.19	2.61	1.50	2.23	2.03	1.82	1.77	1.75	1.64	1.47

Table 12–17. Outside-Sample Errors Computed for the Same Prediction Period.

Variable	One quarter ahead	Two quarters ahead	Length of Forecast Three quarters ahead	Four quarters ahead	Five quarters ahead	No. of observations
MAE						
GNP_t	2.50	3.70	3.58	4.96	6.98	13
CD_t	1.35	1.78	1.63	2.49	2.62	13
CN_t	1.76	2.23	2.25	2.73	3.39	13
CS_t	.43	.68	1.04	1.57	1.98	13
IP_t	1.46	1.56	1.83	2.30	2.50	13
IH_t	.96	1.78	2.56	3.19	3.86	13
$V_t - V_{t-1}$	3.39	3.80	3.77	3.66	3.66	13
IMP_t	.71	1.19	1.61	1.65	1.61	9
PD_t	.17	.32	.49	.69	.89	13
$GNPR_t$	2.47	3.73	3.74	4.24	5.14	13
M_t	121	182	253	310	374	13
D_t	178	204	161	222	245	13
LF_{1t}	62	69	70	69	73	13
LF_{2t}	291	454	597	730	847	13
UR_t	.0024	.0041	.0057	.0076	.0094	13

MAEΔ						
GNP_t	2.50	3.01	3.07	2.74	2.74	13
CD_t	1.35	1.39	1.37	1.34	1.45	13
CN_t	1.76	1.57	1.63	1.76	1.89	13
CS_t	.43	.41	.43	.45	.48	13
IP_t	1.46	1.36	1.42	1.39	1.39	13
IH_t	.96	1.13	1.20	1.18	1.27	13
$V_t - V_{t-1}$	3.39	4.61	4.89	4.93	4.66	13
IMP_t	.71	.65	.68	.75	.72	9
PD_t	.17	.20	.21	.25	.29	13
$GNPR_t$	2.47	2.89	2.31	2.18	1.92	13
M_t	121	89	137	158	161	13
D_t	178	183	178	175	175	13
LF_{1t}	62	56	57	57	57	13
LF_{2t}	291	246	239	230	230	13
UR_t	.0024	.0019	.0015	.0013	.0014	13
1968–1969 Period Only						
MAE for GNP_t	2.61	3.20	2.71	2.12	2.88	8
MAEΔ for GNP_t	2.61	2.23	1.82	1.75	1.47	8

LF_{2t} increases from 291 thousand for the one-quarter-ahead forecast to 847 thousand for the five-quarter-ahead forecast. This then causes the MAE for the unemployment rate to increase substantially as the forecast horizon lengthens.

The quarter-by-quarter results of the outside-sample forecasts are presented in Table 12–18 for eleven variables. The eleven variables are the same as those considered in Table 11–6 for the within-sample forecasts: GNP_t, $CD_t + CN_t + CS_t$, IP_t, IH_t, $V_t - V_{t-1}$, IMP_t, PD_t, $GNPR_t$, M_t, $LF_{1t} + LF_{2t}$, and UR_t. As in Table 11–6, the first line for each quarter gives the actual change in each of the variables for that quarter, and the next five lines give, respectively, the one- through five-quarter-ahead forecast of the change in each of the variables for that quarter. The prediction period began in 654, so there was only one forecast generated for 654. Similarly, only two forecasts could be generated for 661, only three for 662, and only four for 663.

Looking at the GNP_t forecasts in Table 12–18 first, the largest errors occurred for 671, where the errors ranged from 5.03 to 13.72 billion dollars. Again, this was due primarily to the failure of the model to forecast the 10.9 billion dollar drop in inventory investment in 671. The model is just not capable, aside from perhaps the one-quarter-ahead forecast, of accounting for the slowdown in 671. The other quarters were forecast much better, and there do not appear to be any other GNP forecasts that would be considered to be highly misleading. Looking at errors of larger than 5 billion dollars, the forecast for 654 was about 5 billion dollars too low, the last three forecasts for 663 were about 5 billion dollars too high, the three-quarter-ahead forecast for 673 was about 5 billion dollars too low, and the last two forecasts for 682 were about 5 billion dollars too low.

With respect to the forecasts of the price deflator in Table 12–18, the (relatively) small increase in the deflator in 671 and 672 was substantially overpredicted (due in large part of the overprediction of GNP in 671) and the large increases in 1969 were somewhat underpredicted, but otherwise the forecasts were fairly good. As discussed in the previous section, the underprediction of the rate of inflation in 1969 was not unexpected.

The employment forecasts in Table 12–18 appear to be reasonable, but the unemployment rate forecasts are not. The labor force was consistently underpredicted throughout most of the period, and the compounding of the errors in predicting the level of the labor force led to substantial underprediction of the unemployment rate. Only in 1969 could the unemployment rate prediction more than one quarter ahead be considered to be at all reasonable. Notice from the results in Table 12–17, however, that the errors in predicting the change in the unemployment rate are quite small and do not compound as the forecast horizon lengthens. The failure of the model to

Table 12–18. Actual and Forecasted Changes for Selected Variables of the Model. (Forecasts are outside-sample forecasts and are based on actual values of the exogenous variables. Forecasts for UR_t are in terms of levels.)

Quarter	Length of Forecast	GNP_t	$CD_t + CN_t + CS_t$	IP_t	IH_t	$V_t - V_{t-1}$	IMP_t	PD_t	$GNPR_t$	M_t	$LF_{1t} + LF_{2t}$	UR_t
654		18.90	11.10	3.80	.20	.60	1.50	.34	14.10	731	358	.0411
	1	13.71	8.32	1.81	.13	−.55	.70	.74	7.25	536	129	.0378
661		19.50	10.30	2.60	.0	1.60	1.50	.78	12.05	584	345	.0386
	1	19.12	8.73	3.75	.20	.99	.96	.79	12.08	777	216	.0326
	2	17.85	8.93	3.64	−.31	.10	.91	.83	10.72	717	263	.0309
662		13.80	4.10	1.50	−1.50	4.90	1.10	1.07	5.90	603	507	.0383
	1	15.46	8.71	2.45	−.40	−.26	.83	.87	8.45	596	232	.0309
	2	15.92	9.79	2.44	−.54	−.88	.80	.90	8.73	867	328	.0242
	3	16.16	8.74	2.46	−.25	.13	.83	.93	8.81	617	308	.0245
663		12.60	9.30	2.70	−1.20	−4.30	2.20	.88	5.20	656	576	.0377
	1	10.26	7.78	2.79	−1.25	−6.59	.57	.96	2.73	316	145	.0334
	2	17.34	9.27	3.12	−1.05	−1.27	.93	.99	8.85	727	310	.0252
	3	18.00	8.96	3.16	−1.21	−.20	.90	1.01	9.30	662	317	.0193
	4	17.97	8.74	3.12	−.95	−.23	.92	1.04	9.18	561	305	.0204
664		14.80	3.40	1.20	−2.70	8.00	.60	.88	7.90	290	688	.0369
		10.84	7.01	2.15	−2.07	−1.06	.68	1.02	3.63	342	217	.0316
	2	11.12	7.21	2.16	−2.12	−1.21	.62	1.06	3.70	342	304	.0286
	3	12.77	8.14	2.21	−1.81	−.78	.69	1.11	4.79	417	351	.0207
	4	13.33	8.67	2.24	−1.71	−.90	.67	1.14	5.13	421	353	.0149
	5	12.43	7.81	2.17	−1.94	−.66	.64	1.15	4.33	334	335	.0165

Table 12–18 (cont.)

Quarter	Length of Forecast	GNP_t	$CD_t + CN_t + CS_t$	IP_t	IH_t	$V_t - V_{t-1}$	IMP_t	PD_t	$GNPR_t$	M_t	$LF_{1t} + LF_{2t}$	UR_t
671		3.50	6.60	−.90	−.60	−10.90	.50	.60	−1.60	258	358	.0376
	1	8.53	5.96	.58	−.37	−7.22	.52	1.07	.31	115	70	.0333
	2	13.88	7.21	.75	−1.13	−2.19	.87	1.11	4.83	412	257	.0278
	3	16.06	8.06	.85	−1.28	−.78	.89	1.15	6.55	261	282	.0264
	4	16.81	9.01	.83	−1.35	−.88	.90	1.22	6.71	313	304	.0186
	5	17.22	9.10	.85	−1.37	−.60	.86	1.25	6.90	330	306	.0127
672		9.30	8.60	−.30	1.60	−5.60	−.30	.57	4.00	32	171	.0386
	1	8.95	5.09	−.05	2.09	−2.22	.55	.99	1.47	−4	6	.0356
	2	7.78	5.44	−.32	1.80	−2.96	.47	1.14	−.34	−6	125	.0332
	3	12.52	8.23	−.20	1.70	−.72	.78	1.19	3.48	191	228	.0273
	4	14.83	9.29	−.10	1.71	.46	.82	1.24	5.24	225	264	.0262
	5	14.40	9.68	−.19	1.19	.20	.77	1.33	4.27	240	273	.0186
673		16.90	6.00	.50	3.40	4.40	.60	1.12	7.50	186	752	.0386
	1	17.45	8.87	1.68	1.80	2.84	1.02	1.01	8.56	290	272	.0353
	2	12.97	8.86	1.37	1.75	−1.63	.79	1.03	4.58	161	287	.0338
	3	11.32	7.93	1.17	1.95	−2.44	.69	1.18	2.35	−11	291	.0331
	4	16.45	9.80	1.41	2.10	.77	1.03	1.25	6.31	211	367	.0263
	5	18.31	10.82	1.51	2.11	1.48	1.01	1.31	7.59	286	389	.0250
674		15.70	6.90	1.50	2.40	1.70	2.10	1.05	5.50	453	571	.0392
	1	14.00	9.99	1.03	.52	−2.24	.80	1.04	4.06	226	218	.0369
	2	17.47	9.36	1.13	.73	1.88	1.03	1.05	7.04	379	330	.0329
	3	17.67	9.26	1.13	.53	2.42	1.08	1.05	7.20	268	335	.0325
	4	14.83	8.80	.84	.25	.43	.90	1.19	4.01	88	315	.0332
	5	16.98	10.04	.89	.26	1.45	1.06	1.30	5.21	236	361	.0257

681		19.20	18.10	4.10	−.30	−7.90	3.10	.98	9.80	434	106	.0369
	1	20.28	11.27	3.10	−.11	−.81	1.27	1.05	10.33	426	243	.0362
	2	23.11	10.22	3.30	−.22	3.22	1.31	1.06	12.70	476	278	.0338
	3	21.02	9.79	3.12	.02	1.42	1.23	1.07	10.86	458	342	.0302
	4	21.28	10.02	3.13	−.20	1.73	1.30	1.06	11.10	423	352	.0303
	5	19.44	9.42	3.01	−.70	1.00	1.18	1.19	8.85	253	326	.0321
682		23.40	9.60	−2.70	1.70	8.30	1.40	1.15	12.50	533	508	.0360
	1	26.65	7.84	1.10	.17	11.64	2.00	1.07	15.70	690	316	.0328
	2	19.68	10.07	.82	−.98	2.90	1.24	1.06	9.81	598	285	.0331
	3	19.30	10.32	.82	−.58	1.74	1.10	1.08	9.40	537	306	.0314
	4	18.21	9.76	.68	−.27	1.00	1.07	1.08	8.42	477	341	.0284
	5	18.11	9.39	.67	−.41	1.46	1.11	1.07	8.43	442	344	.0289
683		17.70	14.60	1.70	−.30	−2.70	2.40	1.03	7.00	253	146	.0356
	1	18.37	10.48	3.22	−1.12	.34	1.34	1.09	7.26	461	283	.0349
	2	15.25	11.24	2.18	−1.07	−2.76	1.14	1.09	4.60	562	316	.0312
	3	18.19	10.55	2.45	−.87	.41	1.14	1.08	7.15	412	268	.0326
	4	19.34	10.60	2.53	−.35	.87	1.10	1.10	8.00	427	298	.0311
	5	18.28	10.16	2.44	−.45	.41	1.07	1.11	7.07	383	321	.0286
684		16.10	5.80	3.40	2.00	3.30	1.30*	1.20	5.70	399	226	.0340
	1	18.92	9.32	.89	−.04	5.13	1.47	1.09	8.62	391	325	.0349
	2	13.26	8.78	.55	−1.40	1.21	.97	1.09	3.94	405	280	.0338
	3	13.07	8.33	.16	−1.28	1.74	.98	1.09	3.75	248	275	.0312
	4	13.24	9.29	.26	−.87	.30	.83	1.08	3.98	261	264	.0325
	5	13.62	9.50	30	−1.04	.54	.77	1.10	4.16	301	292	.0311
691		16.20	11.30	3.80	1.40	−3.90	1.40*	1.40	4.60	733	959	.0336
	1	20.63	12.26	5.72	−.29	−2.25	1.61	1.13	9.73	423	378	.0330
	2	18.86	10.69	6.11	−.38	−.69	1.46	1.13	8.28	486	336	.0330
	3	18.15	10.29	6.12	−.65	−.88	1.33	1.11	7.80	321	288	.0327
	4	16.69	10.24	5.32	−.32	−1.90	1.25	1.12	6.59	254	297	.0308
	5	17.50	10.13	5.33	−.64	−.83	1.10	1.10	7.35	265	288	.0320

Table 12–18 (cont.)

Quarter	Length of Forecast	GNP_t	$CD_t + CN_t + CS_t$	IP_t	IH_t	$V_t - V_{t-1}$	IMP_t	PD_t	$GNPR_t$	M_t	$LF_{1t} + LF_{2t}$	UR_t
692		16.10	10.80	2.50	−.60	.30	1.40*	1.55	3.60	439	280	.0349
	1	19.12	10.69	1.23	−.16	3.15	1.48	1.23	7.78	405	246	.0321
	2	16.01	10.04	.63	−.42	3.11	1.25	1.16	5.55	432	376	.0316
	3	14.04	10.03	.81	−.15	.55	1.09	1.16	3.97	288	330	.0323
	4	14.88	10.10	.79	.66	.53	1.09	1.14	4.81	258	318	.0322
	5	14.41	9.72	.67	.60	.59	1.08	1.14	4.43	212	325	.0306
693		18.00	7.00	3.30	−1.30	3.80	1.40*	1.41	3.90	334	688	.0363
	1	20.75	11.87	2.94	−1.17	2.32	1.61	1.33	6.56	274	247	.0369
	2	18.29	11.29	3.17	−1.12	1.16	1.42	1.25	4.95	443	206	.0332
	3	17.41	11.39	2.94	−.73	−.03	1.36	1.19	4.58	234	241	.0340
	4	17.77	11.07	3.18	.16	−.47	1.38	1.18	4.90	207	228	.0348
	5	17.97	10.81	3.18	.06	.04	1.32	1.16	5.25	198	223	.0347
694		9.40	9.60	1.40	.10	−3.00	.70	1.36	−.80	210	417	.0359
	1	6.58	8.62	−.82	−.73	−1.89	.51	1.31	−2.76	−17	148	.0398
	2	11.26	8.53	−.43	−.88	2.81	.87	1.32	.86	241	244	.0374
	3	9.92	8.28	−.27	−1.04	1.62	.77	1.26	.12	101	207	.0349
	4	9.72	8.16	−.51	−.48	1.21	.76	1.19	.26	87	257	.0360
	5	9.22	8.09	−.42	−.74	.90	.72	1.19	−.10	86	254	.0367

* Adjusted value rather than the actual value.

forecast the level of the unemployment rate with any degree of accuracy is due to the failure to account for the large growth of the secondary labor force in the last half of the 1960s. To the extent that the equation explaining the labor force participation of secondary workers continues to perform poorly in the future, the forecasts of the level of the unemployment rate will continue to be poor.

It can be seen from the results in Table 12–18 why in Table 12–17 the mean absolute errors in terms of levels for GNP are so much smaller for the 1968–1969 period than they are for the entire period. The errors that were made in 671 were carried forward in terms of levels into the rest of 1967, which contributed substantially to the size of the overall error measure in terms of levels for the four- and five-quarter-ahead forecasts. No such compounding problem occured in 1968 and 1969, and thus the size of the error measure in terms of levels for the four- and five-quarter-ahead forecasts was much smaller for this period.

Results from the Monthly Housing Starts Equation

In order to compare the within-sample forecasts of HSQ_t with the outside-sample forecasts, the mean absolute errors (both in terms of levels and changes) of the forecasts of HSQ_t in Chapter 11 and of the forecasts of HSQ_t in this chapter were computed for the same prediction period. The results are presented in Table 12–19. As was the case for the results in Table 11–7, the errors in Table 12–19 are in thousands of units at annual rates. Table 12–19 is similar to Table 12–16 in that the results in the table are meant to be used only for comparing the within-sample and outside-sample forecasts.

Comparing the one-quarter-ahead forecasts in Table 12–19, the difference between the mean absolute errors is 26.3 thousand units (at annual rates). For the level errors for the two- through five-quarter-ahead forecasts the differences are respectively, 63.2, 93.4, 125.4, and 200.6 thousand units. For the change errors the differences are respectively, 40.3, 45.0, 52.4, and 67.4 thousand units. As was the case for the results in Table 12–16, the differences are smaller for the errors in terms of changes than for the errors in terms of levels. For the three-, four-, and five-quarter-ahead forecasts the differences for the errors in terms of levels are quite large.

In order to compare how the accuracy of the outside-sample forecasts of HSQ_t varies with the length of the forecast horizon, the mean absolute errors for the one- through four-quarter-ahead forecasts were computed

Table 12–19. Comparison of the Within-Sample and Outside-Sample Forecasts of HSQ_t. (Errors are in thousands of units at annual rates.)

Error Measure	One Quarter Ahead (17 observations)		Two Quarters Ahead (16 observations)		Three Quarters Ahead (15 observations)		Four Quarters Ahead (14 observations)		Five Quarters Ahead (13 observations)	
	Within-sample	Outside-sample	Within-sample	Outside-sample	Within-sample	Outside-sample	Within-sample	Outside-sample	Within-sample	Outside-sample
MAE	58.3	84.6	74.8	138.0	79.6	173.0	82.9	208.3	77.8	278.4
MAEΔ	58.3	84.6	47.8	88.1	53.8	98.8	57.0	109.4	53.3	120.7

for the same period (13 observations) that was used in Table 12–19 for the five-quarter-ahead forecasts. The results are presented in Table 12–20. There is definitely a tendency for the errors in terms of levels to compound as the forecast horizon increases, but only a very slight tendency for the errors in terms of changes. For the errors in terms of levels the five-quarter-ahead forecast error is about three times as large as the one-quarter-ahead error.

Table 12–20. Outside-Sample Forecast Errors of HSQ_t Computed for the Same Prediction Period. (Errors are in thousands of units at annual rates.)

	Length of Forecast					
Error Measure	One Quarter Ahead	Two Quarters Ahead	Three Quarters Ahead	Four Quarters Ahead	Five Quarters Ahead	No. of Observa-tions
MAE	98.5	155.0	192.0	222.5	278.4	13
MAEΔ	98.5	103.0	104.6	114.1	120.7	13

In Table 12–21 the quarter by quarter results of the outside-sample forecasts of HSQ_t are presented for the 654–694 period. As in Table 11–8, the forecasts of HSQ_t in Table 12–21 are at annual rates, since this is the form in which the housing starts series is most widely followed. It is quite evident from the results in Table 12–21 that the model has consistently underpredicted the level of housing starts. This is contrary to the case for the within-sample forecasts in Table 11–8, where no such tendency was observed. The reason for this underprediction is clear from the estimates of the demand equation in Table 12–14. As the mortgage rate rose throughout the 1965–1969 period, the negative influence that it had on housing starts in the demand equation fell. Therefore, when the demand equation was used to forecast housing starts beyond the sample period, using the actual values of the mortgage rate, the equation tended to underpredict the level of housing starts. In other words, the equation was extrapolated into the future using values of the mortgage rate that were consistently larger than had been observed during the period of estimation. One generally cannot expect an equation to perform well under these circumstances, and the present case is no exception. Whether the demand equation will perform better in the future is not clear, but at least the strong (and misleading) negative effect that the mortgage rate had in the demand equation no longer exists.

It is now clear why there was so much compounding of the level errors of HSQ_t in Table 12–20, and why the outside-sample forecast errors in Table 12–19 were so much larger than the within-sample errors. The underprediction of the level of housing starts became larger and larger as the forecast horizon lengthened.

Table 12–21. Actual and Forecasted Levels of HSQ_t. (Forecasts are outside-sample forecasts and are based on actual values of the exogenous variables. Figures are in thousands of units at annual rates.)

		Length of Forecast				
Quarter	Actual Value	One Quarter Ahead	Two Quarters Ahead	Three Quarters Ahead	Four Quarters Ahead	Five Quarters Ahead
654	1463	1377				
661	1349	1359	1268			
662	1267	1303	1280	1243		
663	1018	1043	1116	1095	1042	
663	883	858	846	910	889	788
671	1038	891	790	772	881	786
672	1206	1220	1174	1132	1112	1112
673	1316	1228	1249	1201	1156	1136
674	1420	1318	1239	1239	1172	1115
681	1436	1256	1214	1160	1141	1038
682	1434	1350	1236	1212	1173	1152
683	1449	1292	1214	1140	1104	1045
684	1548	1401	1201	1143	1068	1009
691	1604	1456	1346	1200	1136	1031
692	1507	1533	1455	1402	1289	1234
693	1341	1376	1402	1348	1294	1153
694	1290	1417	1371	1396	1335	1254

Conclusion

In conclusion, in terms of predicting the changes in the variables, the outside-sample forecasts were nearly as good as the within-sample forecasts. The two exceptions to this were the forecast of the change in the price deflator and the forecast of the change in housing starts. In terms of predicting the levels of the variables, the outside-sample forecasts were in general not as good, although much of this was due to the larger errors made in 671 by the outside-sample forecasts. The forecasts for 671 were clearly misleading, as they were for the within-sample forecasts as well, but few of the other forecasts in terms of changes could be considered to be poor. In terms of levels, the size of the labor force and the level of housing starts were consistently under-predicted.

The result in this chapter are thus encouraging. The relationships in the model do appear to be stable enough over time to allow accurate outside-sample forecasts to be made. The major questions for the future are how stable the price equation, the labor force participation equation for secondary workers, and the demand equation for housing starts will prove to be.

13 Sensitivity of the Forecasting Results to Errors Made in Forecasting the Exogenous Variables

13.1 Introduction

The outside-sample forecasts presented in Chapter 12 cannot be considered to be forecasts that could have been generated *ex ante*, since the actual values of the exogenous variables were used. The purpose of this chapter is to examine how sensitive the results of the model are to errors made in forecasting the exogenous variables. The procedure that was used to examine this sensitivity is discussed in Section 13.2, and the forecasts are examined in Section 13.3. The forecasts in Section 13.3 are close to being forecasts that could have been generated *ex ante*. This chapter concludes with an examination in Section 13.4 of the accuracy of the model with respect to making annual forecasts.

13.2 Forecasting the Exogenous Variables

The Variability of the Exogenous Variables

Before discussing the procedure that was used to forecast the exogenous variables, it will be useful to examine the variability of each of the variables. The exogenous variables in the money GNP sector will be examined first, then the exogenous variables in the price and employment and labor force sectors, and finally the exogenous variables in the monthly housing starts sector. This examination will be quite informal and is meant to be used only to give the reader a rough idea as to the variability of each of the exogenous variables. The more important question is how much forecasting accuracy is lost by having to forecast the exogenous variables ahead of the overall forecast, and this question will be examined in Section 13.3.

In Table 13–1 the quarterly changes in each of the exogenous variables in the money GNP sector are presented from 602 through 694. Because it is the first quarter considered after the steel strike, 602 was chosen as the starting point. The exogenous G_t variable has been broken into four components in the table: federal government nondefense expenditures, federal government defense expenditures, state and local government expenditures, and farm housing investment.

Table 13–1. Quarterly Changes in the Exogenous Variables of the Money GNP Sector for the 602–694 Period.

Quarter	Federal Government Nondefense Expenditures	Federal Government Defense Expenditures	State and Local Government Expenditures	Farm Housing Investment	Exports	$MOOD_t$	$PE2_t$
602	.9	−.6	1.6	0	1.3	−6.0	2.51
603	.7	.2	.7	0	.1	−1.4	.59
604	−.5	1.2	.7	0	.5	−1.4	−.60
611	−.4	1.1	1.7	0	.6	1.0	−2.00
612	1.2	.8	.4	0	−.8	1.2	−1.10
613	.4	0	1.2	0	.7	1.1	.80
614	.3	1.2	1.5	0	.9	1.0	1.30
621	.5	2.2	.4	0	−.2	2.8	.60
622	.1	1.9	.6	0	1.7	−1.8	.10
623	1.1	−1.7	1.0	0	−.3	−3.8	1.10
624	1.5	−.4	.9	0	−.2	3.4	.25
631	.3	.3	1.9	0	−.3	−.2	−.25
632	−.9	−.7	.6	0	2.3	−3.4	.95
633	.3	.5	1.2	0	.1	4.8	1.30
634	.9	−.7	1.1	0	1.8	.7	1.20
641	.4	.2	1.6	0	2.2	2.1	−.40
642	.8	.2	1.8	−.1	−.4	−.9	1.95
643	.1	−.9	1.1	0	1.4	2.1	1.60
644[a]	.1	−.9	1.0	0	.8	−.8	1.84
651[a]	.3	−.3	1.7	0	−3.1	2.1	1.75
652[a]	.4	.6	1.9	0	5.6	.7	1.75
653[b]	1.2	.9	2.4	0	−.5	1.0	1.15
654	.2	2.4	1.9	0	.2	−.6	2.15
661	−.1	2.8	2.0	0	1.7	−2.8	3.75
662	−.3	3.2	2.5	0	.5	−4.0	2.20
663	.0	4.8	2.4	0	1.0	−4.7	2.75
664	−.7	2.3	2.9	1	1.1	−2.8	1.90
671	1.4	4.3	3.4	0	1.0	3.9	−.10
672	.5	2.0	1.7	0	.1	2.7	−1.20
673	.0	1.1	1.9	0	.4	1.6	.55
674	.5	1.6	2.9	0	.4	−3.6	−.15
681	1.2	1.5	4.2	0	1.0	2.1	2.40
682	1.0	1.8	2.3	0	3.0	−2.6	−.75
683	1.0	.9	2.3	−.1	2.7	.5	1.75
684[b]	.4	.5	3.1	0	−2.8	−.8	−.90
691[b]	.1	−.3	3.7	0	−3.0	3.0	6.00
692[b]	−.5	−.5	3.8	0	9.5	−3.5	−.30
693[b]	.8	1.8	1.5	0	.7	−5.2	2.60
694	.2	−1.1	2.2	0	.8	−6.7	−1.35

[a] Excluded from all periods of estimation because of the automobile strike.
[b] Excluded from the import equation because of the dock strikes.

With respect to federal government expenditures, without some knowledge of the proposed federal budget these expenditures do not appear to be particularly easy to forecast. Defense expenditures in particular are subject to rather large fluctuations. Fortunately, during at least certain times, knowledge of the proposed federal budget should aid in forecasting federal government expenditures. The state and local government expenditure series is smoother than the federal series and does not appear to be too difficult to forecast within the accuracy expected of the overall model. Farm housing investment is trivial to forecast within the accuracy expected of the model.

The export series in Table 13–1 does not appear to be too difficult to forecast, aside from the quarters in which there are dock strikes. On the average, exports appear to increase about one billion dollars each quarter. The last two series in Table 13–1, $MOOD_t$ and $PE2_t$, are subject to large fluctuations. Fortunately, observations for $PE2_t$ are available about five months ahead, and proxies for $PE2_t$ are available as much as eleven months ahead. Forecasting $PE2_t$ thus does not pose as much difficulty as is indicated by its large variance in Table 13–1. $MOOD_t$ enters the model with lags of one and two quarters, and so forecasting $MOOD_t$ is really only a problem for three-quarter-ahead forecasts and beyond. Nevertheless, the series does not appear to be particularly easy to forecast, and as mentioned above, the sensitivity of the accuracy of the model to errors made in forecasting variables like $MOOD_t$ will be examined in the next section.

In Table 13–2 the quarterly changes in each of the exogenous variables in the price and employment and labor force sectors are presented from 602 through 694. As expected, the two population variables, P_{1t} and P_{2t}, do not appear to pose any forecasting difficulties. Likewise, real agricultural output YA_t, and real government output, YG_t, appear to be fairly smooth series. The change in government output in current dollars, GG_t, is also fairly constant over time, except for those quarters like 683 and 693, in which large federal government pay increases occurred. The agricultural employment series, MA_t, is not very smooth, and much of the short-run variation is probably due to measurement error. This series, however, is not too important within the context of the overall model. With respect to the two government employment series, MCG_t and AF_t, the former is, as expected, somewhat smoother than the latter. AF_t is, of course, significantly influenced by federal government defense policy, although MCG_t is to some extent as well.

In Table 13–3, $DHF3_t$, $DSF6_t$, and the change in the mortgage rate, ΔRM_t, are presented monthly for the January 1965–December 1969 period. $DHF3_t$ is the three-month moving average of the flow of advances from the Federal Home Loan Bank (FHLB) to Savings and Loan Associations (SLAs), and $DSF6_t$ is the six-month moving average of private deposit flows into SLAs and Mutual Savings Banks.

Table 13–2. Quarterly Changes in the Exogenous Variables of the Price Sector and of the Employment and Labor Force Sector for the 602–694 Period.

Quarter	P_{1t}	P_{2t}	YA_t	MA_t	GG_t	YG_t	MCG_t	AF_t
602	22.3	291.0	1.3	121	1.0	.7	60	−16
603	33.0	338.0	.5	202	1.1	−.1	74	−2
604	48.0	392.0	−.3	−38	.7	.1	25	26
611	46.0	386.0	0	−97	.7	.3	58	0
612	31.0	333.7	−.1	−355	.8	.2	66	−17
613	32.3	347.7	−.3	57	.9	.5	88	18
614	23.7	355.9	.4	−60	1.4	.8	59	189
621	23.3	317.7	−.1	158	1.2	.8	52	153
622	−39.3	480.7	.6	−241	.6	.4	77	1
623	47.0	445.6	−1.2	−96	.4	.2	96	−56
624	26.3	584.0	−.1	−116	.9	−.1	102	−66
631	24.3	543.3	1.4	27	1.1	.2	34	−26
632	22.3	517.7	.2	−53	.7	.5	58	12
633	20.7	493.7	−.6	−43	.8	.4	83	11
634	21.3	491.0	.1	17	1.6	.1	144	−7
641	27.7	484.0	−.5	−145	1.4	.3	43	−8
642	28.0	480.3	.2	−14	1.0	.5	84	14
643	27.7	507.7	.1	42	1.4	.3	62	−1
644†	26.3	506.6	.3	−138	1.0	.3	148	−13
651†	24.3	477.4	1.2	−96	.7	.1	75	−27
652†	23.7	467.3	.2	192	1.1	.6	131	−21
653	−24.0	459.0	−.5	−228	1.9	.7	149	20
654	30.7	491.7	−.2	−124	2.5	.9	148	96
661	29.0	443.4	−.1	−107	2.3	1.0	189	131
662	30.3	448.9	−.9	−52	2.1	1.1	210	121
663	38.3	457.7	−.7	−136	2.8	1.2	158	130
664	53.7	478.3	.5	−8	1.8	1.1	185	150
671	52.3	457.0	1.1	−2	2.3	.6	91	83
672	54.7	466.0	.7	−123	1.8	.5	127	36
673	105.7	536.4	−.1	134	2.2	.7	74	5
674	111.0	494.3	−.2	45	2.8	0	110	13
681	93.0	423.7	.3	23	2.3	.6	132	6
682	93.3	414.6	−1.0	−79	2.5	1.0	111	63
683	93.3	495.4	.4	−140	3.3	.5	72	53
684	73.0	509.0	−.5	−51	1.4	0	124	−49
691	70.0	471.6	.8	44	1.7	.3	95	−55
692	79.0	500.4	0	−2	1.9	.4	87	35
693	92.7	492.6	.4	−216	4.1	.3	19	11
694	70.3	536.4	−1.5	−133	1.8	.4	132	−44

† Excluded from all periods of estimation because of the automobile strike.

Table 13–3. Monthly Values of $DHF3_t$, $DSF6_t$, and ΔRM_t for the January 1965–December 1969 Period.

Month	$DHF3_t$	$DSF6_t$	ΔRM_t	Month	$DHF3_t$	$DSF6_t$	ΔRM_t
1/65	49.0	1281.7	0	7/67	−187.0	1423.7	5
2/65	22.3	1227.3	0	8/67	−89.3	1404.3	0
3/65	−192.7	1236.2	0	9/67	−60.0	1331.2	5
4/65	91.7	1058.5	0	10/67	−35.7	1328.2	0
5/65	125.3	1047.0	0	11/67	11.7	1196.2	0
6/65	279.7	1005.8	0	12/67	88.0	1142.7	10
7/65	191.3	867.8	0	1/68	109.3	1081.2	5
8/65	181.0	864.0	0	2/68	53.3	1076.2	5
9/65	72.0	844.8	0	3/68	−39.0	1107.3	0
10/65	11.0	984.5	0	4/68	34.3	934.2	5
11/65	−15.3	981.7	5	5/68	123.7	992.0	10
12/65	65.0	1009.5	5	6/68	206.7	948.2	25
1/66	24.0	1072.7	10	7/68	147.7	875.2	10
2/66	5.0	1064.7	0	8/68	92.7	822.2	5
3/66	−103.3	1018.0	5	9/68	45.7	774.3	0
4/66	206.0	711.3	10	10/68	15.7	945.8	0
5/66	321.7	630.7	10	11/68	14.3	907.8	−5
6/66	365.3	490.2	5	12/68	77.7	970.3	5
7/66	275.3	249.7	10	1/69	107.3	1062.8	10
8/66	174.0	174.2	5	2/69	86.0	1114.7	15
9/66	130.7	139.5	10	3/69	24.0	1178.0	5
10/66	−31.0	329.7	10	4/69	135.7	949.2	5
11/66	−47.3	372.3	5	5/69	224.3	932.7	10
12/66	−80.0	534.3	0	6/69	360.7	826.2	0
1/67	−303.0	852.8	−5	7/69	429.7	591.0	25
2/67	−428.0	987.0	−5	8/69	524.3	449.2	10
3/67	−586.7	1186.3	−10	9/69	509.0	309.7	10
4/67	−519.3	1294.2	−5	10/69	462.0	329.5	5
5/67	−459.7	1431.0	−5	11/69	419.3	259.5	5
6/67	−291.0	1463.8	5	12/69	449.7	233.3	5

As can be seen in Table 13–3, RM_t has generally been increasing throughout the 1965–1969 period, and at times quite substantially. Only in early 1967 did the rate fall to any degree. The fluctuations in the two deposit flow variables are quite large, although the variables to some extent offset one another. When private deposit flows are small, the flow of advances from the FHLB tend to be large, and vice versa. When, for example, private deposit flows began to increase in early 1967, SLAs paid back their borrowings from the FHLB quite rapidly. It is interesting to note, however, that in early 1970 the FHLB in an effort to stimulate the housing sector has been encouraging the SLAs not to pay back their borrowings as their private deposit flows increase. The offsetting relationship between $DHF3_t$ and $DSF6_t$ observed in Table 13–3 may thus be less pronounced in the future.

Of the four major sectors in the model, the monthly housing starts sector relies the most heavily on hard-to-forecast exogenous variables. Values of $DHF3_t$, $DSF6_t$, and RM_t are not available much ahead of the forecast period, and the variables enter the housing starts equations only with a lag of one or two months. It is beyond the scope of this study to attempt to explain $DHF3_t$, $DSF6_t$, and RM_t within the context of the model, and fortunately the results below suggest that the accuracy of the model is not seriously affected by having to forecast these three variables exogenously.

The Forecasts of the Exogenous Variables and the Tests Performed

In order to examine how sensitive the forecasts of the model are to errors made in forecasting the exogenous variables, the following test was performed. Two sets of forecasts were made, one on the assumption that the forecasts would have been made in late January, April, July, and October of each year and the other on the assumption that the forecasts would have been made in the middle of March, June, September, and December. Both sets of forecasts were outside-sample forecasts and the coefficient estimates that were used in Chapter 12 were also used here. The difference between the forecasts in this chapter and those in Chapter 12 is that here the values of all but four of the exogenous variables were not assumed to be known beyond what they would have been in actual practice. The remaining values of the exogenous variables were projected in the manner specified in Table 13–4. From Table 13–4 it can be seen that the remaining values of the variables were essentially projected in a naive manner. Either the variable was assumed to remain unchanged from the last available value or the future changes in the variable were assumed to be the same as some average past change. With respect to the $PE2_t$ variable, data (including the proxies) from the OBE–SEC survey were used as far as they went, and then the changes in $PE2_t$ beyond this were assumed to be the same as the last observed change from the survey.

Notice from Table 13–4 that the four variables for which the actual values continued to be used all pertain, at least in part, to the federal government. As mentioned above, knowledge of the proposed federal budget should aid in forecasting federal government purchases of goods and services. The proposed budget is not always a useful guide, however, since the federal government can (and sometimes does) decide to escalate one of its defense commitments or make some other significant policy change during the middle of the fiscal year. It is beyond the scope of the study to attempt to forecast the policy decisions of government officials, and thus the actual values of

Table 13–4. Assumptions Made in Forecasting the Exogenous Variables.

Actual Values Used
Federal government component of G_t (Federal defense plus nondefense expenditures)
AF_t
YG_t
GG_t

No Change from Last Available Value
$MOOD_t$
YA_t
$DHF3_t$
$DSF6_t$
RM_t

Future Changes Equal to the Average of the Last Four Observed Changes
State and local government component of G_t
MCG_t
MA_t
P_{1t}
P_{2t}

Other Assumptions
EX_t: Change of 1.0 billion dollars each quarter
Farm Housing Investment Component of G_t: Level of .5 billion dollars each quarter
$PE2_t$: Future changes equal to the last observed change

federal government spending and the level of the armed forces have been used for the work in this chapter. Both real and current dollar government output, YG_t, GG_t, are also significantly influenced by federal government policy decisions (such as the effect of federal government pay increases on GG_t), and so the actual values of these two variables have been used for the work here as well. The forecasts in this chapter can thus be considered to be conditional on the actual policy decisions of federal government officials being known.

With respect to the late January, April, July, and October forecasts (to be referred to as the January et al. forecasts), data on all of the variables in the model are available for the previous quarter. At the end of January, for example, the data for the fourth quarter are available. At this time the model can be reestimated using these data, and forecasts for the first, second, third, and fourth quarters of the current year and the first quarter of the next year can be made. At this time, values or proxies for $PE2_t$ are available for the first and second quarters. The value of $MOOD_{t-1}$ is available for the first quarter (and thus values of $MOOD_{t-2}$ are available for the first and second quarters); the value of RM_t is available for January; and values of the deposits of SLAs and MSBs (including the FHLB advances to SLAs) are available for December.

The other four times when it appears desirable to make forecasts are the middle of March, the middle of June, the middle of September, and the middle of December. These are the times when the figures from the OBE–SEC on plant and equipment investment expectations become available. In March, for example, the value of the one-quarter-ahead expectation of plant and equipment investment, $PE1_t$, is available for the first quarter, and the value of $PE2_t$ is available for the second quarter. Also, proxies for $PE2_t$ are available for the third and fourth quarters. It was seen in Chapter 4 that plant and equipment investment was better explained by the use of $PE1_t$ instead of $PE2_t$, and for the March, June, September, and December forecasts (to be referred to as the March et al. forecasts) the equation that uses $PE1_t$, equation (4.7), can be used for the one-quarter-ahead forecasts. Using these one-quarter-ahead forecasts, equation (4.4) can then be used for the two- through five-quarter-ahead forecasts. The one-quarter-ahead forecasts for the March et al. set of forecasts are, of course, really only forecasts for about one month ahead. With respect to the other exogenous variables, by the middle of March the figures on housing starts for January and February are available; one more value for $MOOD_{t-1}$ (and thus for $MOOD_{t-2}$) is available; values of RM_t are available for February and March; and values of the deposits of SLAs and MSBs are available for January.

Aside from using different values for the exogenous variables, the forecasts presented below were generated in the same manner as was done for forecasts in Chapter 12. In particular, the forecasts were all outside-sample forecasts and were based on the coefficient estimates presented in Tables 12–1 through 12–15. Also, the same adjustments were made here for the 684–693 period with respect to the export and import series as were made above.

13.3 The Forecasting Results

The January et al. Quarterly Forecasts

In Table 13–5 the results of the January et al. forecasts are compared with the results of the outside-sample forecasts of Chapter 12. The mean absolute errors in terms of both levels and changes are presented for 15 endogenous variables. The endogenous variables are the same as those considered in Table 12–16. Likewise, the prediction period is the same as the one considered in Table 12–16, namely 654–694. At the bottom of Table 13–5 the error measures for GNP_t for the shorter 1968–1969 period are presented.

Looking first at the level errors for GNP_t in Table 13–5, the one- and two-quarter-ahead results are nearly the same, but the gap widens for the three-, four-, and five-quarter-ahead forecasts. The differences between the mean absolute errors for the three- through five-quarter-ahead forecasts are respectively 2.19, 4.02, and 6.21 billion dollars. For the errors in terms of changes, however, the gap between the two sets of forecasts of GNP is fairly constant for the three- through five-quarter-ahead forecasts. The differences are respectively 1.51, 1.36, and 1.45 billion dollars. The same conclusion also tends to hold for the other endogenous variables: the gap between the two sets of forecasting results for most variables widens as the forecast horizon lengthens for the errors in terms of levels, but not for the errors in terms of changes.

In general, for the errors in terms of changes the results of the two sets of forecasts are fairly close. Some accuracy has been lost by having to extrapolate the values of the exogenous variables, but not enough to indicate that the model is of little use unless the actual values of all of the exogenous variables are known.

In order to compare the accuracy of the forecasts generated in this chapter to changes in the forecast horizon, the mean absolute errors for the one- through four-quarter-ahead forecasts were computed for the same prediction period (664–694) that was used for the five-quarter-ahead forecasts in Table 13–5. The results are presented in Table 13–6. At the bottom of the table the error measures for GNP for the 1968–1969 period are also presented.

The errors in terms of levels in Table 13–6 definitely compound as the forecast horizon lengthens. The compounding in Table 13–6 is more pronounced than it was in Table 12–17 for the outside-sample forecasts based on actual values of the exogenous variables. With respect to the errors in terms of changes in Table 13–6, the errors tend to compound for a few of the variables, but in general error compounding does not appear to be a serious problem for the errors in terms of changes.

The quarter by quarter results of the January et al. forecasts are presented in Table 13–7 for eleven variables. The eleven variables are the same as those considered in Table 12–18. The first line for each quarter gives the actual change in each of the variables for that quarter, and the next five lines give, respectively, the one- through five-quarter-ahead forecast of the change in each of the variables for that quarter.

The same conclusions that were made about the forecasts in Table 12–18 can generally be made for the forecasts in Table 13–7, and these conclusions

Table 13–5. Comparisons of Forecasts Based on Actual and Extrapolated Values of the Exogenous Variables. (Both sets of forecasts are outside-sample forecasts. The forecasts based on extrapolated values are January et al. forecasts.)

Variable	One Quarter Ahead (17 observations)		Two Quarters Ahead (16 observations)		Three Quarters Ahead (15 observations)		Four Quarters Ahead (14 observations)		Five Quarters Ahead (13 observations)	
	Actual Values	Extra-polated Values	Actual Values	Extra-polated Values	Actual Values	Extra-polated Values	Actual Values	Extra-polated Values	Actual Values	Extra-polated Values
MAE										
GNP_t	2.47	2.55	3.94	4.22	3.88	6.07	4.67	8.69	6.98	13.19
CD_t	1.46	1.50	1.90	2.12	1.77	2.16	2.41	2.84	2.62	3.82
CN_t	1.62	1.65	2.15	2.25	2.48	2.60	2.77	2.86	3.39	4.05
CS_t	.43	.43	.75	.76	1.13	1.11	1.59	1.56	1.98	1.95
IP_t	1.36	1.35	1.54	2.20	1.75	2.80	2.17	3.85	2.50	4.70
IH_t	.82	.81	1.62	1.69	2.36	2.85	3.05	3.62	3.86	4.19
$V_t - V_{t-1}$	3.13	3.14	3.78	3.65	3.92	3.59	3.64	3.53	3.66	3.57
IMP_t	.73	.75	1.20	1.34	1.66	1.80	1.78	1.92	1.61	1.91
PD_t	.17	.17	.30	.31	.45	.46	.67	.71	.89	.98
$GNPR_t$	2.61	2.54	4.11	4.10	4.05	4.81	4.06	6.09	5.14	8.91
M_t	136	135	184	205	253	265	298	472	374	665
D_t	188	190	228	243	204	236	256	239	245	261
LF_{1t}	52	55	61	82	63	110	65	143	73	182
LF_{2t}	283	281	438	433	588	584	735	729	847	819
UR_t	.0031	.0032	.0055	.0058	.0071	.0076	.0083	.0092	.0094	.0012

MAEΔ										
GNP_t			2.98	3.41	3.18	4.69	2.93	4.29	2.74	4.19
CD_t			1.51	1.62	1.57	1.65	1.37	1.49	1.45	1.54
CN_t			1.47	1.52	1.45	1.52	1.66	1.75	1.89	2.15
CS_t			.46	.45	.49	.48	.47	.47	.48	.50
IP_t			1.25	1.41	1.32	1.74	1.32	1.89	1.39	1.97
IH_t			1.01	1.05	1.13	1.30	1.11	1.33	1.27	1.42
$V_t - V_{t-1}$	s		4.39	4.47	4.83	4.96	4.87	5.07	4.66	4.83
IMP_t	a		.66	.78	.71	.85	.80	.95	.72	.87
PD_t	m		.18	.18	.20	.21	.24	.26	.29	.32
$GNPR_t$	e		2.86	2.63	2.47	3.38	2.31	2.90	1.92	3.00
M_t			102	109	120	168	154	262	161	270
D_t			171	170	175	178	170	178	175	192
LF_{1t}			51	57	53	57	56	59	57	65
LF_{2t}			233	232	241	244	236	248	230	236
UR_t			.0026	.0027	.0020	.0021	.0015	.0021	.0014	.0021
1968–1969 Period Only (8 observations)										
MAE for GNP_t	2.61	2.38	3.20	3.72	2.71	5.07	2.12	5.25	2.88	7.66
MAEΔ for GNP_t	2.67	2.38	2.23	2.89	1.82	3.30	1.75	2.21	1.47	2.53

Table 13–6. Errors Computed for the Same Prediction Period for the Forecasts Based on Extrapolated Values of the Exogenous Variables. (Forecasts are outside-sample forecasts and are January et al. forecasts.)

Variable	One Quarter Ahead	Two Quarters Ahead	Three Quarters Ahead	Four Quarters Ahead	Five Quarters Ahead	Number of Observations
	Length of Forecast					
MAE						
GNP_t	2.60	4.03	6.01	9.34	13.19	13
CD_t	1.40	2.00	1.97	2.86	3.82	13
CN_t	1.81	2.35	2.66	2.84	4.05	13
CS_t	.44	.69	1.03	1.56	1.95	13
IP_t	1.45	2.30	2.97	3.96	4.70	13
IH_t	.96	1.87	2.98	3.71	4.19	13
$V_t - V_{t-1}$	3.39	3.64	3.44	3.59	3.57	13
IMP_t	.72	1.34	1.76	1.80	1.91	9
PD_t	.17	.32	.51	.73	.98	13
$GNPR_t$	2.38	3.69	4.52	6.39	8.91	13
M_t	118	214	267	487	665	13
D_t	176	216	193	201	261	13
LF_{1t}	64	90	118	149	182	13
LF_{2t}	287	447	592	724	819	13
UR_t	.0027	.0047	.0066	.0087	.0112	13
MAEΔ						
GNP_t	2.60	3.37	4.72	4.18	4.19	13
CD_t	1.40	1.52	1.50	1.54	1.54	13
CN_t	1.81	1.62	1.70	1.84	2.15	13
CS_t	.44	.41	.43	.45	.50	13
IP_t	1.45	1.63	1.94	2.01	1.97	13
IH_t	.96	1.18	1.33	1.40	1.42	13
$V_t - V_{t-1}$	3.39	4.70	4.99	5.10	4.83	13
IMP_t	.72	.78	.87	.91	.87	9
PD_t	.17	.19	.23	.27	.32	13
$GNPR_t$	2.38	2.44	3.27	2.79	3.00	13
M_t	118	113	188	272	270	13
D_t	176	177	179	183	192	13
LF_{1t}	64	65	64	62	65	13
LF_{2t}	287	244	243	244	236	13
UR_t	.0027	.0020	.0017	.0019	.0021	13
1968–1969 Period Only						
MAE for GNP_t	2.38	3.72	5.07	5.25	7.66	8
MAEΔ for GNP_t	2.38	2.89	3.30	2.21	2.53	8

Table 13–7. Actual and Forecasted Changes for Selected Variables of the Model. (Forecasts are outside-sample forecasts, are based on extrapolated values of the exogenous variables, and are January et al. forecasts. Forecasts for UR_t are in terms of levels.)

Quarter	Length of Forecast	GNP_t	$CD_t + CN_t + CS_t$	IP_t	IH_t	$V_t - V_{t-1}$	IMP_t	PD_t	$GNPR_t$	M_t	$LF_{1t} + LF_{2t}$	UR_t
654		18.90	11.10	3.80	.20	.60	1.50	.34	14.10	731	358	.0411
	1	14.82	8.53	1.87	.27	−.49	.76	.74	8.25	566	118	.0370
661		19.50	10.30	2.60	.0	1.60	1.50	.78	12.50	584	345	.0386
	1	18.24	8.57	3.70	.24	.94	.91	.79	11.30	730	203	.0332
	2	15.53	8.64	1.92	.20	.07	.79	.83	8.63	656	250	.0307
662		13.80	4.10	1.50	−1.50	4.90	1.10	1.07	5.90	603	507	.0383
	1	15.50	8.72	2.45	−.48	−.26	.83	.87	8.49	554	202	.0319
	2	16.25	10.09	2.17	−.26	−.83	.81	.89	9.09	813	295	.0261
	3	16.44	9.09	2.15	.22	.12	.84	.92	9.12	543	276	.0260
663		12.60	9.30	2.70	−1.20	−4.30	2.20	.88	5.20	656	576	.0377
	1	10.13	7.76	2.78	−1.15	−6.60	.56	.96	2.61	257	125	.0334
	2	16.92	9.61	2.64	−1.18	−1.14	.91	.99	8.49	659	297	.0257
	3	18.87	9.92	2.45	−.72	.36	.94	1.00	10.16	645	307	.0207
	4	18.30	9.63	2.36	−.73	.38	.94	1.02	9.56	524	291	.0215
664		14.80	3.40	1.20	−2.70	8.00	.60	.88	7.90	290	688	.0369
	1	9.78	6.83	2.09	−2.00	−1.12	.61	1.02	2.70	290	155	.0326
	2	12.25	8.09	2.23	−1.24	−.95	.68	1.06	4.67	355	237	.0293
	3	15.10	9.63	2.60	−.94	−.08	.81	1.11	6.86	476	303	.0212
	4	15.92	10.30	2.36	−.60	.06	.80	1.13	7.48	519	308	.0163
	5	14.76	9.40	2.22	−.78	.27	.75	1.14	6.47	410	287	.0179

Table 13–7 (cont.)

Quarter	Length of Forecast	GNP_t	$CD_t + CN_t + CS_t$	IP_t	IH_t	$V_t - V_{t-1}$	IMP_t	PD_t	$GNPR_t$	M_t	$LF_{1t} + LF_{2t}$	UR_t
671		3.50	6.60	−.90	−.60	−10.90	.50	.60	−1.60	258	358	.0376
	1	7.53	5.77	.52	−.18	−7.21	.46	1.07	−.58	115	66	.0330
	2	15.44	7.75	2.46	−.53	−2.08	.96	1.12	6.18	466	246	.0285
	3	21.28	10.12	2.77	.44	.34	1.18	1.18	10.97	488	279	.0258
	4	22.58	11.27	3.08	.32	.43	1.21	1.24	11.64	582	315	.0170
	5	22.49	11.34	2.81	.38	.48	1.12	1.26	11.46	601	312	.0121
672		9.30	8.60	−.30	1.60	−5.60	−.30	.59	4.00	32	171	.0386
	1	11.40	5.55	.10	2.14	−2.19	.70	1.00	3.57	125	56	.0338
	2	10.92	5.54	1.20	2.05	−3.11	.66	1.15	2.33	116	167	.0311
	3	18.33	9.25	2.63	2.07	−.08	1.15	1.21	8.38	444	273	.0256
	4	21.60	10.68	2.79	2.14	1.58	1.20	1.30	10.71	587	299	.0225
	5	21.80	11.66	3.06	1.64	1.12	1.17	1.38	10.30	637	318	.0130
673		16.90	6.00	.50	3.40	4.40	.60	1.12	7.50	186	752	.0386
	1	18.97	9.15	1.77	1.80	2.87	1.11	1.02	9.84	372	180	.0352
	2	15.06	9.08	1.78	1.59	−1.26	.92	1.05	6.26	311	215	.0311
	3	11.04	6.68	1.19	1.63	−2.28	.67	1.21	1.96	56	197	.0305
	4	17.67	9.53	2.59	1.55	.91	1.10	1.31	7.02	379	275	.0239
	5	18.53	10.66	2.61	1.10	.99	1.03	1.41	7.10	455	278	.0205
674		15.70	6.90	1.50	2.40	1.70	2.10	1.05	5.50	453	571	.0392
	1	14.17	10.02	1.04	.55	−2.24	.80	1.05	4.20	241	172	.0366
	2	18.39	9.39	1.86	.53	2.08	1.08	1.06	7.72	456	263	.0324
	3	17.74	8.68	1.90	.12	2.32	1.09	1.09	7.02	321	269	.0292
	4	12.30	7.14	1.24	−.26	−.58	.75	1.24	1.62	5	217	.0306
	5	16.83	9.74	2.54	−.22	.62	1.05	1.38	4.57	270	269	.0230

681		19.20	18.10	4.10	−.30	−7.90	3.10	.98	9.80	434	106	.0369
	1	17.95	10.84	2.96	−.13	−.89	1.13	1.04	8.38	370	229	.0370
	2	19.54	10.08	1.51	−.28	3.24	1.11	1.06	9.67	394	246	.0343
	3	17.26	9.46	1.75	−.41	1.27	1.01	1.09	7.51	383	279	.0306
	4	16.74	9.24	1.80	−.60	.92	1.02	1.11	6.94	314	288	.0277
	5	13.51	7.69	1.31	−.75	−.01	.82	1.24	3.60	27	234	.0308
682		23.40	9.60	−2.70	1.70	8.30	1.40	1.15	12.50	533	508	.0360
	1	24.72	7.46	.97	.26	11.68	1.85	1.06	14.09	606	348	.0326
	2	17.90	9.28	1.80	−.71	2.45	1.12	1.05	8.41	474	299	.0340
	3	18.03	10.25	1.37	−.43	1.66	1.02	1.07	8.41	403	307	.0318
	4	17.46	9.75	1.73	.02	.68	1.02	1.11	7.66	357	311	.0289
	5	17.94	9.60	1.85	.13	.96	1.10	1.14	7.95	320	320	.0259
683		17.70	14.60	1.70	−.30	−2.70	2.40	1.03	7.00	253	146	.0356
	1	16.96	10.19	3.15	−1.10	.36	1.24	1.08	6.08	412	340	.0334
	2	12.96	10.94	1.62	−1.06	−3.07	.97	1.08	2.75	449	352	.0298
	3	15.03	9.67	1.59	−.46	−.12	.94	1.05	4.68	271	287	.0324
	4	16.81	10.06	1.26	.21	.94	.95	1.08	6.02	308	212	.0302
	5	16.91	9.90	1.68	.38	.54	.99	1.14	5.75	302	308	.0277
684		16.10	5.80	3.40	2.00	3.30	1.30*	1.20	5.70	399	226	.0340
	1	18.77	9.29	.88	.03	5.13	1.46	1.09	8.50	367	323	.0351
	2	15.10	8.99	2.52	−.98	.97	1.11	1.09	5.47	402	310	.0319
	3	14.75	8.94	1.74	−1.00	1.57	1.10	1.08	5.25	228	296	.0295
	4	14.41	9.42	1.52	−.19	.16	.91	1.04	5.22	208	266	.0324
	5	14.28	9.70	1.07	−.29	.21	.81	1.08	4.89	242	284	.0300
691		16.20	11.30	3.80	1.40	−3.90	1.40*	1.40	4.60	733	959	.0336
	1	21.05	12.34	5.75	−.24	−2.25	1.64	1.13	10.07	448	364	.0338
	2	13.82	9.69	1.35	−.36	−.59	1.07	1.12	4.20	359	303	.0347
	3	14.71	9.63	2.31	−.15	−.59	1.08	1.11	5.00	271	300	.0313
	4	14.02	9.79	1.70	.12	−1.03	1.05	1.09	4.54	213	305	.0296
	5	14.21	9.40	1.49	.08	−.18	.89	1.05	4.99	196	280	.0326

Table 13–7 (cont.)

Quarter	Length of Forecast	GNP_t	$CD_t + CN_t + CS_t$	IP_t	IH_t	$V_t - V_{t-1}$	IMP_t	PD_t	$GNPR_t$	M_t	$LF_{1t} + LF_{2t}$	UR_t
692		16.10	10.80	2.50	−.60	.30	1.40*	1.55	3.60	439	280	.0349
	1	17.99	10.45	1.17	−.22	3.18	1.40	1.22	6.87	388	222	.0325
	2	13.87	9.37	−.29	−.44	3.23	1.08	1.16	3.82	392	351	.0329
	3	12.05	9.14	1.14	−.17	−.12	.94	1.14	2.51	154	299	.0348
	4	14.32	9.56	2.16	.80	.05	1.05	1.13	4.43	194	330	.0307
	5	13.59	9.22	1.67	.84	.18	1.02	1.11	3.97	151	332	.0294
693		18.00	7.00	3.30	−1.30	3.80	1.40*	1.41	3.90	334	688	.0363
	1	22.83	12.31	3.06	−1.12	2.26	1.77	1.34	8.16	348	345	.0343
	2	19.24	11.70	3.20	−1.67	.90	1.49	1.26	5.70	468	285	.0313
	3	13.70	10.08	−.30	−1.24	−.47	1.07	1.18	1.64	113	285	.0337
	4	15.36	9.81	1.21	−.35	−.72	1.19	1.15	3.20	102	289	.0355
	5	17.42	10.29	2.23	−.07	−.16	1.28	1.14	4.91	177	330	.0306
694		9.40	9.60	1.40	.10	−3.00	.70	1.36	−.80	210	417	.0359
	1	7.88	8.89	−.75	−.63	−1.92	.61	1.31	−1.74	−16	152	.0395
	2	15.12	9.96	1.18	−1.18	2.94	1.17	1.36	3.71	340	282	.0338
	3	14.62	10.54	2.85	−2.41	1.67	1.13	1.27	3.76	195	236	.0321
	4	9.27	8.77	−.54	−1.69	.24	.72	1.18	.00	−41	240	.0358
	5	10.80	9.02	.92	−1.47	.07	.84	1.15	1.46	25	262	.0372

* Adjusted value rather than the actual value.

will not be repeated here. The results in the two tables differ primarily in the forecasts for 671 and 672. The last three forecasts of GNP for 671 and 672, for example, are much worse in Table 13–7 than they are in Table 12–18. In Table 13–7 plant and equipment investment was forecast to grow much more in 671 and 672 than it was forecast to grow in Table 12–18, which caused the forecasts of GNP in Table 13–7 to be much larger in 671 and 672. The large plant and equipment investment forecasts in Table 13–7 for 671 and 672 are caused by large (and erroneous) extrapolations of the $PE2_t$ series. Otherwise, the forecasts in Table 12–18 and 13–7 are similar: only a few of the forecasts of GNP in Table 13–7 besides those for 671 and 672 could be considered to be at all misleading. The same problems still occur, of course, with respect to the forecasts of the labor force and thus of the level of the unemployment rate. Likewise, the inflation in 1969 is still somewhat underpredicted.

The March et al. Quarterly Forecasts

In Table 13–8 the results of the March, June, September, and December forecasts are compared with the results of the January, April, July, and October forecasts that have just been presented. The format of Table 13–8 is the same as the format of Table 13–5, aside from the different comparisons being made. The March et al. forecasts differ from the January et al. forecasts in that more data for the March et al. forecasts are available. These data differences were discussed in Section 13.2.

The results for the two sets of forecasts in Table 13–8 are not very different. The one- and two-quarter-ahead forecasts of GNP are actually better for the January et al. set of forecasts. The forecasts of plant and equipment investment and housing investment are better for the March et al. set, but error cancellation has caused the forecasts of GNP to be slightly better for the January et al. set. For the three- through five-quarter-ahead forecasts of the level of GNP, however, the March et al. forecasts are better. For the forecasts of the change in GNP, the two sets of forecasts are about the same. In short, the overall accuracy of the model appears to be only slightly improved by making forecasts about one and one-half months later.

The January et al. Forecasts from the Monthly Housing Starts Equations

In Table 13–9 the outside-sample forecasts of HSQ_t from Chapter 12 are compared with the January et al. forecasts of HSQ_t in this chapter. The format of Table 13–9 is the same as the format of Table 12–19 in Chapter 13.

Table 13–8. Comparisons of the January et al. and March et al. Forecasts.

Variable	One Quarter Ahead (17 observations) Jan.	March	Two Quarters Ahead (16 observations) Jan.	March	Three Quarters Ahead (15 observations) Jan.	March	Four Quarters Ahead (14 observations) Jan.	March	Five Quarters Ahead (13 observations) Jan.	March
MAE										
GNP_t	2.55	2.83	4.22	4.60	6.07	5.48	8.69	8.13	13.19	11.66
CD_t	1.50	1.52	2.12	1.95	2.16	2.13	2.84	2.77	3.82	3.33
CN_t	1.65	1.66	2.25	2.25	2.60	2.52	2.86	2.75	4.05	3.34
CS_t	.43	.43	.76	.77	1.11	1.18	1.56	1.68	1.95	2.08
IP_t	1.35	1.01	2.20	1.66	2.80	2.27	3.85	3.12	4.70	4.21
IH_t	.81	.77	1.69	1.38	2.85	2.59	3.62	3.55	4.19	4.18
$V_t - V_{t-1}$	3.14	3.12	3.65	3.74	3.59	3.75	3.53	3.37	3.57	3.59
IMP_t	.75	.75	1.34	1.27	1.80	1.77	1.92	1.84	1.91	1.71
PD_t	.17	.17	.31	.37	.46	.46	.71	.69	.98	.96
$GNPR_t$	2.54	2.79	4.10	4.35	4.81	4.74	6.09	6.08	8.91	8.15
M_t	135	130	205	146	265	193	472	344	665	549
D_t	190	184	243	251	236	226	239	257	261	228
LF_{1t}	55	55	82	82	110	82	143	143	182	182
LF_{2t}	281	283	433	429	584	582	729	729	819	828
UR_t	.0032	.0032	.0058	.0057	.0076	.0077	.0092	.0092	.0112	.0107

MAEΔ										
GNP_t			3.41	3.28	4.69	4.37	4.29	4.83	4.19	4.25
CD_t			1.62	1.54	1.65	1.68	1.49	1.51	1.54	1.53
CN_t			1.52	1.46	1.52	1.51	1.75	1.76	2.15	2.03
CS_t			.45	.47	.48	.49	.47	.48	.50	.49
IP_t			1.41	1.13	1.74	1.57	1.89	1.89	1.97	2.05
IH_t	s		1.05	1.00	1.30	1.45	1.33	1.29	1.42	1.42
$V_t - V_{t-1}$	a		4.47	4.48	4.96	4.92	5.07	5.02	4.83	4.81
IMP_t	m		.78	.72	.85	.80	.95	.97	.87	.88
PD_t	e		.18	.18	.21	.21	.26	.25	.32	.31
$GNPR_t$			2.63	2.97	3.38	3.29	2.90	3.28	3.00	2.87
M_t			109	79	168	139	262	226	270	281
D_t			170	174	178	174	178	178	192	187
LF_{1t}			57	57	57	57	59	59	65	65
LF_{2t}			232	231	244	239	248	247	236	240
UR_t			.0027	.0028	.0021	.0021	.0021	.0018	.0021	.0020
1968–1969 Period Only (8 observations)										
MAE for GNP_t	2.38	2.54	3.72	4.96	5.07	5.94	5.15	6.79	7.66	7.41
MAEΔ for GNP_t	2.38	2.54	2.89	3.13	3.30	3.27	2.21	3.53	2.53	2.58

Table 13–9. Comparison of Forecasts of HSQ_t Based on Actual and Extrapolated Values of the Exogenous Variables. (Both sets of forecasts are outside-sample forecasts. The forecasts based on extrapolated values are January et al. forecasts. Errors are in thousands of units at annual rates.)

	One Quarter Ahead (17 observations)		Two Quarters Ahead (16 observations)		Three Quarters Ahead (15 observations)		Four Quarters Ahead (14 observations)		Five Quarters Ahead (13 observations)	
Error Measure	Actual Values	Extra-polated Values	Actual Values	Extra-polated Values	Actual Values	Extra-polated Values	Actual Values	Extra-polated Values	Actual Values	Extra-polated Values
MAE	84.6	78.8	138.0	124.1	173.0	171.6	208.3	218.4	278.4	234.0
MAEΔ	84.6	78.8	88.1	93.8	98.8	94.8	109.4	94.8	120.7	101.2

The errors are in the thousands of units at annual rates. The results in Table 13–9 indicate that the January et al. forecasts of HSQ_t are in general slightly better than the outside-sample forecasts of HSQ_t from Chapter 12, which are based on the actual values of the exogenous variables. The reason for this is that the extrapolated values of the mortgage rate, which were used for the January et al. forecasts, were in general smaller than the actual values (the extrapolated values being based on the assumption of no change in the mortgage rate), and this caused the forecasts from the demand equation to be better. The forecasts from the demand equation were better because the large (and erroneous) negative estimates of the coefficient of the mortgage rate in the demand equation (see Table 12–14) were multiplied by smaller values of the mortgage rate. The January et al. forecasts from the demand equation were actually better (compared with the forecast based on the actual values of the exogenous variables) than the results in Table 13–9 indicate. The January et al. forecasts from the supply equation were worse, since extrapolated values of the deposit flow variables had to be used, and this lessened the accuracy of the overall forecasts of HSQ_t.

In order to compare how the accuracy of the January et al. forecasts of HSQ_t varies with the length of the forecast horizon, the mean absolute errors of HSQ_t computed for the same prediction period are presented in Table 13–10. The format of Table 13–10 is the same as the format of Table

Table 13–10. Errors Computed for the Same Prediction Period for the Forecasts of HSQ_t Based on Extrapolated Values of the Exogenous Variable. (Forecasts are outside-sample forecasts and are January et al. forecasts. Errors are in thousands of units at annual rates.)

	Length of Forecast					
Error Measure	One Quarter Ahead	Two Quarters Ahead	Three Quarters Ahead	Four Quarters Ahead	Five Quarters Ahead	No. of Observations
MAE	91.4	140.2	176.9	222.8	234.4	13
MAEΔ	91.4	101.4	95.2	97.6	101.2	13

12–20 in Chapter 12. As was the case in Table 12–20, the level errors in Table 13–10 compound rather substantially as the forecast horizon increases. There is, however, little evidence that the change errors compound.

Finally, the quarter-by-quarter results of the January et al. forecasts of HSQ_t are presented in Table 13–11 for the 654–694 period. The format of Table 13–11 is the same as the format of Table 12–21. There is a tendency

Table 13–11. Actual and Forecasted Levels of HSQ_t. (Forecasts are outside-sample forecasts, are based on extrapolated values of the exogenous variables, and are January et al. forecasts. Figures are in thousands of units at annual rates.)

		Length of Forecast				
Quarter	Actual Value	One Quarter Ahead	Two Quarters Ahead	Three Quarters Ahead	Four Quarters Ahead	Five Quarters Ahead
654	1463	1398				
661	1349	1370	1376			
662	1267	1290	1333	1373		
663	1018	1060	1089	1186	1183	
664	883	874	996	1042	1158	1124
671	1038	925	893	1089	1119	1211
672	1206	1225	1211	1197	1329	1307
673	1316	1224	1208	1178	1159	1258
674	1420	1324	1195	1165	1129	1093
681	1436	1258	1208	1102	1060	1021
682	1434	1370	1292	1266	1201	1200
683	1449	1300	1216	1216	1188	1143
684	1548	1415	1272	1206	1225	1191
691	1604	1464	1360	1294	1221	1224
692	1507	1525	1456	1403	1369	1328
693	1341	1380	1308	1227	1233	1222
694	1290	1430	1313	1155	1141	1132

in Table 13–11, as there was in Table 12–21, for the model to underpredict the level of housing starts and for the size of the underprediction to increase as the forecast horizon increases. This is somewhat less pronounced in Table 13–11 than it was in Table 12–21, however, which is due in large part to the use of smaller values for the mortgage rate.

Conclusion

The forecasts presented in this chapter are close to being forecasts that could have been made *ex ante*. There are essentially only four reasons why the forecasts cannot be considered to be completely *ex ante* forecasts:

1. The actual values of AF_t, YG_t, GG_t, and the federal government component of G_t were used for the forecasts.
2. For the estimates of the production function parameter α_t, two of the interpolation peaks (in Figure 9–1) occurred within the 654–694 period;

for the estimates of the potential agricultural output and potential agricultural employment series (in Chapter 10), interpolation peaks occurred within the 654–694 period; and for the construction of the series on the potential number of hours worked per private nonfarm worker, the HP_t regression in (10.2) was estimated through 694.
3. *The data used in this study are based on 1969 revisions.*
4. The model was specified and experimented with in 1968 and 1969 and the final version was chosen in early 1970.

The first two of these points have been discussed above. With respect to the first point, it is beyond the scope of this study to attempt to forecast federal government policy changes that are not reflected in the proposed federal budget. The second point is a very minor one, since the forecasting results would be little changed if slightly different interpolation procedures had been used to construct the estimates of α_t and of the potential agricultural output and employment series and if a different sample period for the HP_t regression had been used. The third point is more significant. The national income account figures are revised every July for three years back, and many times these revisions are fairly large. An attempt could have been made in this study to consider prerevised as well as revised data, but the extra work involved in doing this would have been considerable and would have complicated the presentation of the results. The extra information that could have been gained from considering the prerevised data did not appear to warrant the cost involved, and thus only the revised data were used. In general, the conclusions reached in this study should not be too sensitive to the use of revised data.

The fourth point is an important one. Had the model been specified and worked on in 1964 and 1965 and had the final version been chosen in 1965 (before the 654–694 prediction period), the model undoubtedly would not have been the same as the one chosen in early 1970. In other words, information from the 654–694 period was used in choosing the final specification of the model. Little can be done about this problem, however, since it is very hard for one to behave as if he does not know something that he actually knows. Consequently, the results in this chapter may be atypical of what the model can actually achieve, since information from the 654–694 period was used in the specification of the model. It should perhaps be pointed out, however, that the money GNP sector of the model (which was the first sector developed) was developed in early 1968, and except for a change in the inventory investment equation, it has remained unchanged to the present.

The four points listed above all indicate that the forecasting results achieved in this chapter may be better than the results that can actually be achieved in practice. There are, however, two reasons for arguing that the model may be able to do better in actual practice than the results in this chapter indicate. The first is that one may be able to do better in forecasting the exogenous variables than merely extrapolating past levels or changes. To the extent that one can do better than these naive extrapolations, the forecasting results of the model should be closer to results achieved in Chapter 12 than to the results achieved in this chapter. Secondly, as can be seen from the results in Chapter 12, the coefficient estimates of many of the equations of the model have been more stable in 1968 and 1969 than they were previously, and if the estimates continue to be as stable in the future, the forecasting results of the model should be closer to the within-sample results. Also, the future forecasting results of the model should be improved to the extent that the demand equation for housing starts and the equation explaining the labor force participation of secondary workers become more stable than they were throughout the 654–694 period.

The major conclusions of this study will be discussed in Chapter 15, but it should be noted here that no constant terms adjustments have been made for any of the forecasts. The conclusion that Evans, Haitovsky, and Treyz reached that econometric models cannot forecast well without constant term adjustments does not appear to be true for the present model.

13.4 Annual Forecasting Results

This study is primarily concerned with quarterly forecasting results, but in this section the annual implications of the quarterly results will be briefly discussed. Implicit in any one-, two-, three-, and four-quarter-ahead set of forecasts is an annual forecast, and in Tables 13–12 and 13–13 the annual forecasts that are implicit in the above quarterly forecasts are presented. In both tables the first line for each quarter gives the actual annual change in each of eleven variables, the second line gives the forecasted annual change in each variable based on the one-, two-, three-, and four-quarter-ahead set of forecasts, and the third line gives the forecasted annual change in each variable based on the two-, three-, four-, and five-quarter-ahead set of forecasts. Table 13–12 presents the forecasts from Chapter 12, which are outside-sample forecasts and are based on actual values of the exogenous variables; and Table 13–13 presents the January et al. forecasts from this chapter, which are outside-sample forecasts and are based on extrapolated values of the exogenous variables. The eleven variables considered in the tables are the same as those considered in Tables 11–6, 12–18, and 13–7 for the quarterly forecasts. As in the other tables, the forecasts for UR_t in Tables 13–12 and 13–13 are in terms of levels rather than changes.

The annual change in a variable (say, GNP) for a given quarter (say, 663) is defined as the average level of GNP for 654, 661, 662, and 663 (i.e.,

$[GNP_{654} + GNP_{661} + GNP_{662} + GNP_{663}]/4)$ minus the average level of GNP for 644, 651, 652, and 653. The forecasted annual change for GNP for the year ending in 663 is then defined as the average of the one-quarter-ahead forecast of the level of GNP for 654, the two-quarter-ahead forecast of the level of GNP for 661, the three-quarter-ahead forecast of the level of GNP for 662, and the four-quarter-ahead forecast of the level of GNP for 663 minus the average level of GNP for 644, 651, 652, and 653. In other words, for the 663 annual forecast of GNP, the equation estimates through 653 were used to forecast the levels of GNP for 654, 661, 662, and 663, and then the forecasted annual change was taken to be the average of these four levels minus the average level of GNP for 644, 651, 652, and 653.

The second forecasted annual change in a variable (say, GNP) for a given quarter (say, 664) is defined as follows. The forecasted *level* of GNP for the year ending in 664 is defined as the average of the two-quarter-ahead forecast of the level of GNP for 661, the three-quarter-ahead forecast of the level for GNP for 662, the four-qarter-ahead forecast of the level for GNP for 663, and the five-quarter-ahead forecast of the level of GNP for 664. The forecasted annual *change* in GNP for the year ending in 664 is then defined to be this forecasted level of GNP minus the average of the one-quarter-ahead forecast of the level of GNP for 654 and the actual levels of GNP for 653, 652, and 651. The horizon for the second set of annual forecasts in Tables 13–12 and 13–13 is thus one quarter longer than the horizon for the first set.

Looking at the GNP results in the two tables, relatively large errors were made for the years ending in 671, 672, 673, and 674 because of the large error made in forecasting 671. The largest error made in Table 13–12 was 12.39 billion dollars for the second forecast for the year ending in 672, and the largest error made in Table 13–13 was 18.48 billion dollars for the same forecast. The GNP forecasts for the years ending in 681 through 694 in Table 13–12 are all quite good. Only one forecast (the first forecast for the year ending in 694) is even off by as much as 4 billion dollars. The GNP forecasts for the years ending in 681 through 694 in Table 13–13 are also fairly good, although the second forecast for the year ending in 691 is off by 9.78 billion dollars. For the GNP forecasts for the years ending in the fourth quarter (i.e., for the years ending in 664, 674, 684, and 694), the mean absolute errors are 2.69 and 3.74 billion dollars respectively for the first and second forecasts in Table 13–12 and 3.40 and 5.99 billion dollars respectively for the first and second forecasts in Table 13–13.

The other results in Tables 13–12 and 13–13 are as expected from the quarterly results above. In particular, the model has consistently underpredicted the level of the unemployment rate throughout the period and has slightly underpredicted the rate of inflation in 1969.

Table 13–12. Actual and Forecasted Annual Changes for Selected Variables of the Model. (Forecasts are outside-sample forecasts and are based on actual values of the exogenous variables. Forecasts for UR_t are in terms of levels.)

Year Ending in	GNP_t	$CD_t + CN_t + CS_t$	IP_t	IH_t	$V_t - V_{t-1}$	IMP_t	PD_t	$GNPR_t$	M_t	$LF_{1t} + LF_{2t}$	UR_t
663	66.00	36.27	11.47	−.70	3.12	5.60	2.22	44.48	2488	1595	.0389
	62.09	34.65	10.85	−.31	−.52	3.90	2.63	38.75	2377	1138	.0284
664	64.95	33.42	10.27	−2.20	5.17	5.77	2.73	40.32	2420	1725	.0379
	68.48	37.27	12.62	−1.04	.05	4.37	2.74	43.39	2847	1249	.0228
	63.26	34.28	10.99	−1.30	−.90	3.75	3.12	36.69	2381	1099	.0231
671	59.45	29.81	8.47	−3.73	4.50	5.12	3.13	32.80	2257	1876	.0376
	66.98	37.36	10.68	−2.26	−.27	4.05	3.28	38.01	2381	1291	.0239
	68.02	37.31	11.58	−2.32	−.54	3.56	3.36	39.13	2754	1226	.0178
672	52.60	28.31	6.45	−4.20	−.52	4.77	3.27	25.53	1938	1956	.0377
	55.16	30.54	8.18	−4.14	−3.15	3.63	3.91	24.28	1687	1222	.0287
	64.99	36.76	9.24	−3.04	−1.49	3.84	3.90	32.98	2177	1229	.0208
673	47.53	25.76	3.92	−3.15	−2.25	3.55	3.29	20.77	1486	2002	.0379
	52.85	30.59	6.39	−3.20	−3.25	4.55	4.16	20.54	1739	1388	.0282
	54.62	31.06	6.62	−3.40	−3.29	3.30	4.31	21.25	1407	1193	.0266
674	43.70	25.99	2.12	−.10	−7.40	2.93	3.23	16.53	1185	1936	.0385
	44.58	24.44	3.75	−.99	−5.47	3.27	4.18	12.23	823	1319	.0332
	53.63	31.72	4.87	−1.28	−3.70	4.12	4.43	18.69	1456	1280	.0268

681	47.80	30.05	2.45	3.18	−8.67	3.20	3.30	18.18	1009	1804	.0383
	46.00	27.84	2.92	1.52	−7.05	3.23	3.67	15.33	859	1234	.0330
	45.49	26.64	3.43	1.28	−6.81	2.97	4.38	11.12	488	1123	.0329
682	56.55	33.21	2.62	5.70	−3.85	4.25	3.64	23.82	1102	1839	.0377
	58.04	33.82	3.88	2.51	−2.44	2.85	3.55	25.55	1148	1255	.0317
	53.54	30.83	3.76	2.54	−3.69	3.34	3.89	19.91	883	1156	.0314
683	64.42	39.37	3.65	6.15	−2.98	6.15	3.89	28.07	1328	1680	.0369
	64.01	35.91	4.54	3.17	−.96	3.03	3.93	27.51	1178	1392	.0333
	65.52	36.73	5.30	2.50	.15	3.50	3.86	29.18	1355	1216	.0300
684	72.18	34.38	5.07	5.22	−.13	7.48†	4.14	32.97	1501	1463	.0356
	69.99	36.74	6.31	2.40	3.72	4.78	4.15	31.13	1586	1504	.0336
	71.93	38.27	6.20	1.39	4.21	3.70	4.18	32.58	1438	1311	.0318
691	75.25	44.92	5.57	4.65	2.97	7.73†	4.41	33.72	1704	1523	.0348
	75.27	41.52	8.09	.48	5.99	7.18	4.24	34.65	1897	1317	.0315
	71.60	38.57	7.32	−.26	4.49	4.94	4.28	31.37	1696	1346	.0326
692	72.98	45.27	7.17	3.47	.60	7.55†	4.63	30.13	1759	1442	.0345
	72.19	42.71	7.29	−.61	3.63	6.13	4.35	30.96	1720	1293	.0334
	70.51	41.70	8.37	−1.46	2.95	6.34	4.30	29.87	1775	1185	.0310
693	70.57	41.70	9.28	2.93	1.62	6.68†	4.97	25.87	1817	1648	.0347
	74.31	45.39	7.62	.19	4.92	6.73	4.40	31.99	1516	1189	.0337
	69.08	41.43	8.42	−1.61	3.25	5.32	4.41	27.65	1546	1203	.0334
694	66.40	39.35	10.40	2.10	.67	5.85†	5.31	19.95	1841	1987	.0352
	70.55	41.58	10.20	.68	3.57	5.94	4.60	27.15	1445	1214	.0337
	69.47	42.15	9.04	−.35	4.28	5.80	4.51	26.78	1380	1205	.0342

† Based on adjusted values.

Table 13–13. Actual and Forecasted Annual Changes for Selected Variables of the Model. (Forecasts are outside-sample forecasts and are based on extrapolated values of the exogenous variables. Forecasts for UR_t are in terms of levels.)

Year Ending in	GNP_t	$CD_t + CN_t + CS_t$	IP_t	IH_t	$V_t - V_{t-1}$	IMP_t	PD_t	$GNPR_t$	M_t	$LF_{1t} + LF_{2t}$	UR_t
663	66.00	36.27	11.47	−.70	3.12	5.60	2.22	44.48	2488	1595	.0389
	61.69	35.04	9.28	.49	−.33	3.88	2.62	38.43	2314	1097	.0288
664	64.95	33.42	10.27	−2.20	5.17	5.77	2.73	40.32	2420	1725	.0379
	68.94	38.22	12.04	−.27	.57	4.39	2.72	43.89	2775	1195	.0240
	62.74	35.24	8.72	.06	−.35	3.72	3.10	36.31	2287	1034	.0240
671	59.45	29.81	8.47	−3.73	4.50	5.12	3.13	32.80	2257	1876	.0376
	69.30	38.93	11.08	−1.58	.50	4.18	3.28	40.65	2384	1159	.0240
	70.97	39.59	11.29	−.65	.65	3.71	3.33	41.86	2769	1155	.0188
672	52.60	28.31	6.45	−4.20	−.52	4.77	3.27	25.53	1938	1956	.0377
	60.18	32.56	9.91	−2.40	−2.12	3.91	3.94	28.48	1841	1159	.0277
	71.08	39.84	10.98	−1.63	.05	4.17	3.91	38.17	2356	1176	.0192
673	47.53	25.76	3.92	−3.15	−2.25	3.55	3.29	20.55	1486	2002	.0379
	56.17	31.24	9.32	−2.62	−2.87	4.76	4.18	23.25	1896	1316	.0277
	63.02	34.13	9.83	−1.18	−1.75	3.76	4.39	28.06	1769	1098	.0245
674	43.70	25.99	2.12	−.10	−7.40	2.93	3.33	16.53	1185	1936	.0385
	45.17	23.27	4.95	−.89	−5.75	3.30	4.22	12.55	928	1274	.0313
	59.31	32.67	9.66	−.73	−3.29	4.47	4.50	23.21	1752	1187	.0253

681	47.80	30.05	2.45	3.18	−8.67	3.20	3.30	18.88	1009	1804	.0383
	48.92	27.99	3.43	1.14	−6.99	3.41	3.72	17.57	1100	1181	.0304
	44.93	24.38	4.70	1.17	−7.60	2.94	4.45	10.32	563	1018	.0307
682	56.55	33.21	2.62	5.70	−3.85	4.25	3.64	23.82	1102	1839	.0377
	58.18	33.97	4.10	2.22	−2.41	2.86	3.59	25.47	1221	1073	.0318
	55.22	30.93	4.49	2.04	−3.91	3.45	3.98	20.84	1084	1035	.0285
683	64.42	39.37	3.65	6.15	−2.98	6.15	3.89	28.07	1328	1680	.0369
	60.24	35.37	3.17	3.28	−.96	2.81	3.92	24.39	1035	1327	.0332
	64.04	36.63	5.41	2.32	.14	3.41	3.92	27.60	1357	1014	.0299
684	72.18	34.18	5.07	5.22	−.13	7.48†	4.14	32.97	1501	1463	.0356
	65.04	35.32	6.78	2.97	3.00	4.47	4.11	27.20	1353	1511	.0339
	66.44	37.89	4.39	1.95	4.13	3.39	4.16	28.11	1193	1251	.0316
691	75.25	44.92	5.57	4.65	2.97	7.73†	4.41	33.72	1704	1523	.0348
	71.79	41.11	7.44	.81	5.92	6.92	4.22	31.89	1708	1390	.0304
	65.47	36.68	7.21	.83	3.68	4.55	4.21	26.68	1380	1363	.0328
692	72.98	45.27	7.17	3.47	.60	7.55†	4.63	30.13	1759	1442	.0345
	70.29	42.12	7.13	.01	3.50	6.00	4.35	29.45	1628	1381	.0318
	66.49	41.21	7.35	−.90	2.86	6.04	4.26	26.80	1549	1267	.0296
693	70.57	41.70	9.28	2.97	1.62	6.68†	4.97	25.87	1817	1648	.0347
	68.78	43.86	3.72	.14	4.60	6.30	4.37	27.66	1304	1161	.0350
	66.87	40.54	7.92	−.76	2.95	5.16	4.40	25.93	1431	1318	.0311
694	66.40	39.35	10.40	2.10	.67	5.85†	5.31	19.95	1841	1987	.0352
	67.40	40.66	7.97	.16	3.19	5.69	4.59	24.65	1347	1199	.0340
	62.02	40.38	3.88	−.73	3.55	5.22	4.45	21.05	1067	1179	.0356

† Based on adjusted values.

14 Comparisons of the Forecasting Results of this Study with the Results of Other Models and Techniques

14.1 *Introduction*

In this chapter the results that have been achieved above will be compared with the results that have been achieved by other models and techniques. It is very difficult to make such comparisons because of different assumptions and time periods involved, and the comparisons below must be considered to be quite informal. Because of its informal nature, this chapter will be brief. The results in this chapter are merely meant to give a rough indication of how the present model compares with other models and techniques. In Section 14.2 the forecasting results of this study will be compared with the results achieved by noneconometric techniques, and in Section 14.3 the results will be compared with the results achieved by the Wharton and OBE models.

14.2 Comparisons with Noneconometric Techniques

Zarnowitz [48] has examined the forecasting records of a number of economic forecasters. The forecasts examined were primarily forecasts by groups of business economists, and it did not appear that these forecasts were generated by econometric models.[1] The forecasts were generally annual forecasts made at the end of the calendar year. The period examined was 1953–1963.

Zarnowitz reports a mean absolute error of between 6.9 and 14.4 billion dollars for the annual forecasts of money GNP for the 1953–1963 period.[2] The annual results presented at the end of Chapter 13 for the 1966–1969 period compare favorably with this error range, although the periods considered differ. In general, however, the present model appears capable of forecasting the yearly level or change of GNP with an average error of less than 6.9 billion dollars.

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[1] "As far as one can see, very little use has been made so far of formal econometric models in forecasts of business activity." Zarnowitz [48], p. 10.
[2] Zarnowitz [48], Table 1, p. 13.

The Federal Reserve Bank of Philadelphia tabulates a large number of noneconometric forecasts made at the end of the calendar year for the year ahead. As reported in Evans, Haitovsky, and Treyz (Evans et al.) [14], the GNP root mean square error of the average of these forecasts for the 1959–1968 period was 8.1 billion dollars. Again, the results presented above appear to compare favorably with this figure.

Since this study is primarily concerned with quarterly forecasts, no further discussion of the annual results will be made. There does not appear to be any convenient tabulation of quarterly forecasts of noneconometric forecasters, and so the discussion in the rest of this chapter will concentrate on forecasts from econometric models.

14.3 Comparisons with the Wharton and OBE Models

Evans et al. [14] have concluded a rather thorough examination of the Wharton and OBE models, and their results can be compared with the results achieved in this study. As mentioned in Chapter 1, Evans et al. conclude that neither the Wharton nor the OBE model tracks the economy well when simulated in a mechanical way. This is true even for the within-sample forecasts based on actual values of the exogenous variables. In Table 14–1 the results of the within-sample forecasts of the present model, the Wharton model, and the OBE model are compared. The root mean square errors of the one-through five-quarter-ahead forecasts of money GNP and real GNP are presented in the table for the three models. The errors for the present model are based on the within-sample forecasts presented in Table 11–6. The errors were computed for the 602–694 period excluding the three quarters that were omitted from the sample period because of the automobile strike. The results for the Wharton model were taken from Tables III.1 and III.4 of Evans et al. There are two versions of the Wharton model, one that uses expectational variables and one that does not, and the results for both versions are presented in Table 14–1. The version that includes expectational variables is used only for computing one- and two-quarter-ahead forecasts. The Wharton model was estimated for the 481–644 period, and the errors presented in the table were computed for the 531–644 period. The results for the OBE model in Table 14–1 were taken from Tables III.13 and III.16 of Evans et al. The OBE model was estimated through 664, and the errors presented in Table 14–1 were computed for the 553–664 period.[3]

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[3] Some of the forecasts actually extended by mistake into 1967. See Evans et al. [14], footnote 10, p. 72.

Table 14–1. Root Mean Square Errors of the Within-Sample Forecasts of the Present Model, the Wharton Model, and the OBE Model.

Length of Forecast	Present Model (602–694)	Wharton Model A (531–644)	Wharton Model (531–644)	OBE Model (553–664)
GNP_t				
One-quarter-ahead	2.86	5.11	6.75	4.62
Two quarters-ahead	4.32	5.70	8.20	6.48
Three-quarters-ahead	4.46		7.70	7.62
Four-quarters-ahead	4.11		8.17	8.06
Five-quarters-ahead	3.71		8.19	8.41
$GNPR_t$				
One-quarter-ahead	2.81	4.90	6.53	3.67
Two-quarters-ahead	4.25	5.20	7.54	5.06
Three-quarters-ahead	4.31		7.55	5.97
Four-quarters-ahead	3.77		8.96	6.44
Five-quarters-ahead	3.27		10.63	6.78

Notes: Wharton model A uses expectational variables.
The basic prediction period for each model is in parentheses.

The errors for the different models presented in Table 14–1 are comparable in the sense that they are all based on within-sample forecasts that were computed using actual values of the exogenous variables. They are not comparable in the sense that they are based on different sample periods. Nevertheless, the results should give a basic indication of how good the models are in tracking the economy.

The results in Table 14–1 indicate that the present model is better at tracking the economy than the other two. With respect to the Wharton model, the errors generally differ by about a factor of two; and with respect to the OBE model, the errors generally differ between a factor of about one and one-half and two. It should be noted that various mechanical constant-adjustment techniques that Evans et al. tried did not in general improve the forecasting results of the Wharton and OBE models. The results of the Wharton and OBE model are thus unimpressive, as Evans et al. acknowledge; but this inability to track the economy well within the sample period does not appear to carry over to the present model.

In Tables 14–2 and 14–3 the outside-sample forecasts of the present model, the Wharton model, and the OBE model are compared. The results presented in the tables for the Wharton and OBE models were obtained from the Evans et al. study, Tables IV.1a, IV.1P, IV.4A, IV.4P, IV.11, IV.12, IV.13, and

Table 14–2. Comparisons of the Outside-Sample Forecasts of Money GNP from the Present Model, the Wharton Model, and the OBE Model.

		The Present Model				The Wharton Model				The OBE Model			
		Extrapolated exog. Values		Actual exog. Values		*Ex Ante*		Actual exog. Values		*Ex Ante*		Actual exog. Values	
The Period Fore-cast	Actual Change	Fore-casted Change	Error	Fore-casted Change	Error	Fore-casted Change	Error	Fore-casted Change	Error	Fore-casted Change	Error	Fore-casted Change	Error
661	19.5	18.2	−1.3	19.1	−.4	10.4	−9.1	−2.0	−21.5				
662	13.8	16.3	2.5	15.9	2.1	12.7	−1.1	12.0	−1.8				
663	12.6	18.9	6.3	18.0	5.4	13.1	.5	24.1	11.5				
664	14.8	15.9	1.1	13.3	−1.5	12.1	2.7	19.2	4.4				
671	3.5	22.5	19.0	17.2	13.7	7.4	3.9	19.9	16.4				
MAE			6.04		5.34		3.46		11.12				
662	13.8	15.5	1.7	15.5	1.7	15.0	1.2	−4.1	−17.9				
663	12.6	16.9	4.3	17.3	4.7	14.0	1.4	11.9	−.7				
664	14.8	15.1	.3	12.8	−2.0	14.0	−.8	24.0	9.2				
671	3.5	22.6	19.1	16.8	13.3	12.9	9.4	20.9	17.4				
672	9.3	21.8	12.5	14.4	5.1	7.2	−2.1	17.0	7.7				
MAE			7.58		5.36		2.98		10.6				
663	12.6	10.1	−2.5	10.3	−2.3	16.8	4.2	−4.1	−16.7				
664	14.8	12.3	−2.5	11.1	−3.7	13.5	−1.3	14.8	0				
671	3.5	21.3	17.8	16.1	12.6	8.4	4.9	25.2	21.7				
672	9.3	21.6	12.3	14.8	5.5	9.9	.6	16.2	6.9				
673	16.9	18.5	1.6	18.3	1.4	10.6	−6.3	11.4	−5.5				
MAE			7.34		5.10		3.46		10.2				

664	14.8	9.8	−5.0	10.8	−4.0	13.3	−1.5	−.6	−15.4				
671	3.5	15.4	11.9	13.9	10.4	9.1	5.6	14.6	11.1				
672	9.3	18.3	9.0	12.5	3.2	11.4	2.1	19.7	10.4				
673	16.9	17.7	.8	16.5	−.4	10.5	−6.4	13.0	−3.9				
674	15.7	16.8	1.1	17.0	1.3	13.6	−2.1	15.4	−.3				
MAE			5.56		3.86		3.54		8.22				
671	3.5	7.5	4.0	8.5	5.0	10.2	6.7	−7.3	−10.8				
672	9.3	10.9	1.6	7.8	−1.5	10.5	1.2	11.7	2.4				
673	16.9	11.0	−5.9	11.3	−5.6	5.0	−11.9	15.7	−1.2				
674	15.7	12.3	−3.4	14.8	−.9	8.7	−7.0	16.3	−1.4				
681	19.2	13.5	−5.7	19.4	.2	22.5	3.3	32.9	13.7				
MAE			4.12		2.64		6.02		5.90				
672	9.3	11.4	2.1	9.0	−.3	11.8	2.5	−3.7	−13.0	11.1	1.8	16.7	7.4
673	16.9	15.1	−1.8	13.0	−3.9	20.0	3.1	10.7	−6.2	14.7	−2.2	15.9	−1.0
674	15.7	17.7	2.0	17.7	2.0	13.1	−2.6	18.9	3.2	18.1	2.4	18.2	2.5
681	19.2	16.7	−2.5	21.3	2.1	19.1	−.1	37.3	18.1			17.6	−1.6
682	23.4	17.9	5.5	18.1	5.3	10.8	−12.6	26.8	3.4				
MAE			2.78		2.72		4.18		8.78		2.13		3.12
			1.97 (3 obs.)		2.08 (4 obs.)								
673	16.9	19.0	2.1	17.5	.6	19.4	2.5	−.8	−17.7	19.0	2.1	11.0	−5.9
674	15.7	18.4	2.7	17.5	1.8	21.1	5.4	7.7	−8.0	20.1	4.4	14.0	−1.7
681	19.2	17.3	−1.9	21.0	1.8	7.9	−11.3	40.3	21.1	21.1	1.9	17.9	−1.3
682	23.4	17.5	−5.9	18.2	−5.2	14.1	−9.3	32.0	8.6	19.0	−4.4	19.8	−3.6
683	17.7	16.9	−.8	18.3	.6	14.6	−3.1	.6	−17.1				
MAE			2.68		2.0		6.32		14.5		3.20		3.13
			3.15 (4 obs.)		2.35 (4 obs.)								

Table 14–2 (cont.)

The Period Fore-cast	Change	The Present Model: Extrapolated exog. Values: Fore-casted Change	Error	The Present Model: Actual exog. Values: Fore-casted Change	Error	The Wharton Model: *Ex Ante*: Fore-casted Change	Error	The Wharton Model: Actual exog. Values: Fore-casted Change	Error	The OBE Model: *Ex Ante*: Fore-casted Change	Error	The OBE Model: Actual exog. Values: Fore-casted Change	Error
674	15.7	14.2	−1.5	14.0	−1.7	16.6	.9	−9.7	−25.4	13.6	−2.1	13.9	−1.8
681	19.2	19.5	.3	23.1	3.9	26.2	7.0	27.2	8.0	23.2	4.0	19.9	.7
682	23.4	18.0	−5.4	19.3	−4.1	19.6	−3.8	34.3	10.9	17.7	−5.7	18.0	−5.4
683	17.7	16.8	−.9	19.3	1.6	4.0	−13.7	4.6	−13.1	12.3	−5.4	15.8	−1.9
684	16.1	14.3	−1.8	13.6	−2.5	10.8	−5.3	11.5	−4.6				
MAE			1.98 2.03 (4 obs.)		2.76 2.83 (4 obs.)		6.14		12.40		4.30		2.45
681	19.2	18.0	−1.2	20.3	1.1	21.5	2.3	3.3	−15.9	19.2	0	21.5	2.3
682	23.4	17.9	−5.5	19.7	−3.7	17.3	−6.1	15.4	−8.0	7.9	−15.5	13.6	−9.8
683	17.7	15.0	−2.7	18.2	.5	12.0	−5.7	11.9	−5.8	10.8	−6.9	13.1	−4.6
684	16.1	14.4	−1.7	13.2	−2.9	7.1	−9.0	14.3	−1.8	8.4	−7.7	3.0	−13.1
691	16.2	14.2	−2.0	17.5	1.3								
MAE			2.78 (4 obs.)		2.05 (4 obs.)		5.78		7.88		7.53		7.45
682	23.4	24.7	1.3	26.7	3.3	19.3	−4.1	.2	−23.2	21.1	−2.3	18.3	−5.1
683	17.7	13.0	−4.7	15.3	−2.4	9.8	−7.9	−2.6	−20.3	13.7	−4.0	14.9	−2.8
684	16.1	14.8	−1.3	13.1	−3.0	6.0	−10.1	21.3	5.2	8.0	−8.1	10.5	−5.6
691	16.2	14.0	−2.2	16.7	.5								
692	16.1	13.6	−2.5	14.4	−1.7								
MAE			2.43 (3 obs.)		2.90 (3 obs.)		7.37		16.23		4.80		4.50

683	17.7	17.0	−.7	18.4	.7	9.7	−8.0	−22.7	−40.4	9.8	−7.9	3.1	−14.6
684	16.1	15.1	−1.0	13.3	−2.8	12.5	−3.6	7.9	−8.2	8.1	−8.0	2.0	−14.1
691	16.2	14.7	−1.5	18.2	2.0								
692	16.1	14.3	−1.8	14.9	−1.2								
693	18.0	17.4	−.6	18.0	0								
MAE			.85 (2 obs.)		1.75 (2 obs.)		5.80		24.30		7.95		14.35
684	16.1	18.8	2.7	18.9	2.8	13.3	−2.8	−26.4	−42.5	13.2	−2.9	5.8	−10.3
691	16.2	13.8	−2.4	18.9	2.7								
692	16.1	12.1	−4.0	14.0	−2.1								
693	18.0	15.4	−2.6	17.8	−.2								
694	9.4	10.8	1.4	9.2	−.2								
MAE			2.7 (1 obs.)		2.8 (1 obs.)		2.8		42.5		2.9		10.3

Table 14–3. Comparisons of the Outside-Sample Forecasts of Real GNP from the Present Model, the Wharton Model, and the OBE Model.

		The Present Model				The Wharton Model				The OBE Model			
		Extrapolated exog. Values		Actual exog. Values		*Ex Ante*		Actual exog. Values		*Ex Ante*		Actual exog. Values	
The Period Fore-cast	Actual Change	Fore-casted Change	Error	Fore-casted Change	Error	Fore-casted Change	Error	Fore-casted Change	Error	Fore-casted Change	Error	Fore-casted Change	Error
661	12.5	11.3	−1.2	12.1	−.4	6.5	−6.0	−7.4	−19.9				
662	5.9	9.1	3.2	8.7	2.8	7.7	1.8	8.6	2.7				
663	5.2	8.5	3.3	9.3	4.1	8.4	3.2	17.4	12.2				
664	7.9	7.5	−.4	5.1	−2.8	7.5	−.4	15.9	8.0				
671	−1.6	11.6	13.2	6.9	8.5	3.7	5.3	14.9	16.5				
MAE			4.26		3.72		3.34		11.86				
662	5.9	8.5	2.6	8.5	2.6	6.7	.8	−7.6	−13.5				
663	5.2	8.5	3.3	8.9	3.7	7.1	1.9	7.2	2.0				
664	7.9	6.9	−1.0	4.8	−3.1	8.7	.8	21.2	13.3				
671	−1.6	11.6	13.2	6.7	8.3	6.8	8.4	15.5	17.1				
672	4.0	10.3	6.3	4.3	.3	2.6	−1.4	11.8	7.8				
MAE			5.28		3.60		2.66		10.74				
663	5.2	2.6	−2.6	2.7	−2.5	8.8	3.6	−9.0	−14.2				
664	7.9	4.7	−3.2	3.7	−4.2	7.8	− .1	14.2	6.3				
671	−1.6	6.2	7.8	6.6	8.2	3.6	5.2	20.1	21.7				
672	4.0	10.7	6.7	5.2	1.2	5.3	1.3	10.9	6.9				
673	7.5	7.1	− .4	7.6	.1	5.7	−1.8	6.1	−1.4				
MAE			4.14		3.24		2.40		10.10				

664	7.9	2.7	−5.2	3.6	−4.3	5.9	−2.0	−1.9	−9.8				
671	−1.6	6.2	7.8	4.8	6.4	2.9	4.5	12.9	14.5				
672	4.0	8.4	4.4	3.5	− .5	6.6	2.6	14.8	10.8				
673	7.5	7.0	−.5	6.3	−1.2	5.2	−2.3	7.2	−.3				
674	5.5	4.6	−.9	5.2	−.3	8.1	2.6	8.9	3.4				
MAE			3.76		2.54		2.80		7.76				
671	−1.6	−.6	1.0	.3	1.9	2.9	4.5	−9.5	−7.9				
672	4.0	2.3	−1.7	−.3	−4.3	4.7	.7	10.4	6.4				
673	7.5	2.0	−5.5	2.4	−5.1	.1	−7.4	10.5	3.0				
674	5.5	1.6	−3.9	4.0	−1.5	4.7	−.8	9.7	4.2				
681	9.8	3.6	−6.2	8.9	−.9	15.3	5.5	25.6	15.8				
MAE			3.66		2.74		3.78		7.46				
672	4.0	3.6	−.4	1.5	−2.5	5.1	1.1	−6.1	−10.1	3.9	−.1	22.4	18.4
673	7.5	6.3	−1.2	4.6	−2.9	12.9	5.4	8.9	1.4	7.0	−.5	4.3	−3.2
674	5.5	7.0	1.5	7.2	1.7	7.0	1.5	12.5	7.0	9.8	4.3	7.6	2.1
681	9.8	6.9	−2.9	11.1	1.3	12.4	2.6	29.6	19.8			8.4	−1.4
682	12.5	8.0	−4.5	8.4	−4.1	5.0	−7.5	19.3	6.8				
MAE			2.10		2.50		3.62		9.02		1.63		6.28
			1.03	(3 obs.)	2.10	(4 obs.)							
673	7.5	9.8	2.3	8.6	1.1	13.7	6.2	−4.3	−11.8	10.8	3.3	6.4	−1.1
674	5.5	7.7	2.2	7.0	1.5	2.1	−3.4	5.0	−.5	10.5	5.0	8.8	3.3
681	9.8	7.5	−2.3	10.9	1.1	12.9	3.1	32.9	23.1	12.4	2.6	13.0	3.2
682	12.5	7.7	−4.8	8.4	−4.1	9.4	−3.1	23.6	11.1	9.9	−2.6	12.5	0
683	7.0	5.8	−1.2	7.1	.1	8.8	1.8	−7.2	−14.2				
MAE			2.56		1.58		3.52		12.14		3.38		1.90
			2.90	(4 obs.)	1.95	(4 obs.)							

Table 14–3 (cont.)

The Period Forecast	Actual Change	The Present Model: Extrapolated exog. Values: Forecasted Change	Error	The Present Model: Actual exog. Values: Forecasted Error	Error	The Wharton Model: *Ex Ante*: Forecasted Change	Error	The Wharton Model: Actual exog. Values: Forecasted Change	Error	The OBE Model: *Ex Ante*: Forecasted Change	Error	The OBE Model: Actual exog. Values: Forecasted Change	Error
674	5.5	4.2	−1.3	4.1	−1.4	6.3	.8	−13.4	−18.9	5.0	−.5	7.3	1.8
681	9.8	9.7	−.1	12.7	2.9	18.1	8.3	23.9	14.1	14.9	5.1	14.5	4.7
682	12.5	8.4	−4.1	9.4	−3.1	12.0	−.5	26.7	14.2	10.0	−2.5	12.0	−.5
683	7.0	6.0	−1.0	8.0	1.0	−1.0	−8.0	−4.0	−11.0	4.1	−2.9	8.9	1.9
684	5.7	4.9	−.8	4.2	−1.5	4.2	−1.5	8.4	2.7				
MAE			1.46		1.98		3.82		12.18		2.75		2.23
			1.63	(4 obs.)	2.10 (4 obs.)								
681	9.8	8.4	−1.4	10.3	.5	10.9	1.1	−1.0	−10.8	10.1	.3	11.1	1.3
682	12.5	8.4	−4.1	9.8	−2.7	10.2	−2.3	13.7	1.2	1.8	10.7	6.6	−5.9
683	7.0	4.7	−2.3	7.2	.2	3.4	−3.6	3.9	−3.1	3.1	−3.9	8.0	1.0
684	5.7	5.2	−.5	4.0	−1.7	1.0	−4.7	10.1	4.4	2.2	−3.5	2.0	−3.7
691	4.6	5.0	−.4	7.4	2.8								
MAE			2.07 (4 obs.)		1.28 (4 obs.)		3.18		4.88		4.60		2.98
682	12.5	14.1	1.6	15.7	3.2	10.1	−2.4	−2.2	−14.7	11.3	−1.2	8.8	−3.7
683	7.0	2.8	−4.2	4.6	−2.4	1.3	−5.7	−5.4	−12.4	4.8	−2.2	2.3	−4.7
684	5.7	5.3	−.4	3.8	−1.9	.1	−5.6	17.2	11.5	1.6	−4.1	−.3	−6.0
691	4.6	4.5	−.1	6.6	2.0								
692	3.6	4.0	.4	4.4	.8								
MAE			2.07 (3 obs.)		2.50 (3 obs.)		4.57		12.87		2.50		4.80

683	7.0	6.1	−.9	7.3	.3	.5	−6.5	−25.8	−32.8	.2	−6.8	−1.3	−8.3
684	5.7	5.5	−.2	3.9	−1.8	4.9	−.8	8.2	2.5	1.7	−4.0	−.1	−5.8
691	4.6	5.0	.4	7.8	3.2								
692	3.6	4.4	.8	4.8	1.2								
693	3.9	4.9	1.0	5.3	1.4								
MAE			.55 (2 obs.)		1.05 (2 obs.)		3.65		17.65		5.4		7.05
684	5.7	8.5	2.8	8.6	2.9	4.9	−.8	−26.3	−32.0	6.2	.5	2.9	−2.8
691	4.6	4.2	−.4	8.3	3.7								
692	3.6	2.5	−1.1	4.0	.4								
693	3.9	3.2	−.7	4.9	1.0								
694	−.8	1.5	2.3	−.1	.7								
MAE			2.8 (1 obs.)		2.9 (1 obs.)		.8		32.0		.5		2.8

IV.14. Two sets of forecasts are presented in Tables 14–2 and 14–3 for each model. For the present model, the forecasts in the first set are based on extrapolated values of the exogenous variables (the January et al. forecasts presented in Chapter 13), and the forecasts in the second set are based on actual values of the exogenous variables (the forecasts presented in Chapter 12). For the Wharton and OBE models, the forecasts in the first set are actual *ex ante* forecasts (i.e., forecasts that were actually made ahead of the forecast period by the people associated with the models), and the forecasts in the second set are *ex post* forecasts based on actual values of the exogenous variables. The *ex ante* forecasts presented in the two tables for the Wharton and OBE models are really not so much forecasts generated by the models as they are subjective forecasts made by the econometricians associated with the models. This point is emphasized by Evans et al. As mentioned in Chapter 1, in an actual forecasting situation the Wharton and OBE econometricians fine tune the models until the models are generating forecasts that appear reasonable to them. Nevertheless, these forecasts can be compared with the forecasts generated by the present model to see how the forecasting record of the present model compares with the record of the econometricians. The *ex post* forecasts presented in the tables for the Wharton and OBE models are forecasts that were generated from the models with no fine tuning (i.e. no constant adjustments) involved.

The forecasts in Tables 14–2 and 14–3 are all in terms of changes. Forecasts of money GNP are considered in Table 14–2 and forecasts of real GNP in Table 14–3. Each group of one- through five-quarter-ahead forecasts is examined separately in the tables. For the first group, the forecasts were made (or were considered to have been made) at the beginning of 661 for the 661–671 period; for the second group, the forecasts were made at the beginning of 662 for the 662–672 period; and so on through the 684–694 period. The error of each of the forecasts (predicted change minus actual change) is also presented in the tables, and the mean absolute error of each group of forecasts is presented.[4] For the OBE model, forecasts were not available before 672, and for both the Wharton and OBE models, forecasts were not available for 1969. In those cases in which more forecasts were available from the present model than from the Wharton and OBE models, the mean absolute errors that are presented in Tables 14–2 and 14–3 for the present

[4] It should be noted that the mean absolute errors presented in Tables 14–2 and 14–3 differ in concept from the mean absolute errors presented in the previous chapters. In Tables 14–2 and 14–3 the mean absolute errors are measuring the accuracy of one particular set of one- through five-quarter-ahead forecasts, whereas in previous chapters the mean absolute errors measured the accuracy of all one-quarter-ahead forecasts, then all two-quarter-ahead forecasts, and so on.

model were computed for the same period that was used to compute the mean absolute errors for the other models. With respect to the Wharton and OBE forecasts in Tables 14–2 and 14–3, it should be pointed out that Evans et al. adjusted the forecasts to be comparable with the July 1969 revised data. The forecasts from the present model are also, of course, comparable with the July 1969 revised data.

Comparing the Wharton model with the present model first, the one conclusion that is immediately clear is that the *ex post* forecasts from the Wharton model are extremely poor. Evans et al. tried a number of mechanical constant adjustment techniques for the Wharton *ex post* forecasts, but none of these resulted in any noticeable improvement in the results. These are the results which led Evans et al. to conclude that the Wharton model cannot be used in a mechanical way (i.e., without fine tuning) for forecasting purposes. With respect to the *ex ante* forecasts of the Wharton forecasters, the mean absolute errors are smaller than those of the present model for the first four groups of forecasts, but are larger for the remaining groups.[5] The large errors made by the present model in 671, and in some cases in 672, led to large mean absolute errors for those periods that included 671 and 672; and for these periods the Wharton forecasters did better on average. For the forecasts from the beginning of 671 on, however, the present model has done consistently better than the Wharton forecasters, and in most cases the difference in results is substantial.

The results in Tables 14–2 and 14–3 for the OBE model are better than the results for the Wharton model. In particular, the *ex post* forecasts are much better. Comparing the *ex post* forecasts of money GNP from the present model with those from the OBE model, the present model performs slightly better in terms of the mean absolute error criterion for the groups of forecasts beginning with 672 and 673, slightly worse for the group beginning with 674, and considerably better for the remaining four groups. For the real GNP forecasts, the present model performs considerably better for the group beginning with 672, about the same for the groups beginning with 673 and 674, noticeably better for the groups beginning with 681, 682, and 683, and about the same for the group beginning with 684. Comparing the first set of money GNP forecasts of the present model (the ones based on extrapolated values of the exogenous variables) with the *ex ante* money GNP forecasts of the OBE forecasters, the present model performs better in terms of the mean absolute error criterion for all groups of forecasts. For the groups beginning with 674, 681, 682, and 683 the differences are substantial; for the

[5] The one exception to this is the one-quarter-ahead forecast of real GNP for 684, where the Wharton forecast is more accurate.

other groups the differences are quite small. The OBE forecasters consistently underpredicted the change in money GNP for the last half of 1968. For the real GNP forecasts, the present model performs better for all groups except the one beginning with 684.

It was stressed above that the comparisons in this chapter are only informal comparisons. It should now be clear why this is so. In order to compare the forecasting ability of different models in a rigorous way, common ground rules should be set up and forecasts should be generated by each model under this common set of rules. In particular, rules should be set up regarding how often the models are to be reestimated and how the values of the exogenous variables are to be forecast. Since some models may be more closely tied to exogenous variables than others, actual values of all of the exogenous variables should not necessarily be used for the comparisons. Actual values of some of the exogenous variables, such as federal government expenditures, should perhaps be used, with extrapolated (or proxy) values being used for the others. The forecasts should also be free from nonmechanical constant-adjustment procedures.

It is clear that a common set of ground rules was not followed for the comparisons in this chapter. All of the forecasts were outside-sample forecasts, but the models were estimated using sample periods that ended in different quarters. (The Wharton sample period ended in 644, the OBE sample period in 664, and the present model sample period in quarters varying from 654 and 683.) Also, as mentioned above, the *ex ante* forecasts of the Wharton and OBE models are really closer to being forecasts made by the model builders than they are to forecasts made by the models. Nevertheless, given the much better within-sample results of the present model in Table 14–1 and the generally better outside-sample results in Tables 14–2 and 14–3, the Wharton and OBE models, especially the Wharton model, do not appear to be as accurate a forecasting tool as the model developed in this study.

Unfortunately, there do not appear to be any other models that have been analyzed to the degree necessary to make the kinds of comparisons made above for the Wharton and OBE models. The analysis must thus end here, although the results presented in Chapters 11, 12, and 13 above should be useful for future model builders in comparing the accuracy of their models. In particular, it would be useful to see how the results of large-scale structural models compare with the above results.

15 Summary and Conclusions

The purpose of this study was to develop an econometric model of the United States economy that was designed primarily for forecasting purposes. In designing the model an attempt was made to make maximum use of various expectational variables that are available; and an effort was made to avoid, whenever possible, the use of exogenous variables that are hard to forecast. The model was also kept relatively small, so that it can be easily updated and reestimated each quarter and so that the various properties of the model can be analyzed in detail. Aside from its size, the model differs from large-scale structural models in two main ways. One is its avoidance of the use of hard-to-forecast exogenous variables and the other is its treatment of the expectational variables as exogenous. The model is still structural, however, in the sense that theoretical considerations have been used in the specification of the equations.

The econometric techniques that have been used to estimate the model in general differ from those used to estimate previous models. Almost all of the equations have been estimated under the assumption of first order serial correlation of the error terms; and in the money GNP sector, account has also been taken of possible simultaneous equation bias. The monthly housing starts equations have been estimated under the assumption that the housing and mortgage market is not always in equilibrium, and the technique that was used to estimate the equations is designed to take account of coefficient restrictions across equations. It should be pointed out that the use of more sophisticated econometric techniques in this study is not necessarily inconsistent with the desire to keep the model as simple as possible. Once a technique has been programmed for computer use, it is generally as easy to use as any other technique; and with present-day computers, the fact that the technique may use a few more seconds (or microseconds) of computer time is not likely to be much of a restriction.

Some of the conclusions that emerged from estimating the individual equations of the model are the following. With respect to the consumption equations, the Michigan Survey Research Center index of consumer sentiment was significant in explaining short-run consumer behavior. The Bureau of the Census index of expected new car purchases was also significant when considered separately, but it did not appear to contain information not already contained in the consumer sentiment index. GNP rather than disposable personal income was used as the income variable in the consumption equations. No loss of explanatory power in the durable consumption and service consumption equations resulted from doing this, and only slight loss of explanatory power occurred in the nondurable consumption equation. It was conjectured that GNP may in part be acting as a proxy for consumer confidence and that this is the reason why its use in the durable consumption equation did not result in any loss of explanatory power.

With respect to the plant and equipment investment equation, the OBE–SEC investment expectation variable was highly significant in explaining actual investment. The current GNP variable was also significant in explaining actual investment, which suggested that firms do have some flexibility in changing their expected investment expenditures in light of unexpected changes in current economic activity.

For the housing sector the central problem was explaining housing starts, since housing investment proved to be rather easy to explain given housing starts. Housing starts, unfortunately, were not particularly easy to explain, and a relatively complicated model had to be developed. The housing market was treated as a disequilibrium market, and under a particular assumption about how prices are determined, two equations explaining housing starts—one demand equations and one supply equation—were estimated. Aside from the mortgage rate, trend factors and the number of houses in existence appeared to be significant in determining the demand for housing starts, and deposit flows into Savings and Loan Associations and Mutual Savings Banks appeared to be significant in determining the supply of housing starts.

With respect to the inventory investment equation, four approaches aimed at modifying the basic stock adjustment model were tried. The attempt to account for the effect of sales expectations on inventory investment did meet with some success, but the other three aproaches did not. The attempt at disaggregation failed; no evidence of a more complicated adjustment process was found; and none of the various inventory expectational variables that were tried proved to be significant. The sales variable that was used in the inventory equation was the sum of durable and nondurable consumption, and the one-quarter-lagged value of this variable had a large positive coefficient and the current value of the variable a small negative coefficient in the equation. This result was consistent with a simple assumption about how sales expectations are formed.

The price equation was based on the simple theory that current price changes are determined by current and past demand pressures. A potential real GNP series was constructed, and the demand pressure variable was taken to be the potential real change in GNP less the actual money change. An eight quarter moving average of this variable was then used as the measure of current and past demand pressures. The approach taken in this study avoided the need to develop a complete wage–price sector in order to explain prices, and the equation that was finally chosen for the model appeared to provide an adequate explanation of price changes.

The employment equation was based on the idea that the number of hours paid for per worker does not always equal the number of hours actually worked per worker and that during any one time there is either a positive or negative amount of excess labor on hand. A simple short-run production function was specified and estimated, and from this function a series on man-hour requirements was derived. The man-hour requirements series was then used to construct a measure of the amount of excess labor on hand. The amount of excess labor on hand proved to be significant, along with the current and the one-quarter-lagged value of the change in output, in explaining the change in employment.

With respect to the labor force equations, the labor force participation of primary workers did not appear to be sensitive to labor market conditions and was merely taken to be a function of time. The labor force participation of secondary workers did appear to be sensitive to labor market conditions, and the participation rate of secondary workers was taken to be a function of the employment–population ratio. The equation did not appear to be capable of accounting for the rapid growth of the secondary labor force in the last half of the 1960s, however, and this growth was left largely unexplained in the model.

A relatively small model such as the present one has the advantage that it can be rather easily analyzed. In this study, various versions of the model were simulated and analyzed before the final version was chosen; the stability of the estimated relationships over time was examined and the outside-sample forecasting results were compared with the within-sample results; and the sensitivity of the forecasting results of the model to likely errors made in forecasting the exogenous variables was examined. The general conclusions that emerged from this exercise were the following. It appeared to be important in the money GNP sector to test each equation within the context of the overall model. Certainly with respect to the inventory investment equation and perhaps with respect to the nondurable consumption equation, different choices would have been made had the equations not been tested within the overall model. This was not true for all equations, but it was true for enough to indicate that in a simultaneous-equation model, the equations should not be chosen merely by looking at the properties of the estimated equations.

With respect to the stability of the estimated relationships, all but about five of the equations were fairly stable over the 653–694 period. The demand equation explaining housing starts was not very stable over this period, nor was the equation explaining the labor force participation of secondary workers. The supply equation explaining housing starts, the price equation, and the inventory investment equation were also somewhat unstable, but to a lesser extent than the other two. When all of these equation estimates were used to generate outside-sample forecasts for the 654-694 period, the results were in general fairly close to the within–sample results. For the mean absolute errors in terms of levels, the within–sample results were better, but for the errors in terms of changes, the two sets of results were quite close. Also, for the 1968–1969 period the errors in terms of both levels and changes were close for the two sets of forecasts.

The forecasting results were a little more sensitive to the use of extrapolated values of the exogenous variables rather than the actual values. Again, however, the errors in terms of changes were much closer for the two sets of forecasts than were the errors in terms of levels. For the three-, four-, and five-quarter-ahead forecasts, the GNP mean absolute errors in terms of changes differed by about 1.5 billion dollars for the two sets of forecasts (see Table 13–5). For the one- and two-quarter-ahead forecasts, the results were much closer.

For the within-sample forecasts there was little evidence of error compounding as the forecast horizon lengthened. For the outside-sample forecasts based on actual values of the exogenous variables, error compounding occurred for the errors in terms of levels, but not in general for the errors in terms of changes. For the outside-sample forecasts based on extrapolated values of the exogenous variables, error compounding occurred for both error measures, but much less for the errors in terms of changes.

A comparison of results achieved in this study with the results achieved by the Wharton and OBE models indicated that the present model is an improvement over both of these models. The comparison also indicated that the forecasts generated by the present model are likely to be an improvement over the forecasts generated by the econometricians associated with the Wharton and OBE models. In particular, no fine tuning devices appeared to be necessary in this study in order to generate accurate forecasts.

There are a number of possible reasons why the present model gave better results than the Wharton and OBE models. One possible reason is that closer attention was paid in the study to the question of how the model performs as a unit. In line with this, an attempt was also made to design the model in such a way as to minimize potential simulation errors. This was especially true in the specification of the price sector, where the entire wage–price nexus was avoided. Another possible reason why the present model performed better relates to the estimation techniques used. Estimating each equation under the assumption of first order serial correlation of the error terms and then using the estimates of the serial correlation coefficients in the generation of the forecasts appears to be quite helpful. The fits of the equations were generally much worse if account was not taken of the serial correlation of the error terms (see Appendix B). Finally, the fact that account was also taken in this study of possible simultaneous equation bias may have improved the forecasting results.

Although the model was designed primarily for forecasting purposes, it is not completely useless as a policy tool. Fiscal policy actions affect the model in two main ways. First, the level of government spending (purchases of goods and service) affects the forecasts of GNP and related variables directly through the exogenous G_t variable. As was seen in Chapter 11, the short-run government spending multiplier is 1.232 for GNP. Secondly, tax law changes affect the forecasts of GNP and related variables indirectly through the effects they have on consumer sentiment and plant and equipment investment expectations. Since tax laws are generally debated and discussed considerably ahead of their actual enactment, these debates and discussions may affect the consumer sentiment and investment expectations variables far enough ahead so that these effects are reflected in the forecasts of the model. Personal tax law changes in the quarter in which they are enacted do not appear to have any systematic effect on personal consumption expenditures, and the argument given here for why this is so is that consumers to some extent have already discounted these changes. In other words, it is argued here that in explaining or forecasting short-run changes in consumption, it is more important to explain or forecast consumer sentiment than it is to account for the direct effects of tax rate changes on disposable personal income.

Monetary policy actions also affect the model in two main ways. First, the mortgage rate enters the housing starts equations; and thus, to the extent that monetary policy affects the mortgage rate, this has an affect on housing starts. Secondly, monetary policy actions may be reflected in the consumer sentiment and investment expectation variables. As discussed in Chapter 4, for example, no evidence could be found that short-term credit conditions affect the relationship between actual and expected investment expenditures, but that evidence was found that long-term interest rates affect expected investment expenditures. For short-run forecasting purposes, however, it did not appear to be necessary to include the equation explaining expected investment expenditures in the model. For policy purposes, of course, one would want to include such an equation in the model (as well as including a monetary sector), and even for present purposes, the exogenous forecasts of the investment expectation variable that have to be made after the available data or proxies for the variable run out should be guided in part by current and expected future monetary policy.

The final policy issue that should be mentioned here relates to the monthly housing starts sector. The advances of the Federal Home Loan Bank to Savings and Loan Associations were quite significant in explaining the supply of housing starts, but no evidence could be found that the activity of the Federal National Mortgage Association had an effect on the supply of housing starts. Even the Federal Home Loan Bank will, however, have an effect on actual housing starts only to the extent that supply and not demand is the constraint in the housing market.

The primary weakness of the model is probably its inability to account for large quarterly changes in inventory investment, such as those that occurred in 664, 671, 681, and 682 (see Tables 11–4, 12–18, and 13–7). To some extent, errors in forecasting the change in inventory investment are offset by errors in the opposite direction in forecasting consumption expenditures. But for some quarters, such as 671, there is no error offsetting. After a large change in inventory investment in one quarter, there tends to be a large change in the opposite direction in the next quarter (witness 664–671 and 681–682), and aside from the one-quarter-ahead forecast for the second quarter, for which the actual investment of the first quarter is known, the model is not capable of forecasting the changes for either quarter.

Another weak point of the model is its inability to account for the large growth of the secondary labor force during the last half of the 1960s. Whether the model will continue to perform poorly in this area in the future is perhaps still uncertain, but the past performance is not particularly encouraging. Other questions that remain are whether the housing starts equations will be more stable in the future than they were in the past and whether the nonlinear version of the price equation will be stable.

The art or science of building econometric models is still in its infancy, and it is probably much too early to tell how useful econometric models will be for forecasting and policy purposes. The results in this study run contrary to the results reported by Evans, Haitovsky, and Treyz [14] for the Wharton and OBE models and indicate that econometric models can be built that do not need to be extensively (and subjectively) fine tuned in order to produce reasonable forecasts. The results also indicate that the present model is more capable of producing accurate forecasts than are noneconometric forecasting techniques. All of these results are, of course, preliminary. Just how useful the model will be in the future and whether large-scale structural models will be able to produce even better results are open questions.

Appendix A

In this appendix some of the data that have been considered in this study are presented. The data that are presented are primarily data that are not conveniently available elsewhere. In Table A–1 the data from the money GNP sector are presented, in Table A–2 the data from the employment and labor force sector are presented, and in Table A–3 the data from the monthly housing starts sector are presented. In Table A–4 the seasonal adjustment coefficients that were used for HSQ_t are presented. It should be noted that not all of the data presented in Table A–1 were used in the final version of the model.

The quarterly data are presented in the tables for the 551–694 period and the monthly data for the January 1959–December 1969 period. The adjustments that were made in some of the data series are noted in the tables.

Table A–1: Data for Selected Variables Considered in the Money GNP Sector.

Quarter	$MOOD_t$	$ECAR_t$	$PE2_t$	$PE1_t$	$VE1_t$	$VE2_t$	VH_t
551	98.0[a]	NA	26.03	26.04	NA	NA	NA
552	99.1	NA	28.42	27.86	NA	NA	NA
553	99.4[a]	NA	28.83	29.03	NA	NA	NA
554	99.7	NA	29.73	30.86	NA	NA	NA
561	99.0[a]	NA	31.60	33.21	NA	NA	NA
562	98.2	NA	35.32	34.77	NA	NA	NA
563	99.9	NA	36.74	36.26	NA	NA	NA
564	100.2	NA	38.00	37.33	NA	NA	NA
571	96.3[a]	NA	37.96	36.89	NA	NA	NA
572	92.4	NA	38.00	37.33	NA	NA	NA
573	88.1[a]	NA	37.89	37.23	NA	NA	NA
574	83.7	NA	37.17	37.47	NA	NA	NA
581	78.5	NA	35.52	34.05	NA	NA	NA
582	80.9	NA	32.55	31.36	NA	NA	NA
583	86.5[a]	NA	30.31	30.32	NA	NA	NA
584	90.8	NA	31.02	29.93	NA	NA	NA
591	93.0[a]	83.8	30.51	31.16	NA	NA	10
592	95.3	81.0	32.03	32.29	NA	NA	12

Table A–1 (cont.)

Quarter	$MOOD_t$	$ECAR_t$	$PE2_t$	$PE1_t$	$VE1_t$	$VE2_t$	VH_t
593	94.6[a]	87.4	33.39	34.29	NA	NA	4
594	93.8	93.7	35.34	33.95	NA	NA	15
601	98.9	88.2	34.40	35.32	NA	NA	24
602	92.9	90.6	36.91	37.00	NA	NA	27
603	91.5[a]	86.6	37.50	36.90	NA	NA	23
604	90.1	86.2	36.90	35.60	NA	NA	23
611	91.1	88.9	34.90	34.40	NA	NA	17
612	92.3	86.7	33.80	33.85	NA	NA	13
613	93.4[a]	92.8	34.60	34.80	NA	54.6	8
614	94.4	90.8	34.90	35.90	55.7	55.3	8
621	97.2	93.4	36.50	36.10	56.3	56.4	12
622	95.4	95.6	36.60	36.95	57.3	57.0	12
623	91.6	92.0	37.70	37.75	57.8	57.5	13
624	95.0	96.8	37.95	38.35	58.0	57.6	12
631	94.8	96.1	37.70	37.95	57.9	57.6	12
632	91.4	100.4	38.65	38.40	58.4	58.8	13
633	96.2	101.1	39.95	39.95	59.4	59.5	15
634	96.9	99.2	41.15	40.75	60.1	59.7[b]	11
641	99.0	103.1	40.75	41.25	60.1[b]	60.4	14
642	98.1	105.6	42.70	43.35	61.4	60.7	10
643	100.2	103.5	44.30	44.55	61.4	60.8	10
644	99.4	110.3	46.15	46.70	61.5	62.2	10
651	101.5	109.4	47.90	48.85	62.8	63.6	13
652	102.2	108.9	49.65	49.60	64.5	64.4	12
653	103.2	110.7	50.80	51.15	65.2	65.5	13
654	102.6	109.7	52.95	54.85	66.0	66.7	12
661	99.8	109.2	56.70	57.20	67.1	69.0	11
662	95.8	108.2	58.90	59.60	70.3	70.9	14
663	91.1	109.4	61.65	61.10	72.5	74.3	19
664	88.3	105.4	63.55	62.60	75.5	77.5	26
671	92.2	104.8	63.45	62.60	79.4	79.7	30
672	94.9	95.2	62.25	61.55	81.0	81.0	29
673	96.5	103.1	62.80	62.50	82.2	81.0	23
674	92.9	97.1	62.65	62.05	83.0	82.9	22
681	95.0	102.8	65.05	64.80	83.6	84.4	22
682	92.4	104.6	64.30	64.60	86.3	85.3	22
683	92.9	105.7	66.05	64.90	87.1	85.9	21
684	92.1	102.0	65.15	67.25	88.3	89.2	16
691	95.1	99.4	71.15	71.65	91.1	89.9	18
692	91.6	103.3	70.85	72.00	92.3	92.8	19
693	86.4	104.0	73.45	72.25	95.1	94.5	22
694	79.7	100.8	72.10	73.30	96.8	96.4	23

NA = not available.
[a] Value constructed by interpolation.
[b] First value of the revised series.

Table A–2. Data for Selected Variables of the Employment and Labor Force Sector.

Quarter	M_t	HP_t	MA_t	AF_t	MCG_t	E_t	LF_{1t}	LF_{2t}	P_{1t}	P_{2t}
551	52386	40.19	6029	3206	5863	60815	31088	35947	31906	80413
552	53021	40.12	6314	3065	5930	61643	31144	36397	31955	80644
553	53611	40.12	6637	2969	5959	62753	31130	37290	31987	80866
554	54297	40.23	6756	2954	6027	63312	31249	37808	32040	81101
561	54850	40.06	6397	2906	6132	63561	31357	37788	32085	81303
562	55087	39.96	6403	2863	6268	63765	31297	38129	32136	81514
563	54892	39.93	6323	2822	6358	63963	31315	38233	32218	81729
563	55133	39.96	5964	2824	6452	63893	31344	38114	32259	81999
571	55340	39.78	5949	2817	6549	64098	31480	38076	32300	82238
572	55514	39.61	5905	2820	6619	64076	31518	38100	32357	82509
573	55437	39 53	5956	2827	6654	64207	31530	38332	32440	82817
574	54872	39.14	5846	2734	6657	63879	31503	38427	32475	83125
581	53811	39.04	5640	2646	6720	62950	31444	38376	32504	83380
582	53198	39.00	5542	2641	6787	62745	31657	38723	32534	83640
583	53543	39.18	5495	2634	6870	62979	31789	38799	32550	83931
584	54034	39.36	5483	2626	6896	63498	31728	38712	32573	84337
591	54533	39.44	5500	2589	6987	63940	31640	38833	32597	84706
592	55427	39.53	5760	2553	7021	64773	31698	39121	32621	85071
593	55421	39.43	5430	2535	7057	64870	31712	39324	32643	85443
594	55607	39.28	5386	2529	7135	64926	31732	39578	32660	85788
601	56250	39.27	5207	2521	7166	65215	31835	39457	32813	86416
602	56410	39.23	5328	2504	7226	66062	31890	40327	32836	86707
603	56170	39.28	5530	2502	7301	66025	31936	40480	32869	87045
604	55892	39.01	5492	2529	7326	65839	32029	40739	32917	87437
611	55773	38.96	5395	2529	7383	65738	31909	41143	32963	87823
612	55652	38.94	5040	2512	7449	65606	32062	40984	32994	88156
613	55929	38.91	5097	2530	7538	65668	32054	40908	33026	88504
614	56517	38.96	5037	2719	7597	65966	32043	40990	33050	88860
621	56964	38.97	5195	2871	7649	66381	31991	41218	33073	89178
622	57361	39.14	4954	2872	7726	66579	32048	41275	33034	89658
623	57384	39.07	4858	2816	7822	66881	32109	41519	33081	90104
624	57200	38.92	4742	2750	7924	66965	32105	41520	33107	90688
631	57461	39.02	4769	2724	7958	67149	31998	42003	33131	91231
632	57763	39.03	4716	2736	8015	67638	32040	42419	33154	91749
633	58175	38.91	4673	2748	8098	67996	32059	42649	33174	92243
634	58294	39.05	4690	2740	8242	68254	32180	42850	33196	92734
641	58738	38.93	4545	2732	8284	68616	32219	43099	33223	93218
642	59196	38.90	4531	2746	8368	69400	32255	43726	33251	93698
643	59499	38.90	4573	2745	8430	69467	32217	43654	33279	94206
644	59934	39.03	4435	2731	8578	69716	32227	43861	33305	94712
651	60464	39.10	4339	2705	8653	70196	32268	44236	33330	95190
652	61011	39.02	4531	2683	8784	70903	32334	44728	33353	95657
653	61608	38.96	4303	2703	8934	71363	32259	45067	33329	96116
654	62339	38.97	4179	2799	9082	71806	32263	45420	33360	96608
661	62923	38.93	4072	2929	9271	72202	32316	45712	33389	97051
662	63526	38.82	4020	3051	9481	72595	32331	46204	33419	97500
663	64182	38.77	3884	3181	9639	73069	32323	46788	33458	97958
664	64472	38.61	3876	3330	9824	73648	32444	47355	33511	98436
671	64730	38.43	3874	3413	9915	73861	32567	47590	33564	98893
672	64762	38.21	3751	3450	10043	73911	32522	47807	33618	99359
673	64948	38.26	3885	3455	10117	74631	32562	48519	33724	99895
674	65401	38.22	3930	3467	10227	75122	32660	48991	33835	100390
681	65835	38.08	3953	3474	10359	75392	32802	48956	33928	100813
682	66368	38.13	3874	3536	10470	75898	32824	49441	34021	101228
683	66621	38.25	3734	3589	10542	76017	32883	49528	34115	101723
684	67020	38.02	3683	3540	10666	76409	32926	49711	34188	102232
691	67753	38.04	3727	3485	10761	77418	33077	50519	34258	102704
692	68192	38.12	3725	3521	10847	77550	33017	50860	34337	103204
693	68526	38.16	3509	3531	10866	78089	33099	51466	34429	103697
694	68736	37.92	3376	3487	10998	78570	33117	51865	34500	104233

Table A–3. Data for Selected Variables of the Monthly Housing Starts Sector.

Month	RM_t	W_t	Month	RM_t	W_t	Month	RM_t	W
1/59	577*	21	9/62	590	19	5/66	625	21
2/59	577*	20	10/62	590	23	6/66	630	22
3/59	578*	22	11/62	590	21	7/66	640	20
4/59	580*	22	12/62	590	20	8/66	645	23
5/59	580*	21	1/63	590	22	9/66	655	21
6/59	581*	22	2/63	585	20	10/66	665	21
7/59	597*	23	3/63	585	21	11/66	670	21
8/59	597*	21	4/63	585	22	12/66	670	21
9/59	598*	21	5/63	580	22	1/67	665	21
10/59	618*	22	6/63	580	20	2/67	660	20
11/59	618*	20	7/63	580	22	3/67	650	23
12/59	619*	22	8/63	580	22	4/67	645	20
1/60	628*	20	9/63	580	20	5/67	640	22
2/60	628*	21	10/63	580	23	6/67	645	22
3/60	627*	23	11/63	580	20	7/67	650	20
4/60	625*	21	12/63	580	21	8/67	650	23
5/60	625	21	1/64	580	22	9/67	655	20
6/60	625	22	2/64	580	20	10/67	655	22
7/60	625	20	3/64	580	22	11/67	655	21
8/60	625	23	4/64	580	22	12/67	665	20
9/60	620	21	5/64	580	21	1/68	670	22
10/60	620	21	6/64	580	22	2/68	675	21
11/60	615	21	7/64	580	23	3/68	675	21
12/60	615	21	8/64	580	21	4/68	680	22
1/61	615	21	9/64	580	21	5/68	690	22
2/61	610	20	10/64	580	22	6/68	715	20
3/61	605	23	11/64	580	20	7/68	725	22
4/61	600	20	12/64	580	22	8/68	730	22
5/61	600	22	1/65	580	20	9/68	730	20
6/61	595	22	2/65	580	20	10/68	730	23
7/61	590	20	3/65	580	23	11/68	725	20
8/61	595	23	4/65	580	22	12/68	730	21
9/61	595	20	5/65	580	20	1/69	740	22
10/61	595	22	6/65	580	22	2/69	755	20
11/61	595	21	7/65	580	21	3/69	760	21
12/61	595	20	8/65	580	22	4/69	765	22
1/62	595	22	9/65	580	21	5/69	775	21
2/62	595	20	10/65	580	21	6/69	775	21
3/62	595	22	11/65	585	21	7/69	800	22
4/62	595	21	12/65	590	22	8/69	810	21
6/62	595	22	1/66	600	20	9/69	820	21
6/62	595	21	2/66	600	20	10/69	825	23
7/62	595	21	3/66	605	23	11/69	830	19
8/62	595	23	4/66	615	21	12/69	835	22

* Value constructed from an FHA series on the average of new and existing conventional mortgage rates.

Table A–4. Seasonal Adjustment Coefficients for HSQ_t.

Quarter of Calendar Year	Coefficient (SQ_t)
First	1.253
Second	.826
Third	.896
Fourth	1.079

Appendix B

In this appendix different estimates of the seven expenditure equations of the model will be compared. In Table B–1 three estimates are presented for each of the seven equations. The first estimate for each equation is the one included in the model and was obtained by using the technique described in Chapter 2. The second estimate for each equation was obtained by using the Cochrane–Orcutt technique. The Cochrane–Orcutt technique differs from the technique described in Chapter 2 in that no account is taken of possible simultaneous equation bias when using the Cochrane–Orcutt technique. The third estimate for each equation in Table B–1 was obtained by using ordinary least squares. Ordinary least squares does not take account of possible simultaneous equation bias nor of possible serial correlation of the error terms. The three estimates for each equation are denoted as TSCORC, CORC, and OLSQ respectively.

Comparing the TSCORC and CORC estimates first, the results are actually quite close. The largest differences occurred for the plant and equipment investment equation (4.4), the inventory investment equation (6.15), and the import equation (7.3). For equation (4.4), the TSCORC estimate of the coefficient of GNP_t is smaller than the CORC estimate (.0686 vs. .0626), the TSCORC estimate of the coefficient of $PE2_t$ is larger (.687 vs. .624), and the TSCORC estimate of the serial correlation coefficient is smaller (.689 vs. .741). For equation (6.15), the TSCORC estimate of the coefficient of the $CD_{t-1} + CN_{t-1} - CD_t - CN_t$ variable is smaller (.0954 vs. .2290), and the TSCORC estimate of the coefficient of V_{t-1} is larger in absolute value (−.357 vs. −.313). For equation (7.3), the TSCORC estimate of the coefficient of GNP_t is larger (.0780 vs. .0737).

One would expect the CORC estimates of the GNP_t coefficients to be biased upward for the first five equations in Table B–1 and biased downward for the import equation. One would thus expect the CORC estimates of the GNP_t coefficients in Table B–1 to be larger than the TSCORC estimates for the first five equations and smaller for the import equation. The results in Table B–1 are consistent with this, except for the housing investment equation (5.5), where the CORC and TSCORC estimates are the same. One would also expect the CORC estimate of the coefficient of $CD_{t-1} + CN_{t-1} - CD_t - CN_t$ in equation (6.15) (which is the same as the estimate of coefficient of $-CD_t - CN_t$, since $CD_{t-1} + CN_{t-1}$ is included as a separate variable

Table B–1. Comparison of the Expenditure Equations of the Model Estimated by the Technique Described in Chapter 2 (TSCORC), by the Cochrane–Orcutt Technique (CORC), and by Ordinary Least Squares (OLSQ).

Estimation Technique	Equation		$\hat{r}$	SE	No. of Observations
TSCORC	(3.1)	$CD_t = -25.43 + .1027\widehat{GNP}_t + .110MOOD_{t-1}$ (4.22) (39.78) (1.88) $+ .092MOOD_{t-2}$ (1.54)	.648 (6.01)	1.125	50
CORC	(3.1)	$CD_t = -25.52 + .1029GNP_t + .110MOOD_{t-1}$ (4.22) (39.42) (1.88) $+ .091MOOD_{t-2}$ (1.53)	.649 (6.03)	1.125	50
OLSQ	(3.1)	$CD_t = -25.94 + .1018GNP_t + .099MOOD_{t-1}$ (6.26) (78.52) (1.33) $+ .114MOOD_{t-2}$ (1.53)	0	1.515	50
TSCORC	(3.7)	$CN_t = .0807\widehat{GNP}_t + .646CN_{t-1} + .147MOOD_{t-2}$ (5.40) (9.30) (4.67)	−.381 (2.47)	1.383	36
CORC	(3.7)	$CN_t = .0816GNP_t + .642CN_{t-1} + .148MOOD_{t-2}$ (5.51) (9.32) (4.76)	−.378 (2.45)	1.383	36
OLSQ	(3.7)	$CN_t = .0976GNP_t + .567CN_{t-1} + .182MOOD_{t-2}$ (4.86) (6.08) (4.31)	0	1.482	36
TSCORC	(3.11)	$CS_t = .0218\widehat{GNP}_t + .945CS_{t-1} - .023MOOD_{t-2}$ (4.15) (47.77) (7.37)	−.077 (0.55)	.431	50
CORC	(3.11)	$CS_t = .0235GNP_t + .938CS_{t-1} - .023MOOD_{t-2}$ (4.70) (49.66) (7.78)	−.077 (0.53)	.431	50
OLSQ	(3.11)	$CS_t = .0237GNP_t + .938CS_{t-1} - .023MOOD_{t-2}$ (4.39) (40.11) (7.28)	0	.432	50
TSCORC	(4.4)	$IP_t = -8.50 + .0626GNP_t + .687PE2_t$ (4.86) (8.87) (8.34)	.689 (6.72)	1.011	50
CORC	(4.4)	$IP_t = -9.40 + .0686GNP_t + .624PE2_t$ (4.56) (9.25) (7.32)	.741 (7.80)	1.007	50
OLSQ	(4.4)	$IP_t = -6.78 + .0491GNP_t + .835PE2_t$ (9.04) (11.72) (16.42)	0	1.345	50
TSCORC	(5.5)	$IH_t = -3.53 + .0157\widehat{GNP}_t + .0242HSQ_t + .0230HSQ_{t-1}$ (2.31) (13.12) (5.37) (4.45) $+ .0074HSQ_{t-2}$ (1.66)	.449 (3.01)	.582	36
CORC	(5.5)	$IH_t = -3.50 + .0157GNP_t + .0242HSQ_t$ (2.30) (13.12) (5.37) $+ .0230HSQ_{t-1} + .0074HSQ_{t-2}$ (4.45) (1.67)	.447 (2.99)	.582	36
OLSQ	(5.5)	$IH_t = -3.17 + .0151GNP_t + .0246HSQ_t$ (3.00) (20.15) (4.92) $+ .0229HSQ_{t-1} + .0073HSQ_{t-2}$ (3.11) (1.46)	0	.644	36

Table B–1 (cont.)

Estimation Technique	Equation		r	SE	No. of Observations
TSCORC	(6.15)	$V_t - V_{t-1} = -114.76 + .728(CD_{t-1} + CN_{t-1})$ (4.09) (4.27) $-.357V_{t-1}$ (3.94) $+ .0954(CD_{t-1} + CN_{t-1} - \widehat{CD}_t - \widehat{CN}_t)$ (0.42)	.791 (9.15)	2.540	50
CORC	(6.15)	$V_t - V_{t-1} = -101.04 + .645(CD_{t-1} + CN_{t-1})$ (4.57) (4.77) $-.313V_{t-1}$ (4.36) $+ .2290(CD_{t-1} + CN_{t-1} - CD_t - CN_t)$ (1.68)	.772 (8.58)	2.515	50
OLSQ	(6.15)	$V_t - V_{t-1} = -52.98 + .345(CD_{t-1} + CN_{t-1}) - .154V_{t-1}$ (3.46) (3.60) (3.04) $+ .0651(CD_{t-1} + CN_{t-1} - CD_t - CN_t)$ (0.32)	0	3.592	50
TSCORC	(7.3)	$IMP_t = .0780\widehat{GNP}_t$ (8.70)	1.0	.637	45
CORC	(7.3)	$IMP_t = .0737GNP_t$ (8.64)	1.0	.635	45
OLSQ	(7.3)	$IMP_t = -8.45 + .0627GNP_t$ (7.70) (34.44)	0	1.787	45

in the equation) to be biased downward. The results in Table B–1 are not consistent with this, however, since the CORC estimate of the coefficient is larger than the TSCORC estimate.

Comparing the OLSQ estimates with the TSCORC and CORC estimates, the results are much different. The fits tend to be much worse for the OLSQ estimates, and many of the coefficient estimates are quite different. The most dramatic results occur for the inventory equation, where the OLSQ coefficient estimates are much smaller in absolute value than the TSCORC and CORC estimates.

The results in Table B–1 thus indicate that it is more important to account for serial correlation problems than it is to account for simultaneous equation bias. For a more formal test of this conclusion, the regular two-stage least squares estimates should have been computed as well, but the results in Table B–1 are sufficiently striking to indicate that further attempts to support the conclusion are not needed. If serial correlation is less pronounced in larger models than it is in the present model, the conclusion reached here may need modifying, but for small or even medium-sized models the results in

Table B–1 indicate that serial correlation problems are likely to be more severe than are problems of simultaneous equation bias.

Given that serial correlation problems are to be accounted for, the question arises as to whether the TSCORC procedure is worth the extra effort. The TSCORC and CORC results for equations (4.4) and (7.3), and perhaps for equation (6.15), in Table B–1 indicate that the TSCORC procedure may be worth the extra effort. There does appear to be at least some degree of simultaneous equation bias that needs to be accounted for. It should also be noted that the TSCORC procedure was needed in Chapter 9 to estimate the equation explaining the labor force participation of secondary workers, where there was evidence of rather large bias. The bias in this case was due to measurment error problems.

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About the Author

Ray C. Fair was born in 1942 in Fresno, California. He received a B.A. degree in economics from Fresno State College in 1964 and a Ph.D. degree in economics from the Massachusetts Institute of Technology in 1968. Since 1968 he has been an Assistant Professor of Economics at Princeton University. His primary fields of interest are econometrics, macro-economics, and income distribution. He is the author of *The Short-Run Demand for Workers and Hours* (North-Holland, 1969)and various journal articles.

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