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Description of the Models

2.1 INTRODUCTION

Our primary interest is in structural quarterly econometric forecasting models of the United States. With all the quarterly models already in existence or being developed, at the time our research was taking place only two forecasting groups had econometric models and forecasting records that met the needs of this study. One of these was a group in the Office of Business Economics (OBE) of the U.S. Department of Commerce; the other was the Econometric Forecasting Unit at the Wharton School of Finance and Commerce (Wharton). In this study we analyze the models used at the Wharton School of Finance and Commerce from the third quarter of 1966 to the third quarter of 1969 and the models used at the Office of Business Economics from the second quarter of 1967 to the third quarter of 1969.

Chapter 2 presents first the 1969 versions of the Wharton and OBE models in detail and follows this up with a brief comparison of the two.

2.2 DESCRIPTION OF THE WHARTON MODELS: THIRD QUARTER, 1966–THIRD QUARTER, 1969

Historical Summary

Forecasts have been made at the Wharton School by the Econometric Forecasting Unit since 1963. At the outset, joint forecasts were made by two antecedent models. One—the Evans model—grew out of a Ph.D.

dissertation submitted at Brown University by Michael Evans.[1] The other, known as the Wharton Model, was presented at the 1962 Conference on Models of Income Determination by Lawrence Klein.[2] After a year of joint forecasting, these two were forged into a single model. Following a substantial revision of the national income data in August 1965, it was decided to formulate a completely new model, which was first used for forecasting purposes at the beginning of 1966.[3] Refined during early 1966 and published in 1967,[4] it was used for forecasts through the spring of 1968 without any further changes.

The published version of the model contained forty-seven stochastic equations and twenty-nine identities, and the sample period covered sixty-eight quarterly observations from 1948 to 1964. All unknown parameters were estimated by the method of two-stage least squares, using twelve principal components of the predetermined variables, with two exceptions. Equations that had only one unlagged endogenous variable were estimated by the method of ordinary least squares. The tax functions were estimated by less sophisticated curve fitting techniques, since in some cases only a few observations were available between changes in the tax laws.

This model was used for forecasts from the third quarter of 1966 to the fourth quarter of 1968, but the monetary sector was completely restructured and enlarged in the second quarter of 1968. This new monetary sector, which followed the structural specifications developed by F. de Leeuw for the Brookings Model,[5] was incorporated into the Wharton model to generate the forecasts from the second quarter through the fourth quarter of 1968.

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[1] "A Postwar Quarterly Model of the United States Economy, 1947–1960." See also his "Multiplier Analysis of a Postwar Quarterly U. S. Model and a Comparison with Several Other Models," *Review of Economic Studies*, Vol. 33, No. 4, 1965, pp. 337–360.

[2] Lawrence R. Klein, "A Postwar Quarterly Model," *Models of Income Determination*, Princeton University Press for NBER, 1964, pp. 11–30.

[3] For analyses of the results before the third quarter of 1966, see Michael K. Evans, Yoel Haitovsky, and George Treyz, with the assistance of Vincent Su, "An Analysis of the Forecasting Properties of U. S. Econometric Models," in Bert G. Hickman, ed., *Econometric Models of Cyclical Behavior*, New York, NBER, 1972, pp. 949–1139.

[4] Michael K. Evans and Lawrence R. Klein, *The Wharton Econometric Forecasting Model*, Philadelphia, Wharton School of Finance and Commerce, 1967. This model was also published in Evans, *Macroeconomic Activity*, New York, Harper and Row, 1969.

[5] F. de Leeuw, "A Condensed Model of Financial Behavior," in E. Kuh, ed., *The Brookings Model: Some Further Results*, Chicago, Rand McNally, 1968.

In the fall of 1968 the model was reestimated, with new sample data and some new specifications, the most important of which concerned the price equations. The estimation procedure was similar to that used in the earlier model. Fifty-two stochastic equations and forty-one identities were included, and the new sample period covered sixty-three observations from the first quarter of 1953 to the third quarter of 1968. With some minor alterations, this model was used for the forecasts of the first three quarters of 1969.

Since we are not able to report on all of the versions of the Wharton Model, only the 1969 model is presented in detail here. However, we also discuss the major equations that had alternative specifications in the earlier models mentioned above. The equations and variables of the 1969 model, which are not published elsewhere, are presented, together with a glossary of symbols, on pages A 1 through A 23 of the appendix.

Description of the 1969 Model[6]

For convenience of discussion, the structural equations and identities of this model have been grouped into the following eight sectors: GNP components; prices and wage rates; capacity and utilization; labor force and employment; income; taxes, transfers, and fiscal balance; interest rates and money supply; and output, sales, and unfilled orders.

GNP COMPONENTS

The GNP sector includes four subsectors: consumption, investment, foreign trade, and government. The government sector is treated as totally exogenous to the system.

Total consumption (*C*) is disaggregated into three groups: automobiles (*CA*), other durables (*COD*), and nondurables and services (*CNS*). Both the consumption function for automobiles and for other durable goods are formulated on the stock adjustment principle. The current demand is a fraction of the difference between desired stock and actual stock. The desired stock is specified as a function of income and relative prices, while the actual stock is the accumulation of previous sales at an annual depreciation rate of 7 per cent. In the automobile function, transfer payment receipts are excluded from relevant income (since they

[6] Much of this discussion follows Evans and Klein, *The Wharton Econometric Forecasting Model*, pp. 21–49.

are not usually spent on automobile purchases), the general unemployment rate is used to catch the cyclical variation in automobile sales, and two dummy variables are added—one to indicate the supply restraints in the period immediately following World War II and in the third quarter of 1952, and the second, to show changes in credit conditions. In the consumption function for other durables, the effect of relative prices is excluded. Consumption of nondurables and services is measured on a per capita basis. Since this kind of consumption is probably more affected by changes in recent income than by changes in distant past income, geometrically declining weights are assigned to past income changes. This leads to the use of a Koyck transformation and the introduction of lagged dependent variables to the equation.

Total investment (*I*) is also divided into three groups: fixed investment (*IP*), housing investment (*IH*), and inventory changes (ΔII). Fixed investment is further broken down into the standard industrial classification categories. The fixed investment in manufacturing industries (*IMP*) depends on capital requirement variables (such as lagged output originating, *XM*, and previous capital stock, *KM*), lagged capacity utilization (*CP*), and former financial variables (such as cash flow, *LM*, and the interest rate, *IL*). The influence of all of these independent variables is distributed over several quarters in the general shape of an inverted V distribution, so that the Almon[7] lag structure is imposed on all independent variables. Fixed investment in regulated and mining industries (*IPR*) depends on previous final sales (*Z*) and the long-term interest rate (*IL*). However, the effect of the last two quarters' sales has been separated from distant past sales in order to stress their importance. The Almon lag structure is used to spread the effects of final sales and the long-term interest rate in the past. The fixed investment in commercial and other industries (*IPC*) is determined by lagged capital (*KC*), total consumption (*C*), and the difference between long-term and short-term interest rates ($IL - IS$). The effects of these variables are assumed to have an Almon lag distribution with the independent variable observations bearing on a given *IPC*, starting at ten quarters in the past and going up to the period two quarters back.

The housing investment equation contains elements of supply and

[7] Shirley Almon, "The Distributed Lag Between Capital Appropriations and Expenditures," *Econometrica*, 33, January 1965, pp. 178–196.

demand, since in the short run the amount of construction put in place measures the amount of housing built rather than bought. Cost variables, such as the ratio of the price of new housing relative to a rent index (*PH/PR*), and the availability of credit (represented by the difference between the long-term and short-term interest rates: IL − IS), have always been used in all versions. In addition, disposable income (*Y*) represents the effect of income on spending in this equation. The capital stock used in different investment functions is defined as the sum of previous capital stock and current investment minus depreciation. Depreciation is a simple linear function of total capital stock.

Total inventory (*II*) is broken down into manufacturing (*IIM*), nonmanufacturing (*IIN*), and farm (*IIF*) sectors, with the change in farm inventory treated as an exogenous variable. The inventory change equation of the manufacturing sector is formulated according to the partial adjustment principle and the accelerator theory. Change in inventory is a function of previous production (*XM*), the stock of inventory (*IIM*) two quarters before, and the change in unfilled orders ($U_{-1} - U_{-4}$). It is also related to a dummy variable to account for the effect of steel strikes, and government inventory investment in defense is used to explain the relationship between changes in manufacturing inventory and government inventory. The nonmanufacturing inventory equation is based on the partial adjustment principle, too. In addition, the previous purchase of consumer durables (*CD*), and the unsold manufacturing product (*XM* − *SN*) have been included in this equation as independent variables.

The foreign trade sector contains two import functions and one export function. With a large portion of the imports of raw materials and manufactured goods (*FM*) used as input in the manufacturing sector, the sales (*SM*) and inventory (ΔIIM) in the manufacturing sector are substantial determinants of these imports. The relative price (*PIM/PM*) also plays an important role in this function, and the average of previous imports (*FIM*) is included to explain the historical stability of imports. Since service imports (*FIC*) are purchased mainly for consumer use, only personal disposable income (*Y*) and lagged service imports (*FIC*) are used as independent variables. Total export (*FE*) is mainly determined exogenously. It is a function of a world trade index (*XWT*), relative prices (*PWT/PE*), and lagged exports (*FE*).

PRICES AND WAGE RATES

There are fifteen equations in the price and wage rates sector, ten explaining different prices and five explaining wage rates.

The price deflator of gross national product (*P*) is a weighted average of the prices of all components. Some are exogenous and some are endogenous. All endogenous component price equations are estimated as annual rates of change and are specified according to the Phillips curve theory. Consumer prices of durable goods, automobiles (*PA*) as well as other durables (*POD*), depend on normal unit labor cost in the manufacturing sector (*NULCM*) and change in capacity utilization (*CP*). The normal unit labor cost variable used in the automobile price equation is lagged one quarter to indicate the delayed reaction of automobile prices to changes in wages. In addition, an indirect business tax dummy variable (*DTB*) is used in both equations to take account of the effect of tax law changes on consumer expenditures. In the price of nondurables and services function (*PNS*), the independent variables are normal unit labor cost in the nonmanufacturing sector (*NULCN*) and current and previous food prices (*PF*). They are all measured as annual rates of change. This price is also positively related to the reciprocal of average idle capacity ($1 - CP$). This relationship is explained by changing demand elasticity and diminishing marginal productivity. Price of total consumption (*PC*) is, of course, a weighted average of these three component prices. In the equation for fixed investment price (*PK*), the independent variables are normal unit labor cost of manufacturing (*NULCM*), capacity utilization (*CP*), and the ratio of nonfarm fixed investment to real GNP (*IP/X*), all measured in annual rates of change. The determinants of the price of housing investment (*PH*) are normal unit labor cost of the nonmanufacturing sector (*NULCN*), capacity utilization (*CP*), and the reciprocal of idle capacity. The nonfarm inventory is deflated by the price of gross output originating in the manufacturing sector (*PM*). The structure of this price equation (*PM*) is identical to that of the price of housing investment. The price of exports (*PE*) is determined by cost factors like the lagged manufacturing unit labor cost (*ULCM*), capital utilization (*CP*), and the reciprocal of average idle capacity. All other prices of GNP components—such as farm inventory, government purchases, and imports—are assumed to be exogenous to the system.

The wage rates of both manufacturing (*WRM*) and nonmanufacturing (*WRN*) employees are measured by the rate of annual change in this 1969 version. Since wage earners may demand higher wages through collective bargaining if the consumer price index (*PC*) moves up, the lagged rate of change in consumer price is used as a determinant. On the other hand, idle capacity, an indicator of unemployment, is also used as a determinant, since wage earners can push wage rates up rapidly at nearly full employment. In general, nonmanufacturing wage changes tend to follow manufacturing wage changes. Therefore, the manufacturing wage (*WRM*) change is used as an explanatory variable in the equation for the nonmanufacturing wage (*WRN*) rate. In addition, the lagged dependent variable is included in this equation. It is positively related for the most recent year and negatively related for the year before, on the theory that wages reflect performance in the recent past and compensation for overadjusting in the more distant past.

Unit labor cost in the manufacturing sector (*ULCM*) is defined as the total wage bill divided by the output in the manufacturing sector. Normal unit labor costs in both manufacturing (*NULCM*) and nonmanufacturing (*NULCN*) sectors are the weighted average, with arithmetically declining weights, of the unit labor cost in the respective sectors over the past eight quarters.

CAPACITY AND UTILIZATION

In the capacity and utilization sector, the potential output in the manufacturing sector (*XMC*) is defined by a simple Cobb-Douglas production function, in which labor employment (*NMC*), capital (*KM*), and technological changes approximated by a productivity trend index (*PROD*) are the independent variables. The Wharton School index of capacity (*CP*) is the ratio of actual output to potential output in the manufacturing sector.[8]

LABOR FORCE AND EMPLOYMENT

The labor force, employment, and hours sector includes eight equations. The labor force participation rate (*NIM/N*) is positively related to the reciprocal of the unemployment rate, reflecting the idea that, as

[8] L. R. Klein and R. Summers, *The Wharton Index of Capacity Utilization*, Studies in Quantitative Economics, No. 1, Philadelphia, Wharton School of Finance and Commerce, 1966.

unemployment gets close to its minimum value, workers will enter the labor force at an increasing rate. The labor force participation rate is also negatively related to time trend, indicating the increasing average number of years of education and the declining average retirement age in the postwar period. The total labor force is disaggregated into (1) the manufacturing and (2) the nonmanufacturing, nonfarm sectors. The labor force in the farm and government sectors is exogenous to this model. In order to explain the number of employees in the manufacturing (*NM*) and nonmanufacturing (*NN*) sectors, it is necessary to estimate production functions first. The production functions for these sectors follow the general Cobb-Douglas form. Transforming this logarithmic production function into a function that has only the number of employees on the left hand side gives the determination of the number of employees in different sectors.

The index of hours worked in the manufacturing sector (*HM*) is determined by the level and the change of gross output in that sector, since the hours worked can be adjusted much more easily as the level of output changes. The hours are also negatively related to the wage rate (*WRM*). The index of hours worked in the nonmanufacturing sector (*HN*) depends on the reciprocal of the previous unemployment and wage rates. The total unemployment rate (*UN*) is the difference between the total civilian labor force and total employment. The civilian labor force (*NLC*) is the total labor force minus the number of military personnel. The unemployment rate of the primary labor force (*UN**) is a function of the total unemployment rate and its own lagged value.

INCOME

Total income is divided into wage and nonwage groups. Following the disaggregation used in the labor force sector, wage income is divided into manufacturing (*WM*) and nonmanufacturing (*WN*) sectors. Each is a product of the respective wage rate, hours worked, and number of employees. Nonwage personal income is divided into three subgroups: income of unincorporated business enterprises (*PB*), rent and interest (*RI*), and dividend payments (*DV*). The lagged endogenous variables, entering as averages over the past four quarters, play a prominent role in all three equations. In addition, changes in respective prices, from current quarter back to three quarters before, are used as independent variables in the first two equations. In the dividend equation, the lagged dividend values, corporate profit after taxes (*PCA*), and depreciation for different investments (*DM* + *DR* + *DC*) are the independent variables. The inventory valuation adjustment (*IVA*) is related negatively to the change in the current price of gross output originating in the manufacturing sector. The rest of the equations in this sector are identities based on the national accounting definitions.

TAXES

All equations in the tax sector are reasonably straightforward. Corporate income taxes (*TC*), personal tax and nontax payments (*TP*), and indirect business taxes and business transfers (*TB*) are all simple linear functions of their tax objects. In order to reflect the effect of changes in the tax law, all tax functions have an adjustable slope, which can be changed whenever tax rates are changed. Transfer payment is a linear function of the total number of unemployed and a trend dummy. The coefficient of unemployment is also adjustable with respect to changes in regulations. The last equation in this sector is an identity which states that the total government deficit is the difference between government revenues and government spending.

INTEREST RATES AND MONEY SUPPLY

The monetary sector includes three equations of interest rates and three equations of monetary stock. The change in the short-term interest rate (ΔIS) is related to the discount rate (*ID*), the level and the change in free reserves (*RF*) held by member banks, government deficit (*DEF*), change in inventory (ΔII), and the previous short-term interest rate. The long-term interest rate (*IL*) is a function of the current and previous short-term interest rates and the previous long-term interest rate. The average interest rate paid on time deposits (*IT*) is determined by its own lagged value, the previous short-term interest rate, and a dummy variable.

All money stock components are measured in first differences and deflated by a current price-wealth surrogate (*PW*). The wealth surrogate is formed as a weighted sum of past real GNP. The monetary stock equations may be considered as a representation of the liquidity preference theory. All monetary components are a function of a transaction variable and relative interest rates. In addition, there are two minor equations in this sector—cash flow in the manufacturing sector

(*LM*) and free reserves (*RF*) held by member banks.

OUTPUT, SALES, AND UNFILLED ORDERS

The last sector includes the equations for output, sales, and unfilled orders. Gross output originating in the manufacturing sector (*XM*) is a function of consumption of nondurables and services (*CNS*), consumption of durables (*CD*), nonfarm investment in plant and equipment (*IP*), and government purchases for national defense (*GD*). The determinants of the gross output originating from rent (*XH*) are the stock of housing (*KH*) and personal disposable income (*Y*). Sales originating in the manufacturing (*SM*) and nonmanufacturing (*SN*) sectors are the respective gross outputs minus the respective inventory changes. Subtracting the change in inventory and government purchase from real GNP gives the final total sales in the private sector (*Z*). Unfilled orders (*U*) are made a function of changes in manufacturing sales (ΔSM) and defense progress payments (*GP*).

Review of the Earlier Model

The earlier model, used unchanged (except for the addition of monetary equations in the second quarter of 1968) from the third quarter of 1966 to the fourth quarter of 1968, may be most easily explained if we contrast it with the 1969 model described above.

The consumption equations are the same in both, except for the automobile function. In the earlier model, the price of automobiles relative to other consumer prices was treated as an explanatory variable, not as the product of the relative price and disposable income as in the 1969 version. The 1969 reestimation meant revisions for all coefficients in the consumption sector due to the change in sample data. This altered the value of marginal propensities to consume in individual consumption functions, but the sum of the marginal propensities to consume did not change substantially. In the older version, the stock of automobiles and other durables was defined as the accumulation of consumption in the past forty quarters, whereas in the 1969 model, equations are used to generate these values.

The investment sector was affected more significantly than the consumption sector by the 1969 respecification. In the *IPR* equation (regulated and mining industries), the earlier version included—while the later version omits—the average of capital stock in the past two quarters as an explanatory variable. In fixed investment of commercial industries, the old equation, in contrast to the 1969 edition, did not apply the Almon lag structure to the capital stock and did not include the interest rate spread in previous quarters as an explanatory variable. The old housing function had a simpler specification than the 1969 version: except for income, only the relative prices and interest rate spread in the three previous quarters entered into the determination of housing investment. The inventory investment subsector was substantially different from the later version. In the manufacturing inventory change equation, total sales of manufactured goods and the change in unfilled orders in the preceding quarter were used as explanatory variables. The nonmanufacturing inventory change function, too, showed an entirely different specification than the 1969 model's equation: the change in manufacturing production, final sales of nonmanufactured goods, and the change in manufacturing prices were used as independent variables in addition to consumption of durables in previous quarters and the lagged dependent variables.

Foreign trade is the only sector that has decreased in size through model revisions. In contrast to the 1969 version, which contains only two import equations, the earlier model had three; imports of food products were separated from those of raw materials and manufactured goods, and, measured on a per capita basis, were a function of income and relative prices. The old import function of materials and manufactured goods did not include relative prices and lagged imports; instead, imports were related to unfilled orders and a steel strike dummy variable. The old model's third import equation explained all other residual imports (mainly purchased by consumers), and had the general form of a consumption function. On the export side, the relevant export function has not been respecified since the model was first published. Changes in coefficients are mainly due to new sample data.

The price sector is substantially different in the two models. The respecification in the spring of 1969 changed all of the price equations that were originally in the first-difference form in the 1966 model to annual percentage changes. None of the price variations in the early version were related to unit labor cost and capacity as in the 1969 model. Instead, in the third quarter, 1966 version (a) consumer prices depended on current and previous manufacturing prices, (b) the variation in capital price was a function of the general price level and the ratio of plant and equipment investment to total private output, (c) the housing price was determined by the general price level and the change in total construction investment, (d) the export price was directly related to the current and previous changes in manufacturing prices, and (e) the price of output originating in the manufacturing sector was a function of the wage bill-output ratio in manufacturing, capacity, a dummy variable for the Korean War, and the lagged endogenous variables in the four quarters just past.

Before the 1969 respecification, wage rate equations were measured in annual changes. In the third quarter, 1966 model, the wage rate function for manufacturing employees, based on a general formulation of the Phillips curve, represented the difference between the total and prime unemployment rates, the consumer price index, and its own lagged value. The equation for nonmanufacturing wage changes, designed to follow the manufacturing wage changes, used the latter as an independent variable in addition to the consumer price index and its own lagged value.

From the third quarter of 1966 through the first quarter of 1968, the monetary sector was purely exogenous. The behavior of interest rates was explained by only two equations: one related the short-term interest rate to the discount rate and the free reserve ratio; the other related the current long-term interest rate to the short-term rate and its past value (the long-term interest rate being a geometrically distributed lag function of short-term interest rates).

In the second quarter of 1968, the monetary sector was restructured and expanded to include six stochastic equations, three for different interest rates and another three for different monetary stocks. The new equation for the short-term interest rate was similar to the one in the previous version. But, in addition to its own lag and the discount rate, the level and change in free reserves were also included as explanatory variables, and the free reserves were made a function of total deposits, depending, in turn, on economic activity. Thus, the feedback between the real and monetary sectors was incorporated in this equation. Finally, in order to link fiscal policy to monetary policy, government deficits were also included in this equation. The long-term interest rate was expressed as a function of current and previous short-term interest rates, both with a geometrically declining distributed lag structure. The declining weights in both lags were assumed to be identical, so that this equation could be reduced by a Koyck transformation. In the reduced form, only current and previous short-term interest rates and the lagged long-term interest rate appeared as independent variables.

In addition, a new interest rate equation was also introduced to explain the average rate paid on time deposits, quasi as a supply equation for time deposits, since a negative relationship was found between time rate and time deposits. A dummy variable that was a function of the maximum allowable rate payable by commercial banks on time deposits indicated the effect of the monetary authorities on this interest rate. The net marginal profit for commercial banks on loans was also implicitly included in this equation.

Otherwise, the model has remained almost the same, except for the coefficients revised by the 1969 reestimation. Slight changes were found in the equations on indices of hours worked, where capacity was not used as an independent variable in the early version. Finally, the equations for gross output originating from rent and unfilled orders were also slightly changed in the 1969 revision.

2.3 DESCRIPTION OF THE OBE MODELS:[9] SECOND QUARTER, 1967–THIRD QUARTER, 1969

Historical Summary

In contrast to the Wharton model, which was retained intact over an extended period, the OBE model has undergone constant revision and expansion, never retaining its identity for long.

The forecasting results from 1963 to the present are recorded at the Office of Business Economics, U. S. Department of Commerce. In the early years the OBE group used the original Klein model (see above, p. 24) essentially as it was used at the Wharton School (i.e., using a subset of all the equations with prices exogenous).

In 1965, the OBE group introduced an explicit equation for the overall price level, and by 1966 a model which differed in significant

[9] Much of the rest of this chapter is drawn from "Short- and Long-Term Simulations with the OBE Econometric Model" by George Green in association with Maurice Liebenberg and Albert A. Hirsch, *Econometric Models of Cyclical Behavior*, Vol. 1, Studies in Income and Wealth, No. 36, New York, NBER, 1972, pp. 25–123.

ways from the original Wharton model was published for the first time.[10] This version of the OBE model contained thirty-six stochastic equations and thirteen identities. There have been many revisions and additions to this model since, but essentially the later versions are an outgrowth of this published model.

Unfortunately, over the entire period from 1963 to early 1967 the record of the specific models was not available. The variables shown on the print-outs were not designated and the parameters imbedded in matrix form could not be recalled after a long period of time had elapsed. All attempts to recreate the ex ante forecasts prior to the second quarter of 1967 were unsuccessful. None of the forecasts beyond the third quarter of 1969 were available to us in time for this study. Therefore, the forecasting period of this model starts with the second quarter of 1967 and ends with the third quarter of 1969.

The version of the OBE model used in the second quarter, 1967 forecast was similar to the one published in 1966. A major addition to the model was an employment equation. Furthermore, the complete import sector was restructured, with total imports divided into merchandise imports, other nonmilitary imports, and military imports. (The latter were exogenously determined.) An alternative investment anticipation function was also added for optional use, and an autoworker strike dummy was included in the consumption function of automobiles and parts. Finally, all price equations and some wage equations were reestimated.

A substantial revision took place in the third quarter of 1967. The merchandise import function was respecified, and so were the wage rate, the civilian labor force, and the wages and salaries plus other labor income equations. Since the wage rate was an important determinant of most price deflators, this had a significant effect on most current value variables.

The version used in the fourth quarter of that year was identical to that in the third, but one more alternative anticipation version of the fixed nonresidential investment equations was added and could be substituted at will.

Another significant change in the model occurred in the first quarter of 1968. The number of stochastic equations was increased to fifty-six,

[10] Maurice Liebenberg, Albert A. Hirsch, and Joel Popkin, "A Quarterly Econometric Model of the United States: A Progress Report," *Survey of Current Business*, May 1966, pp. 13–39.

with 180 variables. Housing investment was made endogenous in the system, the monetary sector was greatly enlarged, and a new sector was introduced for orders, shipments, and unfilled orders. All consumption functions and investment functions were restructured and reestimated. The merchandise import equation was respecified to make private production capacity and input prices explain merchandise imports. All price equations were reestimated as well, and several of them were restructured.

The second quarter model, on the other hand, was almost identical to the preceding one, with the minor exceptions that the employment and state unemployment transfer equations were respecified, and that the equations for automobile consumption and for the average cost per new private housing unit started were reestimated.

The specification of the third and fourth quarter models was very similar to that of the second quarter model. However, the equations for *IS, IE, IMT, CUW,* and *PIE* were respecified in the third quarter, 1968, and the new orders, shipments, and unfilled orders sector was restructured in the fourth. In addition, several variables, such as *KS* and *RL*, were made endogenous, and the change in business inventory was separated into automobile and nonautomobile inventory changes.

The only difference between the first quarter, 1969 and the fourth quarter, 1968 models was the slight change in the two anticipation equations of investment. Since then the model used in this study has not been changed.

A list of the structural equations in the 1969 model and the definition of the symbols are shown on pages A24 through A50 in the appendix.

Description of the 1969 Model

The version of the OBE model presented here is the model used in the three quarters of 1969. It is not published elsewhere, and has the advantage of being contemporary with the Wharton 1969 model. The structural equations and identities of the OBE model can be grouped into eight sectors similar to the Wharton groupings above:[11] GNP components; prices and wage rates; capacity and productivity; labor force and

[11] These groupings were first suggested by George Green.

employment; incomes, taxes, and fiscal balance; interest rates and money supply; and orders and shipments.

GNP COMPONENTS

The GNP sector has been further broken down into five subsectors. The first is the consumption subsector, which includes equations for automobiles (*CA*), other durables (*COD*), nondurables (*CN*), and services (*CS*). Housing services are separated from total services and treated as an exogenous variable. The explanatory variables used in various consumption equations are disposable income (*DPI*), transfer payments (*TRP*), relative prices, lagged endogenous variables, and measures of cyclical activity. The stock of automobiles and total consumption are defined by identities.

Total investment, the next GNP subsector, is divided into fixed investment (*ISE*), housing investment (*IH*), and inventory changes (ΔII). There are five optional ways to determine total fixed investment: by either of the two anticipation equations, with different hypotheses of the future; by an equation of capacity output with an Almon lag distribution; by its components treated as endogenous variables; or, by considering total fixed investment as completely exogenous to the system. Private housing investment is a function of its own price and of the product of housing starts and their cost. Housing starts (*HS*) are determined by the relevant economic activities in the previous quarters. Net change in business inventories (*II*) is separated into two parts. Inventory of automobiles (*IIA*) is a function of the consumption of automobiles (*CA*), stock of automobiles (*KIA*), and a strike dummy (*DCA*). Inventory of nonautomobiles is mainly dependent on private production, inventory changes, and unfilled orders in previous quarters.

In the foreign subsector, total export is an exogenous variable. Imports are divided into merchandise (*IMT*), other services (*IMS*), and military expenditures. Military expenditures are exogenous to the system. Merchandise imports are a function of private production (*X*), relative price (*PIM/P*), a dock strike dummy (*DIM*), and the domestic industrial capacity utilization (*CUW*), which reflects the cyclical sensitivity of merchandise imports. The imports of other services are determined by disposable income (*DPI*), import prices (*PIM*), and the moving average of the past four quarters' service import (*IMS*).

Finally, government purchases and wage payments in current dollars are treated as exogenous variables. However, the total of government expenditures in 1958 dollars is the sum of government purchases and wage payments deflated by corresponding prices. The GNP sector is closed by adding in three identities to define GNP, GNP in 1958 dollars, and private production.

PRICES AND WAGE RATES

Turning to prices and wage rates, the basic price used in this model is the implicit price deflator for real private GNP excluding housing (*P*). Its determinants are unit labor cost [(*W* − *WG*)/*X*], recent relative changes in final demand, and a trend factor (*T*). Variations in the prices of consumer goods are mainly related to variation in the GNP deflator. The price of consumer services (*PS*) fluctuates with the wage rate (*WR*) and average weekly hours (*HM*). Automobile prices are treated as exogenous to the system. The price of housing starts (*PHS*) is determined exclusively by the price of housing investment (*PIH*), which is a function of unit labor costs, total investment, and the average of previous price levels. The price index for manufacturers' durables is determined by the GNP deflator and the order and shipment ratio in the previous period. While the price of government purchases (*PGG*) is assumed to vary with the GNP deflator, in an alternative version it is simply treated as exogenous to the model. Total consumption and total fixed investment prices are, of course, the weighted averages of the corresponding component prices. The equation of wage per employee in the private sector is based on the Phillips curve. The relative change in the wage rate (*WR*) is a function of the reciprocal of the unemployment rate (*UR*). In addition, this equation also includes the rate of change in manufacturing hours (*HM*) and in consumer prices (*PC*) as determinants.

CAPACITY AND UTILIZATION

In the capacity utilization and productivity sector, equations for potential private employment (*EC*) and for potential private weekly hours (*HC*) are derived from a constrained Cobb-Douglas production function in which the capacity utilization index (*CUW*) is set equal to 1.0 and the unemployment rate is set at the frictional level. The potential private GNP (*XC*) is also constrained by a Cobb-Douglas production function, in which, in addition to lagged capital stock and current man-hours, time trend is also used to reflect technological change.

LABOR FORCE AND EMPLOYMENT

Seven stochastic equations are used to explain the component variables in the labor force employment and hours sector. The prime labor force (*LFP*) is assumed to grow with total population (*NP*) and to decline slightly with the passage of time.

A curvilinear relationship is assumed between the secondary labor force (*LFS*) and the unemployment rate in the prime labor force (*URP*) at full employment. In addition, a dummy variable indicating the secondary labor force transition after the Korean War (*DLFS*), as well as a time trend, are also included in the equation explaining the relative growth of the secondary labor force. Private civilian employment (*E*) and private man-hours (*H*) are both explained by partial adjustment equations which imply that full employment will be realized if current output in the private sector reaches its capacity. The civilian unemployment rate is defined as the ratio of the unemployed to the total labor force. The unemployment rate in the prime labor force (*URP*) is determined by the total unemployment rate and the relative share of the prime labor force.

INCOME

In the income sector, the corporate profits and inventory valuation adjustment (*CPR* + *DC$*) is a logarithmic function of current output ($P \cdot X$), the wage share, and the capacity index (*CUW*). The dividends income (*DIV*) is linearly related to corporate profits and its own lag. Change in proprietor income (*PRI*) is a function of the change in consumption of nondurables and services and the change in wage rate. Wage and salary income (*W*) is the product of wage rate and total private employment plus the government wage bill. Personal income (*PI*) is the sum of its income components, and subtracting the federal and local personal taxes (*TPF* and *TPSW*) gives the disposable personal income (*DPI*).

TAXES

The federal, state, and local personal taxes are determined by the tax base, which is simply the sum of all taxable income. All other tax items are related to the appropriate tax rates and the other relevant variables. These equations can be easily understood by inspection.

INTEREST RATES AND MONEY SUPPLY

The monetary sector is patterned after the work of the FRB-MIT model. Liquid assets of households (*LH*) depend on disposable income (*DPI*) and the level of liquid assets in the last quarter. The item is also negatively related to corporate bond yield (*RL*) and positively related to the interest rate on savings deposits (*RT*). Demand and time deposits are assumed to vary with disposable income, different interest rates, and their own lags. Various interest rates are determined by the levels of nonborrowed reserves, the discount rate, and reserve requirements.

NEW ORDERS, SHIPMENTS, AND UNFILLED ORDERS

Finally, in the orders and shipments sector, three equations explain the new orders, shipments, and unfilled orders of manufacturing durables. The change in unfilled orders (ΔUMD) is the difference between new orders (*OMD*) and shipments (*SMD*). The former is determined by changes in the demand for durables, the change in gross private output (*X*), and inventory stock (*KI*); the latter, by the rate at which new orders were received in the past. The main impact of this sector on the rest of the model is through the equation for inventories other than auto inventories.

Estimation and Solution

The model was estimated by two-stage least squares. In the first stage the principal components technique was used in order to reduce the collinearity among predetermined variables and to increase the degrees of freedom. Nevertheless, for some equations the ordinary least squares results were adopted without clear explanation. The parameters of tax functions were estimated by a more primitive method, and reestimated whenever the tax laws were changed. The sample period extended over fifty-five quarters, from the second quarter of 1953 to the fourth quarter of 1966, but the sample size varied in the estimation of some equations.

The multiperiod forecast is generated by a computer program, lately named SIMEMOD, after the estimates of all parameters are given. The forecasting solution is obtained by using the structural form rather than the reduced form of the model. All endogenous variables are grouped into three types: predetermined or recursive, simultaneous, and post-simultaneous. The first type includes those variables which are either themselves a function of predetermined variables only, or a function of a current endogenous variable which is itself a function of predetermined variables only. The second type comprises those endogenous variables which are a function of other current endogenous variables not of the first group. The last type are those endogenous variables that are determined by other endogenous variables but are not themselves used in the determination of any other variables. As soon as all of the data are read in, the values for the first type of variables can be established. Then the values for the second type of variables are found by the Gauss-Seidel iteration method. After these two types of endogenous variables are forecast, the third type of variables can be easily determined.

2.4 COMPARISON OF THE WHARTON AND OBE MODELS

General Structure

The viewpoints and opinions of model builders are often reflected in the structure of their models. Therefore, econometric models of an economy may differ in many aspects, according to their builders' definition of exogenous and endogenous, their disaggregation of the economy, their specification of equations, and their estimation of the parameters.

Both the Wharton and the OBE models feature a similar disaggregation of the economy, with macroeconomic activities divided into eight comparable sectors (though the components in each sector may be different). The methods used to estimate the parameters in every stochastic equation are also very similar.

In general, the Wharton model and the OBE model are only slightly different in what they consider exogenous and endogenous. Despite the similarities noted above, the emphasis of these two models is substantially different. The OBE model stresses the government sector, whereas the Wharton model emphasizes the private sector. In the OBE model, government expenditure, which is assumed to be exogenous to the system, is disaggregated into three categories—federal defense expenditures (*GFD$*), federal nondefense expenditures (*GFND$*), and state and local government expenditures (*GSL$*)—in order to separate the impact of different types of government spending. By contrast, the Wharton model has only one variable for total government expenditure, although a government defense expenditure is added in the 1969 model.

The taxes and fiscal balance sector in the OBE model includes sixteen equations, while there are only five equations in the same sector of the Wharton model. On the other hand, the disaggregation of the sectors in the Wharton model follows industrial classification. Investment, labor force, wage bill, gross output, and sales are all divided into manufacturing and nonmanufacturing categories. An industrial orientation can also be detected in the income, price, and employment sectors.

Sector-by-Sector Comparison

Since these two models differ as to components in each sector and as to specifications of equations, it is worthwhile to make a sector-by-sector comparison.

In the consumption sector, the Wharton model has only three components: automobiles (*CA*), other durables (*COD*), and nondurables and services (*CNS*). The OBE model breaks down the last components further into nondurables (*CN*), services (*CS*), and housing consumption (*CH*), where the latter is assumed to be exogenous. Automobile functions are similar in both models. In other durables, the OBE model includes a relative price element, which is omitted in the 1969 Wharton model.

The breakdown in the investment sector is different in the two models. In the Wharton model, which follows the industrial classification, fixed investment and inventory are disaggregated into manufacturing and nonmanufacturing, while fixed investment in the OBE model is divided into residential and nonresidential components, and inventory changes are separated into automobile and nonautomobile. With such differences in breakdowns, there is no way to compare individual equations in this sector. The housing investment function in the OBE model is an identity. Housing investment is determined by new housing starts (*HS*) and its price (*PHS*), while the number of housing starts, in turn, is explained by its own lagged values and interest rates. In the Wharton model, on the other hand, the housing equation is a demand function, where income, relative price, and interest rates are the determinants.

In the foreign trade sector, the OBE model treats exports as totally exogenous, whereas the Wharton model explains total exports by some predetermined variables. On the import side, the OBE model also separates government imports from total imports and considers them exogenous. The imports of services functions are identical in both models, but the specifications of the equation for merchandise imports are quite different.

The price sector in the OBE model is similar to the one in the 1967 version of the Wharton model. The prices are in the form of first differences, and the explanatory variables in the price equations are changes in other prices. On the other hand, the 1969 Wharton model measures all prices in terms of annual rate of change, and the unit labor cost and capacity are the common determinants in all price equations. A major distinction between these two models exists in the procedure of obtaining the GNP price deflator: in the Wharton model, the GNP price deflator is a weighted average of its component prices; in the OBE model, it is determined by a stochastic equation that includes private output, capacity, and the wage bill as explanatory variables. If the price deflator obtained in this way does not coincide with the weighted average of all components, all of the component prices are adjusted.

There are some similarities in the wage rate functions of the two models, with the consumer price index and capacity as the major determinants. However, the wage rate is not broken down into manufacturing and nonmanufacturing categories in the OBE model (as it is in the Wharton model).

The capacity utilization and production sector in the OBE model is more complicated than its counterpart in the Wharton model. Potential private employment and potential private weekly hours are included in the OBE version, but not in its Wharton counterpart. In both models, labor participation equations have the same structure, and the unemployment rate of the primary labor force is determined by a stochastic equation, while the unemployment rate of the total labor force is determined by a residual equation.

The structure of the income sector, however, is quite different in these two models. In the OBE model, all income components are explained by stochastic equations; total income is the sum of all component incomes. The difference between total income so calculated and total product obtained in the GNP sector is the statistical discrepancy. Restrictions are placed on the value of the statistical discrepancy when the model is used for forecasting. The absolute level of the statistical discrepancy must be less than or equal to the larger of 4 billion dollars or $0.00522 \cdot GNP_{-1}$. The change in the statistical discrepancy from the previous period must be no larger than 1 billion dollars. If the calculated value of the statistical discrepancy does not meet these restrictions, its value is changed and the income items are adjusted. Thus, the importance of the income determination equations in this model are severely circumscribed. In the Wharton model, on the other hand, corporate profit is treated as a residual; it is determined by a residual identity that defines corporate profit as the difference between national income and all other income items. National income is the total product minus indirect business taxes, all depreciation, and the statistical discrepancy (*SD*), which is exogenously determined. Therefore, corporate profits actually bear the error of inconsistency between total income and total product.

The tax sectors in the two models differ mainly in size. The more disaggregated breakdown of the OBE model facilitates the introduction of specific tax changes, while calculations outside the model may be required to translate tax changes into changes in the tax equation coefficients for the Wharton model.

The monetary sector shows similar components in both models, but the explanatory variables used in each equation are different. Moreover, the OBE model also includes mortgage yield (*RM*) and household liquid assets (*LH*) as endogenous variables, whereas the Wharton model determines cash flow in the manufacturing sector (*LM*) endogenously.

In the last sector, the OBE model contains only three equations to explain the orders and shipments of manufacturing durables. The Wharton model, on the other hand, has seven equations to explain output, sales, and orders in the manufacturing and nonmanufacturing sectors.