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Price Determination in the Indiana Econometric Model of the U.S.

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Abstract

At the end of 1995 the Bureau of Economic Analysis introduced chain weighted Fisher ideal indexes as the primary measures both for real GDP and its components and for the price data associated with the output measures. In response to these changes macroeconomic modelers were forced to rework the affected sections of their models. This paper describes the accommodation of the Indiana University Econometric Model of the U.S. (Indiana EMUS) to these changes. We briefly describe the overall structure of the Indiana EMUS and outline our overall strategy for dealing with the chain-weighted data. We chose to focus the model on output data stated in terms of chained 1992 dollars, rather than the index numbers themselves. We decided to utilize implicit deflators rather than the chain weighted indexes as our price variables. The main focus of our discussion is the price determination portion of the model, and some of the issues, in that regard, we have confronted in adjusting to the new data regime.

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Prior to 1996, the basic data for real output in the National Income and Product Accounts produced by the Bureau of Economic Analysis (BEA) were constructed by valuing output at the prices of a fixed base year. The BEA referred to the resulting data as “fixed-weight” measures. It was well understood that this procedure introduced significant bias (so-called substitution bias) into the resulting output estimates. To reduce this bias in recent data, the BEA would shift the base year forward every five years. Beginning in the early 1990s they also began experimenting with an alternative procedure using recent prices to estimate growth rates which can then be chained together to produce an index number series for overall output and its components.[1] Beginning in 1996, the Bureau switched to these “chain-weighted” indices as their primary measures of real output. A parallel procedure is used to produce chain-weighted indices of prices for GDP and its components. In response to these changes macroeconomic modelers were forced to rework the affected sections of their models. This paper will describe the accommodation which were implemented for the Indiana University Econometric Model of the U.S. (Indiana EMUS). At Indiana we took the new data regime as an opportunity to make some significant changes in the structure of the model. The main focus of our discussion in this paper will be the price determination portion of the model, and some of the issues, in that regard, we have confronted in adjusting to the new data regime. Prior to that, we will briefly describe the overall structure of the Indiana EMUS (in section 1), and then outline our overall strategy for dealing with the chain-weighted data (in section 2). The price sector is taken up in section 3.

1. The Indiana Econometric Model of the U.S.

The Indiana Econometric Model of the U.S. is a medium scale model of the U.S. economy.[2] The model currently has a total of 217 variables, 162 of them endogenous. These are determined by 59 estimated

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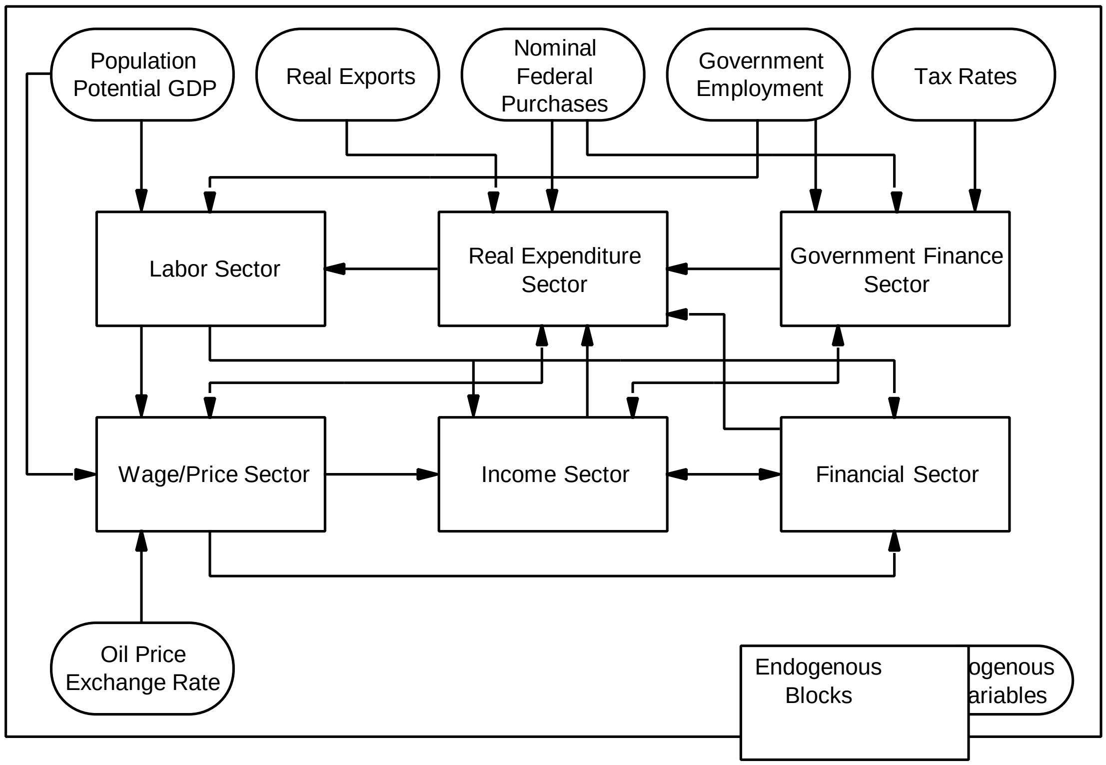
1 Technically, the new numbers are Fisher Ideal indices each calculated as the geometric mean of a Laspeyres index (constrtucted using period ago prices) and a Paasche index (constructed using current period prices). The BEA decided to use annual average prices to construct the Laspeyres and Paasche ingredients, for quarterly as well as annual data. This means that initial quarterly estimates can only be calculated as a Laspeyres number (since full current year price data will not be available). The BEA then adjusts these initial estimates when the data needed to construct the Paasche index is available. The result is that the last several quarterly numbers are a “Laspeyres tail” not a Fisher index.

2 The EMUS was developed by the Indiana University Center for Econometric Model Research (CEMR). It has been used to produce medium-term (2-3 year horizon) forecasts on a quarterly basis since the early 1980s. The Center also produces regular forecasts using a medium size econometric model of the Indiana state economy (the EMI), and a relatively simple model which disaggregates certain state level variables to the sub-state level. Periodically both the EMUS and the EMI models are used to produce long-run projections (20 year horizon). Behavioral equations of the models are estimated, primarily using the RATS econometric package. Equations described later in this paper were estimated using RATS, Version 4. See Doan (1995). Data are obtained from the DRI/McGraw-Hill Basic Economics database. Most forecasts are done using software developed at the Center. Some features of an earlier version of the model are documented in Green et. al. (1991).

Figure 1. Flow chart of the Indiana Econometric Model of the U.S.



behavioral equations and 103 identities. The structure of the model can be broken down into six sectors: equations related to the determination of aggregate expenditures, to the determination of income, to labor market variables, to financial variables, to government finance, and to wage/price levels. The last of these will be taken up in section 3. The others are described briefly below. Figure 1 is a flow chart showing some of the main linkages between sectors of the model. A set of tables in an appendix provide additional detail about the five sectors discussed below.

Expenditure sector. The model has a Keynesian structure with the level of output determined proximately by aggregate expenditures. In the current version of the model, expenditures are disaggregated into 12 categories. Real levels for two of these [inventory change and exports] are treated as exogenous. Federal expenditures (defense and nondefense) are exogenous in nominal terms, with their real levels arrived at using their associated implicit deflator. The equations for the real levels of the others are reasonably standard, reflecting variables from the income side of the model, financial sector variables, relative price variables, and labor market variables. Consumption equations are permanent income type specifications, based adaptively on real disposable personal income. The equations also contain some short-run effects associated with changes in the labor market situation (specifically changes in the unemployment rate), and the real prime rate enters the equation for consumption of durable goods. Business fixed investment in structures and in equipment are modeled as functions of their respective stocks relative to potential output, and of user cost variables. The latter include tax and depreciation effects and are related to the AAA bond rate. Residential investment is linked to housing starts which in turn depend on income, wealth, and interest rates.

Income sector. The income side of the model has 18 behavioral equations for a number of the components of national income, and also for several variables related to the determination of personal income. Other components of these two totals are determined exogenously (for example, rental income and farm proprietors' income) or via identities (for example, employee compensation is given by a wage rate variable times an hours variable). The relationship between GNP and national income is achieved by treating corporate profits as a residual income category.

Labor market sector. The central component of the labor market are behavioral equations for the unemployment rate and the labor force. The former is an Okun's Law relationship in which changes in the unemployment rate are a function of changes in the output gap. The latter models the participation rate as a distributed lag of past levels of unemployment. Given these two values, civilian employment is determined by an identity. Other identities determine related employment and man-hours variables.

Financial sector. The most important element of the model's financial sector is a "reaction function" determining the three month T-bill rate. Changes in payroll employment and in the inflation rate are central independent variables in this equation. Given the links in the model between output and employment, this equation implies Federal Reserve behavior which is qualitatively much like the "Taylor Rule." [See Taylor (1993)] The other two interest rates in the model (the prime rate and the AAA bond rate) are related to the T-bill rate with term structure equations which have an error-correction specification. The sector also contains money demand equations which determine M1 and M2. However, these monetary aggregates play little role in the current specification of the model.

Government finance sector. The NIPA budget of the federal government contains several behavioral equations (for example for transfer payments) and a number of variables which are set exogenously (for example, several tax rate variables, the levels of nominal federal defense and nondefense purchases, and the level of federal investment expenditures). These interact with variables determined elsewhere in the model to determine components of the budget. The state and local NIPA budget situation is similar, but the proportion determined endogenously is higher.

2. Strategy for the New Data Regime

Faced with an inevitable need to rework major portions of the Indiana EMUS model to accommodate the switch to chain-weighted output, we decided to use the opportunity to rethink the basic structure of the model. In doing so we came to the conclusion that in several regards the model was more complex than was needed for our purposes. Aggregate expenditures, for instance, were disaggregated into 27 basic categories which were added to form broader components and ultimately GDP. Many of these subcomponents were of little intrinsic interest to us. Further, it was not at all clear that we could get better estimates of the more important broader aggregates by building them up from individual estimates of their components than we could achieve by estimating equations for the broader aggregates directly.[3] In addition, with the chain-weighted indexes, each level of aggregation would introduce an adding up residual into the model.

Our eventual response to these issues was to significantly reduce the level of detail regarding aggregate expenditures.[4] As mentioned earlier there are now only 12 basic components. These are aggregated into 5 broader aggregates, each with an associated residual.[5] Equations for the 8 basic components which are endogenous are estimated using data expressed in terms of chained 1992 dollars. In general, we have found that these series can be modeled much as could the earlier fixed-weight data series. The aggregation residuals are modeled as simple AR processes with order 4 or lower.

In dealing with prices and nominal expenditures we adhered to the KISS principle. To begin with, we felt that the *real x price = nominal* identity has a basic intuitive appeal. The most direct way to achieve this is to work with prices in the form of implicit price deflators.[6] This approach also has the advantage of familiarity. As will be discussed in more detail in the following section, we model the implicit deflators for most of our basic expenditure components using behavioral equations.[7] The various nominal components of expenditures are then derived via the real x price identity.[8] Broader nominal aggregates

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[3] This is an issue which we regard as an open question for our model. We do have an extensive history of our forecasting performance using the old structure, and we are now accumulating experience with the current version of the model.

[4] The model was downsized in other ways, as well. In all, it lost over one hundred variables.

[5] The five broader aggregates are personal consumption expenditures, federal government purchases, total government purchases, final sales, and GDP.

[6] In principle, of course, the chain-type price indexes also satisfy the real-nominal identity.

[7] The exception is the import price deflator which we treat as exogenous.

[8] Nominal inventory change is estimated directly.

are calculated by adding up identities. Price deflators for the broader aggregates (including the GDP deflator) come from nominal/real identities.

The choice between implicit deflators and the chain-weighted price indexes raises some interesting issues. In general, the pairs of price series for a given aggregate track each other closely. Figure 2 shows the percentage differences between nine pairs associated with major GDP components. There is little discernible pattern to the deviations, which are neither persistent nor large.[9]

3. Price Determination in the Indiana EMUS Model

The price sector of the model has become simpler over time. Until recently the heart of the sector was a Phillips curve type equation which determined a wage rate variable. The implied unit labor costs then fed into an equation for the behavior of the deflator for private sector output (designated PXPD). This price variable was a primary determinant of the deflators for the subcomponents of expenditures. In the current version of the model, PXPD is determined directly by a Phillips curve equation. It then plays a role in subcomponent deflator equations. In what follows we first discuss the PXPD equation more fully, and then comment on the subcomponent deflator specifications.

Basic price equation. The current form of the PXPD equation has the basic form:

$$\Delta \ln PXPD_t = f\left(X_{t-j}\right) + \sum b_i \Delta \ln PXPD_{t-1-i}$$

where X represents aggregate demand and supply shock variables.[10] In the version of the equation discussed here, these include the unemployment rate, a GDP gap variable, and dummy variables for the Nixon price controls. The distributed lag on past inflation has four lags using quarterly data. If estimated unconstrained, the coefficients in this lag structure (the β_i) sum to less than one. In this case, the equation implies a steady state tradeoff between inflation and unemployment. In a typical estimation,[11] the price level would be stable at a maintained unemployment rate somewhat above 6%. If the unemployment rate

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9 At times we have noticed some more significant divergence in the final few observation for some series (especially the three pairs down the right side of Figure 2), with the deflator lower that the chain index. These data points comprise the extreme end of the "Laspeyres tail" of the chain-weighted series. For such quarters the chain indexes are calculated using only previous year weights. If this tail problem results in an upward bias to both a chain-weighted price index and the corresponding chain-weighted quantity index, it would produce the pattern observed. Eventually, of course, as the data becomes available to calculate the Fisher index number, any tail problem will be revised away. Further, the problem is not present in the most recent data (shown in Figure 2). Even so, it suggests that care should be exercised in interpreting the final few observations in the chain-weighted series.

10 This specification is a version of what Robert Gordon has dubbed the "triangle" model since it contains three determinants of inflation: inertia, supply variables, and demand variables. See Gordon (1997).

11 The model is reestimated on a quarterly basis, so there is no definitive version of its equations.

Table 1.

Unemployment Rate	Initial Inflation Rate	Inflation After 1 Year	Inflation After 2 Year	Inflation After 5 Year
4.5%	2.0%	3.9%	5.6%	10.6%
5.0%	2.0%	3.1%	4.0%	6.8%
5.75%	2.0%	2.0%	2.0%	2.1%
6.5%	8.0%	7.0%	6.2%	3.8%
7.5%	8.0%	5.9%	4.0%	–1.2%
8.5%	8.0%	4.8%	2.1%	–5.5%

Note: These simulations assume that the unemployment rate is held constant at the rate shown in the first column, starting with the inflation rate stable at the rate in the second column. The GDP gap is calibrated to rise by 2.5% for each 1% fall in unemployment. This calibration is based on the coefficients from an Okun's Law equation in the model.

were held at 4.5%, inflation would eventually reach over 16%, but the convergence to that level would be quite slow. Starting from a stable rate of 2%, inflation would reach just over 4% after a year, and 6% after 9 quarters.

On theoretical grounds, we feel more comfortable with a specification in which there is no long-run tradeoff.[12] This requires that the lag distribution coefficients sum to unity. In this case, the price equation has a NAIRU. If unemployment is maintained below the NAIRU, inflation will rise without limit, and conversely. A typical estimation using data since 1970 gives a NAIRU of about 5.75%.[13] Although this is similar to many estimates in the literature, recent experience suggests it may be too high. On the other hand, the equation implies that for unemployment rates within ±1% of NAIRU the acceleration/deceleration of inflation will be relatively slow. Table 1 gives several examples. The first three rows illustrate the effects of a sustained stimulus beginning with inflation at 2%. The second row, for instance, shows that if unemployment were held at 5%, the inflation rate would rise by a little over 1% after one year and about twice that after two years.[14] The last three rows show the degree of disinflation

12 This opinion, which not long ago would have been non-controversial, is currently being challenged. See Akerlof, Dickens, and Perry (1996), Fair (1996), Eisner (1997), and Galbraith (1997).

13 Actually, since the equation also contains a GDP gap variable, the implied value of NAIRU depends on the relationship between the unemployment rate and the GDP gap. The examples in Table 1 are based on a calibration which assumes that the economy was operating at potential in 1995. Estimates of NAIRU like this one are subject to significant statistical uncertainty. See Staiger, Stock, and Watson (1996, 1997a, 1997b).

14 Estimates by others indicate even less responsiveness. Stiglitz (1997) reports that equations estimated at the CEA find that unemployment one percentage point below NAIRU will raise inflation by only 0.3 to 0.6 of a percent after one year.

from different degrees of slack starting with inflation at 8%. The perhaps surprising negative values in the last column are the result of holding the unemployment rate at 8.5% for five straight years. Nothing like that has been experienced since the depression, of course.[15]

For short-run forecasting purposes, the difference between the equation in constrained and unconstrained form is quite small. With an unemployment rate of 4.5%, for example, the unconstrained equation gives inflation of 4.1% after one year (compared with the 3.9% shown in Table 1 for the constrained NAIRU model). After two years the rate is 5.6% for both equations; at five years the unconstrained model inflation is at 9.1% (versus 10.6%).

Subcomponent deflators. The deflators for the base-level components of aggregate expenditures are modeled with behavioral equations of the general form:

$$D\,ln\,P_t = f\left(X_{t-j}\right) + \sum b_i D\,ln\,P_{t-1-i} + \sum d_i D\,ln\,PXPD_{t-i}$$

where P is a component deflator and X represents aggregate demand and supply variables. The presence of PXPD terms in these equations means that the component variables are basically being estimated relative to this overall price measure.

Figure 3 shows the ratio of nine subcomponent deflators to the GDP deflator.[16] There is very substantial variation in the patterns of these relative price measures. Several show a pattern of secular decline, in particular those associated with goods production [consumer durable and nondurable goods (PCD and PCN), business investment in equipment (PIFNE), and exports (PEX)]. Others are generally increasing [consumer services (PCS) and the government sector deflators (PGVPF and PGVPS)]. Some show signs of cyclical effects [PCN, PEX, and residential investment (PIFR)]. PCN has sharp spikes at about the times of major oil price increases, while PEX increases dramatically during the period of dollar depreciation following the collapse of the Bretton Woods system. Table 2 summarizes X variables which enter our component deflator equations in an economically significant way. A few equations contain variables not shown in table 2, but these generally play little role when the model is used for forecasting (for example, dummy variables used to handle idiosyncratic events in the data).

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15 These are, of course, a partial equilibrium results. In any macro model, including ours, a change in inflation will produce feedback effects on output and employment. In our model these will include a significant move in interest rates from a Federal Reserve reaction function. If inflation rises significantly, the feedback effects will push unemployment up. A more sophisticated procedure for examining the employment-inflation tradeoff would be to apply a sustained shock to unemployment from a tracking solution of a model. Experiments along these lines are being undertaken by Michael Donihue.

16 The patterns relative to the PXPD measure are virtually identical.

Table 2.

Equation [1]	Independent Variables [2] Unemployment	Oil Price	Wage Rate	Exchange Rate	Trend Effect [3]
PCD		X			X
PCN	X	X			X
PCS		X	X		
PIFNE					X
PIFNS		X			
PIFR	X				
PEX	X	X	X	X	X
PGVPFO	X	X	X		
PGVPFD			X		
PGVPS	X	X	X		X

Notes: 1. PCD - consumer durable goods; PCN - consumer nondurable goods; PCS - consumer services; PIFNE - fixed investment in equipment; PIFNS - fixed investment in structures; PIFR - residential investment; PEX - exports of goods and services; PGVPFO - federal government nondefense purchases; PGVPFD - federal government defense purchases; PGVPS - state and local government purchases

2. All equations also contain an overall price level variable and lagged terms of the dependent variable. The independent variables shown enter in transformed fashion.

3. Since equations are estimated in log difference form, a trend effect is produced by a significant constant in the equation.

4. Conclusion

Our experience to date using the chain-weighted data suggest several tentative conclusions. First, and perhaps most important, the basic relationships in an empirical macro model do not seem to be drastically altered in the new data as compared to the old. In principle this is not surprising, since the new data should be a better approximation of the underlying reality, but it is comforting to find it holds in practice. Second, the need to deal with the aggregation residuals which arise from the chain-weighting procedure is a rationale for working at higher levels of aggregation. Third, the Laspeyres tail in the chain-weighted data may pose some forecasting problems. One issue presented by the tail is whether to use tail observations when estimating behavioral equations. Our current answer is yes, but with attention to the residuals for those observations. Another problem involves the appropriate standard for evaluating forecast accuracy. Models like ours will forecast Fisher numbers, but initially the actual data will be

Laspeyres. Fourth, and finally, it is still too early for us to adequately evaluate our overall ability to forecast using the chain-weighted data. We now have five quarterly forecasts for which we can evaluate the accuracy of year ahead results. Based on this period, the verdict is mixed at best. Our forecasts of real GDP growth have been systematically too low, by an average of close to 1.5%. Those for the change in the GDP deflator have been too high by an average of 0.4%. Over seven quarters our one quarter ahead forecast errors have been similar. The period in question was, of course, characterized by real growth much above the norm of the past twenty years, and by inflation well below the norm (especially given the rate of growth).

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Table A1. Expenditure Sector

Item	Label	Type[a]	Units
Consumption			
Personal consumption expenditures[b]	C92	I	Billions of chained 1992 $
Durable goods	CD92	B	Billions of chained 1992 $
Nondurable goods	CN92	B	Billions of chained 1992 $
Services	CS92	B	Billions of chained 1992 $
Investment			
Nonresidential structures	IFNS92	B	Billions of chained 1992 $
Producers durable equipment	IFNE92	B	Billions of chained 1992 $
Residential	IFR92	B	Billions of chained 1992 $
Change in business inventories	IBIT92	X	Billions of chained 1992 $
International trade			
Net exports	NEX92	I	Billions of chained 1992 $
Exports	EX92	X	Billions of chained 1992 $
Imports	IM92	B	Billions of chained 1992 $
Government			
Total consumption and gross investment[b]	GVP92	I	Billions of chained 1992 $
Federal purchases[b]	GVPF92	I	Billions of chained 1992 $
National defense	GVPFD92	I	Billions of chained 1992 $
Nondefense	GVPFO92	I	Billions of chained 1992 $
State and local purchases	GVPS92	B	Billions of chained 1992 $
Aggregates			
Gross domestic product[b]	GDP92	I	Billions of chained 1992 $
Final sales[b]	FS92	I	Billions of chained 1992 $

Notes: a. Variable types: B - behavior; X - exogenous; I - identity.

b. Aggregate identities include aggregation residuals which are modeled as autoregressions.

Table A2. Income Sector

Item	Label	Type[a]	Units
National income			
Compensation of employees	WSC	I	Billions of current $
Wages/salaries - government	WSCO	I	Billions of current $
Wages/salaries - other	WSCO	I	Billions of current $
Supplements	SUPT	I	Billions of current $
Employer social ins. contributions	CSIB	I	Billions of current $
Other labor income	OLI	B	Billions of current $
Proprietors’ income	YPROT	I	Billions of current $
Farm	YPROF	X	Billions of current $
Nonfarm	YPRON	B	Billions of current $
Rental income	YRENT	X	Billions of current $
Corporate profits with IVA and CCCAD	CPNIA	I	Billions of current $
Profits before tax	CPBT	I	Billions of current $
Corporate taxes	TCPT	I	Billions of current $
Profits after tax	CPAT	I	Billions of current $
Dividends	YDIV	B	Billions of current $
Undistributed profits	CPU	I	Billions of current $
Inventory valuation adjustment	IVA	X	Billions of current $
Capital consumption adjustment	CCCAD	B	Billions of current $
Net interest	YINT	B	Billions of current $

Notes: a. Variable types: B - behavior; X - exogenous; I - identity.

Table A3. Labor Market Sector

Item	Label	Type[a]	Units
Population			
Total population	N	X	Millions of persons
Age 16 population	N16	X	Millions of persons
Household survey			
Labor force	LFC	B	Millions of persons
Unemployment rate	NRUT	B	Percent
Employment	EHH	I	Millions of persons
Unemployment	UHH	I	Millions of persons
Establishment survey			
Employment	EET	I	Millions of persons
Government employment[b]	EEG	X	Millions of persons
Hours			
Average hours	AHPN	X	Hours per week
Private hours	MHP	I	Billions of hours per year
Government hours[b]	MHG	I	Billions of hours per year

Notes: a. Variable types: B - behavior; X - exogenous; I - identity.

b. Government variables are also disaggregated into federal and state/local components.

Table A4. Financial Sector

Item	Label	Type[a]	Units
Interest rates			
Three month T-bill rate	RTB3M	B	Percent
AAA bond rate	RAAA	B	Percent
Prime rate	RPRIME	B	Percent
Monetary aggregates			
M1	M1	B	Billions of current $
Other M2	NM1	B	Billions of current $
M2	M2	I	Billions of current $

Notes: a. Variable types: B - behavior; X - exogenous; I - identity.

Table A5. Government Finance Sector[b]

Item	Label	Type[a]	Units
Federal government			
Total receipts	GVRF	I	Billions of current $
Personal tax/nontax	TPF	I	Billions of current $
Corporate profit tax	TCF	B	Billions of current $
Indirect business tax/nontax	IBTF	X	Billions of current $
Contributions for social insurance	CSIF	B	Billions of current $
Current expenditures	GVEF	I	Billions of current $
Consumption expenditures	GVCF	I	Billions of current $
Net transfer payments	TRF	B	Billions of current $
Grants to state/local governments	GRANTF	X	Billions of current $
Net interest	FNI	B	Billions of current $
Current surplus	SURPF	I	Billions of current $
Investment expenditures	GVIF	X	Billions of current $

Notes: a. Variable types: B - behavior; X - exogenous; I - identity.

b. A few minor components (all exogenous) are omitted from this listing -- subsidies less current surpluses of government enterprises, dividends received, wage accruals less disbursements.