AN ECONOMETRIC MODEL OF THE
CHICAGO STANDARD METROPOLITAN STATISTICAL AREA

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
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By

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* * * * *

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Bez pracy nie ma kolaczy

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INTRODUCTION

This study develops an annual econometric model for the Chicago Standard Metropolitan Statistical Area (SMSA). This area includes Cook, DuPage, Kane, Lake, McHenry, and Will counties in Illinois.

Income and product are major variables in this study. These refer to the well-being of people. Thus, the principal which was used in selecting the region is that of grouping people together whose income is jointly determined. That the SMSA is the appropriate region is obvious from its very definition. An SMSA is an urban place consisting of a central city of at least 100,000 persons and the counties surrounding it whose activity is closely linked to that central city.

For purposes of this study all economic activity within the Chicago SMSA is assumed to occur at a point. There is no analysis of the spatial distribution of economic activity within the region. The only spatial distinction made is between activity inside and activity outside the boundary of the region.

Since the major focus is upon industrial activity and employment, some parts of the model are not treated in as much detail as others. But, then this study is designed to be the first step in an ongoing process.

The flows among the major variables of the Chicago Econometric Model are illustrated in Figure 1. It can be seen, that income, employment, and output are major variables.

The plan of this study is as follows. Chapter I reviews several econometric models which have been constructed for SMSA's. Chapter II develops the concept of Gross Metropolitan Product (GMP). Estimates of GMP are also presented there. Chapter III presents the theoretical structure of the Chicago Econometric Model as well as the empirical specification of the equations. Chapter IV deals with the estimation of the model. There the causal ordering of the system is used to determine the underlying block-recursive nature of the system. This aids in the discussion of the identification of the system and its estimation. Then the structural estimates are presented. Finally, Chapter V presents tests of the model's accuracy.

CHAPTER I

A BRIEF REVIEW OF THE LITERATURE

Introduction

There has been a growing interest in the construction of regional econometric models in recent years. This reflects a greater concern with the disaggregation of gross national economic components. These regional studies add a geographic dimension to the national income accounting system.

Many of the models that have been constructed use the state as the basic geographic unit. Yet, there is little discussion of the appropriateness of the state as the proper geographic unit for study. Few models have been constructed for regions smaller than a state.¹ But, these smaller regions, consisting of cities, counties, and Standard Metropolitan Statistical Areas (SMSA's), are the geographic units most often studied by economists. As a result, this study examines a metropolitan economy, the Chicago SMSA, and its relations with the national economy.

To date only three studies of a similar nature have been attempted. These include: Glickman's model of Philadelphia (74) (76), in its several versions; Hall and

Licari's model of Los Angeles (96); Loxley's model of Cleveland (152); and Engle's model of Boston (53). A brief review of each is presented in this Chapter.

The Philadelphia Model

The first model developed for a region as small as an SMSA was Glickman's model of Philadelphia (74). This model has grown through four versions. Here the original version is presented.

The Philadelphia model consists of 26 equations and is estimated for the period 1949 - 1966. The 26 equations in the model are divided into two blocks. Block 1 includes all those equations relating to the private sector. And, block 2 consists of two equations explaining local government revenues and expenditures. Of the 26 equations, 17 are stochastic and 9 are identities.

The model is divided into 4 sectors: 1) manufacturing, 2) wholesale and retail trade and selected services, 3) all other private business, and 4) local government. The major variables determined are output, employment, and wages in each sector. In addition, gross regional product, personal income, the consumer price index, and population are determined.

Gross regional product is taken to be the sum of output of the three private sectors. Thus, local government is treated as not contributing to regional product.

Neither are local government payments to workers counted as part of personal income.

Output in manufacturing is a function solely of U. S. gross national product. And, output in the 'local' industries depends only on personal income. There is no attempt to calculate disposable income.

U. S. gross national product (GNP) drives the model. Increases in GNP cause increases in manufacturing output. These in turn lead to increases in personal income and manufacturing output. Employment in each sector depends on output. Finally, money and real wages are determined. Glickman asserts 'that in order to keep laborers from migrating to higher wage areas, competitive wages must be paid by local firms; thus local wages should vary directly with their national counterparts and inversely with the proxy for labor market conditions, the number of unemployed.'²

The consumer price index is a function of average unit labor costs and total employment. Inclusion of the second term is justified on the ground that it is a good proxy for phases in the region's business cycle. But, this seems to be inconsistent with an earlier note stating that tests of the "Phillips' hypothesis" caused it to be rejected.

Engle (47) points out that the Glickman model leads to conclusions contrary to standard economic theory. He notes

that the effects of an increase in the labor force are an increase in unemployment and a decrease in the wage rate. This is followed by a drop in local demand and more unemployment and lower wages and on and on. He asserts that this paradox occurs as a result of the lack of an output supply function.

Glickman estimates the equations of the model using two-stage least squares except for those equations which are solely a function of exogenous variables. These equations are estimated using ordinary least squares.

Given the estimates of the coefficients, the model 'simulated' the workings of the Philadelphia economy for the years 1950 - 1966. That is, the values of all the endogenous variables for each year in the 1950 - 1966 period were calculated. Then, the calculated and actual values for each variable were compared by computing the mean absolute percent error (MAPE).³ Of the 23 values calculated, 21 are smaller than 10 percent, 12 are below 5 percent, and 9 are less than 3.5 percent.

The Los Angeles Model

Glickman asserts that his model is intended to be a general prototype for small area econometric models. Hall and Licari (96) use this prototype in estimating a model of the Los Angeles area. They alter the model slightly to allow feedback from the government sector to the private

sector. In Glickman's original model local government's activity was affected by flows from the private sector, specifically, personal income. But, local government's activities in no way affected the private sector.

Hall and Licari expand the government sector to include explanations of government employment and the wage level in this sector. The flow of the Los Angeles model is essentially the same as that of the Philadelphia model, with U. S. gross national product being the prime exogenous variable.

Here the mean absolute percent error was computed for each endogenous variable. Only selected values were presented. They state that the average MAPE value was approximately one to two percent.

Back to Philadelphia

As was mentioned above, the Philadelphia model has undergone quite a metamorphosis since its inception. The most recent version, published in book form (76), is reviewed here.

The Philadelphia model now consists of 228 equations. It predicts nineteen classes of output and employment as well as wages, income, retail sales, and several other important regional variables. Among the latter are gross regional product, personal income, and the number of unemployed. Of the 228 equations, 105 are stochastic. The

model takes as exogenous 30 variables from the U. S. economy as well as 17 regional exogenous variables and 44 lagged endogenous variables for a 1947 - 1971 sample period.

The model emphasizes the importance of the City of Philadelphia by specifying a separate submodel. In addition, a suburban submodel is calculated. Together the two models also generate values for the entire Philadelphia SMSA.

The model is designed to be "plugged in" to the Wharton Annual and Industry Forecasting Model taking as exogenous many of the latter's national forecasts. The dynamics of the Philadelphia model are such that forecasts derived from the national model can be translated into regional forecasts.

The most distressing thing about the Philadelphia model is a lack of any explanation of the theory underlying the equations. For example, the very first stochastic equation presented shows output in the printing and publishing industry to be a function of the region's population and lagged output in the printing and publishing industry. Is this a supply relation, a demand relation, or some sort of reduced form equation? And so it goes. Nowhere is the theoretical basis for the relations presented. In some cases the equations presented are

confusing if not contrary to intuition and established theory. For example, Glickman uses input-output relationships in many of his output equations. He takes the current output of textiles to be a determinant of apparel output; last year's output of primary metals enters the fabricated metals equation; fabricated metal's output is a determinant of electrical machinery output; and non-electrical machinery output is an argument in the transportation equipment equation. These equations appear to be supply equations. But, can such specifications be correct? In addition these same relations are included in the employment equations.

Glickman tests the accuracy of the model via calculated MAPE statistics and simulations. He also conducts several forecasts and performs several policy-analytic simulation experiments. His tests show that the model performs quite well.

The biggest objection to the Philadelphia model is the lack of an explicit structure for the model. A clear statement of the theory behind each equation would serve to clarify what can now, at best, be called confusing relations.

The Cleveland Model

Extensive use of input-output techniques appears in the Cleveland model by Loxley (152). This model has a

number of special features. Loxley developed a table of intermediate flows for Cleveland manufacturing and used the information of the industrial interrelationships of the region to better specify the output equations. Thus, fabricated metals output was taken as depending in part on local automobile production, since the latter was a major consumer of regional fabricated metals. Secondly, the model is quarterly in order to better catch business cycle movements. Since output data on a quarterly basis are not available, the model shortcuts by using manhours directly as an output measure. The dynamics of the model are quite rich, including lags in the capital goods industry of up to 16 quarters for user costs of capital.

The Boston Model

Engle et al. (52) have sketched the outline of a model for the Boston Metropolitan Area. Their proposal was to build a model which contained three major parts: a macroeconomic non-spatial model of output, employment, and income distribution; a model of long-term adjustments of population and capital stocks; and a model of spatial allocation. The paper sketches out the authors' thinking about how to construct such a model. They leave many specification questions unanswered. Unfortunately, the entire Boston model has yet to be completed, although parts of it do exist. Specifically, Engle (53) has completed

the first major part of the model - the macroeconomic non-spatial model of output, employment, and income distribution.

Engle's paper departs in one significant way from the previous works reviewed here. He makes a determined effort to ground each relationship in the model in solid economic theory. As a result, his model looks rather different than some of the existing alternative econometric models of small areas.

As an example, in the manufacturing sector Engle begins with a demand function. He adds to this a Cobb-Douglas production function and derives the demand for labor by setting the marginal value product equal to the wage rate. Under the assumption of a fixed capital stock he is able to solve for the quantity of labor employed as a function of other 'observable' variables. Reduced form equations such as this form the basis of the model.

Engle's model is also distinctive since he recognizes that some of what have traditionally been called local products can be exported. Specifically, he allows the 'products' of the finance, insurance, and real estate sector as well as those of the business sector to be exported.

Summary

The regional models reviewed above represent the current state of the art. These models have several common characteristics. Regional econometric models are satellite models driven by the movement of national aggregates. The direction of causation is one way - from the national economy to the regional economy. These models focus upon output, employment, wages, and personal income determination. In many cases the export base concept is used. Thus, industries that sell to national markets are driven by national variables. These industries compete with similar industries in other regions. The principal feedback loop in the models involves production, employment, and income generated in the export base industries. These industries in turn drive the activity of the locally oriented industries.

Often the central identity of these models is the so called 'third method' of computing regional product as the sum of gross products originating.

Although the regional models are simultaneous, the pervading influence of national economic variables tends to cause these models to have a largely recursive structure.

The coefficients in the models' behavioral equations are often estimated by ordinary least squares, even though the use of a simultaneous equation estimator is more

appropriate. This is usually due to a lack of observations and is typically justified by citing the 'robustness' of ordinary least squares estimates.

Of all the models described here Engle's appears to be the most promising. It is an attempt to formulate a macroeconomic model with what Fair (58) has called microeconomic foundations. It is this approach that is used in the present study. To the extent possible the basic underlying theory for each equation is presented. The structural form of the equations are deduced. Then the system is estimated.

The Chicago Econometric Model has many of the characteristics cited above which are common to regional models. But, in some ways it is much different than what has come before. This study was undertaken with the idea of 'improving' upon previous efforts. By no means are all of the problems associated with building small region models solved. With that caveat, the presentation of the model begins with Chapter II describing the estimation of Gross Metropolitan Product.

FOOTNOTES TO CHAPTER 1

1. See L'Esperance et al. (141), Bell (10), Green(80), and Moody and Puffer (168), for example.
2. See Glickman (74), p. 18.
3. The Mean Absolute Percent Error for a given variable, y, is equal to

$$\frac{\sum_{i=1}^N |y_i^p - y_i^a| / y_i^a}{N} \cdot 100$$

where y_i^a = the actual value of the endogenous variable

y_i^p = the predicted value of the endogenous
variable

N = the number of observations

CHAPTER II

THE CONCEPT AND ESTIMATION OF CHICAGO GROSS METROPOLITAN PRODUCT

Introduction

Since their inception in the early 1930's, the national income accounts have proven a useful measure of economic activity within the United States. Although a flurry of articles (See Leven (147)(149), Hochwald et al.(109), and Hirsch et al. (106), (for example.) and conferences in the early 1960's advocated the establishment of a similar system of regional income accounts, no system has yet been established. The only major economic series which has been available for all states on a consistent basis has been personal income by major components. Recently, the Department of Commerce revised this series and began reporting income received by major industry division. This latter series is now also available for selected years since 1929 for Standard Metropolitan Statistical Areas.

Personal income estimates do measure the income of the largest economic sector, households, but households are only a part of the economy. The activities of the remainder of the economy do not always follow the movements of personal income. This can be seen by examining Table 1

TABLE 1
UNITED STATES GROSS NATIONAL PRODUCT (GNP)
AND PERSONAL INCOME (PI)
(Billions of dollars)

YEAR	GNP	%ΔGNP	PI	%ΔPI
1954	366.3		288.2	
1955	399.3	9.00	308.8	7.15
1956	420.7	5.36	330.9	7.16
1957	442.8	5.25	349.3	5.56
1958	448.9	1.38	359.3	2.86
1959	486.5	6.10	382.1	6.35
1960	506.0	8.38	399.7	4.61
1961	523.3	3.42	415.0	3.83
1962	563.8	7.56	440.7	6.19
1963	594.7	5.48	463.1	5.08
1964	635.7	6.89	495.7	7.04
1965	688.1	8.24	537.0	8.33
1966	753.0	9.43	584.9	8.92
1967	796.3	5.75	626.6	7.13
1968	868.5	9.07	685.2	9.35
1969	935.5	7.71	745.8	8.84
1970	982.4	5.01	801.3	7.44
1971	1063.4	8.25	859.1	7.21
1972	1171.1	10.13	942.5	9.71
1973	1306.6	11.57	1052.4	11.66
1974	1412.9	8.14	1154.9	9.74
1975	1528.8	8.20	1253.4	8.53
1976	1706.5	11.62	1382.7	10.32
1977	1890.4	10.78	1536.1	11.09

SOURCE: Economic Report of the President -
January 1978

which presents figures for personal income and GNP in the U. S. It is gross product which reflects the net result of all economic activity in an area. Thus, gross product will be one of the major variables to be examined in the Chicago Econometric Model.

This chapter is concerned with the estimation of Gross Metropolitan Product (GMP) by industry for the Chicago SMSA. Two alternate methods for estimating GMP will be presented and examined. First, GMP will be derived from the estimates of the Gross State Product of Illinois derived in this chapter. Second, GMP for the Chicago SMSA is derived directly from the series on GNP by industry. The estimates are compared and then combined to yield a continuous series for GMP for the period 1954 to 1975. These industry estimates of GMP will serve as endogenous variables in the Chicago Econometric Model.

The Concept of Gross Metropolitan Product

The following discussion is couched in terms of Gross Metropolitan Product (GMP), but it also applies exactly for estimates of Gross State Product (GSP).

Gross Metropolitan Product is defined as the value of all goods and service produced within the region during a given year. The definition of GMP used here is analogous to the concept of Gross Domestic Product used in the

national accounts series.¹

Conceptually, GMP can be estimated from any one of three approaches. The income generated by the production process in a region may be summed to yield GMP. Or, the expenditures for the purchase of that product may be summed. And finally, the value-added by each industry in the region may be summed to yield an estimate of GMP. Each of these three methods of estimating GMP will yield an equivalent measure.

The first attempt to estimate gross product for a region smaller than the nation was that of Kendrick and Jaycox (126). They set out a method for estimating Gross State Product (GSP) using published data on income received. These data can be "blown-up" to yield gross product by industry. Since the publication of their estimates, several modifications to their estimating method have been suggested by L'Esperance et al. (141), L'Esperance and Fromm (143), and Neimi (181). Other estimation methods have been outlined by Romans (194) and Polenske et al. (189).

Which of these methods yields the "best" estimate is difficult to ascertain. L'Esperance et al. (145) make comparisons among these three general approaches to estimating GSP. They conclude that if a time series is desired, then the Kendrick-Jaycox method, in its original or modified form, has a distinct advantage over the Polenske method. The Kendrick-Jaycox uses existing time series data

consistently reported for all states, whereas the Polenske method uses extensive expenditure series which are only intermittently reported. In comparing Roman's method and the Kendrick-Jaycox method, they find little difference in the estimates. This is attributed to the reliance of both methods upon the use of federally collected data on wages and salaries.

The Kendrick-Jaycox method is used here to estimate GSP for the State of Illinois. This method was chosen since data to implement it were readily available. The application of the method is explained in the next section.

The Estimation of the Gross State Product of Illinois

The estimation of Gross State Product (GSP) for Illinois is presented here, since it will be used to "fill-in" missing observations in the Gross Metropolitan Product (GMP) series for the Chicago SMSA. The estimate of GSP will also be used for comparison purposes.

The estimation of GSP is conducted on the following component breakdown:

- Government
- Farm
- Private Nonfarm
 - Mining
 - Construction
 - Manufacturing
 - Trade
 - Finance, Insurance, and Real Estate
 - Transportation, Communication, and Public Utilities
 - Services
 - Other

Gross product originating is estimated separately for each of the major industry categories.

For lack of a better measure, gross government product is defined, consistent with convention, as the compensation of general government employees. This includes wages and salaries plus supplements. The latter item is unavailable. It was estimated by multiplying the ratio of national income originating in government, which includes supplements, to national wages and salaries in government by wages and salaries paid to government employees within the State of Illinois. That is

$$GGP_S = (YO/WS)_N \cdot WS_S = WS_S + S_S \quad (1)$$

where GGP_S = Gross State Product originating in government for Illinois.

$(YO/WS)_N$ = the ratio of income originating to wages and salaries paid government employees in the nation.

WS_S = wages and salaries paid government employees in the state.

S_S = supplements received by general government employees in the state.

Gross government product is, then, the sum of wages and salaries and supplements.

Gross farm product can be computed entirely from data published by the United States Department of Agriculture.

The annual supplement to the July issue of the Farm Income Situation contains all the data needed. Table 2 presents the computation of gross farm product for 1970.

For each industry in the private nonfarm sector the following procedure is followed. A series of national scaling coefficients is applied to the available state data.

The foundation for the GSP estimates for the private nonfarm industries is income received by persons for participating in current production. Income received is defined to include wage and salary disbursements, other labor income, and proprietors' income. In contrast to personal income, it does not include transfer payments, rental income, interest, and dividends.

The procedure for a given industry can be illustrated as follows:

$$GSP_{it} = GNP_{it} \cdot YR_{its} / YR_{itn} \quad (2)$$

where GSP_{it} = Gross State Product in industry i during year t.

GNP_{it} = Gross National Product in industry i during year t.

YR_{its} = Income Received in industry i during year t in the state.

YR_{itn} = Income Received in industry i during year t in the nation.

Gross State Product is now obtained by summing the product originating figures for the various industries in

TABLE 2

CALCULATION OF GROSS FARM PRODUCT ILLINOIS - 1970

(Millions of Dollars)

<u>Value of Total Farm Output:</u>		
1. Cash Receipts from Marketings	2804.1	
2. Value of Home Consumption	23.2	
3. Gross Rental Value of Dwellings	141.7	
4. Less: Net Rent to Nonfarm Landlords	194.4	
5. Net Change in Inventories	180.5	
6. Total (1 + 2 + 3 + 4 + 5)		<u>3343.9</u>
<u>Intermediate Production Expenses:</u>		
7. Feed	275.1	
8. Livestock	186.1	
9. Seed	68.1	
10. Fertilizer	183.6	
11. Repair and Operation of Equipment	298.9	
12. Miscellaneous Operating Expenses	236.9	
13. Total Current Expense (7 + 8 + 9 + 10 + 11 + 12)		<u>1248.7</u>
GROSS FARM PRODUCT (6 - 13)		2095.2

Source: Farm Income State Estimates A Supplement to the July Farm Income Situation / August, USDA - Economic Research Service.

the state for a given year. The estimates are presented in Table 3.

The estimates presented in Table 3 assume that within given nonfarm industries, factor proportions (output/labor ratios) are similar in the nation and the state. The estimate of GSP can be modified to account for possible differences in factor proportions. Unfortunately, the adjustment can only be made for manufacturing, since it is the only industry for which value-added data is available. The adjustment procedure is as follows:

$$GSP'_{mt} = GSP_{mt} \cdot \frac{(VA/P)_s}{(VA/P)_n} \quad (3)$$

where GSP'_{mt} = the adjusted estimate of Gross State Product in manufacturing.

GSP_{mt} = the estimate of gross state product in manufacturing obtained from equation (2).

$(VA/P)_s$ = the ratio of value-added to payroll in the state in manufacturing.

$(VA/P)_n$ = the ratio of value-added to payroll in the nation in manufacturing.

The adjusted estimates of GSP in manufacturing and the new estimates of GSP are presented in Table 4. The GSP figures for the other industries are not shown, since they are the same as in Table 3. The adjustment shows that labor is less productive in Illinois than the U. S. That is, value-added per dollar of payroll in Illinois is less than

TABLE 3

GROSS STATE PRODUCT - ILLINOIS
(Millions of Dollars)

YEAR	MANUFACTURING	CONTRACT CONSTRUCTION	WHOLESALE AND RETAIL TRADE	FINANCE AND INSURANCE	TRANSPORTATION AND COMMUNICATIONS	SERVICES	MINING	GOVERNMENT	FARM	OTHER	TOTAL (EXP.)
1940	6562	758	3683	2038	1829	1596	531	1171	839.1	15	19013
1950	7169	823	3793	2397	2040	1720	513	1316	1065.2	134	20970
1955	9936	1216	4758	3609	2707	2377	524	2022	1027.3	227	28103
1956	10493	1445	5079	3710	2886	2587	540	2088	1150.3	86	30061
1957	10675	1465	5337	3968	2998	2825	527	2271	1127.2	153	31345
1958	9850	1465	5362	4239	3027	3012	515	2473	1196.9	207	31350
1959	11261	1520	5645	4381	3276	3158	518	2633	1039.9	123	33755
1960	11199	1542	5936	4653	3373	3297	523	2819	1061.8	104	34509
1961	11135	1567	6118	4947	3414	3434	533	2831	1128.7	141	35277
1962	12113	1566	6442	5197	3641	3670	536	3150	1168.5	217	37701
1963	12624	1575	6733	5430	3840	3890	540	3340	1200.5	202	39377
1964	13830	1807	7437	5931	4106	4189	563	3592	1155.5	182	42801
1965	15268	1999	7942	6336	4370	4560	589	3828	1333.5	118	46365
1966	16864	2735	8717	6879	4604	5022	604	3988	1421.1	212	50546
1967	17021	2445	9263	7407	4800	5461	603	4756	1478.0	268	52502
1968	18117	2737	10120	7783	5010	5871	618	5331	1271.4	188	57047
1969	18994	3049	10856	8456	5440	6422	638	5760	1420.1	24	60961
1970	18046	3096	11366	9084	5650	6953	696	6506	1345.4	39	63549
1971	19232	3396	12119	9725	6200	7134	653	6458	1543.6	272	66933
1972	20698	3429	13075	10646	6947	7713	784	7317	1968.1	451	73229
1973	23286	3764	14270	11165	7580	8639	874	7802	3222.2	585	81187
1974	24395	3807	15560	12419	8140	9611	1211	8434	3271.3	862	87716
1975	24945	3950	17207	13775	8804	10636	1435	9495	4226.4	699	95192

Source: Calculated.

TABLE 3
GROSS STATE PRODUCT - ILLINOIS
(Millions of Dollars)

YEAR	MANUFACTURING	CONTRACT CONSTRUCTION	WHOLESALE AND RETAIL TRADE	FINANCE AND INSURANCE	TRANSPORTATION AND COMMUNICATIONS	SERVICES	MINING	GOVERNMENT	FARM	OTHER	TOTAL (GSP)
				AND REAL ESTATE	PUBLIC UTILITIES						
1949	6502	758	2683	2038	1828	1594	531	1171	896.1	15	19013
1950	7169	823	3793	2307	2040	1720	513	1316	1045.2	134	20990
1951	9936	1216	4758	3609	2707	2377	524	2022	1027.3	227	28403
1952	10493	1415	5079	3710	2894	2587	510	2088	1170.3	86	30061
1953	10675	1465	5337	3968	2969	2825	527	2271	1127.2	152	31345
1954	9850	1445	5360	4079	2727	3012	518	2173	1104.0	207	31340
1955	11261	1520	5415	4361	3254	3158	518	2433	1030.0	123	33752
1956	11199	1511	5936	4452	3373	2997	523	2810	1061.0	104	34509
1957	11135	1567	6118	4582	3411	3131	533	2831	1100.7	111	35227
1958	12112	1675	6112	5127	3641	3470	534	3150	1148.7	217	37701
1959	12621	1675	6733	5130	3910	3890	510	3340	1200.2	222	39277
1960	13038	1807	7137	5931	4106	4169	563	3592	1180.5	182	40801
1961	15268	1999	7949	6336	4200	4500	577	3821	1133.2	110	46365
1962	14864	2735	7949	6779	4604	5000	601	3988	1121.1	210	40574
1963	17021	2415	8243	7077	4800	5041	622	4756	1179.0	248	49502
1964	18117	2737	10170	7703	5010	4871	610	5221	1201.4	108	57047
1965	18594	3049	10526	8124	5410	4421	638	5760	1100.1	84	60041
1966	18746	3006	11344	9001	5450	4003	604	6506	1145.1	30	63519
1967	19332	3266	12110	9500	6200	4131	603	7200	1213.4	120	67923
1968	20608	3499	13075	10416	6017	4713	701	7317	1068.1	121	73090
1969	23284	3741	14270	11745	7550	5439	774	7002	1220.3	585	81187
1970	24365	3807	15560	13120	8110	5713	1211	8131	1301.3	642	89116
1971	24645	3950	17207	13775	8904	6064	1145	8038	1304.1	609	95110

SOURCE: Calculated.

TABLE 4
 MODIFIED ESTIMATES OF GSP - ILLINOIS
 (Millions of Dollars)

YEAR	GSP _m	GSP _{TOTAL}
1955	9192	27659
1956	9722	29293
1957	10201	30871
1958	10228	31728
1959	10745	33239
1960	10554	33864
1961	10648	34790
1962	11541	37129
1963	11872	38625
1964	13026	41989
1965	14399	45496
1966	16057	49747
1967	16036	52517
1968	16940	55870
1969	17700	59767
1970	17254	61957
1971	17198	64899
1972	19136	71467
1973	20959	78860
1974	22702	86023
1975	22265	92492

SOURCE: Calculated and Table 3.

it is for the U. S. This results in an adjustment factor with value less than unity.

A similar adjustment is not possible for the other industries. This would be a matter of deep concern, if it were not for the fact that the bias resulting from the assumption of similar factor proportions is likely to be much lower in those industries with high relative labor inputs and those producing services (See Neimi (180)). The non-manufacturing private nonfarm industries generally fall into one of these two categories.

Comparison with Previous Estimates

Two other attempts to estimate GSP for Illinois are known by the author. These are contained in Greene (80) and L'Esperance et al. (146).

Greene estimated GSP for the years 1929 - 1963. His estimates are calculated utilizing the income approach mentioned earlier in this Chapter. Many of the necessary components for estimating GSP via the income approach can be obtained from the U. S. Department of Commerce's Series on Personal Income by States. The remaining components were allocated to Illinois from national totals.

L'Esperance et al. (146) estimated GSP for the years 1949 - 1972. Their estimates are calculated using the Kendrick-Jaycox method described in this Chapter.

Comparison of these estimates shows that they are quite similar. Whether this can be taken as an indication of the accuracy of any of the estimates is questionable . It is possible that both sets of estimates contain certain errors in the same direction. One can only hope this is not the case.

The Estimation of Gross Metropolitan Product

The estimation of GMP by industry for the Chicago SMSA follows the same methods outlined above for the estimation of GSP with minor exceptions.

Gross farm product cannot be calculated directly for the Chicago SMSA as it can be for Illinois. The data used for the state estimate is not available for SMSA's. So, following L'Esperance and Chall (144), GMP in farming was obtained by applying the ratio of cash receipts from farm marketings in Chicago to cash receipts from farm marketings in Illinois to GSP in farming.

Data for mining in the Chicago region are scarce since mining is such a small part of the economic activity of the area. Disclosure rules prevent publication of data. As a result, GMP in mining was calculated using the ratio of the value of mining production in Chicago to the value of mining production in Illinois. These were obtained from the Minerals Yearbook published by the Bureau of the Mines.

TABLE 5
COMPARISON OF VARIOUS GSP ESTIMATES - ILLINOIS

Year	(1) Greene	(2) L'Esperance	(3) Present Study	% Difference (1) - (3) (2) - (3)	
1955	26795	28295	27659	-3.12	2.30
1956	29399	30207	29293	.36	3.12
1957	30736	31441	30871	- .44	1.85
1958	31590	31480	31728	- .43	- .78
1959	32957	34077	33239	- .85	2.52
1960	34244	35037	33864	1.12	3.46
1961	35498	35713	34790	2.04	2.65
1962	37555	38023	37129	1.15	2.41
1963	39789	39698	38625	3.04	2.78
1964		42515	41989		1.25
1965		46226	45496		1.60
1966		50516	49747		1.55
1967		53203	52517		1.30
1968		56792	55870		1.65
1969		60869	59767		1.84
1970		63379	61957		2.29
1971		68260	64899		5.17
1972		73492	71467		2.83

SOURCE: Column (1) - L'Esperance et al. (148).
Column (2) - Greene (80).

For all other industries the same procedure was followed as for the calculation of GSP. The estimates of GMP with manufacturing adjusted for possible differences in factor proportions are presented in Table 6. Note the estimates presented are not continuous for the total time period. The missing years can be filled-in using the GSP estimates presented above. The exact method used and justification for the procedure are presented in the next section.

An Alternative Estimate of GMP

GMP can be estimated by using the estimates of GSP by industry presented above. These can be scaled down to the Chicago SMSA. The scalar used is the ratio of wages and salaries in the Chicago SMSA to wages and salaries in Illinois. For all industries except farming and mining² this can be expressed as:

$$GMP_{it} = GSP_{it} \cdot \frac{WS_{itc}}{WS_{itI}} \quad (4)$$

where GMP_{it} = the Gross Metropolitan Product produced by industry i during period t .

GSP_{it} = the Gross State Product produced by industry i during period t .

WS_{itc} = the wages and salaries paid in industry i during period t in Chicago.

TABLE 6

GROSS METROPOLITAN PRODUCT - CHICAGO SMSA
(Millions of Dollars)

YEAR	MANUFACTURING	CONTRACT CONSTRUCTION	WHOLESALE AND RETAIL TRADE	FINANCE INSURANCE AND REAL ESTATE	TRANSPORTATION COMMUNICATIONS AND PUBLIC UTILITIES	SERVICES	MINING	GOVERNMENT	FAIR*	OTHER	TOTAL (CONS)
1950	1,057	602	2614	2175	1192	1384	32	1025	74	150	11,535
1959	7782	1021	1101	3924	2400	2596	36	1972	72	150	24,058
1962	9128	1078	1556	1149	2706	2999	43	2329	77	195	26,860
1965	8702	1380	5945	5185	3223	3511	52	2719	84	151	31,957
1966	10929	1538	6523	5606	3407	3886	53	2908	89	184	37,123
1967	10817	1678	6974	6050	3586	4183	54	3340	91	196	39,969
1968	11253	1930	7655	6383	3733	4491	66	3744	77	154	39,486
1969	11994	2216	8244	6948	4101	4930	71	4063	85	123	42,775
1970	11527	2186	8601	7284	4239	5233	70	4581	78	124	43,923
1971	11790	2394	9152	7914	4599	5477	74	4244	85	206	45,853
1972	12765	2431	9785	8561	5099	5942	73	4668	104	256	49,484
1973	13975	2684	10740	8979	5605	6725	100	4956	162	306	51,232
1974	14188	2645	11692	9763	6006	7484	100	5398	158	416	58,050
1975	11546	2675	12742	11038	6456	8237	103	6133	193	370	62,500

TABLE 6
GROSS METROPOLITAN PRODUCT - CHICAGO SMSA
(Millions of Dollars)

YEAR	MANUFACTURING	CONTRACT CONSTRUCTION	WHOLESALE AND RETAIL TRADE	FINANCE, INSURANCE AND REAL ESTATE	TRANSPORTATION, COMMUNICATIONS AND PUBLIC UTILITIES	SERVICES	MINING	GOVERNMENT	FARM	OTHER	TOTAL (GSP)
1950	4957	402	2444	2175	1192	1384	32	1025	74	150	11535
1951	7782	1031	4101	3924	2400	2596	36	1972	72	150	24058
1952	8128	1078	4524	4119	2706	2999	43	2329	77	195	24860
1953	9702	1360	5215	5185	3223	3511	52	2719	84	151	31982
1954	10929	1538	6223	5626	3027	3954	53	2908	89	184	35123
1957	10717	1678	6274	6000	3584	4183	54	3302	91	196	36969
1958	11253	1930	7655	6383	3723	4421	66	3744	77	154	39486
1959	11994	2216	8244	6918	4101	4930	71	4063	85	123	42775
1960	11527	2156	8401	7081	4239	5223	70	4581	78	124	43923
1961	11700	2394	9152	7244	4589	5477	74	4214	85	206	45853
1962	12765	2431	9785	8551	5009	5942	73	4662	104	256	49681
1963	13975	2684	10740	8979	5605	6725	100	4954	142	304	51232
1964	14168	3415	11692	9503	6006	7481	100	5388	158	316	58050
1965	14546	2675	12742	11036	6156	8237	103	6133	182	320	62500

WS_{itI} = the wages and salaries paid in industry i during period t in Illinois.

This procedure assumes, as explained in L'Esperance and Chall (144), similar production functions in the Chicago SMSA and the State of Illinois. This seems a reasonable assumption given the absolute dominance in the State of Illinois of all but the farm and mining sectors by the Chicago SMSA.

The estimates obtained using equation (4) are presented in Table 7. Comparison of these estimates and those presented in Table 6 shows very little difference. With this comparison in mind, the years 1958, 1960, 1961, 1963, and 1964 were filled-in in Table 6 using those from Table 7. The combined results are finally presented in Table 8.

Comparison of GMP, GSP, and GNP

Table 9 presents a comparison of GMP, GSP, and GNP. The most striking thing to note is the dominance of the Chicago economy within the State of Illinois. Economic activity within the Chicago SMSA has accounted for approximately 70 percent of all activity within the State of Illinois and approximately 4.5 percent of total U. S. economic activity. Chicago's industrial base appears to be somewhat more sensitive to recessions than either the Illinois or U. S. economy. This latter fact is indicated by the decline in Chicago's share of GSP and GNP during recessionary years.

TABLE 7
GROSS METROPOLITAN PRODUCT - CHICAGO
OBTAINED BY 'SCALING' GROSS STATE PRODUCT - ILLINOIS
(Millions of Dollars)

YEAR	MANUFACTURING	CONTRACT CONSTRUCTION	WHOLESALE AND RETAIL TRADE	FINANCE AND INSURANCE	TRANSPORTATION AND COMMUNICATIONS PUBLIC UTILITIES	SERVICES	MINING	GOVERNMENT	FARM	OTHER	TOTAL (GMP)
1958	7448	1014	4007	3554	2207	2284	37	1375	83	190	22199
1959	7728	1025	4354	3614	2417	2393	38	1478	72	118	23237
1960	7669	1053	4428	3862	2499	2494	44	1618	73	95	23835
1961	7718	1096	4579	4092	2482	2587	41	1640	76	136	24447
1962	8391	1093	4794	4251	2632	2762	43	1833	77	195	26071
1963	8531	1075	4979	4415	2774	2917	43	1935	78	154	26941
1964	9304	1204	5580	4806	2954	3139	48	2070	74	173	29352
1965	10267	1327	5872	5134	3134	3418	52	2215	84	100	31603
1966	11414	1453	6402	5500	3322	3766	53	2288	89	180	34467
1967	11616	1575	6834	5941	3506	4073	54	2721	91	179	36390
1968	12008	1828	7390	6280	3673	4352	66	3068	77	140	38892
1969	12538	2111	8101	6932	3983	4752	71	3283	85	125	41884
1970	12106	2058	8394	7348	4084	5117	70	3679	78	136	42970
1971	11967	2270	8950	7894	4511	5228	74	3761	85	198	44938
1972	13282	2337	9626	8621	4982	5634	73	4207	104	243	49119
1973	14304	2554	10392	8699	5479	6315	100	4516	162	294	52815
1974	14614	2526	9805	12419	8140	7000	100	4937	158	461	60100
1975	14983	2555	9648	13775	8804	7723	103	5619	193	350	63753

TABLE 8

FINAL 'COMBINED' ESTIMATE OF GMP - CHICAGO
(Millions of Dollars)

YEAR	MANUFACTURING	CONTRACT CONSTRUCTION	WHOLESALE AND RETAIL TRADE	FINANCE AND INSURANCE	TRANSPORTATION AND COMMUNICATIONS	SERVICES	MINING	GOVERNMENT	FARM	OTHER	TOTAL (GMP)
1958	7448	1014	4007	3554	2207	2284	37	1375	83	190	22199
1959	7782	1021	4101	3926	2400	2596	38	1972	72	150	24058
1960	7669	1053	4428	3862	2499	2494	44	1618	73	95	23835
1961	7718	1096	4579	4092	2482	2587	41	1640	76	136	24447
1962	8428	1078	4556	4449	2704	2999	43	2329	77	195	26860
1963	8531	1075	4579	4415	2774	2917	43	1935	78	194	26941
1964	9304	1204	5580	4806	2954	3139	48	2070	74	173	29352
1965	9702	1380	5945	5165	3223	3511	52	2749	84	151	31982
1966	10929	1538	6523	5606	3407	3886	53	2908	89	184	35123
1967	10817	1678	6974	6050	3586	4183	54	3340	91	196	36969
1968	11253	1930	7655	6383	3733	4191	44	3744	77	154	39486
1969	11994	2215	8244	6948	4101	4930	71	4063	85	123	42775
1970	11527	2186	8601	7294	4239	5233	70	4521	78	124	43923
1971	11708	2394	9152	7914	4599	5477	74	4244	85	206	45853
1972	12765	2431	9785	8561	5099	5942	73	4668	104	256	49484
1973	13975	2684	10740	8979	5605	6725	100	4956	162	306	54232
1974	14188	2645	11692	9963	6006	7484	100	5398	158	416	58050
1975	14546	2675	12749	11038	6456	8247	103	6133	193	370	62500

SOURCE: Table 6 and Table 7.

TABLE 9
COMPARISON OF GMP, GSP, AND GNP

YEAR	$\frac{\text{GMP}}{\text{GSP}}$	$\frac{\text{GMP}}{\text{GNP}}$
1958	.6997	.0495
1959	.7238	.0495
1960	.7038	.0471
1961	.7027	.0467
1962	.7234	.0476
1963	.6975	.0453
1964	.6990	.0462
1965	.7030	.0465
1966	.7060	.0466
1967	.7039	.0464
1968	.7067	.0455
1969	.7157	.0457
1970	.7089	.0447
1971	.7065	.0431
1972	.6952	.0424
1973	.6877	.0415
1974	.6748	.0411
1975	.6757	.0409

SOURCE: TABLE 1, TABLE 4, and TABLE 8.

Use of GMP Industry Estimates in This Study

GMP provides a useful summary statistic of trends in overall economic activity within the Chicago SMSA. The Chicago Econometric Model takes as one of its major tasks the prediction of the individual industry components of GMP. The exact methods used are outlined in detail in the next chapter.

FOOTNOTES TO CHAPTER II

1. The statistic 'GNP' normally published includes earnings of U. S. citizens from investments in foreign enterprises. When these earnings are subtracted from GNP, Gross Domestic Product is the result. Thus, Gross Domestic Product is a measure of the production which actually occurs within the geographical boundaries of the U. S.
2. The estimates for farming and mining do cover the entire period under consideration. Thus, the 'fill-in' technique presented in the next section is not used for these industries.

CHAPTER III

SPECIFICATION OF THE MODEL

Introduction

This chapter presents the Chicago Econometric Model. For each equation presented, the theoretical basis is given first, then the empirical specification is presented, and finally, a discussion of the data used to estimate each equation follows. A discussion of the estimates themselves is postponed until Chapter IV, where the issues of identification and block recursiveness of the model are addressed.

The Chicago Econometric Model can be divided into four major industrial sectors: manufacturing, private nonfarm industries except manufacturing, government, and farming and mining. The discussion in this chapter is divided generally along these divisions.

The Manufacturing Sector

The manufacturing sector of the Chicago Econometric Model is the largest within the model. This is partially due to the wealth of information available for manufacturing relative to that for other sectors and partially a result of a desire to communicate as much information as possible

about the Chicago region. The analysis, then, is carried on at the lowest level of aggregation possible.

Much of the region's manufacturing activity is export-oriented, but a simple export-base hypothesis is not considered.¹ Instead, demand for manufacturers' products is derived from national as well as local sources. The derivation of the local linkages specific to the Chicago region is outlined in detail below. This and the use of a production function which imposes no a priori constraints on production technology sets the Chicago Econometric Model apart from those models reviewed in Chapter I.

The manufacturing sector consists of 14 major two-digit industries plus one 'residual' industry - all other manufacturing. These are listed by two-digit SIC code in Table 10.

Each two digit industry is subject to the technology imposed by its production function. The production function chosen for the model should impose only those a priori assumptions that are appropriate. A list of several production functions was performed to determine which function was most appropriate given the data.

All of the production functions chosen are of the form

$$Q = f(K,L) \quad (5)$$

TABLE 10

MAJOR TWO-DIGIT MANUFACTURING INDUSTRIES

Description	SIC Code
Food and Kindred Products	20
Apparel and Related Products	23
Paper and Allied Products	26
Printing and Publishing Industries	27
Chemicals and Allied Products	28
Petroleum and Coal Products	29
Stone, Clay, and Glass Products	32
Primary Metal Industries	33
Fabricated Metal Products	34
Machinery (Except Electrical)	35
Electrical Machinery	36
Transportation Equipment	37
Instruments and Related Products	38
Miscellaneous Manufactures	39
All Other Manufactures ²	19,21,22,24,25,30,31

That is, output is a function of capital and labor inputs. This leaves open the possibility of some important inputs being omitted.

The data used to perform the test were also not exactly those which would be specified by (5). Value-added in constant dollars was used for output. The number of production worker hours represented labor inputs, and the capital stock was used instead of capital services. Justification for the use of these data are presented below.

The three production functions estimated were the Cobb-Douglas production function written:

$$\ln VA = \ln \alpha_1 + \beta_1 \ln L + \beta_2 \ln K \quad (6)$$

the variable elasticity of substitution production function (VES) written:

$$\ln VA = \ln \alpha_1 + \beta_1 \ln L + \beta_2 \ln K + \beta_3 \ln K \ln L \quad (7)$$

and the transcendental production function (trans-log) written:

$$\begin{aligned} \ln VA = \ln \alpha_1 + \beta_1 \ln L + \beta_2 \ln K + \beta_3 \ln K \ln L \\ + \beta_4 (\ln L)^2 + \beta_5 (\ln K)^2 \end{aligned} \quad (8)$$

Examination of equations (6), (7), and (8) reveals that the Cobb-Douglas and VES production functions can be obtained from the trans-log production function by setting certain coefficients equal to zero. This amounts to imposing restrictions regarding the elasticity of substitution.

To compare the relative explanatory powers of the trans-log and VES production functions, one can test the VES function. This restriction can be formulated as an F test of the form suggested by Chow (32). With reference to equation (8) the hypothesis to be tested is:

$$H_0: \beta_4 = 0$$

$$H_1: \beta_4 \neq 0$$

$$\beta_5 = 0$$

$$\beta_5 \neq 0$$

The computed F statistics are presented in Table 11. The results overwhelmingly reject the trans-log specification in favor of the VES specification. Only two of the computed F statistics exceed the critical value.

Next, the VES specification is tested against the simpler Cobb-Douglas specification. With reference to equation (7) this can be formulated as:

$$H_0: \beta_3 = 0$$

$$H_1: \beta_3 \neq 0$$

Again an F statistic can be used to test the hypothesis. These statistics are presented in Table 12. Only three of these statistics exceed the critical value. These results suggest that the Cobb-Douglas specification is appropriate. But, some further investigation reveals that that may not be the case.

There is the possibility that multicollinearity may cloud the results just presented. This is especially true of the first test involving the trans-log function, since these estimates use the $\ln L$ and $\ln K$ and each of their squared

TABLE 11

TEST OF VES RESTRICTION OF TRANS-LOG

SIC Code	Calculated F
20	3.900
23	.553
26	2.949
27	5.008
28	.146
32	1.125
33	.398
34	.000
35	1.188
36	1.962
37	.353
38	1.629
39	.307
TM	.324

$F_{\text{critical}} = 3.74$

TABLE 12

TEST OF COBB-DOUGLAS RESTRICTION OF VES

<u>SIC</u>	<u>Calculated F</u>
20	2.204
23	16.934
26	11.203
27	.325
28	3.230
29	.144
32	4.587
33	2.440
34	1.027
35	.161
36	.155
37	.261
38	.154
39	.529
TM	1.301

$F_{\text{critical}} = 4.449$

values. With this in mind the test of the Cobb-Douglas restriction of the trans-log function may be written in a slightly different form as:

$$\ln VA = \ln \alpha + \beta_1 \ln L + \beta_2 \ln K + \beta_3 (\ln L - \ln K)^2 \quad (9)$$

Now the hypothesis to be tested is:

$$H_0: \beta_3 = 0 \quad H_1: \beta_3 \neq 0$$

The calculated F statistics are presented in Table 13. Nine of these fifteen statistics are above the critical value. This test gives support to the trans-log specification and casts some doubts on the more restrictive Cobb-Douglas formulation.

An examination of the estimated coefficients also reveals some evidence that the simple Cobb-Douglas specification may be inappropriate. Several of the estimated coefficients, which represent output elasticities, are negative and these coefficients cannot be negative if the Cobb-Douglas function is to make economic sense. These results suggest that the trans-log function may be more appropriate for use in the model.

The transcendental logarithmic production function was first suggested for use by Kmenta (131) as an approximation to the Constant Elasticity of Substitution production function (CES) proposed by Minhas et al. (166). Kmenta derives the trans-log production function as a Taylor series expansion of the CES production function ignoring terms of

TABLE 13

TEST OF COBB-DOUGLAS RESTRICTION OF TRANS-LOG

<u>SIC</u>	<u>Calculated F</u>
20	3.684
23	10.019
26	.060
27	8.460
28	9.219
29	8.121
32	4.186
33	8.221
34	11.743
35	.242
36	4.856
37	.439
38	8.119
39	.051
TM	11.998

$F_{\text{critical}} = 4.49$

order higher than two. The properties of the trans-log production function have been established by Christenson et al. (37) (38). As shown in the articles, the trans-log production function places no a priori restrictions on substitution possibilities among the factors of production. It also allows scale economies to vary with output. The trans-log function can be written:

$$\begin{aligned} \ln VA = \ln \alpha_{10} + \beta_{10.1} \ln L + \beta_{10.2} \ln K + \beta_{10.3} (\ln L)^2 \\ + \beta_{10.4} \ln L \ln K + \beta_{10.5} (\ln K)^2 \end{aligned} \quad (10)$$

If (10) is subject to constant returns to scale, then the following restrictions hold.⁵

$$\beta_{10.1} + \beta_{10.2} = 1, \beta_{10.3} = \beta_{10.4} = \beta_{10.5} = 0 \quad (11)$$

It should be noted that the trans-log function possesses certain uneconomic regions. The marginal product of labor is

$$\partial V^S / \partial L = V^S / L (\beta_{10.1} + \beta_{10.3} \ln L + \beta_{10.4} \ln K) \quad (12)$$

Since the parameters are not constrained to be greater than zero, it is possible that (7) is less than zero for positive input levels. This possibility may be eliminated by requiring

$$\partial \ln V^S / \partial \ln L = \beta_{10.1} + 2 \beta_{10.3} \ln L + \beta_{10.4} \ln K > 0 \quad (13)$$

that is, the output elasticities are required to be positive. This is the case for the estimates made above. These elasticities are not constant and depend on the levels of input services.

If markets are competitive and firms are profit maximizers, then the marginal physical product of labor is set equal to the real wage rate of labor.

$$w = V^S/L (\beta_{10.1} + 2 \beta_{10.3} \ln L + \beta_{10.4} \ln K) \quad (14)$$

or

$$LSH = \frac{W \cdot L}{V^S} = \beta_{10.1} + 2 \beta_{10.3} \ln L + \beta_{10.4} \ln K \quad (15)$$

Equation (15) shows labor's share, LSH, to be a variable function of input levels.

In the short-run, firms may adjust output by varying the amount of labor services they hire, but the capital stock is fixed. Thus, equations (10) and (15) give a supply specification for the firm in the short-run. The assumption of a fixed capital stock is made for three reasons. First, no measure of capital services is available for industries on a regional basis. For that matter, no measure is available nationally. So the measure of maximum potential capital services, the net real capital stock, the estimation of which is outlined below, is used for K. Second, since capital stock is used instead of capital services, there is no way to measure variations in intensity of use in any period. No estimates of capacity utilization are available for the region, and the application of national measures would be questionable. Third, investment plans take several years. So, it would not be reasonable to assume the capital stock can change rapidly in the short-run to deal with variations

in short-run demand. With regards to this last point, it should be noted that the intensity of use of the available capital stock can be varied in the short-run. This means that capital services should be used for K and not capital stock. Several measures of capital services have been suggested.⁶ Unfortunately, none can be implemented here. The best that can be done with the available data is to use an estimate of the real capital stock for K .

Empirical implementation of (10) and (15) as written requires that V^S be in units of output, K be in units of capital input, and L be in units of labor services. The data actually used to estimate (10) and (15) take a slightly different form. First, L is the number of worker hours used per annum. This fulfills the requirements of (10) and (15). For K the number of units of capital services used is not available. Instead, the net real capital stock given in constant dollars is used for K . Finally, the number of units of output cannot be used for V , since it is not available. So value added in constant dollars is used as the output measure.

To complete the demand-supply framework a demand equation and equilibrium condition must be added. First, a demand function is chosen which is homogeneous of degree zero with respect to all prices. 'Income' terms are included to account for changes in demand which may occur over time.

The demand equation takes the following general form.

$$\ln V^d = \ln \alpha_{16} + \beta_{16.1} \ln P + \beta_{16.2} \ln LAL + \beta_{16.3} \ln NAL \quad (16)$$

where V^d is the quantity of good i demanded, P is the price of good i , LAL is the sum of local activity levels of local industries purchasing goods from industry i , and NAL is the sum of the activity levels of national industries purchasing goods from industry i . The derivation of the last two explanatory variables is explained in detail below.

Since equation (16) is in log form, then $\beta_{16.1}$ represents the price elasticity of demand. If $\beta_{16.1} = 0$, then a pure demand model - in the export-base sense - results.

The data used to estimate (16) again are slightly different than those initially suggested by its form. V^d is measured as units of real value-added, that is value added in constant dollars. Since manufacturing competes in the national market, P is taken as the national price of manufacturers from the particular two-digit industry under discussion. These price indices can be found in Eckstein and Wyss (46). Both LAL and NAL are given in current dollars of 'income' of the purchasers of the product. As a proxy for the 'income' of purchasers the current dollar value-added of the consuming industry is used.

The equilibrium condition for each industry is given by equation (17),

$$\ln V^d = \ln V^s \quad (17)$$

It will be useful to add two additional relations for each manufacturing industry.

$$NOE = \alpha_{18} + \beta_{1.18} \cdot L \quad (18)$$

$$L = LSH \cdot (V^s/w) \quad (19)$$

where NOE is the number of employees in industry i , L is, as defined above, the number of worker hours used in industry i , LSH is labor's share of output, V^s is real value added in industry i , and w is the real wage rate. Note that this equilibrium condition does not mean that the interaction of the demand equation plus the production function produce an equilibrium solution. Rather, there is a causal flow implicit in these equations. The demand equation generates the quantity of output to be produced. The production function which specifies this firm's isoquants then shows how much labor must be employed in order to produce the output. The equilibrium condition requires firms to produce the quantity of output demanded. Thus, equilibrium between the quantity supplied and the quantity demanded is attained. But, the adjustment is based on a certain pattern of response inherent in the system. A complete analysis of the causal ordering of the system is postponed until Chapter IV.

Equation (18) serves to translate the number of hours of labor used by the industry into the number of employees used. The coefficient, $\beta_{1.18}$, in equation (18) will vary from industry to industry depending on such things as overtime practices and the number of supervisory personnel employed per production worker.

For each of the two-digit manufacturing industries listed in Table 10, except All Other Manufactures, equations (10), (15), (16), and (18) are estimated.

The Determination of Activity Levels for the Demand Relations

In a region as large as the Chicago SMSA with its large manufacturing sector, some of the output of the local manufacturing industries will be used by those same industries. The local activity term, LAL, in equation (16) is meant to represent the income of those who demand the output of industry i and are located within the region. Value added in current dollars of a consuming industry is used as a proxy for income of that industry. LAL is then defined as the sum of the value added by each consuming industry expressed in current dollars. Or

$$LAL_i = \sum_{j \in c} V_j^S \cdot P_j \quad (20)$$

where LAL_i is the local activity level of consumers of industry i 's output, V_j^S is the output in constant dollars of value-added of consuming industry j , P_j is the price of output from industry j , and c is the set of consuming

industries of industry i's output.

The major industries included in c could be obtained by examining the input-output coefficients from the national table published by the Department of Commerce assuming these hold exactly for the region. But, this procedure would possibly be inappropriate for two reasons. First, there are possible differences between regional and national technologies. Second, the mix of local industries may be different from the national average.⁷ For instance, industry j may demand 5 percent of industry i's output nationally. But, in Chicago industry j may be so large relative to industry i that 30 percent of i's output is required by j.

Very little can be done to correct for the first problem. But the latter difference can be corrected to some extent if a regional input-output table is derived by adjusting national coefficients by regional weights. The best procedure, of course, is to conduct a survey and derive a regional input-output matrix. Given that this is not possible, there are two approaches to deriving the adjustments to the national coefficients. These are to combine the survey data that may be available with indirect data or to just use an indirect method for calculating the weights. In general the methods for adjusting national input-output coefficients can be expressed as

$$r_{ij} = q_{ij} \cdot a_{ij} \quad (21)$$

where r_{ij} is the regional input-output coefficient, q_{ij} is the scaling ratio, and a_{ij} the national input-output coefficient. The constraint here is that $q_{ij} \leq 1$. If $q_{ij} > 1$, then this implies the region can supply its own needs, and; the national coefficient is used for r_{ij} . This implicitly assumes that all of the intermediate product needed by j and manufactured by i actually stays within the region. Realistically, this may not hold exactly.

Many alternative methods for calculating q_{ij} have been suggested in the regional input-output literature.⁸ Two of these methods are presented here for illustrative purposes.

Often the location quotient is used for q_{ij} . The location quotient is defined as

$$LQ_i = (x_i/x) / (X_i/X) \quad (22)$$

where x_i = regional output in industry i

x = total regional output

X_i = national output of industry i

X = total national output

This quotient yields a number comparing the relative importance of industry i in the region to its relative importance in the nation. Several modifications of the location quotient have been suggested. The cross-industry location quotient is a location quotient modified to account for the size of the demanding as well as selling industries.

Tiebout (219) has suggested that the x and X terms in (22) be replaced by the summation of only those industries which

purchase goods from industry i.

Another popular method for calculating q_{ij} has been labelled by Schaffer and Chu (197) as the Supply-Demand Pool Technique. This method relies upon calculating the balance, b_i , between local output of good i, x_i , and local requirements of good i, d_i . Using the national input-output coefficients d_i can be calculated as

$$d_i = \sum_j x_j \cdot a_{ij} \quad (23)$$

where x_j is the output of industry j in the region and a_{ij} is the national input-output coefficient. The balance, b_i , is then

$$b_i = x_i - d_i \quad (24)$$

If $b_i \geq 0$, then local supply is sufficient to cover local demand and the national input-output coefficients may be used in row i the regional input-output table. If, however, $b_i < 0$ local demand is greater than local supply and importation of good i is necessary. In this case the national coefficients of row i are reduced by the factor x_i/d_i . Two things should be noted about this procedure. First, it assumes as does the location quotient technique that all of the output of industry i stays within the region. And second, this procedure assumes a knowledge of local final demands. More complex modifications of the procedure have been suggested by Kokat (132). Several iterative techniques involving the use of some survey data have also been suggested.⁹

Morrison and Smith (173) use five separate tests to examine the performance of eight alternative methods for calculating q_{ij} . Those described above are included in their examination. They compared the predicted input-output table using each method with an input-output table estimated via survey techniques. The iterative technique using survey data was the winner in each of the five tests. Of the seven nonsurvey methods examined the simple location quotient performed 'best'. Their conclusion was that survey data was the best way to obtain a regional input-output table, but when this is not feasible the simple location quotient should be used.

McMenamen and Haring's study (155), where they introduce another iterative technique confirmed Morrison and Smith's conclusions. Even the comparisons of Schaffer and Chu (196) had shown the simple location quotient technique to be the best in the sense that the calculated input-output table most closely approximated the survey derived input-output table.

Given the limited resources of this study, survey techniques were ruled out as a feasible method for deriving an input-output table for the Chicago SMSA. Instead, the best of the non-survey techniques, the simple location quotient method, is used to derive the local linkages within the manufacturing sector.

The technique cannot be applied directly as written above, since gross outputs for two-digit manufacturing industries within the Chicago SMSA are not available. Instead the location quotients calculated are given by

$$LQ_i = (WH_{ic}/WH_c) / (WH_{ius}/WH_{us}) \quad (25)$$

where WH_{ic} = the number of worker hours used in industry i in Chicago

WH_c = the number of worker hours used in Chicago manufacturing

WH_{ius} = the number of worker hours used in industry i in the U. S.

WH_{us} = the number of worker hours used in U. S. manufacturing

Before these location quotients can be applied to the U. S. input-output table, the table must be converted to an SIC basis. This involves two steps. First, the a_{ij} elements of the 1967 input-output table were added vertically for each SIC. That is, for each SIC code there were several i 's in the input-output table which were added together. Then if several j 's belong to the same SIC, a weighted average is calculated to yield the U. S. input-output table on an SIC basis. Then the location quotients were applied to these input-output coefficients to yield a regional input-output table. The national and regional input-output coefficients for manufacturing are presented together in Table 14. The coefficients in Table 14 give the number of dollars of input

TABLE 14
REGIONAL AND NATIONAL INPUT-OUTPUT FLOWS FOR MANUFACTURING
SIC Code

to from	20	23	26	27	28	29	32	33	34	35	36	37	38	39
20	.16576 .16576	.00001 .00001	.00591 .00591	-- --	.01331 .01331	.00114 .00114	.00041 .00041	.00016 .00016	.00004 .00004	.00013 .00013	-- --	-- --	.00114 .00114	.00183 .00183
23	.00127 .00047	.15277 .05645	.00130 .00048	.00089 .00033	.00062 .00023	.00011 .00004	.00222 .00082	.00059 .00022	.00127 .00047	.00081 .00030	.00084 .00031	.00858 .00317	.00133 .00049	.00330 .00122
26	.02880 .02855	.00993 .00984	.24483 .24268	.15309 .15175	.02426 .02405	.00592 .00587	.03296 .03267	.00115 .00114	.01090 .01080	.00287 .00284	.01035 .01026	.00196 .00194	.02038 .02020	.04475 .04436
27	.05640 .05640	.00035 .00035	.00761 .00761	.11003 .11003	.00075 .00075	.00010 .00010	.00029 .00029	.00032 .00032	.00406 .00406	.00192 .00192	.00261 .00261	.00001 .00001	.00042 .00042	.00371 .00371
28	.00849 .00763	.01943 .01746	.04469 .04017	.02099 .01887	.25108 .22567	.02692 .02420	.02602 .02339	.01441 .01296	.01142 .01026	.00277 .00249	.01389 .01248	.00475 .00427	.03181 .02859	.03539 .03178
29	.00244 .00207	.00084 .00071	.00578 .00490	.00182 .00154	.04286 .03631	.06787 .05749	.00748 .00634	.00312 .00264	.00260 .00220	.00382 .00324	.00207 .00175	.00240 .00203	.00138 .00117	.00302 .00254
32	.01120 .00751	.00006 .00004	.00152 .00102	-- --	.00641 .00430	.00215 .00144	.10389 .06966	.00194 .00130	.00547 .00367	.00696 .00467	.01448 .00971	.00749 .00502	.00708 .00475	.00614 .00412
33	.00021 .00021	-- --	.00256 .00256	.00226 .00226	.01237 .01237	.00182 .00182	.01207 .01207	.26502 .26502	.29380 .29380	.20993 .20993	.07239 .07239	.08454 .08454	.05325 .05325	.06598 .06598
34	.02685 .02685	.00292 .00292	.01201 .01201	.01048 .01048	.01990 .01990	.00394 .00394	.00977 .00977	.01877 .01877	.05548 .05548	.04386 .04386	.03629 .03629	.06813 .06813	.03602 .03602	.02944 .02944
35	.00272 .00272	.00118 .00118	.00732 .00732	.00154 .00154	.00918 .00918	.00325 .00325	.01617 .01617	.02600 .02600	.03937 .03937	.15142 .15142	.02645 .02645	.05405 .05405	.01730 .01730	.00627 .00627
36	.00007 .00007	.00023 .00023	.00064 .00064	.00056 .00056	.00076 .00076	.00044 .00044	.00330 .00330	.01118 .01118	.00785 .00785	.06438 .06438	.18604 .18604	.02967 .02967	.06140 .06140	.01143 .01143
37	.00006 .00002	.00008 .00003	-- --	.00006 .00002	.00017 .00016	.00008 .00003	.00100 .00034	.00346 .00118	.01283 .00438	.01675 .00572	.01174 .00401	.23824 .08136	.00949 .00324	.00504 .00172
38	.00014 .00014	.00152 .00152	.00147 .00147	.00836 .00836	.00151 .00151	.00066 .00066	.00084 .00084	.00113 .00113	.00343 .00343	.00404 .00404	.00824 .00824	.00726 .00726	.07753 .07753	.00169 .00169
39	.00010 .00010	.01272 .01272	.00070 .00070	.00164 .00164	.00077 .00077	.00003 .00003	.00322 .00322	.00052 .00052	.00132 .00132	.00090 .00090	.00168 .00168	.00066 .00066	.00382 .00382	.06296 .06296

Source: National Coefficients are Calculated using data from "The Input-Output Structure of the U.S. Economy," Survey of Current Business, (February 1974), pp. 24-56.
For Regional Coefficients see Text.

demand from the producing industry i per dollar of output of the consuming industry j . This table needs to be modified so that the local activity levels can be derived. The modification is accomplished by first multiplying each column entry by the value-added of the consuming industry. This yields a table of flows among industries expressed in millions of dollars. This is Table 15. Next, each row of Table 15 is divided by the value-added of the producing industry. The results, shown in Table 16, are flows among industries expressed as a percentage of the producing industries output.

Table 16 can now be used to determine the set of major consuming industries within the Chicago SMSA for each producing industry. These are the members of set c referred to in equation (20). Any consuming industry which purchased five percent or more of a producing industry's output was counted as a major industry.¹⁰ The linkages derived here can be statistically tested given the specification of the demand function in equation (11). The results of these tests are presented in the next chapter.

National activity also affects the demand for industry i 's output. This is reflected in the inclusion of NAL in equation (16). NAL could be calculated using the national input-output table and gross outputs for all industries. But, a simple approach is taken here. Export demand will come from the sources listed in the national input-output

TABLE 15
INPUT-OUTPUT FLOWS AMONG CHICAGO MANUFACTURING INDUSTRIES
(Millions of Dollars)

SIC Code														
to from	20	23	26	27	28	29	32	33	34	35	36	37	38	39
20	268.1	--	2.5	--	15.5	.2	.1	.2	.1	.2	--	--	.6	.6
23	.8	12.3	.2	.5	.3	--	.2	.2	.7	.5	.6	2.0	.3	.4
26	46.2	2.1	102.2	211.0	28.0	.9	9.0	1.2	16.1	4.9	20.0	1.2	10.9	14.9
27	91.2	.1	3.2	153.0	.9	--	.1	.3	6.1	3.3	5.0	--	.2	1.2
28	12.4	3.8	16.9	26.2	263.0	3.6	6.4	13.4	15.3	4.3	23.9	2.7	15.4	10.7
29	3.3	.2	2.1	2.1	42.3	8.5	1.7	2.7	3.3	5.6	3.4	1.3	.6	.9
32	12.1	--	.4	--	5.0	.2	19.1	1.3	5.5	8.1	18.6	3.2	2.6	1.4
33	.3	--	1.1	3.1	14.4	.3	3.3	274.1	439.0	363.6	138.7	54.0	28.7	22.1
34	43.4	.6	5.1	14.6	23.2	.6	2.7	19.4	82.9	76.0	69.5	43.5	19.4	9.9
35	4.4	.3	3.1	2.1	10.7	.5	4.4	26.9	58.8	262.2	50.7	34.5	9.3	2.1
36	.1	.1	.3	.8	.9	.1	.9	11.6	11.7	111.5	356.5	18.9	33.0	4.8
37	--	--	--	--	.2	--	.1	1.2	6.5	9.9	7.6	51.9	1.7	.6
38	.2	.3	.6	11.6	1.8	.1	.2	1.2	5.1	7.0	15.8	4.6	41.7	.6
39	.2	2.8	.3	2.2	.9	--	.9	.5	2.0	1.6	3.2	.4	2.1	21.1

-- indicates less than .05
Source: See Text

TABLE 16

CONSUMING INDUSTRY'S DEMANDS AS A PERCENTAGE OF PRODUCING INDUSTRY'S OUTPUT
(Percent)

SIC Code														
to from	20	23	26	27	28	29	32	33	34	35	36	37	38	39
20	17	--	--	--	1	--	--	--	--	--	--	--	--	--
23	--	6	--	--	--	--	--	--	--	--	--	1	--	--
26	11	--	24	50	7	--	2	--	4	1	5	--	3	4
27	7	--	--	11	--	--	--	--	--	--	--	--	--	--
28	1	--	1	2	23	--	1	1	1	--	2	--	1	1
29	2	--	1	1	29	6	1	2	2	4	2	1	--	--
32	4	--	--	--	2	--	7	--	2	3	7	1	1	1
33	--	--	--	--	1	--	--	27	42	35	13	5	3	2
34	3	--	--	1	2	--	--	1	6	5	5	3	1	1
35	--	--	--	--	1	--	--	2	3	15	2	2	1	--
36	--	--	--	--	--	--	--	1	1	6	19	1	2	--
37	--	--	--	--	--	--	--	--	1	2	1	8	--	--
38	--	--	--	2	--	--	--	--	1	1	3	1	8	--
39	--	--	--	--	--	--	--	--	--	--	1	--	--	6

-- indicates less than .5
Source: See Text

table in the intensities listed, and this is the same distribution of demand that the national counterparts of the Chicago two-digit manufacturing industries perceive. Therefore, value-added in the national two-digit industry can be used as the measure of the extent of the national market, and this is NAL in equation (16).

Calculation of the Capital Stock

One of the most difficult problems to deal with when taking the production function approach to model estimation, as above, is the lack of a capital stock series. No capital stock data exists at the regional level and only recently have attempts been made to estimate capital stock for the U. S.¹¹ This means that a capital stock series for the Chicago SMSA must be estimated. Estimation is possible using the Perpetual Inventory Method, if an investment series of considerable length is available.¹² Capital expenditure data is available on a consistent basis for two-digit manufacturing within the Chicago SMSA from 1954 to 1975. Unfortunately, the time series required must reach back to the early 1930's. An estimation procedure was developed based on data published by the Bureau of Economic Analysis (19) for U. S. manufacturing.

An investment series for manufacturing in the U. S. is available from (19) reaching back to the nineteenth century.

These figures were 'scaled down' to each two-digit manufacturing industry in the Chicago SMSA. The scalar utilized was the ratio of capital's potential share of output in Chicago in each two-digit industry to an equivalent measure for the U. S. Capital's potential share is defined as value-added minus labor's compensation. This is, of course, exactly capital's share of output if there are constant returns to scale. The scalars were calculated for the four census years for which data for the Chicago SMSA were available - 1929, 1939, 1947, and 1954. Scalars for the intervening years were then linearly interpolated between these benchmark years. Applying the scalars to the investment series in (19) an investment series was obtained for each two-digit manufacturing industry in the Chicago SMSA for the period 1920 to 1975.

All that is needed now to complete the estimation is a benchmark capital stock. This is calculated using a special report in the 1958 Census of Manufactures. This survey reports the capital stock in two-digit manufacturing industries for the State of Illinois. If one now assumes that the capital-labor ratios in the Chicago SMSA manufacturing industries are the same as those for manufacturing industries in the entire State of Illinois, then

$$K_C/L_C = K_I/L_I \quad (26)$$

where K_C and K_I are the capital stock in Chicago and

Illinois in 1958, respectively, and L_C and L_I are the quantity of labor used in Chicago and Illinois in 1958, respectively. Multiplying by L_C

$$K_C = (L_C/L_I) \cdot K_I \quad (27)$$

Equation (22) can then be used to obtain the Chicago benchmark capital stock from those for Illinois.

The assumption of equal capital-labor ratios in Chicago and Illinois may not be exactly correct. But, the Chicago SMSA accounts for 70 percent of Illinois Gross State Product as indicated in Table 9 of Chapter II. If capital goods are purchased in national markets, then producers in both Chicago and other areas of Illinois face the same price for capital goods but different wages. This would be expected to cause a substitution of capital for labor in Chicago as opposed to other areas of Illinois. If this occurs, then the estimate given by (27) is biased downward.

That wages are higher in Chicago than elsewhere in Illinois must be admitted. As shown in Table 17 the average wage in manufacturing in Chicago has exceeded the average wage elsewhere in Illinois by 2.5 to 6.4 percent from 1952 to 1975. This would be a source of deep concern if the Chicago SMSA were small compared to the Illinois economy, but it certainly is not. As Table 17 shows, the Chicago SMSA has contained approximately 70 percent of manufacturing in the State of Illinois as measured by employment.

TABLE 17

COMPARISON OF CHICAGO AND ILLINOIS MANUFACTURING EMPLOYMENT AND WAGES *

Year	Chicago		Illinois		Illinois exc. Chicago		(1) ÷ (5)	(2) ÷ (4)
	H.W. (1)	Emp. (2)	H.W. (3)	Emp. (4)	H.W. (5)	Emp. (6)		
1952	1.77	918.9	1.75	1271.0	1.72	352.1	1.029	.7229
1953	1.87	974.4	1.86	1340.4	1.82	366.0	1.027	.7269
1954	1.92	894.3	1.91	1227.5	1.87	333.2	1.027	.7286
1955	2.02	910.9	2.00	1274.5	1.94	363.6	1.041	.7147
1956	2.13	939.0	2.10	1315.4	2.02	376.4	1.054	.7139
1957	2.23	928.0	2.20	1293.6	2.12	365.6	1.052	.7174
1958	2.32	840.3	2.28	1171.8	2.19	331.5	1.059	.7171
1959	2.41	868.4	2.38	1225.6	2.30	357.2	1.048	.7086
1960	2.49	862.9	2.45	1210.5	2.34	347.6	1.064	.7128
1961	2.55	831.8	2.52	1165.0	2.43	333.2	1.049	.7140
1962	2.63	856.2	2.60	1199.3	2.49	343.1	1.056	.7139
1963	2.71	851.6	2.67	1203.8	2.59	352.2	1.046	.7074
1964	2.80	867.7	2.76	1238.1	2.67	370.4	1.049	.7008
1965	2.87	914.2	2.83	1302.4	2.76	388.2	1.040	.7019
1966	2.99	974.2	2.95	1393.4	2.87	419.2	1.042	.6992
1967	3.10	975.3	3.07	1392.5	2.98	417.2	1.040	.7004
1968	3.28	971.4	3.25	1386.9	3.16	415.5	1.038	.7004
1969	3.50	976.9	3.46	1400.2	3.35	423.3	1.045	.6977
1970	3.69	932.4	3.65	1342.1	3.55	409.7	1.039	.6947
1971	3.97	876.4	3.93	1266.8	3.84	390.4	1.034	.6918
1972	4.27	877.3	4.22	1279.8	4.10	402.5	1.041	.6855
1973	4.54	916.8	4.50	1347.3	4.43	430.5	1.025	.6805
1974		907.5	4.91	1347.2		439.7		.6736
1975		816.3	5.40	1220.1		403.8		.6690

* H.W. = hourly wage in current dollars, Emp. = employment in thousands of persons.

Source: Employment and Earnings - States and Areas, Bureau of Labor Statistics

This means that most of the capital stock included in K_I is located in Chicago anyway. So the expected distortion due to the wage differential is expected to be small. In addition, early experiments with changing benchmark figures found the coefficients to be quite insensitive to these changes.

A sudden death type of depreciation or scrapping is assumed. Since the gross book value of the capital stock is the value of the stock not yet scrapped, measured in original prices, it should be approximately equal to the sum of investment in current dollars over the past n years, where n is the average lifetime before equipment is scrapped or sold.¹³ Using the 1958 benchmarks, average useful lives were calculated. These are listed in Table 18. They are similar to values obtained by Hickman (105) for the U. S., also listed in Table 18. The depreciation rate can be calculated from the useful life of an asset. And, the following formula can be used to calculate the capital stock series.

$$K_{t+1} = K_t + I_t - d(K_t + I_t/2) \quad (28)$$

where K_t equals the capital stock in time t in constant dollars, I_t is investment in constant dollars in time t , and d is the depreciation rate. In this calculation it is assumed that some of the investment made this year comes into being during the course of the year and begins to

TABLE 18.

USEFUL LIVES OF CAPITAL EQUIPMENT IN
TWO-DIGIT MANUFACTURING INDUSTRIES
(Years)

SIC Code	Calculated Useful Life	Hickman's Estimate of Useful Life
20	16	16
23	11	
26	19	20
27	18	
28	15	16
29	22	24
32	16	17
33	21	24
34	13	14
35	22	14
36	12	12
37	14	17
38	11	
39	13	
A0	12	

depreciate. This is accounted for by the term $I_t/2$ in equation (28).¹⁴ The investment series used was first deflated by the investment deflator implicit in the series presented in (19) to obtain the constant dollar investment series used in (28). Thus, (28) yields a net capital stock series valued in constant dollars.

These calculations begin with 1954. The 1954 stock is calculated by applying equation (28) where t is equal to 1954 minus the average useful life for the two-digit industry in question. This assumes that no capital stock was in existence prior to the year during the early 1930's for which the calculation began. The error introduced by this assumption is minor, since only a small fraction of the net stock in existence before the initial year would survive until 1954.

Nonmanufacturing Industries

The manufacturing sector of the Chicago Econometric Model consists of the industries listed in Table 19. These industries are much more highly aggregated than were those for manufacturing. This is due to the lack of detailed data on certain key variables for these industries.

The calculation of capital stock estimates just presented is not possible for the nonmanufacturing industries in the Chicago Econometric Model. There is, then, a need to modify the approach taken above to deal with this

TABLE 19

NONMANUFACTURING INDUSTRIES IN THE
CHICAGO ECONOMETRIC MODEL

Description	SIC Code
Contract Construction	15-17
Transportation, Communication, and Public Utilities	40-49
Wholesale and Retail Trade	50-59
Finance, Insurance, and Real Estate	60-67
Services	70-89

problem. A slightly more 'reduced form' approach is utilized to eliminate the capital stock variable from the specification. The capital stock variable can be eliminated from equations (10) and (15) by positing a theory of investment behavior.

Alternative theories of investment agree on the validity of the fundamental flexible accelerator mechanism for translating changes in desired capital into actual investment expenditures.¹⁵ Denoting the actual level of the capital stock in period t by K_t and the desired level by K_t^* , capital is adjusted toward its desired level by a certain proportion of the discrepancy between desired and actual capital stock in each period.

$$I_t = K_t - K_{t-1} = \lambda(K_t^* - K_{t-1}) \quad 0 < \lambda \leq 1 \quad (29)$$

where I_t is net investment in period t .

Now

$$K_t = K_{t-1} + I_t \quad (30)$$

and substituting for I_t

$$K_t = K_{t-1} + \lambda K_t^* - \lambda K_{t-1} \quad (31)$$

or

$$K_t = \lambda K_t^* + (1 - \lambda) K_{t-1} \quad (32)$$

To complete the theory it is necessary to add to the flexible accelerator a specification of the desired capital stock. Many alternative specifications have been suggested,

many of which are reviewed by Jorgenson (117). Of these, the choice here is guided primarily by ease of implementation of the result. Desired capital is assumed to be proportional to lagged output. The corresponding theory of investment is often referred to as the capacity utilization theory.

Thus

$$K_t^* = \gamma Q_{t-1} \quad (33)$$

where K_t^* is the desired capital stock in time period t , Q_{t-1} is output in period $t-1$, and γ is a coefficient reflecting the desired capital-output ratio. Here only the last period's output enters equation (33) for simplicity.

Substituting equation (33) into (32) yields

$$K_t = \lambda(\gamma Q_{t-1}) + (1 - \lambda) K_{t-1} \quad (34)$$

Now if the capital stock is adjusted to its desired level in one period, then $\lambda = 1$ and

$$K_t = \gamma Q_{t-1} \quad (35)$$

So the capital stock in period t is proportional to output in the previous time period. Substituting equation (35) into equations (10) and (15) yields

$$\begin{aligned} \ln V^S = & \ln \alpha_{36} + \beta_{36.1} \ln \text{NOE} + \beta_{36.2} \ln V_{-1} + \\ & \beta_{36.3} (\ln \text{NOE})^2 + \beta_{36.4} \ln \text{NOE} \ln V_{-1} + \\ & \beta_{36.5} (\ln V_{-1})^2 \end{aligned} \quad (36)$$

$$LSH = (w \cdot NOE) / V^S = \beta_{37.1} + \beta_{37.3} \ln NOE + \beta_{37.4} \ln V_{-1} \quad (37)$$

For each of the nonmanufacturing sectors, equations (36) and (37) are estimated. The data used to estimate these relations are, again, not exactly that specified by (36) and (37).

Real gross metropolitan product originating in each nonmanufacturing sector is used for the measure of output, V and V_{-1} , and NOE is the average annual number of employees used in the industry. These two data series are the only two available which closely approximate the ideal data for use as V and L . This means that the wage rate, w , in equation (37) is the average annual wage per worker employed. To these two equations the identity in equation (37) is added.

$$NOE = LSH (V/w) \quad (38)$$

To these three equations a demand relation must be added. These are specified below and are different for different nonmanufacturing sectors.

Several of the nonmanufacturing industries sell some, but possibly not all, of their output to residents of the region. Because of this, the demand relation for these industries is somewhat different than that given by equation (16) for the manufacturing industries. The appropriate income term to include in the demand equation is Chicago Disposable Income.

Thus,

$$\ln V^D = \ln \alpha_{39} + \beta_{39.1} \ln P + \beta_{39.2} \ln \text{CDI} \quad (39)$$

where V^D is the quantity of goods demanded from industry i , P is the price of good i , and CDI is Chicago Disposable Income. Equation (39) is the demand relation used for transportation, communication, and public utilities, and wholesale and retail trade. For the other three nonmanufacturing sectors the specification is slightly different as described below.

Although it is common to consider services as commodities, which cannot be transported, this is not necessarily the case. Business services can be provided to customers outside the region. Consulting firms and insurance carriers may sell a substantial amount of services outside the region. Thus, the service and finance, insurance, and real estate sectors are treated as potential exporters. Certainly part of the product of these sectors are sold to customers within the region. So, equation (40) is the demand specification for these sectors.

$$\ln V^D = \ln \alpha_{40} + \beta_{40.1} \ln P + \beta_{40.2} \ln \text{CDI} + \beta_{40.3} \ln \text{NAL} \quad (40)$$

where V^D , P , and CDI are as defined for equation (39) and NAL is the national activity level for the industry.

The one remaining sector is contract construction.

Demand for this sector comes from two sources: local businesses, that is, investment in the region, and households through housing demand. Since investment data is only available for manufacturing, this is used as a proxy for all investment demand. Thus demand for contract construction is given by

$$\ln V^D = \ln \alpha_{41} + \beta_{41.1} \ln P + \beta_{41.2} \ln HS + \beta_{41.3} \ln \text{TOTINV}_m \quad (41)$$

where V^D is the quantity of contract construction demanded, P is the price of construction, HS is the value of new housing starts adjusted for size, and TOTINV_m is total investment in manufacturing. The determination of HS is explained in the next section.

The Market for Housing Starts

The market for housing is distinctive in that there are usually three parties involved in transactions in this market. Here financial and real goods markets meet and the interactions may be complex. Since the main function of this section is to explain the determination of the housing starts variable included in the demand for contract construction equation, it is kept quite simple.

A complex examination of the housing market would include a complete explanation of the determination of mortgage rates, the local supply of mortgage funds, and other factors. Many of these factors are taken as exogenous.

The quantity of housing demanded per household is given as:

$$\frac{H^d}{HH} = \alpha \cdot RYPHH^\beta \cdot P_h^\beta \quad (42)$$

where H^d is the quantity of housing demanded in the Chicago SMSA, HH is the number of households in the Chicago region, $RYPHH$ is real income per household, P_h is the real relative price of housing, and α is a constant. The number of households in the Chicago SMSA depends on the population in the region and trends in household formation. Equation (42) can be rewritten as

$$H^d = \alpha \cdot RYPHH^\beta \cdot P_h^\beta \cdot HH \quad (43)$$

and substituting for HH

$$H^d = \alpha \cdot RYPHH^\beta \cdot P_h^\beta \cdot (POP/TR)^\beta \quad (44)$$

where POP is population, TR is the number of persons per household.

Then housing demand is given by

$$\ln H^d = \ln \alpha_{45} + \beta_{45.1} \ln RYPHH + \beta_{45.2} \ln P_h + \beta_{45.3} \ln (POP/TR) \quad (45)$$

Now the quantity of new housing starts in any period is equal to total housing demanded minus the net housing supplied from the previous period. And, net housing supplied from the previous period is equal to the housing stock in the previous period minus retirements. This may be written as

$$HS^d = H^d - (H_{-1} - R) \quad (46)$$

where HS is the quantity of new housing starts demanded, H^d is the quantity of housing demanded, H_{-1} is the housing stock in the previous period, and R is retirements.

Retirements are taken as a constant fraction of the housing stock. Thus

$$R = bH_{-1} \quad (47)$$

Substituting this into (46) yields

$$HS^d = H^d - (H_{-1} - bH_{-1}) \quad (48)$$

or

$$HS^d = H^d - (1 - b)H_{-1} \quad (49)$$

Equation (48) yields the variable HS used in equation (40).

Labor Market

The most distinctive feature of the labor market is that it is allowed to be in disequilibrium in each period. That is, wages are not necessarily expected a priori to clear the market. This possible divergence between the quantity of labor demanded and supplied is caused by the existence of positive information costs. Alchian (2) shows that 'economic theory is capable of being formulated-consistently with each person acting as an individual utility or wealth maximizer without constraints imposed by competitors, and without conventions or taboos about wages and prices- so as to imply shortages, surpluses,

unemployment, queues, idle resources, and nonprice rationing with price stability.¹ The key to his analysis and conclusions is the realization¹ that collating information about potential exchange opportunities is costly and can be performed in various ways.¹¹⁶

The industry equations presented above assume each industry sets the industry average wage equal to marginal revenue product. Thus each industry acts as a competitor in the labor market. Note that this does not imply all industry wages are equal. Each industry will have a different mix of skills from the labor market, thus causing a different average wage for each industry. An industry is making wage offers to individuals based on its perception of the going wage for labor. The wage offer will cause the proper amount of labor to be employed as required by the production function. Then, the average wage can be taken as predetermined for estimation purposes. But, wages do change from period to period as firms revise their wage offers in response to changing expectations concerning the equilibrium wage levels. Data are not available for labor supply by individual skill levels, so only the aggregate labor supply is treated here.

It is assumed that individuals do not have as much information as do firms. They will not participate in the labor market based on their perceptions of the expected wage,

which is determined by past wage levels and job opportunities. The labor force is thus a function of the average wage level and the unemployment rate both lagged one period. Thus

$$LFPR = \alpha_{50} + \beta_{50.1} AVWAGE_{-1} + \beta_{50.2} UNEMPR_{-1} \quad (50)$$

$$LF = LFPR \cdot POP \quad (51)$$

where LFPR is the labor force participation rate, $AVWAGE_{-1}$ is the real average wage lagged one period, $UNEMPR_{-1}$ is the unemployment rate lagged one period, LF is the labor force, and POP is the population.

Individuals who have entered the labor force will accept a job based on their expected wage versus the actual offers they receive. Here individuals may or may not have proper information concerning the labor market. Given this and the labor demand conditions described above, it would be incorrect to assume that the labor market necessarily clears in every period.

The behavior of individuals in the labor market here follows that associated with the search theory of unemployment.¹⁷ Unemployment may occur even though there is 'sufficient' aggregate demand in the 'Keynesian' sense¹⁸, and even though wages are flexible.¹⁹ This is a point of major departure from traditional models. Given this disequilibrium labor market, levels of unemployment above those commonly called frictional may be expected. The

addition of three equations completes the specification of the labor market.

$$\text{TOTEMP} = \sum_i \text{NOE}_i + \text{NOE}_G + \text{NOE}_F \quad (52)$$

$$\text{NUNEMP} = \text{LF} - \text{TOTEMP} \quad (53)$$

$$\text{UNEMPR} = \text{NUNEMP}/\text{LF} \quad (54)$$

where TOTEMP is total employment in the Chicago SMSA, NOE_i is the number of employees in private nonfarm industry i , NOE_G is the number of persons employed by the government, NOE_F is the number of persons employed on farms, NUNEMP is the number of unemployed persons, LF is the labor force, and UNEMPR is the unemployment rate.

Changes in wage and unemployment rates affect the labor supply from the local population as shown above. In addition, labor can be expected to migrate to the region if wage ratios are rising and unemployment levels are falling. A simple model of labor migration is developed in the next section and the labor migration equation is presented.

Labor Migration

Although previous regional econometric models have omitted it, it is desirable to have a separate migration equation. This allows the effects of migration and labor force participation changes to be separated.

The migration of labor into and out of a region affects it in several ways. Migration directly affects the size of the population and labor force. As a result,

per capita income, employment, and the wage rate are affected by migration. As will be seen below, these variables also affect migration flows. Thus, it is appropriate to include an analysis of migration flows in a model simultaneously determining these variables.

The literature on migration is enormous and will not be reviewed here.²⁰ Most of this literature agrees on personal welfare gains as the motivation for migration. Basic consumer theory predicts that an individual migrates to a new region only if there is a net welfare gain for that individual. Welfare gains are defined to include psychic as well as economic gains.

The basic model presented here assumes that migrants change homes in order to improve their lifetime earning prospects. It is similar to that presented in Harris and Todaro (98). The crucial assumption to be made is that migration to Chicago will continue so long as the expected urban real income at the margin exceeds expected real income in the rest of the United States. Prospective migrants maximize expected utility.

For a moment, consider the Chicago SMSA as a single economic unit producing one good utilizing a fixed capital stock and variable labor inputs. Then the production function for the Chicago SMSA can be written

$$X_{CHI} = f(K_{CHI}, L_{CHI}) \quad (55)$$

where X_{CHI} represents output of good X in Chicago, $\bar{K}_{CHI}$ the fixed capital stock in the Chicago SMSA, and L_{CHI} the labor combined with that capital stock.

Of interest is migration to Chicago from the rest of the United States. The production function for the U. S. can be written

$$Y_{US} = g(\bar{K}_{US}, L_{US}) \quad (56)$$

where Y_{US} is output of good Y in the U. S., $\bar{K}_{US}$ is the fixed capital stock in the U. S., and L_{US} is the labor combined with capital stock.

The real terms of trade between the U. S. and Chicago are

$$P = (X_{CHI}/Y_{US}) \quad (57)$$

where P is the real terms of trade, that is the price of a U. S. produced good in terms of a Chicago produced good. So the real terms of trade is a function of relative output in the two regions. If labor is paid the real value of its marginal product, then the U. S. real wage in terms of Chicago produced goods is given by

$$w_{US} = P \cdot MP_{L \cdot US} \quad (58)$$

where w_{US} is the U. S. real wage, P the real terms of trade, and $MP_{L \cdot US}$ is the marginal physical product of labor. And the Chicago real wage is

$$w_{CHI} = MP_{L \cdot CHI} \quad (59)$$

where w_{CHI} is the real wage in Chicago and $MP_{L\cdot CHI}$ is the marginal physical product of labor in Chicago.

Now, the expected wage in Chicago can be expressed as

$$w_{CHI}^e = w_{CHI} \cdot N_{M\cdot CHI} / N_{LF\cdot CHI} \quad (60)$$

where w_{CHI}^e is the expected wage in Chicago, w_{CHI} is the real wage in Chicago, $N_{M\cdot CHI}$ is the number of persons employed in Chicago, and $N_{LF\cdot CHI}$ is the labor force in Chicago. And, the expected wage in the rest of the U. S. is

$$w_{US}^e = w_{US} \cdot N_{M\cdot US} / N_{LF\cdot US} \quad (61)$$

where w_{US}^e is the expected wage in the U. S., w_{US} is the real wage in the U. S., $N_{M\cdot US}$ is the number of persons employed in the U. S., and $N_{LF\cdot US}$ is the labor force in the U. S. The following equilibrium wage must hold

$$w_{US}^e = w_{CHI}^e \quad (62)$$

Note that this does not require that wages or unemployment rates be equalized between the regions. This equilibrium condition is a natural consequence of the hypothesis that migration to an urban area is a positive function of the expected Chicago - U. S. wage differential. Net migration, NM , is defined as

$$NM = f((w_{CHI} \cdot N_{M\cdot CHI} / N_{LF\cdot CHI}) - (w_{US} \cdot N_{M\cdot US} / N_{LF\cdot US})) \quad (63)$$

So net migration ceases only when the expected wage

differential is zero. Note that job creation in Chicago also causes immigration, since $N_{M.CHI}$ and $N_{LF.CHI}$ increases, but $N_{M.CHI}$ by more in proportion, so $w_{CHI} \cdot N_{M.CHI}$ goes up causing immigration. Thus the migration relation used in the Chicago Econometric Model is

$$NM = \alpha_{64} + \beta_{64.1}(w_C^{E^C})_{-1} + \beta_{64.2}(w_{US}^{E^{US}})_{-1} \quad (64)$$

where NM is net migration to the Chicago SMSA, w_C and w_{US} are real wages in Chicago and the U. S., respectively, and E^C and E^{US} are the employment rates in the Chicago SMSA and the U. S., respectively. The -1 indicates the term is lagged one period. The implementation of this relation is complicated by the fact that no migration data are available on an annual basis for the Chicago SMSA. The data, however, may be calculated using published data on population, births, and deaths in the Chicago SMSA. The procedure used is described in the next section.

A Method for Calculating Migration Data

No time series migration data exists for the Chicago SMSA. An estimated migration series is a possibility given the data available. In order to implement the method used here, three data series are necessary - yearly population, the number of births to residents per year, and the number of deaths of residents per year. These three series are available. Population can be obtained from Current Population Reports, and births and deaths are available

from Vital Statistics of the United States.

If one adds to the population the number of births and subtracts the number of deaths occurring in the next twelve months, one obtains the population which would be in the region if no migration occurred during the year. Call this the predicted population. This is compared to actual population. If the actual population of the region is greater than the predicted population, then net in-migration must have occurred. And, if predicted population exceeds actual population net out-migration must have occurred. Thus, net migration can be calculated as follows:

$$NM_t = POP_{t+1} - (POP_t + B_t - D_t) \quad (65)$$

where NM_t is net migration, POP_t is population, B_t is births occurring during the year, and D_t is deaths occurring during the year.

Two implicit assumptions are being made here. Immigrants are assumed not to die during the year they arrive nor do they migrate when pregnant. If a migrant does die immediately after arriving, this will register as a death, if that person has become a resident. That person will not be counted in either POP_t or POP_{t+1} , thus the effect of such deaths is to increase the net migration figure. If a child is born to an immigrant shortly after arriving, that birth is counted in B_t and the child is

counted as part of POP_{t+1} . This event then has no net effect on the migration figure. But, the child possibly should be immigrant. Thus, an understatement of migration occurs. It is, therefore, impossible to say if these estimates of migration are biased one way or the other because of these assumptions. It is hoped that the effects cancel. Even if they do not, they probably would be small.

Government

Government is present in Chicago at three levels: federal, state, and local. These three levels of government are important because they each take income of residents of the region in the form of taxes. And, each level of government buys goods and services in the region as well as employing persons. Expenditures are not expected to equal taxes taken for each level of government.

Much of the federal and state activity within the Chicago SMSA does not vary because of changes in economic activity in the region. These parts are taken as exogenously determined. For example, employment in the State Department of Labor or the Chicago branch of the Bureau of Labor Statistics does not really change because of increases or decreases in GMP. Tax and grant rates are fixed, but, of course, the money flowing in or out of the region from these sources will vary with local activity. It is in this sense that federal and state activity is

treated as exogenous.

For the local government, expenditures and taxes are determined jointly by the residents of the region. Higher services necessarily mean higher taxes since most of local government is constrained to have a balanced budget. Note that all local government in the region is treated as if it were a coordinated unit working towards a common goal. Although there are over one hundred local governments in the region, this appears to be a reasonable as well as necessary assumption.

Local government revenue consists mainly of property taxes, but there may be other sources of income due to licenses and other fees. A complete model of local government would model prices for all real property as well as assessment practices of local government. Since these are omitted here, local government revenue is assumed to take the form of a proportional income tax.

$$\text{LGREV} = \alpha_{66} + \beta_{66.1} \text{RCPI} \quad (66)$$

where LGREV is local government revenue and RCPI is the personal income of Chicago residents. The difference between RCPI and personal income produced in the region is outlined below.

Since most of local government's output is services, local government employment is a function of local government expenditures. The local government competes for labor in the local labor market and thus government wages

follow the average wage in the region as well as the cost of living index. Finally, the local government can neither deficit spend nor generate a surplus. These three statements about local government are made explicit by equations (67), (68), and (69).

$$\text{LGEMP} = \alpha_{67} + \beta_{67.1} \text{LGEXP} \quad (67)$$

$$w_G = \alpha_{68} + \beta_{68.1} \text{AVWAGE} + \beta_{68.2} \text{CCPI} \quad (68)$$

$$\text{LGEXP} = \text{LGREV} + \text{REVFOS} \quad (69)$$

where LGEMP is local government employment, LGEXP is local government expenditures, w_G is the average wage paid to local government employees, AVWAGE is the average wage paid in the nongovernment sector, CCPI is the Chicago consumer price index, LGREV is local government revenue, and REVFOS is revenue from other sources.

The Consumer Price Index

The Chicago consumer price index is estimated as a function of the U. S. consumer price index and the prices of locally produced goods. The U. S. Consumer price index is included since Chicagoans buy many goods produced in other parts of the U. S., thus the price of these goods affects the cost of the local market basket. Thus,

$$\text{CCPI} = \alpha_{70} + \beta_{70.1} \text{USCPI} + \beta_{70.2} \sum_i V_i P_i \quad (70)$$

where CCPI is the Chicago consumer price index, USCPI is the U. S. consumer price index, and $\sum_i V_i P_i$ is the value-added weighted sum of the prices of the output produced

by local industries.

Income Accounts

The last few identities necessary to complete the specification of the model may be loosely called income accounts. These do not even approximate the elaborate systems of accounts described in Hirsch (106), (107), and Hochwald (109). Despite the pioneering work of Leven (147) and several conferences on regional accounts in the early 1960's, the results of which are included in the above referenced volumes, no comprehensive regional income accounting system has been established. The major identities described here are possible only because of data for the Chicago region made available by the Bureau of Economic Analysis.

Total labor and proprietors' income by place of work, TLPYPW, is given in equation (71) as the sum of wages and salaries, WS, other labor income, OLY, and proprietors' income, PY.

$$\text{TLPYPW} = \sum_i \text{WS}_i + \text{OLY} + \text{PY} \quad (71)$$

Other labor income consists of employers' contributions to private pension, health, and welfare plans; compensation for injuries; pay of military reservists; directors' fees; and several other minor items. Proprietors' income includes farm as well as nonfarm income.

It would seem better to express TLPYPW in a different form as in equation (72).

$$\text{TLPYPW} = \sum_i \text{LPYPW}_i + \text{LPYPW}_G + \text{LPYPW}_F \quad (72)$$

where $\sum_i \text{LPYPW}_i$ is the sum of labor and proprietor's income in private nonfarm industry i , and LPYPW_G and LPYPW_F are labor and proprietor's income in government and on farms, respectively. The first term of equation (72) is equal to the sum of the average annual wage in industry i , times the number of employees in industry i . This is shown in equation (73).

$$\sum_i \text{LPYPW}_i = \sum_i \text{NOE}_i \cdot \text{AAW}_i \quad (73)$$

where $\sum_i \text{LPYPW}_i$ is the sum of labor and proprietors' income in the private nonfarm sector, NOE_i is the number of employees in industry i , and AAW_i is the average annual real wage in industry i .

TLPYPW represents the total labor and proprietors' income produced within the Chicago SMSA. To obtain total income received by residents of the region, rent, interest, dividends, and net transfer payments must be added to TLPYPW. This figure then must be adjusted for the amount of income produced in the region which accrues to residents of other regions. This adjustment is made necessary mainly because of net outward commuting of workers. Thus, personal income by place of residence, RCPI, used in equation (66) can be derived as follows. RCPI is equal to total labor and proprietors' income by place of work, TLPYPW, minus personal

contributions for social insurance by place of work, SST, plus a residence adjustment to account for commuting, RA, plus dividends, interest, and rent, DIR, plus transfer payments, TP. So personal income by place of residence is given by equation (74).

$$RCPI = TLPYPW - SST + RA + DIR + TP \quad (74)$$

Chicago disposable income by place of residence, CDI, is then RCPI minus personal taxes including taxes. Thus, the effects of changes in local tax rates can be traced through the system. These last two relations are given by equations (75) and (76).

$$CDI = RCPI - PTAX \quad (75)$$

$$PTAX = FT + ST + LGREV \quad (76)$$

where PTAX equals total personal taxes, and FT, ST, and LGREV are federal, state, and local taxes, respectively.

This chapter has presented the specifications of the individual equations of the Chicago Econometric Model.

The next chapter deals with the identification and estimation of the model presented here.

FOOTNOTES TO CHAPTER III

1. The export-base hypothesis assumes all manufacturing activity is dependent on national demand levels and that all local activity is dependent on manufacturing. Here, since the Chicago SMSA is large, recognition of local demand for manufactured products is appropriate.

2. These two digit industries are:

Description	SIC Code
Ordinance and Accessories	19
Tobacco Products	21
Textile Mill Products	22
Lumber and Wood Products	24
Furniture and Fixtures	25
Rubber and Plastic Products, N.E.C.	30
Leather and Leather Products	31

3. The trans-log function also contains the Variable Elasticity of Substitution (VES) production function as a special case. If $\beta_{5.3} = \beta_{5.5} = 0$, then the translog function reduces to a VES function.

4. Rather returns to scale for the trans-log function can be derived in the following manner.

A production function is homogeneous of degree h if

$$f(tK, tL) = t^h f(K, L) \quad t > 0$$

So $\ln f(tK, tL) = h \cdot \ln t + \ln f(K, L)$

Now, the trans-log function can be written as

$$f(K, L) = \ln \alpha + \beta_1 \ln L + \beta_2 \ln K + \beta_3 (\ln L)^2 + \beta_4 \ln L \ln K + \beta_5 (\ln K)^2$$

and, if all inputs are increased by some multiple equal to t

$$\begin{aligned} f(tK, tL) &= \ln \alpha + \beta_1 \ln(L \cdot t) + \beta_2 \ln(K \cdot t) + \beta_3 (\ln L \cdot t)^2 \\ &\quad + \beta_4 \ln(L \cdot t) \ln(K \cdot t) + \beta_5 (\ln K \cdot t)^2 \\ &= \ln \alpha + \beta_1 (\ln L + \ln t) + \beta_2 (\ln K + \ln t) \\ &\quad + \beta_3 (\ln L + \ln t)^2 + \beta_4 (\ln L + \ln t) (\ln K + \ln t) \\ &\quad + \beta_5 (\ln K + \ln t)^2 \\ &= \ln \alpha + \beta_1 \ln L + \beta_1 \ln t + \beta_2 \ln K + \beta_2 \ln t \\ &\quad + \beta_3 \ln L \cdot \ln L + 2\beta_3 \ln L \ln t + \beta_3 \ln t \ln t \\ &\quad + \beta_4 \ln L \ln K + \beta_4 \ln L \ln t + \beta_4 \ln t \ln K + \beta_4 \ln t \ln t \\ &\quad + \beta_5 \ln K \ln K + 2\beta_5 \ln K \ln t + \beta_5 \ln t \ln t \\ &= \ln \alpha + \beta_1 \ln L + \beta_2 \ln K + \beta_3 (\ln L)^2 + \beta_4 \ln L \ln K \\ &\quad + \beta_5 (\ln K)^2 + (\beta_1 + \beta_2 + 2\beta_3 \ln L + \beta_3 \ln t + \beta_4 \ln L \\ &\quad + \beta_4 \ln K + \beta_4 \ln t + 2\beta_5 \ln K + \beta_5 \ln t) \ln t \\ &= \ln f(K, L) + (\beta_1 + \beta_2 + (2\ln L + \ln t)\beta_3 \\ &\quad + (\ln L + \ln K + \ln t)\beta_4 + (2\ln K + \ln t)\beta_5) \ln t \end{aligned}$$

And using the relation developed above

$$h = (\beta_1 + \beta_2 + (2\ln L + \ln t)\beta_3 + (\ln L + \ln K + \ln t)\beta_4 + (2\ln K + \ln t)\beta_5)$$

And so returns to scale (the degree of homogeneity) depends on the initial values of K and L, the value of t, and the coefficients β_1 through β_5 .

5. These restrictions follow directly from the results shown in footnote 4. The only way to have constant returns to scale is to eliminate those terms involving L, K, and t.
6. See Zellner and Revankar (236), p. 249 for example.
7. See Shen (262).
8. See (44), (72), (104), (128), (132), (155), (157), (173), (196), (197), (202), (204).
9. See Czamanski and Malizia (44), Schaffer and Chu (197), Morrison and Smith (173), and McMenamin and Haring (155) for example.
10. Choosing 5 percent as the cutoff, of course, is arbitrary.
11. For example, see Kendrick (125), Musgrave (175), (176), Bureau of Economic Analysis (19).
12. For an excellent explanation of the issues involved in estimating capital stocks and the Perpetual Inventory Method see Ward (231).

13. A sudden death type of depreciation means that a rectangular survival curve for capital assets is assumed (See Smith (205) and Ward (231)). This means that an asset fully exists for its useful life and then disappears. It is also assumed that all types of capital assets have the same average useful life and survival curve. Thus, the only capital assets in existence at any point in time are those purchased within the past n years, where n is the average useful life. This is the same as saying that all of the assets purchased in the last n years exist and their sum is the gross capital stock.
14. See Hickman (105) Appendix A.
15. See Jorgenson (117).
16. Alchian (2) p. 109.
17. For a elementary but complete discussion of search theory see Darby, Macroeconomics.
18. See Leijonhufvud (136) for a discussion of whether this view is truly part of the Economics of Keynes.
19. For the development of a complete disequilibrium model see Barro and Grossman (9).
20. See Greenwood (86) for a summary of much of the recent literature.

CHAPTER IV

THE IDENTIFICATION AND ESTIMATION OF
THE CHICAGO ECONOMETRIC MODEL

Introduction

This chapter presents the coefficient estimates for the model constructed in Chapter III. The complete model contains 179 equations of which 78 are stochastic. Before the model may be estimated the identification status of each equation must be examined so that an appropriate estimator may be chosen.

In a model as large as the Chicago Econometric Model, it is quite difficult to examine the identification status of each equation with respect to the entire system. Instead, the block recursiveness of the model is made explicit by examining the causal ordering of the system. Using certain results stated in Fisher (64), it is shown that identification with respect to the equations in each block of the system is sufficient to insure identification with respect to the system.

The identification of the equations of the model is complicated by the explicit nonlinearities introduced by use of the trans-log production function. The

modifications to the standard tests for identification made necessary by this nonlinearity are also explained.

Identification of the Equations

The identification of the equations of the Chicago Econometric Model follow the criteria established by Fisher (64).

Any simultaneous system may be written in the following form:

$$A q(x) = u \quad (77)$$

where x is a vector of N "basic" variables of which the first M are endogenous and the remaining $L = N - M$ are pre-determined, u is a column vector of disturbances, $q(x)$ is an N^0 component column vector of exact functions of x , and A is an $M \times N^0$ matrix of parameters to be estimated. For the linear case $q(x) = x$. Then, if only linear restrictions on the first equation are considered they may be written

$$A_1 \phi = 0 \quad (78)$$

where A_1 is the first row of A and ϕ is a matrix of constants. In this case, the necessary and sufficient rank condition for identifiability is that

$$\rho(A\phi) = M - 1 \quad (79)$$

while the necessary order condition is that

$$\rho(\phi) = M - 1 \quad (80)$$

It would be possible to apply the rank condition to each equation of the Chicago Econometric Model. But this

would indeed be an arduous task. This also would ignore the causal ordering inherent in the specification of the model. Causality is defined as an asymmetrical relation among certain variables or subsets of variables. That is, certain endogenous variables affect other variables but not vice-versa. There is a unidirectional flow in the cause-effect sequence of events. Thus, all variables in the model are not determined at once but rather a few at a time.

Due to the size of the Chicago Econometric Model, it is difficult to present a complete and clear diagram of the causal flows. The model consists of 16 blocks. The equations of each block are interdependent. But, each block is independent of the other blocks except that certain endogenous variables of some blocks are treated as predetermined in others. Figure 2 presents a typical block for a manufacturing industry. The dot indicates the equation where the endogenous variable is determined. The arrowheads show where this variable enters other equations. Each manufacturing block contains a similar set of equations. The only difference arises due to the local activity levels which enter the demand relations in each block. The determination of these flows was discussed in Chapter III. These flows are recursive, as Figure 3 illustrates. The dot indicates where the activity level is determined.

ENDOGENOUS

ln VA20

ln PWH20

LSH20

VA20

PWH20

AE20

Z20

EXOGENOUS

ln NAL

ln K20

ln K20, W20

ln K20

FIGURE 2. CAUSAL FLOWS IN A TYPICAL MANUFACTURING BLOCK

FIGURE 3. CAUSAL FLOWS AMONG MANUFACTURING BLOCKS

The arrowhead shows where this activity level enters a demand relation. The activity level is equal to value added in the industry. Thus, some of the blocks in the manufacturing sector take as predetermined the output of other blocks.

The largest block of the Chicago Econometric Model is that involving the locally oriented industries and local government. Each of these industries provides income for residents of the region. And each of these industries is affected by Chicago Disposable Income. Thus, they are all linked together. Figure 4 shows the causal flows within this block. It also shows where the flows from the manufacturing sector enter.

The last block of the model is also shown in Figure 4. This can be called the demographic block. Here net migration and the demand for housing starts are determined. The equations in this block are independent, but they are grouped together for convenience. This block has only flows out into the local block.

As mentioned above any simultaneous equation model may be written as

$$A q(x) = u \quad (81)$$

This may be rewritten as

$$BY + \Gamma Z = U \quad (82)$$

where $A = [B \ \Gamma]$ $q(x) = \begin{bmatrix} Y \\ Z \end{bmatrix}$

Y is the vector of endogenous variables

Z is the vector of predetermined variables
and B and Γ are the matrices of coefficients associated with those variables.

So, the Chicago Econometric Model may be written as equation (82). Now given the causal ordering of the model, this may be written in partitioned form as equation (83) :

$$\begin{bmatrix}
 B^{1,1} & 0 & 0 & \dots & \dots & \dots & 0 & 0 \\
 0 & B^{2,2} & 0 & \dots & \dots & \dots & 0 & 0 \\
 B^{3,1} & 0 & B^{3,2} & \dots & \dots & \dots & \dots & \dots \\
 0 & 0 & 0 & B^{4,4} & \dots & \dots & \dots & \dots \\
 0 & 0 & 0 & 0 & B^{5,5} & \dots & \dots & \dots \\
 0 & 0 & 0 & 0 & B^{6,5} & B^{6,6} & \dots & \dots \\
 B^{7,1} & 0 & B^{7,2} & B^{7,4} & 0 & B^{7,6} & B^{7,7} & \dots \\
 0 & 0 & 0 & B^{8,4} & 0 & 0 & 0 & B^{8,8} \\
 0 & 0 & 0 & 0 & 0 & B^{9,6} & 0 & 0 & B^{9,9} \\
 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & B^{10,10} \\
 0 & 0 & 0 & 0 & B^{11,5} & B^{11,6} & 0 & 0 & 0 & 0 & B^{11,11} \\
 0 & 0 & 0 & 0 & B^{12,5} & B^{12,6} & 0 & 0 & 0 & B^{12,10} & B^{12,11} & B^{12,12} \\
 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & B^{13,13} \\
 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & B^{14,14} \\
 B^{15,1} & B^{15,2} & B^{15,3} & B^{15,4} & B^{15,5} & B^{15,6} & B^{15,7} & B^{15,8} & B^{15,9} & B^{15,10} & B^{15,11} & B^{15,12} & B^{15,13} & B^{15,14} & B^{15,15} & 0 \\
 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & B^{16,16}
 \end{bmatrix}
 \begin{bmatrix}
 y^1 \\
 y^2 \\
 y^3 \\
 y^4 \\
 y^5 \\
 y^6 \\
 y^7 \\
 y^8 \\
 y^9 \\
 y^{10} \\
 y^{11} \\
 y^{12} \\
 y^{13} \\
 y^{14} \\
 y^{15} \\
 y^{16}
 \end{bmatrix}
 + \Gamma Z =
 \begin{bmatrix}
 u^1 \\
 u^2 \\
 u^3 \\
 u^4 \\
 u^5 \\
 u^6 \\
 u^7 \\
 u^8 \\
 u^9 \\
 u^{10} \\
 u^{11} \\
 u^{12} \\
 u^{13} \\
 u^{14} \\
 u^{15} \\
 u^{16}
 \end{bmatrix}$$

where the B 's, y 's, and u 's represent matrices associated with each of the 16 blocks. There is no need to partition Γ or z .

In this system, the variables in y^1 are jointly determined, but causally precede those of y^2 which in turn precede those of y^3 , and so forth. More specifically, the block triangularity of B means that movements in any element of u^i lead through effects on the endogenous variables to movements in the elements of y^j if and only if $j \geq i$.

($i = 1, \dots, 16$). They do not effect the elements of $y^1, \dots, y^{i-1}$.

Further, if it is allowed that the disturbances from an equation in any block may be correlated in the probability limit with the disturbances from any other equation in the same block, but is known to be uncorrelated in the probability limit with the disturbances from any equation in a different block, then Σ , the system covariance matrix, is block diagonal.

The block triangularity of B combined with the block diagonality of Σ allows one to treat endogenous variables from a given block of equations as predetermined with respect to the equations of any higher-numbered block. Further, since the elements of $y^{i+1}, \dots, y^{16}$ do not appear in the i th block of equations and since there is no feedback from higher-numbered blocks to the i th block, one may as well ignore the existence of blocks higher-numbered than i in dealing with the i th block. But all of these facts together suggest that one can forget about the i th block of equations being embedded in a larger system and treat it in isolation, taking all variables as predetermined, except the elements of y^i . In other words, an equation of the i th block will be identified by the block triangularity of B and the block diagonality of Σ if it is identified by further restrictions with respect to other equations of the i th block. This is just a generalization of the results

for recursive systems.

Given this discussion Fisher's Theorem 4.10.1 can be used to test the identifiability of the equations in the system.¹ The theorem states that an equation in the i th block of a system is identified if: 1) B is block triangular, 2) the covariance matrix Σ is diagonal, and 3) the equation is identifiable with respect to others of the i th block.

Conditions 1 and 2 of this theorem are satisfied as shown above. All that needs to be done is to check the identification of each equation with respect to its block in the system.

This task is complicated by the appearance of both labor and the natural logarithm of labor as endogenous functions. This explicit nonlinearity prohibits the application of the rank and order conditions, equations (79) and (80), in their normal form.

Identification in Nonlinear Systems

To explain the results pertaining to nonlinear systems recall equation (77), which is rewritten here:

$$A q(x) = u \quad (84)$$

Further, assume that (84) implicitly determines a single continuous vector function such that $Y = f(Z, U)$, that the elements of $q(x)$ are linearly independent, and that the elements of U are distributed independently of the elements

of Z . Note that the elements of $q(x)$ are not connected by linear identities, but they may be and are connected by nonlinear identities. This is the very nature of the problem with nonlinear systems. These nonlinear identities may cause implied equations to exist in the system which cannot be distinguished from the equations represented by $A q(x) = u$. The possibility of nonlinear transformations yielding implied equations is the essential difference between the linear and nonlinear cases. With this in mind Fisher's two main results on nonlinear identification can be stated.

Suppose there exist precisely $M^* - M$ functions of the disturbances $F^1, \dots, F^{M^* - M}$ such that

$$F^i(u_1, \dots, u_M) = F^i[A_1 q(x), \dots, A_M q(x)] = h^i q(x) \quad i = 1, \dots, M^* - M \quad (85)$$

where A_j is the j th row vector of A and the h^i are constant vectors with the property that the matrix

$$A^* = \begin{bmatrix} A \\ -\frac{1}{h^1} \\ \vdots \\ \frac{1}{h^{M^* - M}} \end{bmatrix} \quad (86)$$

has rank M^* , that is, A^* has full row rank. Define

Let $u_i = F^i(u_1, \dots, u_M)$ and define

$$u^* = \begin{bmatrix} -\frac{u}{h^1} \\ u_1 \\ \vdots \\ u_{M^* - M} \end{bmatrix} \quad (87)$$

Then an N^0 component row vector α can be distinguished from the true A_1 on the basis of a posteriori information if and only if α is not a linear combination of the rows of A^* . Given this the identification of A_1 proceeds as follows.

Let

$$A^* q(x) = u^* \quad (88)$$

replace the original equations (84). Then, if the only prior restrictions on the first equation take the form

$$A_1 \phi = 0 \quad (89)$$

where ϕ is a known constant matrix, then Fisher has shown that a necessary and sufficient condition for the identifiability of the first equation of (84) or (88) is that

$$\rho(A^* \phi) = M^* - 1 \quad (90)$$

and a necessary condition is that

$$\rho(\phi) = M^* - 1 \quad (91)$$

Note that it is valid to count as prior restrictions on the first equation the fact (if true) that certain elements of $q(x)$ do not appear therein. The fact that such elements may be functions also of variables which do appear in the first equation in different form has been taken into account in passing from equations (84) to (88) and in the restatement of the rank and order conditions.

The problem now becomes the determination of M^* and all the vectors h^i , so that equation (90) may be applied. Fortunately, Fisher (64) and Kelejian (123) have both provided methods. Fisher's method proves to be less

computationally burdensome and is used here.

Let $Q'(x)$ be the Jacobian matrix of $q(x)$, where the rows correspond to the elements of $q(x)$ and columns to elements of x . That is, the ij th element is the partial derivative of the i th element of $q(x)$ with respect to the j th element of x . $Q'(x)$ has only $N - 1$ columns since one cannot differentiate with respect to the constant. Furthermore, if the constant variable is the last element of $q(x)$, the N^{th} row of $Q'(x)$ is all zeros which can be omitted from what follows. Given this, Fisher has shown that for all x satisfying $A q(x) = 0$ one need only consider vectors h which satisfy

$$h Q'(x) = 0 \quad (92)$$

in order to derive the implied equations. To illustrate the application of this method, begin by writing Block 1 without a normalization rule imposed:

$$\beta_1 \ln VA20 + \beta_2 \ln PWH20 + \beta_3 \ln K20 + \beta_4 (\ln K20 - \ln PWH20) + \alpha_1 = u_1$$

$$\beta_2 \ln VA20 + \beta_{22} \ln PI20 + \beta_{23} \ln NAL20 + \alpha_2 = u_2$$

$$\beta_3 \ln LSH20 + \beta_{32} \ln PWH20 + \beta_{33} \ln K20 + \alpha_3 = u_3 \quad (93)$$

$$\beta_4 \ln AE20 + \beta_{42} (\ln LSH20 \cdot \ln VA20 / \ln W20) + \alpha_4 = u_4$$

where the linear identity $\ln VA^S = \ln VA^d$ has been substituted into the system where appropriate. Also, each of the nonlinear relations is inserted explicitly. This may be rewritten in matrix form as:

$$\begin{bmatrix}
 \beta_{11} & 0 & 0 & 0 & 0 & 0 & \beta_{12} & \beta_{14} & 0 & 0 & \beta_{13} & \alpha_1 \\
 \beta_{21} & 0 & 0 & \beta_{22} & 0 & 0 & 0 & 0 & 0 & \beta_{23} & 0 & \alpha_2 \\
 0 & \beta_{31} & 0 & 0 & 0 & 0 & \beta_{32} & 0 & 0 & 0 & \beta_{33} & \alpha_3 \\
 0 & 0 & \beta_{41} & 0 & 0 & \beta_{42} & 0 & 0 & 0 & 0 & 0 & \alpha_4
 \end{bmatrix}
 \begin{bmatrix}
 \ln VA20 \\
 LSH20 \\
 AE20 \\
 \ln PI20 \\
 VA20 \\
 \frac{LSH20 \cdot VA20}{\omega 20} \\
 \ln PWH20 \\
 (\ln K20 - \ln PWH20)^2 \\
 \omega 20 \\
 \ln NAL20 \\
 \ln K20 \\
 1
 \end{bmatrix}
 =
 \begin{bmatrix}
 u_1 \\
 u_2 \\
 u_3 \\
 u_4
 \end{bmatrix}
 \quad (94)$$

Now to apply Fisher's method one needs $Q'(x)$, the Jacobian matrix of $q(x)$. This is

$$\begin{bmatrix}
 \frac{1}{VA20} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
 \frac{LSH20}{\omega 20} & \frac{VA20}{\omega 20} & 0 & 0 & \frac{-LSH20 \cdot VA20}{(\omega 20)^2} & 0 & 0 & 0 & 0 \\
 0 & 0 & 0 & 0 & 0 & \frac{1}{PWH20} & 0 & 0 & 0 \\
 0 & 0 & 0 & 0 & 0 & \frac{2(\ln K20 - \ln PWH)}{PWH20} & 0 & 2(\ln K20 - \ln PWH) & 0 \\
 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1
 \end{bmatrix}
 \quad (95)$$

Using this one can find h $Q'(x) = 0$ which yields the following set of equations.

$$h_2 = h_3 = h_4 = h_1 = h_5 = h_7 = h_8 = 0$$

$$h_1 (1/VA20) = 0 \quad (96)$$

$$h_1(LSH20/W20) + h_2(VA20/W20) + h_5(-LSH20 \cdot VA20/(W20)^2) = 0$$

$$h_6(1/PWH20) = 0$$

$$h_6(2(\ln K20 - \ln PWH20)/PWH20) + h_8(2(\ln K20 - \ln PWH20)) = 0$$

This set of equations is obviously only satisfied when the vector h equals zero. Thus, no implied equations exist and $M^* = M$. Then, the rank condition as given by equation (79) may be applied utilizing the A matrix from (94).

Each manufacturing block is the same except for the appearance of certain local activity levels in the demand equation. The equations in each block were examined and found to be identified using the rank condition listed above. The equations of the large nonmanufacturing block may not be identified so easily. Due to the sheer size of this block direct application of the rank condition is not feasible. Instead, the necessary but not sufficient order condition is used. This condition requires that the number of excluded variables be equal to or greater than the number of endogenous variables in the system minus one. The equations which come closest to not fulfilling the order condition would be the production functions which contain 5 variables. The order condition for this equation requires that the number of excluded variables be 38. There are 67 variables in this block. This means that 62 are excluded. The order condition requires that the rank of the exclusion

restriction matrix, ϕ , listed above in equation (80) be at least equal to the number of endogenous variables minus one, in this case 38. It would be a difficult if not impossible task to verify this. This is why the rank condition is not applied. It would require the examination of the $A\phi$ matrix and its rank. Instead, it is hoped that the exclusion of so many variables would lead to matrices of sufficient rank. With this caution in mind, the estimates are presented in the next section.

The Coefficient Estimates

Each block of the model was estimated separately using three stage least squares, since some of the equations were overidentified.

The estimates of the coefficients are presented in Table 17.³ The number in the parenthesis below each coefficient is the 't-statistic' for that coefficient estimate. Of the 254 coefficient estimates presented 165 are significant if ones uses these 't-statistics' as the measure of judgment.

Note that some of the local activity level coefficients indicating linkages in the local manufacturing sector are insignificant. This is the statistical test of the strength of these linkages referred to in Chapter III. These insignificant linkages were omitted and those blocks of the model were rerun. These estimates are presented in Table 18.

TABLE 20

THE ESTIMATED EQUATIONS OF THE
CHICAGO ECONOMETRIC MODEL*

$$VA_{20} = -4.778 - 7.956PWH_{20} + 8.692K_{20} - 1.796Z_{20}$$

(-1.37) (-5.45) (6.30) (-5.67)

$$LSH_{20} = 4.069 \times 10^{-1} + 2.597 \times 10^{-2}PWH_{20} - 3.423 \times 10^{-2}K_{20}$$

(0.37) (0.43) (-0.84)

$$VA_{20} = 6.450 - 8.890 \times 10^{-1}PI_{20} + 7.676 \times 10^{-1}NAL_{20}$$

(13.50) (-13.54) (16.13)

$$AE_{20} = 27.648 + 5.431 \times 10^{-4}WH_{20}$$

(4.25) (9.33)

$$VA_{23} = 18.556 - 3.350 \times 10^{-1}PWH_{23} - 2.577 \times 10^{-1}K_{23} +$$

$$+ 1.425 \times 10^{-1}Z_{23}$$

(8.87) (-1.82) (-1.59)

(0.27)

$$LSH_{23} = -3.90 + 3.660 \times 10^{-1}PWH_{23} + 2.053 \times 10^{-2}K_{23}$$

(-7.54) (13.67) (0.57)

$$VA_{23} = 9.488 - 4.064 \times 10^{-1}PI_{23} + 3.071 \times 10^{-1}NAL_{23}$$

(20.68) (-3.21) (6.04)

$$AE_{23} = -2.304 + 7.606 \times 10^{-4}WH_{23}$$

(-0.60) (7.78)

$$VA_{26} = -7.878 + 3.034PWH_{26} - 1.117K_{26} + 6.180 \times 10^{-1}Z_{26}$$

(-3.93) (1.21) (-0.46) (0.98)

$$LSH_{26} = 2.765 + 9.731 \times 10^{-2}PWH_{26} - 2.742 \times 10^{-1}K_{26}$$

(7.91) (2.35) (-11.55)

$$VA_{26} = 5.885 - 2.067PI_{26} + 6.716 \times 10^{-1}NAL_{26} + 2.0 \times 10^{-7}LVA_{20}$$

(2.37) (-8.71) (2.13) (0.99)

$$+ 3.7 \times 10^{-7}LVA_{27} - .5 \times 10^{-7}LVA_{28} + .7 \times 10^{-7}LVA_{36}$$

(1.38) (-0.28) (0.48)

$$AE_{26} = 7.041 + 4.807 \times 10^{-4}WH_{26}$$

(1.94) (6.26)

$$VA_{27} = -13.893 - 5.594 \times 10^{-1}PWH_{27} + 2.695K_{27} - 4.811 \times 10^{-1}Z_{27}$$

(-5.84) (-0.48) (2.58) (-1.74)

$$LSH_{27} = 4.459 - 1.804 \times 10^{-1}PWH_{27} - 1.550 \times 10^{-1}K_{27}$$

(8.21) (-3.89) (-10.63)

$$VA_{27} = 5.332 - 1.204WPIMND + 9.023 \times 10^{-1}NAL_{27} + 1.0 \times 10^{-7}LVA_{20}$$

(7.81) (-8.39) (10.29) (0.89)

$$AE_{27} = 28.070 + 5.994WH_{27}$$

(1.77) (3.80)

TABLE 20 (Continued)

$$VA28 = -20.676 + 4.075PWH28 - 9.734K28 + 5.492Z28$$

$$(-2.09) \quad (7.48) \quad (-0.18) \quad (0.56)$$

$$LSH28 = 2.775 - 3.843 \times 10^{-2} PWH28 - 1.670 \times 10^{-1} K28$$

$$(5.77) \quad (-1.01) \quad (-5.69)$$

$$VA28 = 4.023 - 1.142PI28 + 9.859 \times 10^{-1} NAL28$$

$$(8.23) \quad (-4.50) \quad (20.11)$$

$$AE28 = -3.18 + 1.112 \times 10^{-3} WH28$$

$$(-0.26) \quad (4.03)$$

$$VA29 = 40.956 + 24.250PWH29 - 22.586K29 + 2.880Z29$$

$$(1.91) \quad (2.86) \quad (2.61) \quad (2.74)$$

$$LSH29 = 3.153 - 1.496 \times 10^{-1} PWH29 - 1.210K29$$

$$(1.60) \quad (-0.58) \quad (-1.84)$$

$$VA29 = 9.259 + 1.515 \times 10^{-1} PI29 + 2.041 \times 10^{-1} NAL29$$

$$(4.66) \quad (0.38) \quad (0.76)$$

$$+ 7.4 \times 10^{-7} LVA28$$

$$(2.82)$$

$$AE29 = -7.279 + 1.786 \times 10^{-3} WH29$$

$$(-1.34) \quad (2.76)$$

$$VA32 = 2.138 - 1.063PWH32 + 1.842K32 - 3.292 \times 10^{-1} Z32$$

$$(0.73) \quad (-0.85) \quad (1.63) \quad (-1.05)$$

$$LSH32 = -4.172 \times 10^{-1} + 1.681PWH32 - 7.855 \times 10^{-2} K32$$

$$(-0.57) \quad (3.02) \quad (-3.17)$$

$$VA32 = 8.990 - 6.642 \times 10^{-1} PI32 - 3.513 \times 10^{-1} NAL32$$

$$(8.51) \quad (-5.99) \quad (2.75)$$

$$+ 1.8 \times 10^{-7} LVA36$$

$$(3.39)$$

$$AE32 = 21.48 - 6.395 \times 10^{-5} WH32$$

$$(9.80) \quad (-0.89)$$

$$VA33 = -8.409 + 4.940PWH33 - 2.787K33 + 6.643 \times 10^{-1} Z33$$

$$(-3.25) \quad (3.97) \quad (2.26) \quad (2.74)$$

$$LSH33 = 3.494 - 2.295 \times 10^{-1} PWH33 - 2.811 \times 10^{-2} K33$$

$$(4.96) \quad (-4.79) \quad (-1.03)$$

$$VA33 = 5.048 - 1.214PI33 + 8.767NAL33 - .8 \times 10^{-7} LVA34$$

$$(3.47) \quad (-6.93) \quad (5.32) \quad (-0.47)$$

$$+ 1.1 \times 10^{-7} LVA35 - .4 \times 10^{-7} LVA36 + 1.7 \times 10^{-7} LVA37$$

$$(1.01) \quad (-0.34) \quad (1.65)$$

$$AE33 = 56.758 + 1.075 \times 10^{-4} WH33$$

$$(5.88) \quad (1.14)$$

TABLE 20 (Continued)

$$\begin{aligned}
VA_{34} &= -13.020 + 5.102 \times 10^{-1} PWH_{34} + 1.591 K_{34} - 1.914 \times 10^{-1} Z_{34} \\
&\quad (-8.24) \quad (0.39) \quad (1.23) \quad (-0.43) \\
LSH_{34} &= 2.809 - 1.105 \times 10^{-2} PWH_{34} - 1.689 \times 10^{-1} K_{34} \\
&\quad (6.20) \quad (-0.24) \quad (-5.53) \\
VA_{34} &= 8.793 - 9.969 \times 10^{-1} PI_{34} + 5.058 \times 10^{-1} NAL_{34} \\
&\quad (16.37) \quad (-11.61) \quad (8.00) \\
&\quad + .6 \times 10^{-7} LVA_{35} + 1.8 \times 10^{-7} LVA_{36} \\
&\quad (1.71) \quad (4.46) \\
AE_{34} &= 58.299 + 2.740 \times 10^{-4} WH_{34} \\
&\quad (4.31) \quad (3.32) \\
VA_{35} &= -7.884 + 2.423 PWH_{35} - 5.998 \times 10^{-1} K_{35} + 3.449 \times 10^{-1} Z_{35} \\
&\quad (-7.19) \quad (3.21) \quad (-0.78) \quad (1.81) \\
LSH_{35} &= 7.502 \times 10^{-1} + 1.760 \times 10^{-2} PWH_{35} - 3.994 \times 10^{-2} K_{35} \\
&\quad (2.64) \quad (0.78) \quad (-2.27) \\
VA_{35} &= 6.753 - 9.357 \times 10^{-1} PI_{35} + 7.429 \times 10^{-1} NAL_{35} \\
&\quad (18.58) \quad (-11.51) \quad (19.93) \\
AE_{35} &= 59.189 + 3.579 \times 10^{-4} WH_{35} \\
&\quad (3.02) \quad (2.94) \\
VA_{36} &= -10.768 + 7.972 \times 10^{-1} PWH_{36} + 1.142 K_{36} + 5.386 \times 10^{-2} Z_{35} \\
&\quad (-7.30) \quad (3.79) \quad (6.33) \quad (0.83) \\
LSH_{36} &= 2.745 + 8.537 \times 10^{-2} PWH_{36} - 2.580 \times 10^{-1} K_{36} \\
&\quad (6.81) \quad (3.65) \quad (-15.47) \\
VA_{36} &= 8.426 - 7.201 \times 10^{-1} PI_{36} + 5.936 \times 10^{-1} NAL_{36} \\
&\quad (8.59) \quad (-2.24) \quad (5.48) \\
&\quad + .4 \times 10^{-7} LVA_{35} \\
&\quad (0.45) \\
AE_{36} &= 111.884 + 1.830 \times 10^{-4} WH_{36} \\
&\quad (5.98) \quad (1.95) \\
VA_{37} &= -37.573 + 9.282 \times 10^{-1} PWH_{37} + 3.275 K_{37} + 2.961 \times 10^{-2} Z_{37} \\
&\quad (-5.95) \quad (0.87) \quad (2.71) \quad (0.09) \\
LSH_{37} &= 7.032 + 5.675 \times 10^{-2} PWH_{37} - 5.900 \times 10^{-1} K_{37} \\
&\quad (3.86) \quad (1.18) \quad (-4.87) \\
VA_{37} &= 5.871 - 7.543 \times 10^{-1} PI_{37} + 7.265 \times 10^{-1} NAL_{37} \\
&\quad (4.89) \quad (-2.62) \quad (6.09) \\
AE_{37} &= 35.854 - 1.221 \times 10^{-4} WH_{37} \\
&\quad (6.99) \quad (-1.19) \\
VA_{38} &= -10.939 + 1.641 PWH_{38} + 5.192 \times 10^{-1} K_{38} + 2.658 \times 10^{-1} Z_{38} \\
&\quad (-6.74) \quad (2.79) \quad (0.90) \quad (1.25) \\
LSH_{38} &= 2.455 + 4.544 \times 10^{-2} PWH_{38} - 2.263 \times 10^{-1} K_{38} \\
&\quad (6.50) \quad (0.98) \quad (-8.28)
\end{aligned}$$

TABLE 20 (Continued)

$$VA38 = 4.180 - 3.262PI38 + 1.040NAL38$$

$$(3.78) \quad (-2.39) \quad (7.66)$$

$$AE38 = 7.495 + 5.690 \times 10^{-4} WH38$$

$$(1.22) \quad (3.77)$$

$$VA39 = -9.464 - 2.232PWH39 + 4.023K39 - 1.212Z39$$

$$(-2.07) \quad (-1.08) \quad (1.88) \quad (-1.33)$$

$$LSH39 = 1.221 + 2.030 \times 10^{-1} PWH39 - 2.569 \times 10^{-1} K39$$

$$(1.33) \quad (4.21) \quad (-3.23)$$

$$VA39 = 13.661 + 8.570 \times 10^{-1} PI39 - 1.314 \times 10^{-1} NAL39$$

$$(7.84) \quad (2.54) \quad (0.64)$$

$$AE39 = 16.856 + 3.022 \times 10^{-4} WH39$$

$$(7.20) \quad (5.54)$$

$$VATCPU = -1.562 + 3.041 \times 10^{-1} AETCPU + 1.004VATCPU_{-1}$$

$$(-1.43) \quad (1.50) \quad (22.80)$$

$$- 3.752ZTCPU$$

$$(-14.64)$$

$$LSHTCPU = 13.162 - 9.020 \times 10^{-3} AETCPU - 1.325VATCPU_{-1}$$

$$(3.78) \quad (-0.01) \quad (-9.83)$$

$$VATCPU = 7.232 - 1.332PITCPU + 3.915 \times 10^{-5} CDI$$

$$(198.94) \quad (-13.06) \quad (22.98)$$

$$VAWRT = -2.082 + 1.303AEWRT + 2.765 \times 10^{-1} VAWRT_{-1}$$

$$(-4.39) \quad (-7.98) \quad (3.04)$$

$$- 9.337 \times 10^{-1} ZWRT$$

$$(-2.67)$$

$$LSHWRT = 8.157 - 9.547 \times 10^{-1} AEWRT - 1.270 \times 10^{-1} VAWRT_{-1}$$

$$(25.05) \quad (-9.22) \quad (-2.15)$$

$$VAWRT = 7.403 - 2.210PIWRT + 6.576 \times 10^{-5} CDI$$

$$(95.11) \quad (-11.13) \quad (14.63)$$

$$VASER = 3.519 + 1.170AESER - 3.426 \times 10^{-1} VASER_{-1} + 2.331ZSER$$

$$(16.36) \quad (32.69) \quad (-8.86) \quad (11.10)$$

$$LSHSER = 2.883 - 2.904 \times 10^{-1} AESER + 2.274 \times 10^{-2} VASER_{-1}$$

$$(6.53) \quad (-3.91) \quad (0.36)$$

$$VASER = -5.619 - 9.850 \times 10^{-1} PISER + 2.014 \times 10^{-5} CDI$$

$$(0.74) \quad (-8.13) \quad (8.20)$$

$$+ 9.099 \times 10^{-1} NALSER$$

$$(10.79)$$

TABLE 20 (Continued)

$$\begin{aligned}
\text{VAFIR} &= -6.365 \times 10^{-3} + 7.524 \times 10^{-1} \text{AEFIR} + 5.473 \times 10^{-1} \text{VAFIR}_{-1} \\
&\quad (-0.01) \quad (5.36) \quad (5.34) \\
&\quad + 1.624 \text{ZFIR} \\
&\quad (1.92) \\
\text{LSHFIR} &= 8.438 - 6.921 \times 10^{-1} \text{AEFIR} - 4.451 \times 10^{-1} \text{VAFIR}_{-1} \\
&\quad (11.27) \quad (-3.79) \quad (-3.40) \\
\text{VAFIR} &= -1.607 - 1.160 \text{PIFIR} + 1.814 \times 10^{-5} \text{CDI} + 1.221 \text{NALFIR} \\
&\quad (-1.66) \quad (-8.89) \quad (5.98) \quad (9.78) \\
\text{VACC} &= 2.452 + 5.289 \times 10^{-1} \text{AECC} + 2.890 \times 10^{-1} \text{VACC}_{-1} \\
&\quad (5.28) \quad (4.80) \quad (3.53) \\
&\quad - 2.577 \times 10^{-1} \text{ZCC} \\
&\quad (-0.83) \\
\text{LSHCC} &= -15.048 + 15.945 \text{AECC} - 7.313 \text{VACC}_{-1} \\
&\quad (-0.95) \quad (4.38) \quad (-3.38) \\
\text{VACC} &= 6.62 - 4.291 \times 10^{-1} \text{PICC} + .3 \times 10^{-7} \text{HS} + 6.451 \times 10^{-4} \text{TOTINVM} \\
&\quad (133.75) \quad (-6.43) \quad (1.23) \quad (7.43) \\
\text{LFPR} &= 5.469 \times 10^{-1} - 5.546 \times 10^{-2} \text{AVWAGEM}_{-1} + 1.459 \times 10^{-2} \text{UNEMPR}_{-1} \\
&\quad (9.07) \quad (-2.90) \quad (4.26) \\
\text{AVWAGELG} &= -7853.754 + 2266.788 \text{AVWAGEM} + 8414.137 \text{CCPI} \\
&\quad (-10.69) \quad (6.08) \quad (17.62) \\
\text{CCPI} &= 6.768 \times 10^{-1} + 9.934 \times 10^{-1} \text{USCPI} - 4.570 \times 10^{-2} \text{WA} \\
&\quad (10.36) \quad (12.21) \quad (-0.68) \\
\text{LGEMP} &= 111.474 + 3.658 \times 10^{-2} \text{LGEXP} \\
&\quad (11.08) \quad (10.94) \\
\text{LGREV} &= -186.543 + 7.286 \times 10^{-2} \text{RCPI} \\
&\quad (-1.57) \quad (19.05) \\
\ln H^d &= 20.681 - 2.71 \times 10^{-2} \ln \text{RYPHH} - 7.49 \times 10^{-3} \ln P_h \\
&\quad (35.45) \quad (-0.97) \quad (-0.68) \\
&\quad - 5.007 \ln(\text{POP/TR}) \quad R^2 = .998 \quad F = 2756.15 \\
&\quad (-17.32) \\
\text{NM} &= 259.789 + 8.058 w^c E^c - 98.726 w^{us} E^{us} \quad R^2 = .477 \quad F = 9.12 \\
&\quad (1.90) \quad (0.03) \quad (-0.50)
\end{aligned}$$

* See Appendix A for a complete list of Variable abbreviations used in this table.

TABLE 21

REVISED ESTIMATES FOR SOME BLOCKS

VA26	=	-8.125	+	3.022	PWH26	-	1.085	K26	+	6.086x10 ⁻¹	Z26
		(-4.10)		(1.22)			(-0.45)			(0.98)	
LSH26	=	2.849	+	8.60x10 ⁻²	PWH26	-	2.712x10 ⁻¹	K26			
		(8.11)		(2.07)			(-11.40)				
VA26	=	4.703x10 ⁻¹	-	1.909	PI26	+	1.360	NAL26			
		(0.94)			(-12.18)			(24.42)			
AE26	=	7.003	+	4.815x10 ⁻⁴	WH26						
		(1.92)		(6.27)							
VA27	=	-13.912	-	5.495x10 ⁻¹	PWH27	+	2.687	K27	-	4.792x10 ⁻¹	Z27
		(-5.85)		(-0.48)			(2.57)			(-1.73)	
LSH27	=	4.451	-	1.797x10 ⁻¹	PWH27	-	1.550x10 ⁻¹	K27			
		(8.19)		(-3.87)			(-10.64)				
VA27	=	4.819	-	1.095	WPIMND	+	9.722x10 ⁻¹	NAL27			
		(13.67)			(-15.08)			(25.99)			
AE27	=	28.479	+	5.953x10 ⁻⁴	WH27						
		(1.80)		(3.77)							
VA33	=	-7.461	+	5.903	PWH33	-	3.731	K33	+	8.561x10 ⁻¹	Z33
		(-3.01)		(5.38)			(-3.42)			(4.02)	
LSH33	=	3.648	-	2.197x10 ⁻¹	PWH33	-	4.719x10 ⁻²	K33			
		(5.51)		(-4.71)			(-1.99)				
VA33	=	4.390	-	1.143	PI33	+	9.525x10 ⁻¹	NAL33			
		(8.20)			(-13.41)			(17.19)			
AE33	=	55.171	+	1.230x10 ⁻⁴	WH33						
		(5.73)		(1.31)							
VA34	=	-12.684	+	1.306	PWH34	+	8.145x10 ⁻¹	K34	+	7.071x10 ⁻²	Z34
		(-7.97)		(0.94)			(0.60)			(0.15)	
LSH34	=	2.786	-	8.508x10 ⁻³	PWH34	-	1.695x10 ⁻¹	K34			
		(6.13)		(-0.19)			(-5.54)				
VA34	=	5.980	-	1.086	PI34	+	8.422x10 ⁻¹	NAL34			
		(17.64)			(-12.13)			(23.36)			
AE34	=	51.64	+	3.147x10 ⁻⁴	WH34						
		(3.83)		(3.83)							
VA36	=	-10.676	+	7.754x10 ⁻¹	PWH36	+	1.155	K36	+	4.893x10 ⁻²	Z36
		(-7.30)		(3.69)			(6.62)			(0.74)	
LSH36	=	2.708	+	8.825x10 ⁻²	PWH36	-	2.578x10 ⁻¹	K36			
		(6.80)		(3.88)			(-15.50)				

TABLE 21 (Continued)

REVISED ESTIMATES FOR SOME BLOCKS

$$VA36 = 8.041 - 6.058 \times 10^{-1} PI36 + 6.389 \times 10^{-1} NAL36$$

(16.96) (-3.29) (13.33)

$$AE36 = 111.114 + 1.86 \times 10^{-4} WH36$$

(5.94) (1.99)

To do an effective job of analyzing the model, one must view the entire system of equations. Here at least two major kinds of difficulties in evaluating regional models are encountered. First, there are few standard statistical tests that may be used in determining a 'best fitting system'. Second, few authors have presented analyses of their models, making comparisons difficult. The problem of evaluating the Chicago Econometric Model as a system is dealt with in the next chapter.

FOOTNOTES TO CHAPTER IV

1. Fisher (64), p. 121.
2. Ibid. p. 140-145.
3. Note that the production functions appear in a slightly different form than when presented before. The Z term which represents $(\ln PWH_{..} - \ln K_{..})^2$ appears instead of $(\ln PWH_{..})^2 + \ln PWH_{..} \cdot \ln K_{..} + (\ln K_{..})^2$ due to problems of severe multicollinearity encountered during estimation.

CHAPTER V

SOME TESTS AND CONCLUSIONS

Introduction

The building of regional econometric models is plagued by many problems. One of these is the lack of a standard against which the model may be measured. To do an effective job of evaluating the model, one must evaluate the entire structure of the model. This requires that one view the complete system of equations.

Together with the need to test hypotheses about the way in which economic variables are related, the generation of predictions constitutes a prime objective of applied econometric analysis. In this chapter attention is turned to the use of the Chicago Econometric Model for various kinds of predictions.

Due to the practical value of the end product, interest often centers on forecasting the future. This is usually referred to as ex ante forecasting.

Predictions of the future obtained from an econometric model can be expected to be subject to error on a number of counts. These include the use of estimated equations, the stochastic nature of the model used which

means that the variable to be forecast is itself a random variable, and shifts in the structure of the relationships used between the observation period and the forecast period.

The difficulty of tracing the sources of error in an ex ante forecast given this array of alternatives can be reduced somewhat from reference to other kinds of forecasts. In particular, the accuracy with which a model 'forecasts' observed past values of certain variables is likely to prove instructive. This is known as ex post forecasting and is examined in the next section.

Ex Post Forecasts of the Endogenous Variables

There are several different methods of preparing ex post forecasts. That which is used here is often referred to as dynamic simulation. A distinction is made in the treatment of exogenous and lagged endogenous variables within the category of predetermined variables. The known values of the exogenous variables are used in preparing the forecast. But, only the initial known values of the lagged endogenous variables are used. The generated values of the lagged endogenous variables are used in subsequent forecasts rather than the actual values. This is what would have to be done in practice in preparing a series of ex ante forecasts over time and ex post forecasts of this kind will help give some indication whether the

dynamic properties of the model are such that it is suitable for this purpose.

Predictions of the endogenous variables of linear models can be obtained simply enough in principle from the reduced form solution of the model in which each endogenous variable is expressed as a function of predetermined variables alone. Consider the following equation system.

$$BY + \Gamma Z = U \quad (97)$$

where the matrices B and Γ represent the parameters of the endogenous and predetermined variables in the two equations and the vectors Y , Z , and U represent the values of the endogenous, predetermined, and disturbance variables in time period t . The reduced form may be written

$$Y = B^{-1}\Gamma Z + B^{-1}\Gamma U \quad (98)$$

Given the array Z the nonstochastic predictions of the endogenous variables are

$$Y = B^{-1}\Gamma Z \quad (99)$$

Where the model is nonlinear, as is the case of the Chicago Econometric Model, things are not so simple. An algebraic solution to the model is difficult if not impossible to obtain. Because of this an alternative method of obtaining the reduced form was used.

The Gauss-Seidel method of solution, an iterative procedure, was used to approximate the reduced form of the model. The procedure may be illustrated best by reference to an example. Consider the supply demand system given by

(100).

$$\begin{aligned} Q_D &= f(P, Y) \\ Q_S &= f(P, C) \\ Q_D &= Q_S \end{aligned} \quad (100)$$

where Q_D and Q_S are quantity demanded and supplied respectively, P is the price of the good, and Y and C are exogenous variables.

First the identity is assumed to hold. Second a renormalization of the system is necessary. Then

$$\begin{aligned} Q &= f(P, Y) \\ P &= f(Q, C) \end{aligned} \quad (101)$$

Now, given the values of the exogenous variables and initial guesses of the values of the endogenous variables, the first equation of (101) is solved for Q . Then this value is substituted for Q on the right-hand side of the system. Then the second equation is solved for P . These "solution" values are then examined. If it is found that they have not changed by less than a prespecified amount from their previous values, the system is considered solved. If one of the endogenous variables has changed by more than the prespecified amount, the system is resolved using the last calculated values of the endogenous variables as the initial guess.

Whether this procedure leads to convergence, and the speed with which convergence is achieved if it is, depends on a number of factors. The ordering of the equations and the particular normalization rule chosen are particularly

important. If the main lines of economic causation are traced through the model and the equations are normalized accordingly, then it is likely that a convergent algorithm will result.

This algorithm was applied to the Chicago Econometric Model and a solution was obtained. The model was simulated during each time period, with the lagged values of the endogenous variables being taken as equal to those generated in the previous year.

To see how well the model approximates the actual values of the endogenous variables, the Mean Absolute Percent Error (MAPE) statistic was calculated for each endogenous variable. The MAPE statistic for a given variable y is equal to

$$\frac{\sum_{i=1}^N |y_i^p - y_i^a| / y_i^a}{N} \cdot 100 \quad (102)$$

where y_i^a is the actual value of the endogenous variable, y_i^p is the predicted value of the endogenous variable, and N is the number of observations.

The individual MAPE statistics for all 175 endogenous variables are presented in Appendix B. Table 22 presents a summary of these statistics along with MAPE statistics from other regional econometric models. The Chicago Econometric Model has a large number of variables for which the MAPE statistics are low. But, it also has a large number for which the MAPE statistics are quite high. This latter

TABLE 22

DISTRIBUTION OF MAPE STATISTICS FOR SEVERAL REGIONAL ECONOMETRIC MODELS

	Philadelphia I	Philadelphia IV	Los Angeles *	Northeast Corridor	Chicago
5% or more	43.5	18.1	21.4	26.5	37.1
4 - 4.99%	8.6	10.2	0.0	16.3	5.7
3 - 3.99%	17.4	11.8	0.0	12.2	16.0
2 - 2.99%	13.0	31.5	14.3	22.4	11.4
1 - 1.99%	17.4	22.0	35.7	18.4	8.6
Less than 1%	0.0	6.3	28.6	4.1	21.1

Source: Philadelphia I - Glickman (74)
 Philadelphia IV - Glickman (76)
 Los Angeles - Hall and Licari (96)
 Northeast Corridor - Crow (43)

* Hall and Licari only include 'selected' MAPE statistics.

category consists mainly of variables which are logarithmic in form. This means that small numerical errors are magnified into large MAPE statistics. Table 23 presents some selected variables from several regional econometric models. The Chicago model does as well as these other models in 'predicting' these major variables.

These statistics seem to indicate that the model performs at least as well as other regional econometric models. This gives one some confidence in using the model to predict outside the sample period.

Multiplier Analysis

Often one of the principle objectives of building econometric models of macroeconomic systems is to assess the influence of various policies on the behavior of certain variables over time. The foundations of this analysis are to be found in the notion of a multiplier as obtained in a simple Keynesian model. This idea may be applied to a static linear model such as (97). The parameters of the exact part of the reduced form of the model, $-B^{-1}\Gamma$, then measure changes in the levels of endogenous variables that are affected by unit changes in the exogenous variables. Since these parameters relate only to immediate first round effects, they are commonly referred to as impact multipliers.

If the system under consideration includes lagged endogenous variables, then the model expresses a dynamic theory. Changes in exogenous variables, in this case, even

TABLE 23

COMPARISON OF MAPE STATISTICS FOR SEVERAL REGIONAL ECONOMETRIC MODELS

Variables	Philadelphia				Northeast Corridor	Buffalo	Los Angeles	Chicago
	I	II	IV					
Gross Metropolitan Product	4.32	0.97	0.98	2.05	1.87	2.08	4.58	
Personal Income	6.69	1.50	1.55	3.13	8.42	1.45	1.71	
Total Employment	1.56	1.21	0.66	1.40	3.39	0.88	1.72	
Manufacturing Output	2.43	1.10	2.19	2.82	1.55	3.07	3.67	
Manufacturing Employment	2.18	2.54	1.42	2.65	3.50	2.81	3.71	

Source: All except Chicago - Glickman (76)

if changed for only one period, will cause effects outside the time period in which they occur. Delayed repurcussions of this kind can be explored by tracing movements in the endogenous variables through successive time periods. When an exogenous variable is changed and that change persists throughout several time periods, dynamic multipliers can be calculated.

Again, with the Chicago Econometric Model and its nonlinear properties, it is not possible to directly compute the reduced form. As a result, the multipliers cannot be computed directly. Instead, the Gauss-Seidel iterative technique is again applied.

All exogenous variables in the model were shocked in order to determine the multipliers. Each exogenous variable was increased by 1%, and the model was simulated. These values were compared to the control situation, where the actual values of the exogenous variables were used. Then the multipliers were computed. The complete list is given in Appendix C. Table 24 contains a few selected multipliers. The problem of comparability that results from variations in units can be eliminated by transforming the impact multipliers into impact elasticities. The impact elasticity of x with respect to y is defined as $E(x/y) = (y/x) (\partial x / \partial y)$, where $(\partial x / \partial y)$ is the impact multiplier for y on x . The resulting impact elasticities

are dimensionless and thus directly comparable. These are also given in Table 24 as well as Appendix C.

Policy Analysis with the Chicago Econometric Model

The Chicago Econometric Model can be a useful tool in analyzing the effects of different policies, both national and local, on the Chicago economy. For example, a policy of transferring money to residents of the region may be simulated by increasing transfer payments in the identity determining Chicago personal income by place of residence. This in turn would affect local government taxes, employment, and Chicago disposable income. This last effect would cause adjustments in output and employment in the local sector. Thus, effects of such a policy can be traced out.

The effects of changing the local tax rate could be examined by changing the coefficients of Chicago personal income by place of residence in equation (66).

If a proposal to increase revenue sharing funds were under examination, the effects could be traced out by changing REVFOS in equation (69) by the proposed amount. These are just a few examples of the types of policies which can be examined with the Chicago Econometric Model.

Conclusion

The major thrust of this study has been to build an econometric model of the Chicago SMSA based on firm

TABLE 24
SELECTED MULTIPLIERS

Variable Name	Absolute Change	Impact Elasticity
LSHTCPU	-.1088	-4.39
VATCPU	203.	8.62
AETCPU	5.	2.67
LSHWRT	-.0039	-0.34
VAWRT	61.	1.48
AEWRT	1.	0.19
LSHSER	.0083	0.60
VASER	-69.	-2.98
AESER	-12.	-3.34
LSHFIR	-.0331	-2.51
VAFIR	179.	4.49
AEFIR	1.	0.90
LSHCC	-.673	-10.84
VACC	20.	1.78
AECC	-10.	-9.80
TLPYPW	1546.	10.77
RCPI	1574.	9.22
PTAX	128.	5.37
CDI	1446.	9.84
LGREV	115.	10.88
LGEXP	117.	9.31
LGEMP	4.	2.55
AVWAGELG	52.	1.07
NUNEMP	-177.	-65.25
UNEMPR	-6.2983	-65.82

Source: Calculated

microeconomic foundations. The equations of the Chicago model have been formulated with this in mind. The resulting model seems to perform well in terms of conventional measures. It also seems to have potential for policy analysis as stated in the last section .

Several areas can be pointed to, though, which should be the subject of future research.

First, the local government sector needs to be expanded. This has been a serious problem with all the small area models constructed to date.

Second, it would be helpful to disaggregate the model regionally. That is, the model might be divided into a city and suburban model. The growth patterns of these two divisions are somewhat different and an aggregate model tends to cloud the differences.

Third, some disaggregation of the local sector would be helpful. This sector should also be included in the input-output analysis to help highlight flows among industries.

Fourth, the Chicago model should be linked with a spatial allocation model similar to that suggested by Engle et al. (52).

All of these suggestions appear feasible with present data sources although some of the series are quite short. The possibilities for improvement are numerous and seem only to be limited by the creativeness of the researchers involved.

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APPENDIX A
LIST OF VARIABLE NAMES

Suffixes

- __20 Food and Kindred Products
- __23 Apparel and Related Products
- __26 Paper and Allied Products
- __27 Printing and Publishing Industries
- __28 Chemicals and Allied Products
- __29 Petroleum and Coal Products
- __32 Stone, Clay, and Glass Products
- __33 Primary Metal Products
- __34 Fabricated Metal Products
- __35 Machinery (Except Electrical)
- __36 Electrical Machinery
- __37 Transportation Equipment
- __38 Instruments and Related Products
- __39 Miscellaneous Manufactures
- __TCPU Transportation, Communication, and Public
Utilities
- __WRT Wholesale and Retail Trade
- __SER Services
- __FIR Finance, Insurance, and Real Estate
- __CC Contract Construction

Prefixes

VA__ the natural logarithm of value-added in constant dollars
 PWH__ the natural logarithm of the number of production worker hours
 K__ the natural logarithm of the constant dollar value of the capital stock
 Z__ ($\ln PWH_ + \ln K_$)
 LSH__ labor's share of output
 PI__ price index
 NAL__ national value added
 AE__ the number of employees
 WH__ the number of worker hours
 LVA__ the natural logarithm of value added in current dollars

Miscellaneous

AAW average annual wage
 AVWAGELG average wage in local government
 AVWAGEM average wage in manufacturing
 B the number of births per year
 b the fraction of the housing stock retired each year
 CCPI Chicago consumer price index
 CDI Chicago disposable income of residents
 D deaths per year
 DIR dividends, interest, and rent
 E^{chi} employment rate in the Chicago SMSA
 E^{us} employment rate in the United States
 FT federal taxes taken from residents of the region

GMP gross metropolitan product

GSP gross state product

H^d the quantity of housing demanded

HH the number of households

HS the value of new housing starts in constant dollars

LF labor force

LFPR labor force participation rate

LGEMP local government employment

LGEXP local government expenditure

LGREV local government revenue

LPYPW labor and proprietors' income by place of work

NM net migration

NOE number of employees

NUNEMP number of persons unemployed

OLY other labor income

P_h the real relative price of housing

POP population

PTAX personal taxes - total

PY proprietors' income

R the quantity of housing retired each year

RA residence adjustment for commuting

RCPI personal income of residents of the Chicago SMSA

RYPHH real income per household

SST social security taxes

ST state taxes

TLYPW total labor and proprietors' income by place
of work

TOTEMP total employment

TOTINVM total investment in manufacturing

TP tran fer payments

TR the number of persons per household

UNEMPR unemployment rate

USCPI United States consumer price index

WA the weighted average of local prices

WPIMND wholesale price index for manufacturing nondur-
ables

WS wages and salaries

APPENDIX B

CALCULATED MAPE STATISTICS

Variable	MAPE	Statistic	Variable	MAPE	Statistic
lnVATCPU	.76		ZFIR	141.86	
lnPITCPU	667.27		lnVACC	.56	
LSHTCPU	3.85		lnPICC	44.49	
VATCPU	6.38		LSHCC	11.32	
AETCPU	4.72		VACC	3.97	
lnAETCPU	.87		AECC	10.48	
ZTCPU	437.50		lnAECC	2.24	
lnVAWRT	.31		ZCC	2096.49	
lnPIWRT	141.97		TLPYPW	2.06	
LSHWRT	2.13		RCPI	1.71	
VAWRT	2.68		PTAX	2.79	
AEWRT	2.12		CDI	2.46	
lnAEWRT	.33		LGREV	5.96	
ZWRT	503.70		LGEXP	4.47	
lnVASER	.40		LGEMP	6.68	
lnPISER	278.15		AVWAGELG	12.13	
LSHSER	2.81		PITCPU	3.27	
VASER	3.11		PIWRT	1.81	
AESER	3.20		PISER	1.60	
lnAESER	.53		PIFIR	2.28	
ZSER	79.02		PICC	6.49	
lnVAFIR	.44		WA	1.96	
lnPIFIR	291.24		CCPI	.36	
LSHFIR	3.77		TOTEMP	1.72	
VAFIR	3.84		LFPR	5.99	
AEFIR	2.54		LF	6.08	
lnAEFIR	.49		NUNEMP	133.46	

Variable	MAPE	Statistic
UNEMPR		139.33
VA20		3.58
PWH20		4.14
AE20		4.01
lnPI20		118.25
LSH20		5.57
lnVA20		.25
lnPWH20		.36
Z20		3.79
VA23		6.22
PWH23		4.02
AE23		6.55
lnPI23		427.93
LSH23		3.59
lnVA23		.50
lnPWH23		.37
Z23		68.41
VA26		4.19
PWH26		2.61
AE26		4.23
lnPI26		1400.48
LSH26		3.34
lnVA26		.33
lnPWH26		.24
Z26		2.83
VA27		3.37
PWH27		1.81
AE27		3.67
lnPI27		2874.03
LSH27		2.48
lnVA27		.24
lnPWH27		.16
Z27		1.91

Variable	MAPE	Statistic
VA28		10.14
PWH28		4.26
AE28		8.76
lnPI28		653.16
LSH28		7.45
lnVA28		.73
lnPWH28		.39
Z28		3.14
VA33		3.97
PWH33		2.21
AE33		13.75
lnPI33		394.83
LSH33		3.25
lnVA33		.29
lnPWH33		.19
Z33		1.75
VA35		1.62
PWH35		1.64
AE35		5.88
lnPI35		39.74
LSH35		1.80
lnVA35		.11
lnPWH35		.14
Z35		1.67
VA36		3.90
PWH36		1.66
AE36		5.84
lnPI36		2064.63
LSH36		3.32
lnVA36		.27
lnPWH36		.14
Z36		2.65
VA37		7.84

Variable	MAPE Statistic
PWH37	5.10
AE37	7.49
lnPI37	837.06
LSH37	6.90
lnVA37	.59
lnPWH37	.47
Z37	6.24
VA38	5.83
PWH38	1.98
AE38	8.61
lnPI38	98.92
LSH38	5.91
lnVA38	.45
lnPWH38	.19
Z38	3.07
VA39	7.87
PWH39	3.04
AE39	2.43
lnPI39	771.84
LSH39	5.38
lnVA39	.62
lnPWH39	.29
Z39	5.14
VA29	18.35

Variable	MAPE Statistic
PWH29	6.22
AE29	14.08
lnPI29	1151.15
LSH29	20.76
lnVA29	1.52
lnPWH29	.65
Z29	2.76
VA32	4.85
PWH32	3.04
AE32	2.75
lnPI32	897.28
LSH32	3.11
lnVA32	.39
lnPI32	.29
Z32	3.36
VA34	3.04
PWH34	2.21
AE34	3.55
lnPI34	10036.11
LSH34	2.24
lnVA34	.22
lnPWH34	.18
Z34	3.17

APPENDIX C
CALCULATED MULTIPLIERS

Variable Name	Absolute Change	Impact Elasticity
lnVATCPU	.0827	1.06
lnPITCPU	-.043	417.00
LSHTCPU	-.1098	-4.39
VATCPU	203.	8.619
AETCPU	5.	2.67
lnAETCPU	.0294	.56
ZTCPU	-.0012	-2.06
lnVAWRT	.0148	.18
lnPIWRT	-.0041	-2.68
LSHWRT	-.0039	-.34
VAWRT	61.	1.48
AEWRT	1.	.19
lnAEWRT	.0015	.02
ZWRT	.0428	60.62
lnVASER	-.03	-.38
lnPISER	.0587	11.74
LSHSER	.0083	.60
VASER	-69.	-2.98
AESER	-12.	-3.34
lnAESER	-.034	-.58
ZSER	.0556	140.40
lnVAFIR	.0441	.53
lnPIFIR	.0362	70.98
LSHFIR	-.0331	-2.51
VAFIR	179.	4.49
AEFIR	1.	.90

Variable Name	Absolute Change	Impact Elasticity
lnAEFIR	.0086	.17
ZFIR	.0014	--
lnVACC	.0174	.24
lnPICC	-.004	-4000.00
LSHCC	-.673	-10.84
VACC	20.	1.78
AECC	-10.	-9.80
lnAECC	-.1073	-2.32
ZCC	.0325	46.36
TLPYPW	1546.	10.77
RCPI	1574.	9.22
PTAX	128.	5.37
CDI	1446.	9.84
LGREV	115.	10.88
LGEXP	117.	9.31
LGEMP	4.	2.55
AVWAGELG	52.	1.07
PITCPU	-.04	-4.22
PIWRT	-.0041	-.42
PISER	.0602	6.05
PIFIR	.035	3.68
PICC	-.004	.39
WA	.0105	1.08
CCPI	.0082	.93
TOTEMP	201.	7.84
LFPR	-.0007	-.15
LF	24.	.85
NUNEMP	-177.0	-65.25
UNEMPR	-6.2983	-65.82
VA20	2838448.	2.36
PWH20	261769.	2.24
AE20	145.	1.59
lnPI20	-1.09768	19.88

Variable Name	Absolute Change	Impact Elasticity
LSH20	-.00655	-2.69
lnVA20	1.21469	8.68
lnPWH20	1.18	10.12
Z20	-3.1571	-76.05
VA23	-5271.	-2.82
PWH23	-1387.	-3.01
AE23	-1.08	3.28
lnPI23	.05364	-3.13
LSH23	.00329	.79
lnVA23	-.02	.16
lnPWH23	-.0306	-.28
Z23	.05316	3.61
VA26	-29923.	-13.41
PWH26	.	
AE26	-4.05	-15.55
lnPI26	.12474	-2.66
LSH26	-.0333	-7.91
lnVA26	-.144	-1.17
lnPWH26	-.2363	-2.23
Z26	1.3629	46.26
VA27	401239.	45.75
PWH27	35251.	36.30
AE27	18.3	21.16
lnPI27	-.0261	-20.37
LSH27	-.0202	-5.58
lnVA27	.3771	2.75
lnPWH27	.3097	2.69
Z27	-.5324	-.21
VA28	2410.	.29
PWH28	-7278.	-16.57
AE28	-8.39	-18.37
lnPI28	.047	26.76
LSH28	-.0226	-15.98

Variable Name	Absolute Change	Impact Elasticity
lnVA28	.0029	.03
lnPWH28	-.18113	--1.69
Z28	1.7598	25.23
VA33	-221114.	-40.30
PWH33	-35878.	-41.77
AE33	-.37	-.64
lnPI33	.4875	761.59
LSH33	-.0065	-1.30
lnVA33	-.5160	-3.91
lnPWH33	-.5391	-4.74
Z33	3.6944	64.59
VA35	-71103.	-7.65
PWH35	-12855.	-9.78
AE35	-3.948	-3.66
lnPI35	.1445	41271.42
LSH35	-.00542	-1.33
lnVA35	-.0796	-.58
ln PWH35	-.0761	-.65
Z35	.9999	26.05
VA36	202241	17.13
PWH36	9640.	5.34
AE36	1.7474	1.20
lnPI36	-.0646	-98.25
LSH36	-.0349	-9.16
lnVA36	.1581	1.13
lnPWH36	.052	.43
Z36	.1793	15.28
VA37	303837.	61.29
PWH37	12278.	21.81
AE37	-.2216	-.74
lnPI37	-.1321	85.68
LSH37	-.0797	-23.72
lnVA37	.8044	6.13
lnPWH37	.1973	1.80

Variable Name	Absolute Change	Impact Elasticity
Z37	-.2078	-9.85
VA38	18622.	6.79
PWH38	-1106.	-3.37
AE38	-.511	-1.89
lnPI38	.00689	-80.58
LSH38	-.0262	-8.61
lnVA38	.0657	.52
lnPWH38	-.0342	-.33
Z38	.3827	26.60
VA39	190366.	70.31
PWH39	21949.	51.38
AE39	5.666	19.04
lnPI39	.2206	10.68
LSH39	-.03678	-10.22
lnVA39	.5324	4.26
lnPWH39	.4146	3.88
Z39	-.5592	-47.09
VA29	-133518.	-96.06
PWH29	-9118.	-96.18
AE29	-13.267	-143.58
lnPI29	-.2511	281.74
LSH29	-.01791	-8.48
lnVA29	-3,2353	-27.32
lnPWH29	-3.339	-36.41
Z29	38.874	258.42
VA32	54776.	26.42
PWH32	6704.	21.95
AE32	-.3131	-1.60
lnPI32	-.1891	83.25
LSH32	-.0097	-2.57
lnVA32	.2344	1.92
lnPWH32	.1984	1.92
Z32	-.2414	-9.97

Variable Name	Absolute Change	Impact Elasticity
VA34	251199.	27.03
PWH34	29200	19.56
AE34	8.273	8.35
lnPI34	-.1893	-70.71
LSH34	-.022	-4.93
lnVA34	.2392	1.74
lnPWH34	.1786	1.49
Z34	-.1176	-7.15