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Working Paper

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Queen's Economics Department Working Paper, No. 14

Provided in Cooperation with:
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AN ECONOMETRIC MODEL OF THE CANADIAN AUTOMOBILE MANUFACTURING INDUSTRY

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11-1969

AN ECONOMETRIC MODEL OF THE CANADIAN AUTOMOBILE MANUFACTURING INDUSTRY

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Discussion Paper No. 14

* I wish to thank Edwin Kuh, Lawrence Officer and Robert Crandall for valuable comments and assistance. The shortcomings which remain are, of course, the sole responsibility of the author.

Recent years have witnessed a tremendous growth in both the sophistication and popularity of econometric models. From humble beginnings macro-econometric models have grown to mammoth proportions consisting of literally hundreds of equations.[1] While there has been a growing concern with sectoral division and the supply mechanism in these models, it is somewhat surprising that more research has not been directed toward industry econometric model building. Given this need for greater sectoral knowledge, quantitative analysis of major industrial sectors is conspicuous by its absence from econometric and model building literature.[2]

This paper presents some results of a study which develops and tests an econometric model of the Canadian automotive manufacturing industry.[3] Annual behaviour over the 1948-1964 period[4] is examined by utilizing eighteen stochastic equations and four major identities. The research

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1. See for example the Brookings SSRC model (Duesenberry, J. S. et. al., The Brookings Quarterly Econometric Model of the United States, Chicago: Rand McNally and Company, 1965).

2. One notable exception is Ueno and Tsurumi's "A Dynamic Supply and Demand Analysis of the United States Automobile Industry, Together with a Simulation Experiment", (Essays in Industrial Econometrics, Volume I, edited by Klein, L.R., Wharton School of Finance and Commerce, University of Pennsylvania, 1969). In addition, there have been numerous commodity or natural resource studies, as well as a few recent econometric studies of regional sectors (see, for example, Vernon, J.M. et. al. "An Econometric Model of the Tobacco Industry", Review of Economics and Statistics, LI (May 1969), 149-158).

3. Wilton, D.A., An Econometric Model of the Canadian Automobile Manufacturing Industry, Ph.D. dissertation, M.I.T., 1969.

4. The change in industrial structure arising from the signing of the Canada-U.S. Automobile Agreement (1965) and the discontinuity of the war years (with its ensuing re-adjustments) dictated the selection of the time horizon.

strategy follows conventional macro-econometric lines as it is hoped that such a key sector or satellite model can be integrated into a suitable Canadian macro economy model.

Section I begins with a brief description of the industry and an outline of the general characteristics of the study. Next, the theoretical specification and single equation estimation of the model are presented. Section III subjects the system to simultaneous equation estimation; and finally, control simulations examine the systems properties of the complete model.

I

The Canadian automobile industry, as referred to in this paper, consists of that section of the durable manufacturing industry which specifically manufactures automobiles and commercial vehicles in Canada. The myriad of small to medium sized firms engaged in the production of parts and accessories are ignored. The two most obvious features of this industry are the domination of the industry by a few producers[5] and the complete control over the Canadian industry by parent United States firms. Historically the tariff provided a basic motivation for the major United States firms to establish and expand operations in Canada. More recently, the Canada-United States Automobile Agreement (1965) has given a tremendous boost to the Canadian industry.[6]

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5. The "Big Three" accounts for over 96% of all automobiles produced in Canada and approximately 85% of all commercial vehicles.

6. The effects of this Agreement are the subject of a forthcoming paper.

The manufacture of automobiles is characterized by a high degree of continuous, automatic production with a well-developed division of labour. This technology places a heavy emphasis on lengthy assembly lines (capital investment) and economies of scale. While Canadian markets are sufficiently large to guarantee efficient production and assembly of several different automobile models, much of the inefficiency in Canadian production stems from a wide variety of models in the production process and the manufacture of certain specialized parts which require much longer production runs.

The automobile industry represents an extremely important sector of an industrialized economy with activity in this industry often regarded as a "bellwether" for the economy as a whole. In terms of employment, the total automotive industry is the second largest manufacturing employer in Canada. The United Automobile Workers (U.A.W.) represent a powerful, efficient, wealthy union, ranking third in total membership in Canada. In addition, the employment contribution of the automobile industry is more than doubled when one considers the employment generated in other industries, such as steel and rubber, by automobile production. On average, consumers spent over 9% of their annual disposable income on automotive products during the nineteen fifties.[7] In view of the cyclical nature of automobile demand (production) and the major repercussions on other sectors, this industry occupies a pivotal position in an industrialized economy.

Very briefly the model is structured in the following manner.

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7. Report, Royal Commission on the Automotive Industry, Ottawa: Queen's Printer, 1961, page 30.

Given the desire to achieve maximum linkages with macro-econometric models and the general "production-to-order" characteristics of the industry, the basic demand equations (disaggregated into automobile and commercial vehicle components) are analyzed at the retail level. Domestic shipments are principally a derived demand with imports and dealer's commissions being important stochastic elements in the determination of industry output.

The key relationship on the supply or production side of the model is the cost schedule. Since this relationship is viewed as the sum of a number of stochastic cost components, the statistical analysis of wages, employment, material inputs, prices, and investment are all linked together by this one fundamental output or supply relationship. Profits are residually determined. Such a strategy for the supply mechanism in the model permits different behavioural patterns for individual expenditure items and a much wider scope for the selection of relevant, underlying explanatory variables. It would appear to be a more useful device than aggregating all costs, thus submerging important behavioural relationships, and well suited to a complete systems analysis. A condensed flow diagram of the entire model is presented in Section III.

II

The model consists of the following endogenous and exogenous variables.

Endogenous variables

AHE : average hourly earnings, hourly-rated employees

AWWSNH : average weekly wages and salaries, non-hourly-rated employees

CCA : capital cost allowances, millions of dollars

COMMIS : dealer markup or retail value-added, millions of dollars

CUMW* : capacity utilization rate

DSH : total shipments to the domestic market, millions of dollars

EH : number of hourly-rated employees

EMT : non-United States imports of motor vehicles, millions of dollars

ENH : number of non-hourly-rated employees

H : average hours worked per week

IBM : investment in buildings, machinery and equipment, millions of dollars

IRM : investment in maintenance and repair, millions of dollars

MATR : material inputs, millions of dollars

NEGAV : base wage rate as negotiated in collective bargaining sessions

PRODT* : trended productivity (real output per man-hour)

PROFIT : total corporate profits, millions of dollars

RPA : retail price index of automobiles, 1957 = 1.0

RPT* : retail price index of total motor vehicles, 1957 = 1.0

RPTR : retail price index of commercial vehicles, 1957 = 1.0

RSA : retail sales of automobiles, millions of dollars

RSACDV* : deviation of retail sales of automobiles from a linear trend, millions of 1957 dollars.

RSTR : retail sales of commercial vehicles, millions of dollars

STKA* : stock of automobiles in Canada on December 31, millions of 1957 dollars

STKTR* : stock of commercial vehicles in Canada on December 31, millions of 1957 dollars

TGKC : total gross capital stock, millions of 1957 dollars

TSH* : total shipments by the automobile industry, millions of dollars

USMT : imports of motor vehicles from the United States, millions of dollars

WB : total wage bill, millions of dollars

WPT : wholesale price index of motor vehicles, 1957 = 1.0

* definitional endogenous variables.

Exogenous Variables

CANW : average hourly earnings in Canadian durable manufacturing industries

CPI : Canadian consumer price index, 1949 = 100.0

DUMCAN : dummy variable for pre-wage parity era, one in 1948-1958, zero elsewhere

DUMDEP : dummy variable for deferred depreciation period, one in 1951-52, zero elsewhere

DUMKW : dummy variable for Korean War period, one in 1950-53, zero elsewhere

DUMTAR : dummy variable for removal of special tariff provisions, one in 1961-64, zero elsewhere

DUMYRI : dummy variable for first year of given wage round, zero elsewhere

DUMUS : dummy variable for wage parity era, one in 1959-64, zero elsewhere

GNEC : Canadian gross national expenditure, millions of 1957 dollars

IDEFL : deflator for investment expenditures, 1957 = 1.0

PCED : deflator for Canadian personal consumption expenditures, 1957 = 1.0

PMAT : price index of materials purchased, 1957 = 1.0

PME : price index of machinery and equipment in Canada, 1957 = 1.0

POP : population of Canada, millions

RESID : residual of unclassified expenditures in the automobile industry, millions of dollars

REVAL : implicit revaluer for gross capital stock

T : time trend, one in 1948, two in 1949, etc.

TOTTAX : total of federal sales and excise tax on motor vehicles

UKCUR : Canadian dollars per British pound

USCUR : Canadian dollars per United States dollar

USW : base wage rate at General Motors in the United States

WPTUS : wholesale price index of motor vehicles in the United States, 1957 = 1.0

WPTUSK : wholesale price index of motor vehicles in the United States, corrected for currency fluctuations, 1957 = 1.0

XSH : total export shipments by the Canadian motor vehicle industry, millions of dollars

YDPC : personal disposable income in Canada, millions of 1957 dollars

Demand for Motor Vehicles

The analysis of retail automobile demand follows conventional lines with a stock adjustment model performing adequately.[8] The desired per capita stock of automobiles is expressed in terms of real per capita income and relative prices. Two major problems are encountered in the empirical analysis. First, a time series for the stock of automobiles must be generated. To construct this stock, Canadian data on depreciation and scrappage rates are employed to obtain a series of weights which can be applied to lagged values of retail sales.[9]

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

9. For a complete description of the construction of these weights see Wilton, D. A., op. cit., 21-23.

$$STKA_t = \sum_{i=1}^{15} W_i \left(\frac{RSA}{RPA}\right)_{t+1-i} \tag{D1}$$

where W_i: combined undepreciated-survival rate for an "i" year old automobile with

W_1 = .725	W_6 = .190	W_{11} = .038
W_2 = .583	W_7 = .148	W_{12} = .028
W_3 = .437	W_8 = .086	W_{13} = .020
W_4 = .349	W_9 = .062	W_{14} = .015
W_5 = .255	W_{10} = .050	W_{15} = .010

In addition, serial correlation is particularly troublesome in the statistical analysis, not completely unexpected given the periodic shifts or innovations in the design of passenger cars. Using a non-linear iterative technique to correct for first order serial correlation,[10] the following ordinary least squares estimates are obtained.

$$\frac{RSA}{POP*RPA} = \underset{(66.87)}{98.35} + \underset{(.0369)}{.1190}\frac{YDPC}{POP} - \underset{(40.06)}{160.16}\frac{RPA}{PCED} - \underset{(.0913)}{.1579}\left(\frac{STKA}{POP}\right)_{-1} \tag{S1}$$

S.E.E. = 4.24 $\qquad R^2$ = .94 $\qquad$ D.W. = 2.40 $\qquad$ p* = .40

Standard errors are presented below the coefficients, with S.E.E., R^2, D.W., and p* signifying the standard error of estimate for the regression, the coefficient of determination, the Durbin-Watson statistic and the first order autoregressive factor which minimizes the S.E.E.

Income and price effects are strongly significant while the stock

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10. Hildreth, C. and Lu, J. Y., Demand Relations with Autocorrelated Disturbances. Michigan State University Agricultural Experiment Station Technical Bulletin #276, 1960.

variable, which is highly correlated with income, is only marginally significant (at the 90% level on a two-tailed test). The annual depreciation-scrappage rate of approximately 26% produces a speed of adjustment of roughly .4, remarkably close to other Canadian quarterly results.[11] Income and price elasticities for desired stocks are 1.7 and -1.8 respectively.[12] Attempts to introduce other explanatory variables, such as interest rates and credit terms, were unsuccessful.

Turning to the demand for commercial vehicles, a flexible accelerator model forms the basis for the empirical investigation. The desired stock of commercial vehicles is assumed to depend primarily on expected output of the Canadian economy which is proxied by current real output and the change in real output. In addition, a relative price effect and a dummy variable for the Korean war period (to capture the increase in military vehicle production, a component of commercial vehicles, during this brief period) are also included. A similar device is used to generate a stock for commercial vehicles, although the underlying data are more fragmentary.[13]

$$STKTR_t = \sum_{i=1}^{15} V_i \left(\frac{RSTR}{RPTR}\right)_{t+1-i} \qquad (D2)$$

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11. Dingle (The Effect of Monetary Policy on the Purchase of Consumer Goods in Canada, unpublished Ph.D. dissertation, M.I.T., 1967) found an annual speed of adjustment of 41% for automobile purchases.

12. These elasticities are quite comparable to those found elsewhere. For example, Chow (op. cit.) found an income elasticity for desired stocks of 1.7 while Dyckman ("An Aggregate-Demand Model for Automobiles", Journal of Business, XXXVIII (July 1965)) estimated the price elasticity to be about -1.2.

13. Data could only be obtained for Canadian depreciation rates on one to six year old commercial vehicles. Consequently, a hyperbolic curve was employed to generate the remaining years in the weight distribution. See Wilton, D. A., op. cit., 34-35.

where V_i: combined undepreciated-survival rate for an "i" year old commercial vehicle with

$V_1 = .654$	$V_6 = .240$	$V_{11} = .147$
$V_2 = .484$	$V_7 = .213$	$V_{12} = .136$
$V_3 = .387$	$V_8 = .191$	$V_{13} = .127$
$V_4 = .321$	$V_9 = .174$	$V_{14} = .119$
$V_5 = .275$	$V_{10} = .159$	$V_{15} = .112$

While the level of income is not strongly significant in the following equation, the removal of ΔGNEC increases its significance level substantially (as well as all other variables) with relatively little effect on coefficient values. Consequently, this variable is retained in the analysis. The limited amount of information available to generate stock data, and the consequent restrictive assumptions imposed, may be responsible for the low level of significance on this variable. Again credit, interest rate and liquidity variables performed poorly.

$$\frac{RSTR}{RPTR} = \underset{(243.85)}{642.55} + \underset{(.003510)}{.003913}\ GNEC + \underset{(.00968)}{.01749}\ \Delta GNEC \qquad (S2)$$

$$- \underset{(242.96)}{460.72}\ \frac{RPTR}{PME} + \underset{(17.17)}{43.40}\ DUMKW - \underset{(.08964)}{.06160}\ (STKTR)_{-1}$$

S.E.E. = 23.88 $\qquad R^2 = .76 \qquad$ D.W. = 1.83

Domestic Production

To translate total retail demand into domestic automotive production, the following mechanism is employed. Such a structural identity conserves

$$TSH = RSA + RSTR - COMMIS - EMT - USMT + XSH \qquad (I1)$$

the true derived demand relationship in the automotive industry, as well as permitting maximum flexibility in analyzing the factors affecting Canadian production. Simply regressing domestic production on total retail sales is unlikely to uncover the true competitive effects of imports and the organizational features of the new car market. The annual nature of the model probably reduces the potential biases of not being able to obtain adequate inventory data to include in (I1).

All exports of Canadian produced motor vehicles are considered as exogenous to the system. This action is prompted primarily because the basic explanatory variables for these flows are either non-quantifiable or outside the general scope of the model.[14] In light of the relatively small role of export production in the Canadian automotive industry (usually about 2-3% of total production during the sample period), this assumption should not seriously weaken the overall systems properties of the model.

The much greater magnitude of imports and their important competitive role in retail demand necessitate the endogenous determination of imports, even though there may again be major non-quantifiable explanatory factors. Given foreign ownership, geographic considerations and product features, the disaggregation of automotive imports between United States and non-United States (hereafter referred to as European) origin would appear quite natural. The relatively minor, stable flow of commercial vehicle imports detracts from the usefulness of further disaggregation between various kinds of motor vehicles. To provide as sharp a statistical analysis as possible, imports are expressed as a percentage of domestic

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14. Much of Canadian automotive exports go to underdeveloped countries, while other exports are determined by special international trade arrangements (such as Commonwealth preferences).

shipments. Such a specification of the dependent variable enables one to concentrate directly on the differentiating explanatory factors for imports without the intrusion of common economy-wide influences.

A strong cyclical element is likely to persist in import shares, particularly if one believes that imports have a relatively high income elasticity.[15] To quantify this cyclical effect, two variables are proposed: the change in total retail sales and the percentage deviation of sales from a simple linear trend.[16] The second major determination of import shares is relative prices and currency variations. As we shall see below, Canadian and United States automobile prices have tended to move together with a principal differentiating factor being the level of the foreign exchange rate.[17] Given the difficulty in obtaining a truly comparable price series for European automotive imports[18], the Canadian price variable is simply

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15. For example the composition of United States imports favours higher priced, "limited demand" models.

16. A regression of retail sales on a time trend produces the following result:

$$\underset{}{RSA/RPA} = \underset{(75.17)}{387.32} + \underset{(6.95)}{75.17\,T} + RSACDV \qquad (D3)$$

S.E.E. = 140.4 $\qquad R^2$ = .89 $\qquad$ D.W. = 1.07

The low Durbin-Watson statistic indicates the presence of a cyclical element with large negative residuals in 1954 and the late fifties, and strong positive residuals in 1950, 1955-56 and the mid-sixties.

17. While a currency corrected relative price variable performed reasonably well for U.S. imports, by all statistical tests it was inferior to simply including the foreign exchange rate as the appropriate price effect.

18. Not only is the mix extremely varied, Volkswagens to Mercedes-Benz, the various national producers create further difficulties in constructing an appropriately weighted average price. Even more important, special provisions granted to European producers permitted dumping in Canada during the late forties and fifties. Consequently, even if a foreign price series could be constructed, it is likely to be irrelevant for comparison with Canadian prices.

employed along with a foreign exchange rate.[19] A low Canadian automobile price, or a devalued (weak) Canadian dollar, should act as a deterrent to large import flows. Finally, a dummy variable is included in the European import equation to reflect the withdrawal of special preferential tariff treatment of automotive imports during the sixties.[20] The lack of a suitable price deflator for European imports necessitates the use of current dollar flows in (S4) as contrasted to real flows for United States imports.

$$\frac{USMT/WPTUSK}{DSH/WPT} = \underset{(.1378)}{.8816} + \underset{(.0467)}{.1097}\ RSACDV/(RSA/RPA) - \underset{(.1359)}{.7868}\ USCUR \tag{S3}$$

S.E.E. = .0117 $\qquad R^2$ = .71 $\qquad$ D.W. = 1.48

$$\frac{EMT}{DSH} = \underset{(.2518)}{-.2048} + \underset{(.00004285)}{.00005647}\ \Delta\left(\frac{RSA}{RPA}\right) + \underset{(.2895)}{.8154}\ WPT - \underset{(.0821)}{.1994}\ UKCUR - \underset{(.03325)}{.03934}\ DUMTAR \tag{S4}$$

S.E.E. = .0302 $\qquad R^2$ = .77 $\qquad$ D.W. = 1.73 $\qquad$ p* = .70

In the United States import equation, both the foreign exchange rate and fluctuations in retail sales play strong roles. For example, a

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19. While it would be desirable to use a weighted index of a number of exchange rates, it is thought that variations in the British exchange rate will broadly represent or dominate all others.

20. After the war, Canada attempted to aid Europe by permitting limited dumping of automobiles in Canada. These special provisions were substantially reduced in 1960.

10% deviation in retail sales from its mean value results in a 23% change in imports.[21] Turning to the European import equation, the significance of the price effect is in direct contrast to the results obtained for United States imports. Given the special tariff provisions, the lack of European ownership considerations, and geographic separation; the prices of Canadian produced motor vehicles are less likely to move in a parallel fashion to European produced automotive imports. Again the foreign exchange rate is significant, although its effect is somewhat less than that obtained in the United States import equation.[22] The low significance level on the cyclical variable may be attributed to the greater diversity in European imports. For example, a slow demand year may result in a greater proportion of inexpensive foreign imports (compacts) and not a fall in import shares. Even though the dichotomous variable is not highly significant, it does have the correct sign (i.e. it represents a removal of special privileges) and its inclusion lowers the standard error of the equation.

The final element in the mechanism to derive domestic shipments from retail demand is dealer value-added or commissions at the retail level. As a proxy for this factor, retail and wholesale price data are employed. To illustrate the type of proxy I have in mind, assume a simple model without imports or a change in final inventories and with only one homogeneous product. Denoting average retail price, average wholesale price and units

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21. Ignoring the sales deviation variable, the 1962 devaluation of the Canadian dollar (7½%) reduces the import share from 10% to approximately 3% of domestic shipments.

22. Devaluation lowers the European import share by less than 5% contrasted to the 7% decline for United States imports.

sold by ARP, AWP, UNITS; dealer value-added (COMMIS) can be expressed in terms of the following identity.

$$\text{COMMIS} = (\text{ARP} - \text{AWP}) * \text{UNITS}$$

Since price indices are used throughout the analysis, we can rewrite the previous identity in terms of ARP57 and AWP57, the average car prices in the base year. Factoring out ARP57 and letting dmk57 represent AWP57/ARP57, we obtain

$$\text{COMMIS} = (\text{RPT} - \text{dmk57} * \text{WPT}) * (\text{ARP57} * \text{UNITS})$$

Assuming that motor vehicle sales have consisted of a homogeneous product over the sample period, then ARP57 * UNITS simply represents total retail sales in constant (1957) dollars.

The most restrictive assumption in this proxy concerns the obvious consumer demand pattern to vehicles with higher priced features and accessories. Since price indices are constructed to abstract from these product mix changes, the assumption of an average (homogeneous) 1957 vehicle which is purchased throughout the sample period is completely unrealistic. A simple time trend is introduced to overcome this deficiency. Corrections for other biases, such as changing import composition, were unsuccessful.

Given common trend elements in dealer value-added and total retail sales, the ratio of COMMIS to retail sales is employed as the dependent variable in order that the statistical analysis will be as sharp as possible. To obtain an estimate of dmk57, various potential values are scanned with the value which minimizes the standard error of the regression being selected.[23]

23. Values between .40 and .90 were scanned using .01 intervals, with only one minimum point obtained for the standard error of the regression. As a check on this minimum point of .65, dealer value-added is calculated as a percentage of retail sales in 1957, obtaining a value of .656, (almost identical to the scanning technique).

While one could presumably improve this simple, derived mechanism for determining retail value-added by playing with more sophisticated (and arbitrary) proxies, the following equation gives reasonable parameter estimates and would appear to be sufficient for its role in determining domestic output.

$$\frac{COMMIS}{\left(\frac{RSA}{RPA} + \frac{RSTR}{RPTR}\right)} = \underset{(.0488)}{-.1050} + \underset{(.1545)}{1.1028}\ (RPT - .65\ WPT) + \underset{(.00118)}{.00575}\ T \qquad (S5)$$

S.E.E. = .0228 $\qquad R^2$ = .88 $\qquad$ D.W. = 1.89

Prices of Motor Vehicles

The inherent problems of a tightly oligopolistic industry structure, not to mention foreign ownership considerations, impose serious limitations in the empirical investigation of wholesale automotive prices in Canada. In the following analysis, the United States parent company's pricing decision is accorded the chief influence in the determination of wholesale Canadian motor vehicle prices. Simply regressing Canadian wholesale prices on United States wholesale prices produced the following results.[24]

$$WPT = \underset{(6.7976)}{-\ 3.4502} + \underset{(.0720)}{1.0672}\ WPTUS$$

S.E.E. = .0309 $\qquad R^2$ = .94 $\qquad$ D.W. = .48

In light of the strong indication of serial correlation in the above equation, two additional secondary explanatory variables are considered.

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24. Since Canadian data on wholesale prices prior to 1956 must be obtained from a dubious source, export prices of Canadian automobiles; it is possible that such data may be based to some extent on published United States data. This data problem also accounts for the lack of disaggregation in wholesale prices.

Cost per unit of output, as measured by basic hourly wages divided by trended output per manhour,[25] is included to capture domestic cost elements in the pricing process. In addition, the level of the foreign exchange rate may affect Canadian prices. A weakening in the Canadian dollar increases the protective tariff margin by increasing the price of all foreign competition, i.e. gives the domestic firm more leeway or flexibility in marking up the Canadian price.

$$\underset{}{WPT} = \underset{(.2097)}{-\ 1.2224} + \underset{(.0338)}{1.1390}\ WPTUS + \underset{(2.1210)}{6.5473}\ NEGAV/PRODT \qquad (S6)$$

$$+ \underset{(.00089)}{.00388}\ USCUR$$

S.E.E. = .0129 R^2 = .99 D.W. = 1.65

All coefficients are highly significant (99% level), the standard error of estimate has been reduced by almost 60% and serial correlation problems are now minimal. Calculating elasticities at means, we obtain the following three price elasticities with respect to

United States prices:	1.11
unit labour costs:	.75
foreign exchange rate:	.40

These estimates all appear quite reasonable. For example, the Wonnacotts' estimate that Canadian automobile costs (ignoring wage elements) are

25. Productivity in the automobile industry is found to be very cyclical; and, since a normal or standard unit cost measure is required, productivity is simply regressed on a time trend to obtain trended values.

$$PRODT = \underset{(.49)}{10.77} + \underset{(.045)}{.573}\ T \qquad (D4)$$

S.E.E. = .908 R^2 = .93 D.W. = 1.26

12-13% higher than in the United States is remarkably close to the above estimate of the effect of United States prices on the Canadian price level.[26]

In view of the manufacturer-controlled franchise system for retailing motor vehicles, the level of wholesale prices is the chief determinant of retail prices. The annual nature of the study complicates the examination of competitive elements in the market place as many short-run price changes "wash out" over the course of the year. However, a third factor, government taxes,[27] is measurable and included in the analysis. Thus, retail prices are simply considered to be a markup on wholesale prices plus government taxes. In spite of limitations from changing import composition, aggregation, and the lack of competitive elements and inventory data, such a specification performs adequately.[28]

$$RPA = \underset{(.0775)}{-.2302} + \underset{(.0592)}{1.0121}\ WPT + \underset{(.1190)}{1.0676}\ TOTTAX \qquad (S7)$$

S.E.E. = .0174 R^2 = .96 D.W. = 2.00

$$RPTR = \underset{(.0889)}{-.4518} + \underset{(.0679)}{1.4086}\ WPT + \underset{(.1365)}{.1879}\ TOTTAX \qquad (S8)$$

S.E.E. = .0199 R^2 = .99 D.W. = 1.80

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26. Wonnacott, P. and Wonnacott, R.J. Free Trade Between United States and Canada, the Potential Effects. Cambridge: Harvard University Press, 1967, Chapter 13.

27. A general sales tax is applicable to motor vehicles, as well as a special excise tax (up until 1961). Both taxes have shown considerable variation over the sample period.

28. The "good" Durbin-Watson statistics may suggest that competitive elements, which tend to be cyclical, are perhaps not that important in the analysis. The somewhat more erratic estimates for commercial vehicles is probably a reflection of the poorer quality of the data on retail prices for commercial vehicles as well as the lack of disaggregation for wholesale prices.

Wage Determination in the Motor Vehicle Industry

As discussed in a previous paper,[29] existing empirical wage research is highly suspect in light of its failure to deal adequately with critical institutional features existing in the labour market (e.g. dominance of powerful unions, multi-year contracts, and spillover effects). Recently I have set forth a model of industry wage determination which first focuses on the discontinuous changes in basic wage rates (as negotiated in periodic collective bargaining sessions) and then links this explained series to average hourly earnings.[30] Following this strategy, eight independent wage rounds are identified in the Canadian automobile manufacturing industry and analyzed in the context of a simple bargaining model. As shown in the following equation, negotiated annual basic wage changes are strongly affected by profitability, rates of price increase and relative wage (spillover) effects. Concerning this latter effect, it is found that union horizons shifted in the latter fifties from domestic to international (parent United States) comparisons.[31]

$$\frac{\Delta NEGAV}{NEGAV} = \underset{(5.410)}{-\ 25.389} + \underset{(5.650)}{45.933}\ PROFIT/TSH + \underset{(.0973)}{.4436}\ \frac{\Delta CPI}{CPI} \qquad (S9)$$

$$+ \underset{(4.441)}{22.308}\ DUMUS * (USW/NEGAV)_{-1} + \underset{(5.753)}{28.258}\ DUMCAN * (CANW/NEGAV)_{-1}$$

S.E.E. = .3211 $\quad R^2$ = .97 $\quad$ D.W. = 2.55 $\quad$ n = 8

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29. Sparks, G. and Wilton, D.A., "Determinants of Negotiated Wage Increases: An Empirical Analysis", Econometrica, forthcoming.

30. "Wage Determination at the Industry Level", Discussion Paper No. 13, Queen's University. This paper should be consulted for an expanded treatment of the industry wage model as tested on the Canadian automobile industry.

31. The inclusion of both relative variables at the same time, or only one of them over the entire sample period, produced unsatisfactory results.

The relatively low coefficient on the cost-of-living variable is presumably a reflection of the introduction of an escalator clause midway through the period, thus picking up part of the price effect independently of basic wage rate negotiations. The coefficients on the relative wage variables are a clear indication of the strong "spillover" effect in the automobile industry. For example, settlements in other Canadian industries which close the wage gap from .85 (the mean value) to .90 will produce a 1½% annual wage increase in basic automotive wage rates regardless of changes in other explanatory variables.

Having examined the factors which affect basic, negotiated hourly wage rates, the second step in the hypothesized wage model concerns the linking of this explained series to average hourly earnings, a key variable in the industry cost function. Since the principal and overwhelming determinant of average hourly earnings is obviously the level of negotiated basic wage rates, the difference of these two series will form the dependent variable. As discussed in the previously cited paper, hours worked per week (multiplied by lagged basic wage rates) and the level of the consumer price index are used to proxy overtime premiums and the escalator clause. In addition, a dummy variable is introduced to correct for potential data biases arising from labour pushing most of the negotiated wage increase into the early part of the contract.[32] Other variables such as changes in employment mix may also be important, but lack of data precluded their inclusion in the following equation.

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32. The construction of the negotiated basic wage rate series assumes that the total increment is spread evenly over the life of the contract. If a larger proportionate increase takes place in the early year(s) of the contract, the negotiated wage rate series will be understated and hence the difference overstated.

$$AHE - NEGAV = \underset{(.137)}{-\ 1.084} + \underset{(.00177)}{.00926}\ CPI + \underset{(.00132)}{.00174}\ H * (NEGAV)_{-1} + \underset{(.0172)}{.0283}\ DUMYRI \qquad (S10)$$

S.E.E. = .0333 $\qquad R^2 = .95 \qquad$ D.W. = 1.22

While the lack of adequate data presents serious difficulties in the specification of the appropriate factors, the above estimates provide a reasonable representation of the forces at work in this linking equation.[33] One should recall that I purposely set up a stiff empirical test for average hourly earnings by expressing the dependent variable in difference form. Thus, the strong effect of negotiated wages on average hourly earnings is implicit in the entire relationship.

The desire to centre attention directly upon the underlying wage determining mechanism in the industry, i.e. the collective bargaining process, necessitates the division of employee compensation into production and non-production categories. Profitability, price effects, and relative wage considerations (a comparison of non-production salaries to union negotiated wages) are again chosen to be representative of the forces at work in the wage determination process for this latter category of employees. A simple distributed lag model is employed on the assumption that the current level of salaries is a function of the past history of these explanatory factors.[34]

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33. For example, the escalator factor is about .9 * CPI (in cents) and the dummy variable implies a re-allocation of 3¢ of the total wage increase to the first year of the contract.

34. To test for serial correlation in this equation, a Hildreth-Lu run resulted in a p* of -.20 with little effect on the coefficients or significance levels. Consequently, I ignored this minor bias in the equation. The high coefficient for the relative wage variable stems from the fact that basic wage rates are expressed per hour while salaries are on a weekly basis.

$$AWWSNH = \underset{(23.737)}{-\ 68.027} + \underset{(22.931)}{49.795}\ PROFIT/TSH + \underset{(.2157)}{.4020}\ CPI \qquad (S11)$$

$$+ \underset{(453.04)}{1542.44}\ (NEGAV/AWWSNH)_{-1} + \underset{(.0900)}{.9301}\ (AWWSNH)_{-1}$$

S.E.E. = 2.19 R^2 = .99 D.W. = 2.48

Employment Relationships

Moving from wage-price determination to other elements in the cost function, the wage bill (as defined by I2) is a key component in total costs. Such an identity

$$WB = [(EH * H * AHE) + (ENH * AWWSNH)] * 52 \qquad (I2)$$

divides employment into "head count" variables, hourly-rated (EH) and non-hourly-rated (ENH) employees, as well as average hours worked per week (H). The basic premise of the employment relationships is a much quicker response of hours worked per week to a change in an underlying factor than the responses of employment.

The level of production worker employment is assumed to be determined by production function requirements and adjustment considerations. The two major variables chosen to represent the first set of factors are the level of real output and capital stock.[35] Given the basic line technology of the industry and the cyclical nature of demand, widely varying degrees of capital utilization occur; and thus the capital stock measure is adjusted by a

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35. Gross capital stock estimates, and a scrappage rate, are obtained from a difference equation employing two benchmark years (taken from taxation statistics) and motor vehicle investment data. The solution to this difference equation results in a scrappage rate of 1.6%, well within acceptable guidelines (see Wilton, D.A., op. cit., Appendix I).

capacity utilization index[36] in order that it will better reflect the flow of services in the production process. Lagged output is also included to permit a better specification of expected output, a key determinant of employment demand.

To capture adjustment factors, hours worked per week and lagged employment are introduced into this relationship. The latter variable is intended to bear the brunt of the adjustment as employment moves slowly toward a desired level. Adjustment costs (e.g. hiring and training) and expectational considerations, reinforced by technological and cyclical demand characteristics of the industry, primarily account for this lagged response. In addition, the hours variable provides an important element of shortrun adjustment, offsetting the required employment response.[37]

In the following derived demand for labour equation, all coefficients are significant at the 95% level with the exception of capital stock

$$EH = \underset{(26164)}{34978} + \underset{(12.232)}{38.315}\, TSH/WPT - \underset{(4.683)}{18.345}\, (TSH/WPT)_{-1} - \underset{(559.2)}{814.8}\, H$$

$$- \underset{(.1933)}{.3001}\, TGKC{*}CUMW + \underset{(.3107)}{.7103}\, (EH)_{-1} \qquad (S12)$$

S.E.E. = 1420 $\quad R^2$ = .82 $\quad$ D.W. = 2.19 $\quad$ p* = -.50

and hours worked (which are signficant at slightly less than 90%). The

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36. A variation in the Wharton capacity utilization technique is employed as capacity between peaks is assumed to increase in proportion to investment increases, not in a simple linear fashion (see Wilton, D.A., op. cit., Appendix II).

37. Felstein ("Specification of the Labour Input in the Aggregate Production Function", Review of Economic Studies, XXXIV (October, 1967), 375-386) also emphasizes the substantially greater elasticity of output with respect to hours than with respect to men, and suggests the inclusion of hours directly in the production function.

presence of negative serial correlation in the derived demand relationship may simply imply positive serial correlation in the underlying production function. Concerning the actual parameter estimates, the above equation suggests an annual adjustment factor of about 30% of the gap between desired and actual levels of employment, and short-run elasticities of employment with respect to output, capital and hours worked of .78, -.54 and -1.39 respectively.[38]

The existence of long, integrated assembly lines and a basic complementary between labour and existing capital places a heavy burden on the hours worked variable for short-run labour adjustments occasioned by changes in output demand. Unfortunately, the annual nature of the model masks much of this short-run adjustment. Consequently, the average hours worked per week decision is simply specified in terms of an adjustment to an optimal or target level (T) of hours worked per week, allowing for a strong transient response to the rate of change in real output.[39]

One problem with such a simple model concerns an asymmetry in the adjustment process. Since a firm cannot readily divest itself of buildings and machinery, it is much more difficult for a firm to raise hours to their target level than to lower hours by changing plant and facilities.[40] This

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38. For purposes of comparison, one should note that Kuh ("Income Distribution and Employment in the Business Cycle", in the Brookings Quarterly Econometric Model of the United States. Edited by Duesenberry, J.S. et. al., Chicago: Rand McNally and Company, 1965) found an annual adjustment of approximately 34% in his quarterly analysis of durable manufacturing employment, as well as similar elasticities with respect to output and capital stock.

39. See Kuh, E., ibid.

40. The highly oligopolistic nature of this industry, the cyclical nature of demand and the complementarity of production factors all militate against any substantial adjustment to raise hours to their target level.

asymmetry will result in an estimate for the adjustment coefficient ("a") which is in a sense an average value.[41] In an attempt to compensate for this bias within the framework of the above model,[42] a correction variable defined as the absolute value of the lagged capacity utilization rate minus 95.0 (the approximate value of a normal or average level of capacity utilization) is included. The rationale for this variable is that it should roughly correspond to $(T - H_{-1})$, the desired change in hours, in absolute value; and, thus, should partially adjust the reaction coefficient for the above mentioned biases.[43] For example, when $(T - H_{-1})$ is negative and hours have to be reduced to their target level (presumably by expanding facilities), this new negative variable amplifies the "a" coefficient to correct for an underestimation of the negative adjustment.

Briefly reviewing the results of such a specification, the average adjustment coefficient is approximately 63% while the target level of hours worked per week is roughly 41. Given the straight-time work week of 40 hours during the entire sample period, this latter estimate would appear reasonable as initial gains in efficiency from longer work weeks will

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41. For negative adjustments in hours, i.e. $H_{-1} > T$, the value of "a" will likely underestimate the true adjustment and potential positive adjustments $(T > H_{-1})$ are presumably overestimated.

42. While it might be more desirable to examine the positive and negative hours adjustments separately to test for different reaction coefficients, such an analysis requires knowledge of the target work week, an unknown in the model.

43. Even though it would be difficult to assign a one-to-one correspondence between capacity utilization and hours worked, these variables do move together and consequently this correction variable should provide a crude adjustment for the above mentioned biases in the reaction coefficient.

eventually be offset by increased overtime premiums. Unfortunately, the correction for biases in the adjustment coefficient is insignificant, although it does have the correct sign.

$$H = \underset{(8.64)}{26.08} + \underset{(.2106)}{.3657}\, H_{-1} - \underset{(.0220)}{.0287}\, \left| (CUMW)_{-1} - 95.0 \right| + \underset{(1.330)}{4.684}\, RTSHC \qquad (S13)$$

S.E.E. = 1.079 $\qquad R^2$ = .75 $\qquad$ D.W. = 1.96 $\qquad p^*$ = .60

where RTSHC: rate of change in real output.

Since non-production labour chiefly performs supervisory or administration functions, the desired level of "overhead" labour is specified in terms of the level of production worker employment (a two year average) and existing capital stock. These two variables are perhaps more directly related to the specific functions of salaried workers than an output variable which is subject to large short-run changes. This desired level of "overhead" employment is inserted into a simple adjustment model with the lagged dependent variable again reflecting the costs involved in altering the employment level. While the adjustment coefficient is only approximately 45% per year, the components of desired non-hourly-rated employment are subject to

$$ENH = \underset{(1408)}{-2520} + \underset{(.0561)}{.1975}\, (.5EH + .5(EH)_{-1}) + \underset{(1.600)}{3.341}\, TGKC + \underset{(.1436)}{.5548}\, (ENH)_{-1} \qquad (S14)$$

S.E.E. = 504 $\qquad R^2$ = .92 $\qquad$ D.W. = 2.10

substantial lags re the important structural variables in the model.[44]

Remaining Cost Variables

Two other components of the cost function, material inputs and capital consumption allowances, are subject to stochastic explanation. The analytical device employed for material inputs, the largest expenditure component of total costs, is the standard production function concept. Since adjustment costs for material inputs are negligible, the explicit production function form is chosen with the actual level of material inputs obtained by inverting this relationship. A simple linear function of real output in terms of the number of employees, average hours worked per week, real material inputs, and capital stock corrected for capacity utilization is found to work quite successfully (all variables are significant at the 99% level); and consequently, I did not experiment with more sophisticated specifications.[45] The application of the Hildreth-Lu technique revealed a p^* of +.40 with little affect on parameter estimates.[46] Variables to proxy technological or structural change were insignificant.

$$\frac{TSH}{WPT} = \underset{(204.72)}{-722.54} + \underset{(.00252)}{.01307}\ EH + \underset{(4.902)}{15.498}\ H + \underset{(.00241)}{.00776}\ TGKC * CUMW \qquad (S15)$$

$$+ \underset{(.1653)}{.5157}\ MATR/PMAT$$

S.E.E. = 23.36 $\qquad R^2$ = .99 $\qquad$ D.W. = 1.38

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44. For example, a 1% increase in output increases overhead personnel by less than .3% in the short run as contrasted to a .8% increase in production worker employment.

45. Output elasticities are .38, .39, .78 and .35 with respect to capital, hourly-rated employment, hours worked and materials input, respectively.

46. This is consistent with the negative serial correlation results obtained in the derived demand for labour equations (see S12).

Capital consumption allowances (CCA) are primarily an accounting phenomenon, based for the most part on tax minimization considerations. The most obvious explanatory variable for CCA is the total value of fixed assets measured in original cost dollars.[47] As a check on the validity of this capital stock evaluation, and to obtain a better estimate of allowable CCA rates, capital stock is lagged one period and current investment (in current dollars) is included in this relationship. Finally, special attention must also be directed to periodic changes in the Income Tax Act which permit temporary increases (decreases) in allowable depreciation charges. In this regard, a dummy variable for the deferred depreciation measures of the early nineteen fifties is added to the CCA equation.

$$CCA = \underset{(2.990)}{-3.374} + \underset{(.0125)}{.0811}\,(TGKC/REVAL)_{-1} + \underset{(.0833)}{.1360}\,IBM \underset{(3.779)}{-3.843}\,DUMDEP \qquad (S16)$$

S.E.E. = 4.329 $\quad$ R^2 = .87 $\quad$ D.W. = 2.37

Given the maximum allowable depreciation rates for income tax purposes of 5% for buildings and 20% for machinery, one would expect a coefficient on IBM midway between these two limits (14% in S16). The lower value for the capital stock coefficient can be attributed to the "gross" specification of this variable which overstates the undepreciated value of capital and thus imparts a downward bias to the coefficient.

The remaining expenditures by the automotive industry, with the

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47. An implicit revaluer based on transportation sector data presented in Fixed Capital Flows and Stocks (T.K. Rymes, Ottawa: Dominion Bureau of Statistics, 1967) is used to convert real capital stock into an original cost evaluation.

exception of residually determined profits, are grouped together and

$$\text{PROFIT} = \text{DSH} + \text{XSH} - \text{MATR} - \text{WB} - \text{CCA} - \text{RESID} \qquad \text{(I3)}$$

considered as exogenous. Incomplete data[48] and the dominance of exogenous factors[49] primarily account for such a treatment. In addition, data for this residual series are generated by subtracting other expenditures from total shipments; and thus the variety of data sources and construction techniques employed for various categorized variables results in large potential measurement errors.[50]

Investment in the Motor Vehicle Industry

As described earlier, a difference equation is employed to generate gross capital stock estimates and a scrappage rate. Thus, a simple identity (I4) is used to specify gross capital stock, with investment expenditures

$$\text{TGKC} = .9836\ (\text{TGKC})_{-1} + \text{IBM}/_{\text{IDEFL}} + \text{IRM}/_{\text{IDEFL}} \qquad \text{(I4)}$$

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48. Such additional items as non-wage payments to labour, advertising and promotional expenditures, and inventory changes are regrettably suppressed into this one residual category.

49. Dividend payments are the best example of this problem. Initial results indicated that while current dividends paid are related to domestic profits and investment decisions, there is a very large unexplained variance. This problem is a reflection of international aspects of the parent-subsidiary relationship. Lack of adequate data precluded testing such variables as "global" liquidity, financial needs, and varying national profit rates which presumably influence the movement of funds (i.e. dividends) among the various firms in an international chain.

50. The end result of these omissions and data discrepancies is a series for residual expenditures which appears to be almost completely random. This series varies from approximately 13 million to over 90 million and has an average value of approximately 4% of total costs. Preliminary analysis revealed no statistical relationship with conventional variables such as output.

disaggregated into buildings and equipment (IBM) and repair and maintenance expenditures (IRM).

Expected output, as proxied by a three year moving average of industry output, is the major determinant of building and equipment investment. In addition, the flexible accelerator mechanism is broadened to include import and capacity considerations. Given the parent-subsidiary relationship of this industry, the flow of United States automotive exports to Canada represents a relatively close substitute for Canadian production, consisting, in part, of models which are in limited demand in Canada. As demand increases for these imported models, the line technology of the industry, with its increasing returns, may permit efficient Canadian production behind tariff protection. Since output measures for the Canadian industry exclude these flows, the level of United States imports may be a significant factor in the Canadian investment decision.[51] Finally, capacity utilization rates should have a direct influence on the speed with which a firm reacts to a change in output expectations. To proxy this effect, the optimal or target level of hours (as derived from equation S13) is subtracted from actual hours worked. To exceed this target level of hours indicates increasing cost disadvantages which outweigh the gains from longer production runs, thus prompting the decision to invest in new facilities.[52]

As shown in equation S17, all variables have the correct sign

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51. United States imports from parent firms may also indicate capacity constraints in domestic production (a spur to investment) or may act as a buffer in investment decisions (a hedge against errors in output projections).

52. While capacity utilization rates also performed reasonably well, this specification gave sharper statistical results.

and are significant at well over the 95% level. Serial correlation is only a minor problem.[53] The relatively low speed of adjustment is in keeping with the long lags and slow responses found in most other flexible

$$\underset{(11.102)}{IBM/IDEFL = 1.402} + \underset{(.0211)}{.0794}\ TSHC3 + \underset{(.1552)}{.3972}\ USMTC2 \qquad (S17)$$

$$+ \underset{(2.189)}{4.728}\ (H\text{-}41) - \underset{(.0337)}{.1317}\ (TGKC)_{-1}$$

S.E.E. = 9.732 $\qquad R^2$ = .63 $\qquad$ D.W. = 1.34

where TSHC3 : three year moving average of real industry output

USMTC2 : two year moving average of real United States imports to Canada

accelerator models.[54] Elasticities of investment with respect to a change in current real output and current real United States imports are .74 and .52 respectively. Again, this output elasticity corresponds quite closely to those found in other studies;[55] and, as expected, the import elasticity is lower. The over-riding importance of expected output, including import considerations, was further substantiated by the insignificance of other variables such as interest rates, liquidity proxies, government policy variables and relative factor prices.

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53. A Hildreth-Lu trial run produced a p* of .30 with all coefficients almost identical in value to those presented above.

54. For example, Kuh found that the speeds of adjustment "rarely exceeded .25, with a value of .10 characterizing our estimates of the median reaction coefficient" (Kuh, E., Capital Stock Growth: A Micro-Econometric Approach, Amsterdam: North-Holland Publishing Company, 1963, p. 64).

55. Kuh, (ibid., pages 221-230) found that median elasticities of investment with respect to sales were generally less than unity.

The use of gross capital stock data, as well as the possibility of different behavioral patterns for various types of investment, prompted the examination of repair and maintenance investment separately. The stock of capital[56] and recent rates of capacity utilization are two obvious choices for explanatory variables. There is also the possibility that recent growth in capital stock may effect the level of repair and maintenance expenditure. To reflect the growth in capital stock and the recent history of capacity utilization rates, the Almon distributed lag technique, as modified by Sparks, is utilized.[57]

As shown in equation S18, a complementary relationship appears to exist between the servicing of existing capital and the addition of new capital.[58] The weak statistical results for the capacity utilization

$$IRM/_{IDEFL} = \underset{(4.3410)}{-.0517} + \underset{(.00407)}{.01316}\,(TGKC)_{-1} + \underset{(.02673)}{.03184}\text{ Almon CUMW} + \underset{(.0269)}{.1290}\text{ Almon }\Delta TGKC \qquad (S18)$$

S.E.E. = 1.209 $\qquad$ R^2 = .72 $\qquad$ D.W. = 1.28

variable may reflect the attempt by firms to reduce cyclical employment

56. While time profiles of investment and capital stock are the more relevant concept to establish repair and maintenance patterns, lack of data forced the use of total capital stock.

57. Sparks, G.R. "Subroutine Almon 2" in User's Manual: Massager System, Ottawa: Bank of Canada, 1968. In particular, a four year quadratic Lagrangian polynomial constrained to have a zero end point and a zero derivative at this point is employed for each variable.

58. A growth in capital stock may place a great premium on maintaining existing capital stock. It is presumably less expensive to incur repair costs than to replace machinery outright, and the growth in investment elsewhere may increase the incentive to keep existing capital in operation.

fluctuations by utilizing excess skilled labour for repair and maintenance work in temporary recessionary periods (i.e. when CUMW is low). Such effects may partially offset (statistically) the technological requirements for maintenance and repair when capacity rates are high.

III

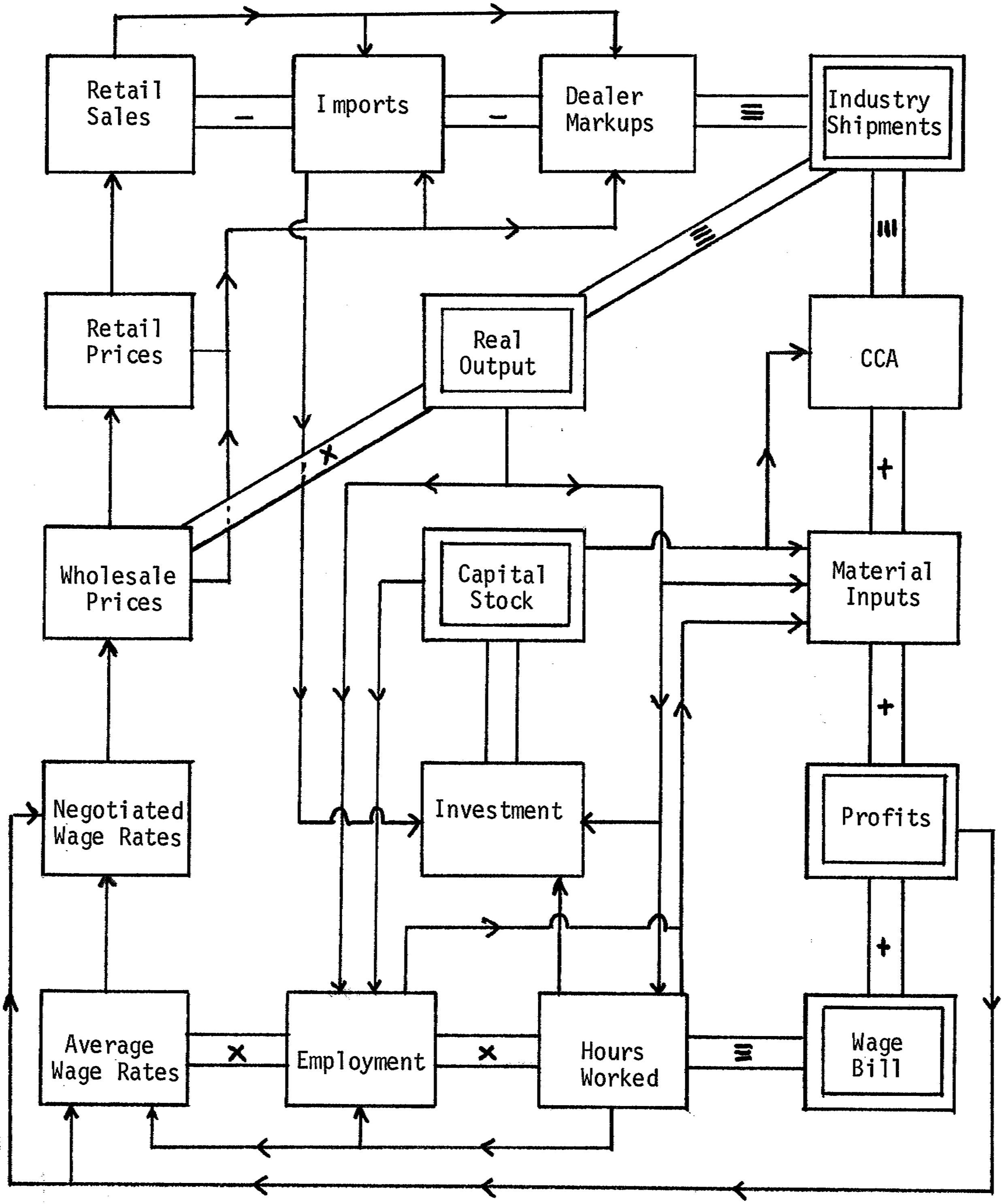
The preceding section describes a system of behavioural, technological and definitional equations designed to quantify the economic behaviour of the Canadian automotive manufacturing industry. As is obvious from this discussion, the model is very tightly knit and highly simultaneous. This point becomes even more apparent in Chart I which depicts the relationships among the major blocks of endogenous variables in the model. Identities are denoted by double lines connecting their individual arguments with the defined variable represented by a double rectangle.

Simultaneous Equation Estimation

While ordinary least squares is a natural way to begin, the high degree of simultaneity in the system necessitates the use of an alternative estimation technique which will give consistent parameter estimates. There are several major problems in applying two-stage least squares to the above system. First, which of the predetermined variables are legitimate instruments. The existence of serially correlated residuals in many equations makes it questionable whether lagged dependent variables can be used in such a capacity. In addition, the model also includes several variables which, while being outside the scope of this industry system, are endogenous to a complete macro model (e.g. disposable income, the consumer price index,

CHART I

A Condensed Flow Diagram
Of the Model



and the foreign exchange rate). Given the key position of the automobile sector in an industrialized economy, there is likely to be a significant influence of industry behaviour on economy-wide variables. Since this potential simultaneous bias is likely to be most severe in certain specific areas, i.e. national income and prices; these particular economy-wide variables will also be excluded from the instrument set. Consequently, the remaining set of predetermined variables is expanded to include lagged values for the lagged endogenous variables and additional economy-wide instruments[59] for the "macro endogenous" variables.

An overriding constraint in the two-stage least squares procedure is the limited degrees of freedom imposed by the annual nature of the model. The above set of instruments, approximately forty in number, must be either reduced or carefully manipulated to produce a much smaller number. To overcome degrees of freedom and collinearity problems, principal components are extracted from the set of excluded predetermined variables for each equation.[60] The two-stage least squares coefficient estimates tend to stabilize rapidly when between five and eight principal components are employed.[61]

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59. The following four economy-wide instruments are included along with the remaining predetermined variables: government expenditures, income level in the United States, cash reserves of the banking system and the level of United States prices.

60. See Kloek, T. and Mennes, L.B.M., "Simultaneous Equation Estimation Based on Principal Components of Predetermined Variables", Econometrica, XXVIII (January 1960) 45-61.

61. At least five principal components are required to capture 90% of the total variance in the complete set of instruments while the first eight principal components account for 98% or more of the total variance in the instrument set.

TABLE 1

Two-Stage Least Squares Estimates Employing Principal Components

$$\frac{RSA}{POP*RPA} = \underset{(78.11)}{83.03} + \underset{(.0467)}{.1093}\ YDPC/POP - \underset{(63.58)}{166.79}\ RPA/PCED - \underset{(.0941)}{.1183}\ (STKA/POP)_{-1}$$

S.E.E. = 4.395
R^2 = .90
D.W. = 2.18
p* = .25

$$\frac{RSTR}{RPTR} = \underset{(360.9)}{686.7} + \underset{(.004296)}{.004457}\ GNEC + \underset{(.01352)}{.01026}\ \Delta GNEC - \underset{(366.6)}{509.5}\ (RPTR/PME) + \underset{(18.74)}{47.35}\ DUMKW - \underset{(.10677)}{.06593}\ (STKTR)_{-1}$$

S.E.E. = 24.75
R^2 = .75
D.W. = 1.82

$$\frac{USMT/WPTUSK}{DSH/WPT} = \underset{(.1454)}{.9144} + \underset{(.0578)}{.1358}\ RSACDV(RSA/RPA) - \underset{(.001433)}{.008188}\ USCUR$$

S.E.E. = .02298
R^2 = .70
D.W. = 1.54

$$\frac{EMT}{DSH} = -\underset{(.1993)}{.1195} + \underset{(.00007568)}{.00008945}\ \Delta\frac{RSA}{RPA} + \underset{(.2119)}{.3929}\ WPT - \underset{(.07724)}{.03745}\ UKCUR - \underset{(.04448)}{.06858}\ DUMTAR$$

S.E.E. = .0400
R^2 = .34
D.W. = 1.10
p* = .36

$$\frac{COMMIS}{\left(\frac{RSA}{RPA} + \frac{RSTR}{RPTR}\right)} = -\underset{(.0513)}{.1261} + \underset{(.1628)}{1.1715}\ (RPT - .65\ WPT) + \underset{(.001193)}{.005597}\ T$$

S.E.E. = .02293
R^2 = .88
D.W. = 1.94

TABLE 1 (cont'd)

$$WPT = \underset{(.228)}{-1.197} + \underset{(2.332)}{6.271}\ (NEGAV/PRODT) + \underset{(.034)}{1.137}\ WPTUS + \underset{(.000928)}{.003952}\ USCUR$$

S.E.E. = .01286
R^2 = .99
D.W. = 1.66

$$RPA = \underset{(.0812)}{-.2053} + \underset{(.0622)}{.9927}\ WPT + \underset{(.122)}{1.037}\ TOTTAX$$

S.E.E. = .01745
R^2 = .96
D.W. = 1.96

$$RPTR = \underset{(.0941)}{-.5044} + \underset{(.072)}{1.449}\ WPT + \underset{(.1422)}{.2525}\ TOTTAX$$

S.E.E. = .02021
R^2 = .99
D.W. = 1.78

$$\frac{\Delta NEGAV}{NEGAV} = \underset{(7.83)}{-24.05} + \underset{(.1714)}{.3555}\ \frac{\Delta CPI}{CPI} + \underset{(.1089)}{.5325}\ (PROFIT/TSH) + \underset{(6.52)}{20.91}\ DUMUS * (USW/NEGAV)_{-1} + \underset{(8.40)}{26.57}\ DUMCAN * (CANW/NEGAV)_{-1}$$

S.E.E. = .4424
R^2 = .95
D.W. = 2.96

$$AHE - NEGAV = \underset{(.139)}{-1.066} + \underset{(.001811)}{.008958}\ CPI + \underset{(.001357)}{.002014}\ H * (NEGAV)_{-1} + \underset{(.01723)}{.02807}\ DUMYRI$$

S.E.E. = .03331
R^2 = .95
D.W. = 1.22

$$AWWSNH = \underset{(85.27)}{-86.34} + \underset{(.6988)}{.4948}\ CPI + \underset{(42.25)}{36.06}\ (PROFIT/TSH) + \underset{(1214.5)}{2003.2}\ (NEGAV/AWWSNH)_{-1} + \underset{(.2225)}{.9269}\ (AWWSNH)_{-1}$$

S.E.E. = 2.290
R^2 = .99
D.W. = 2.36

TABLE 1 (cont'd)

$$EH = \underset{(37611)}{24007} + \underset{(16.52)}{31.30}\frac{TSH}{WPT} - \underset{(8.48)}{12.31}\left(\frac{TSH}{WPT}\right)_{-1} - \underset{(734.1)}{492.2}\,H - \underset{(.3043)}{.2845}\,(TGKC * CUMW) + \underset{(.6529)}{.6420}\,(EH)_{-1}$$

S.E.E. = 1511
R^2 = .80
D.W. = 2.40

$$H = \underset{(7.57)}{15.15} - \underset{(.03365)}{.02908}\,\left|\,95.0 - (CUMW)_{-1}\,\right| + \underset{(1.856)}{5.538}\,RTSHC + \underset{(.1885)}{.6312}\,(H)_{-1}$$

S.E.E. = 1.1847
R^2 = .67
D.W. = 1.20

$$ENH = -\underset{(2636.5)}{811.3} + \underset{(.1028)}{.1077}\,[.5 *(EH) + .5 *(EH)_{-1}] + \underset{(2.170)}{1.809}\,TGKC + \underset{(.2051)}{.7027}\,(ENH)_{-1}$$

S.E.E. = 566.1
R^2 = .90
D.W. = 2.17

$$\frac{TSH}{WPT} = -\underset{(235.1)}{641.9} + \underset{(.00329)}{.01528}\,EH + \underset{(6.15)}{12.17}\,H + \underset{(.002700)}{.006923}\,(TGKC * CUMW) + \underset{(.1868)}{.5789}\,(MATR/PMAT)$$

S.E.E. = 24.83
R^2 = .99
D.W. = 1.43

$$CCA = -\underset{(3.045)}{2.212} + \underset{(.0999)}{.1847}\,IBM + \underset{(.00978)}{.06853}\,(TGKC/REVAL)_{-1} - \underset{(3.797)}{1.430}\,DUMDEP$$

S.E.E. = 4.543
R^2 = .86
D.W. = 2.51

$$\frac{IBM}{IDEFL} = -\underset{(12.499)}{5.660} + \underset{(.02469)}{.09332}\,TSHC3 + \underset{(.1894)}{.3323}\,USMTC2 + \underset{(2.629)}{3.257}\,(H - 41) - \underset{(.0396)}{.1339}\,(TGKC)_{-1}$$

S.E.E. = 10.07
R^2 = .60
D.W. = 1.32

TABLE 1 (cont'd)

$$\frac{IRM}{IDEFL} = \underset{(4.7764)}{.8821} + \underset{(.00437)}{.01247}\ (TGKC)_{-1} + \underset{(.02893)}{.02614}\ \text{Almon}\ (CUMW) + \underset{(.0291)}{.1262}\ \text{Almon}\ (\Delta TGKC)$$

S.E.E. = 1.2127
R^2 = .72
D.W. = 1.30

IV

Having completed the construction and empirical estimation of the model, I now turn to a brief examination of how well this highly simultaneous model functions as a complete industry system. Given the many non-linear features in the system, numerical analysis or simulation experiment is the obvious choice for such a test. In particular, a set of control simulations will explore the dynamic performance of the model over the sample period.[65]

Control Simulation Experiment I

One minor modification of the model is required. The negotiated wage rate is considered as an exogenous variable in light of its peculiar temporal specification (i.e. non-uniform wage rounds). Since three of the four explanatory variables for this particular equation are exogenously

65. Given initial conditions for lagged endogenous variables and values for all exogenous variables throughout the sample period, the model is solved year by year for the endogenous variables. Thus, a time path for all endogenous variables is generated which can be compared to their actual values. The change in structure occasioned by the signing of the United States-Canada Automobile Agreement in 1965 necessitated such a sample period simulation check rather than an evaluation of model predictions of the future.

determined, the damage to the complete system by removing this link is hopefully minimal. Chart 2 depicts the actual and predicted (simulated) values for the major endogenous variables over the 1951-1964 period.[66] In addition, Table 2 presents a comparison of root-mean-square (R.M.S.) errors and the standard error of estimate (S.E.E.) from PC2SLS where applicable.[67]

TABLE 2

A Comparison of Root-Mean-Square Errors from Simulation Control Run I with Standard Errors of Estimate from PC2SLS

	R.M.S. Error (Run I)	S.E.E. (PC2SLS)
Automobile sales	83.	-
Commercial vehicle sales	21.	25.
European imports	13.	-
United States imports	17.	-
Dealer value-added	34.	-
Investment	11.	10.
Production workers	3,048.	1,511.
Non-production workers	893.	566.
Hours worked per week	1.63	1.18
Average weekly salaries	3.86	2.29
Average hourly earnings	.029	.033
Retail automobile price	.022	.017
Retail commercial vehicle price	.011	.020
Wholesale vehicle price	.010	.013

66. In view of data limitations for various time series, 1951 is the earliest possible commencing data for the simulation experiments.

67. Recall that a number of equations are estimated in non-linear form (e.g. import shares), and thus a precise estimate of the S.E.E. for the normalized variable is not available.

CHART 2

Control Simulation I

(1951 - 1964)

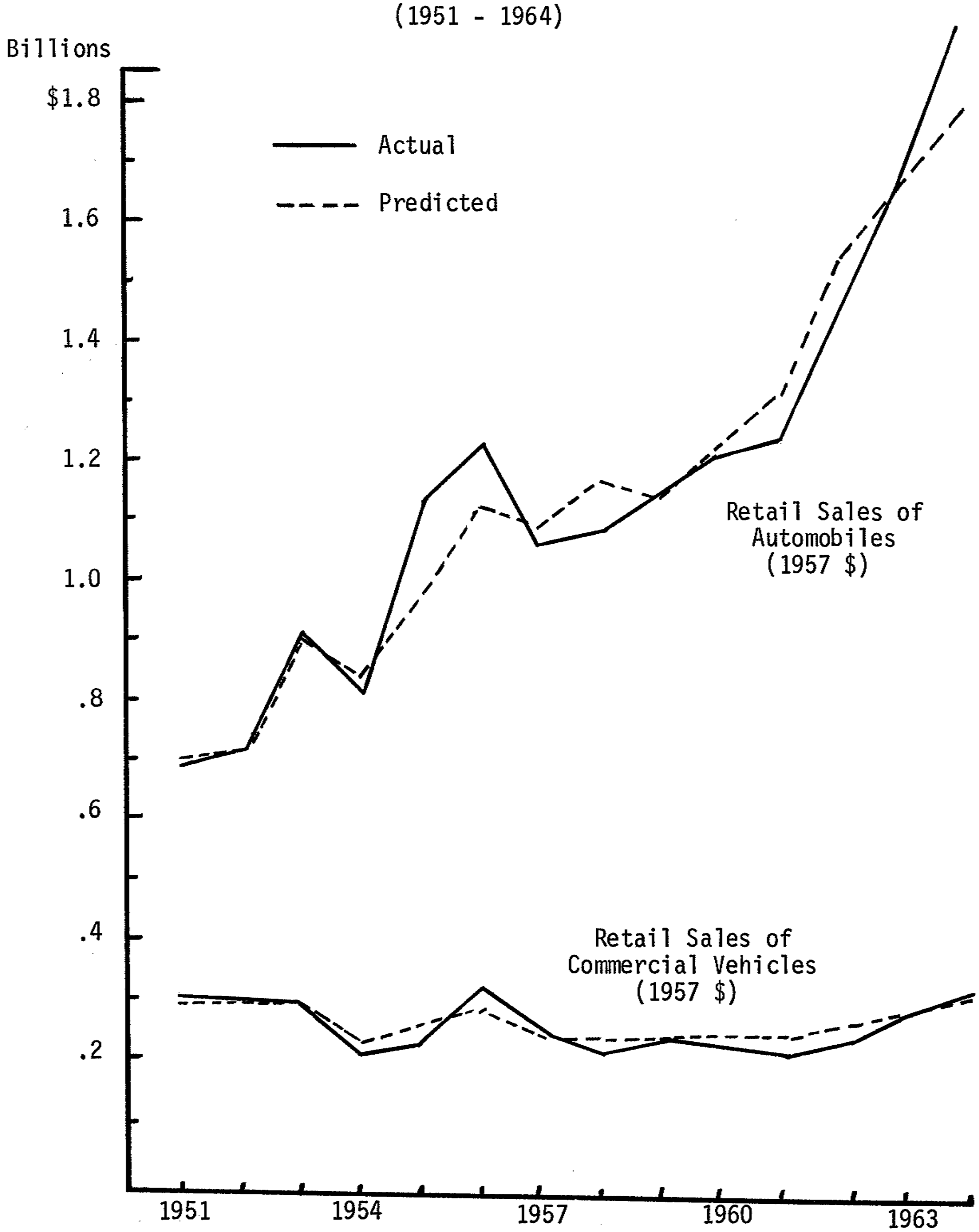

CHART 2

(continued)

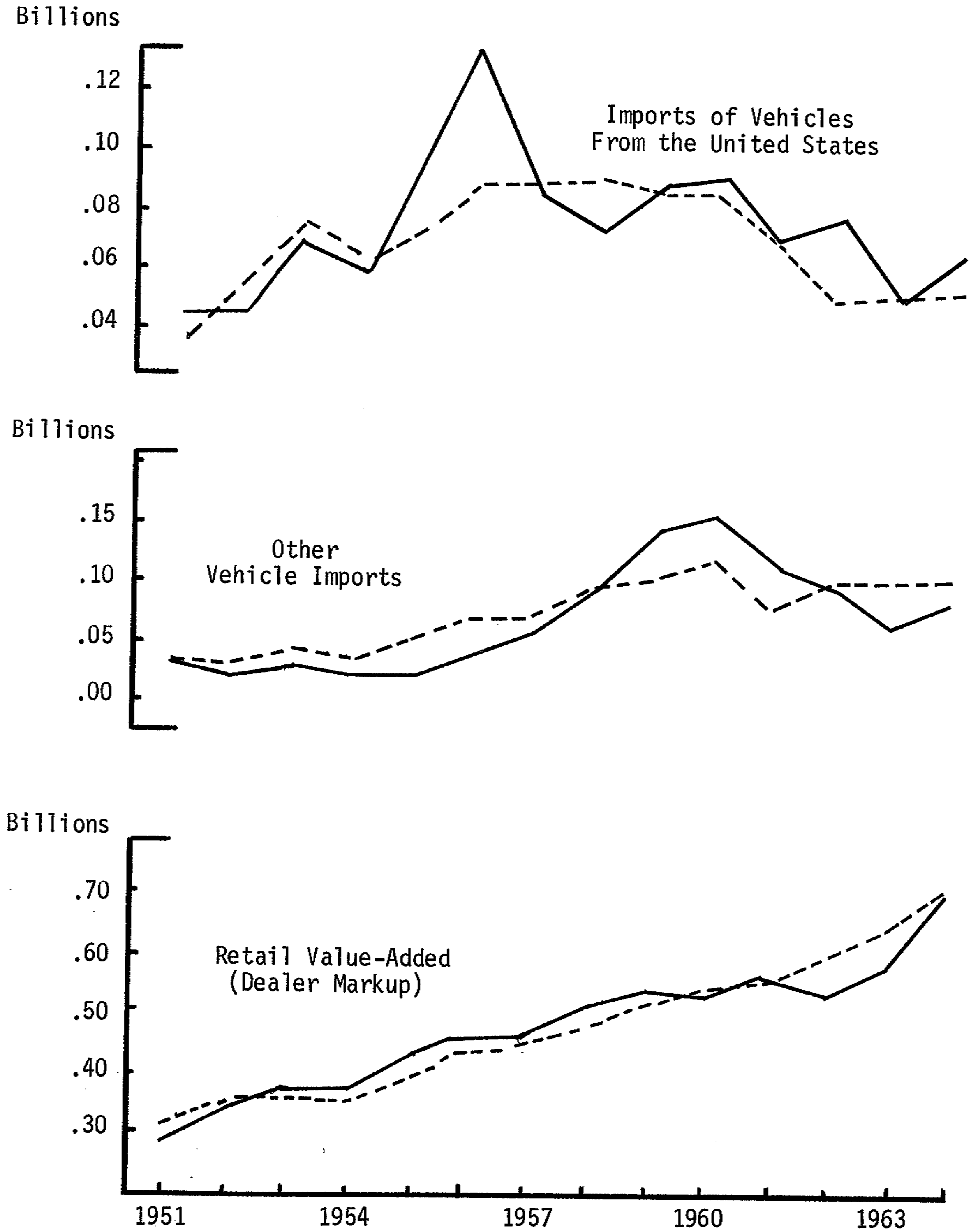

CHART 2

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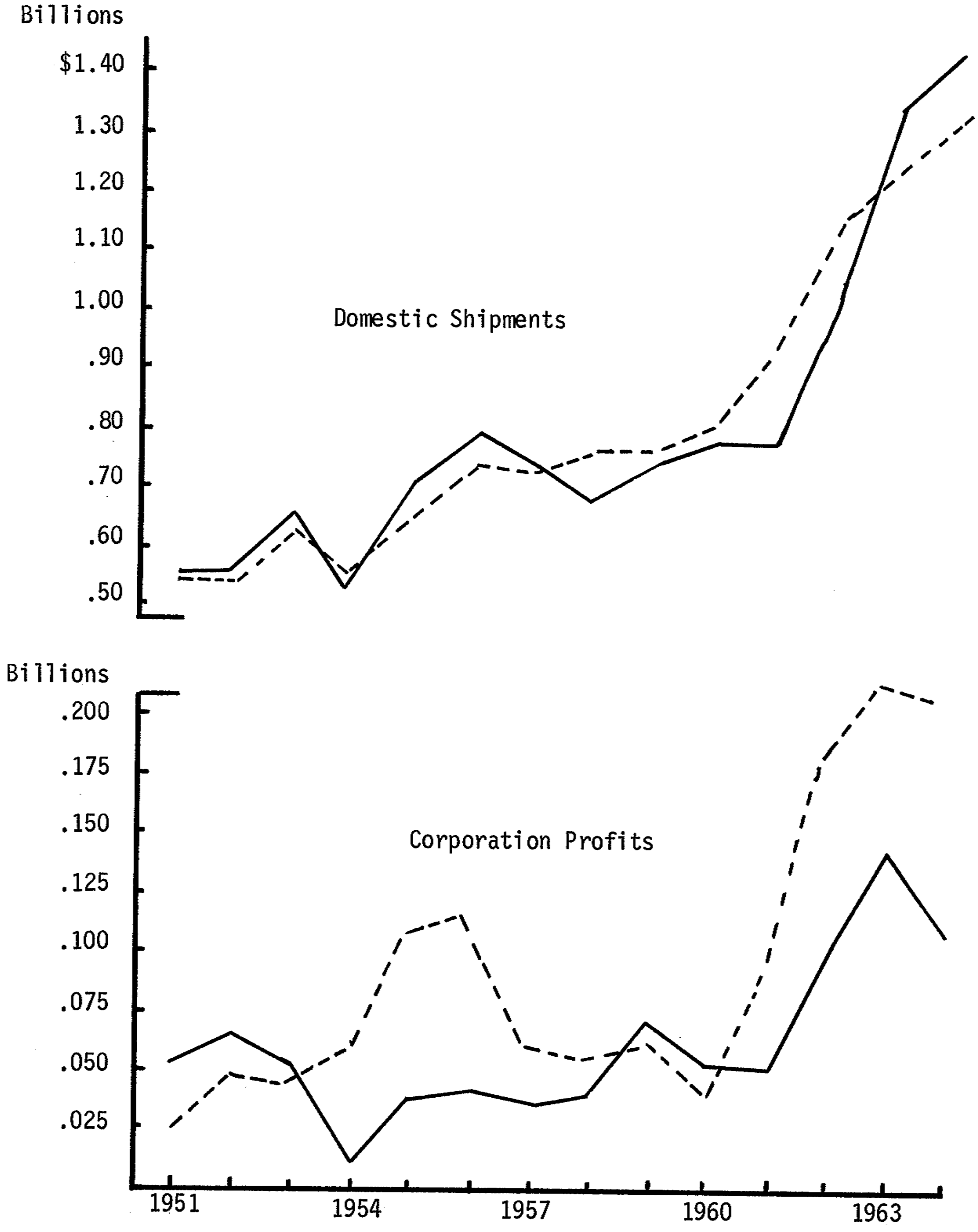

CHART 2

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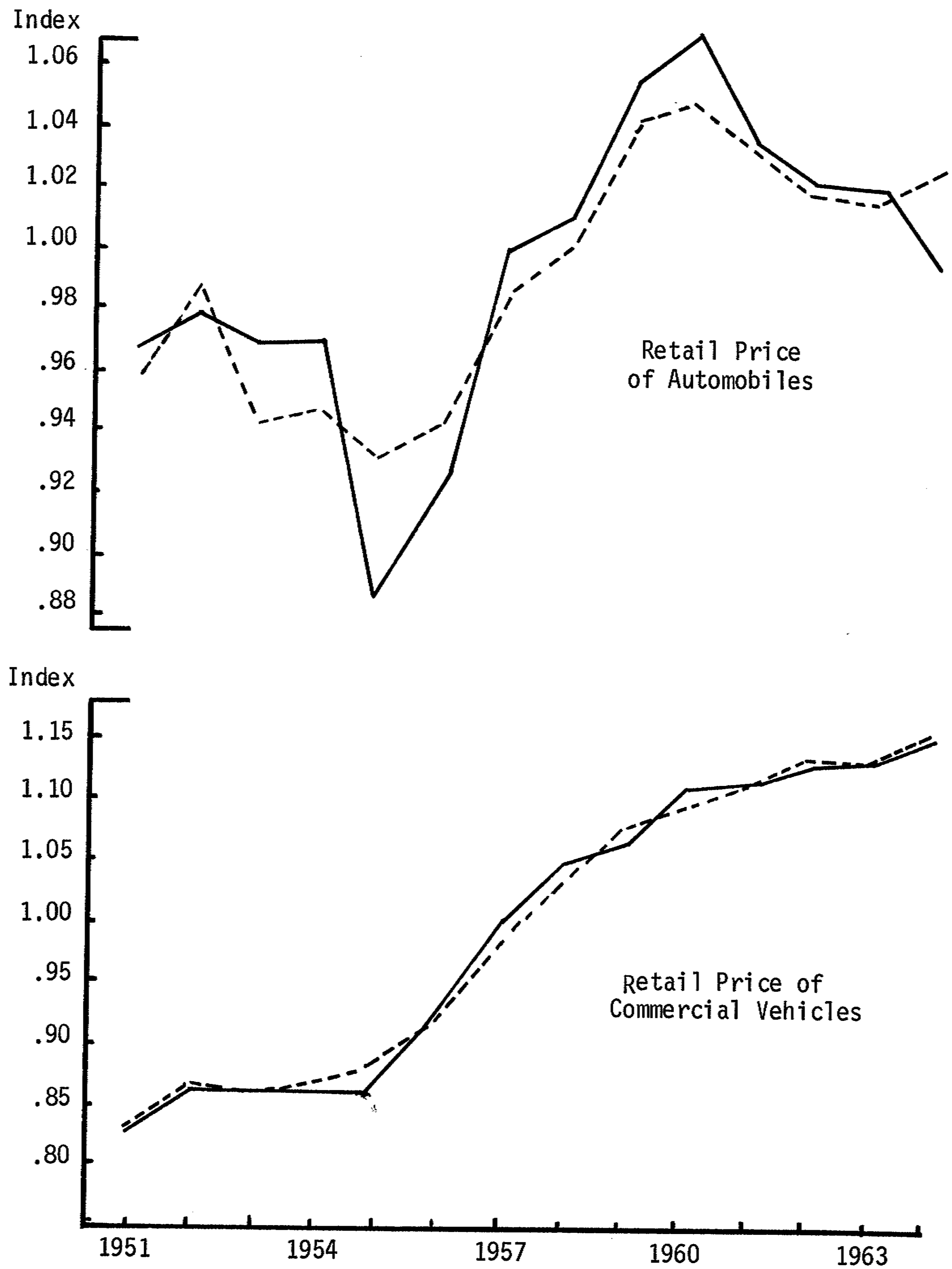

CHART 2

(continued)

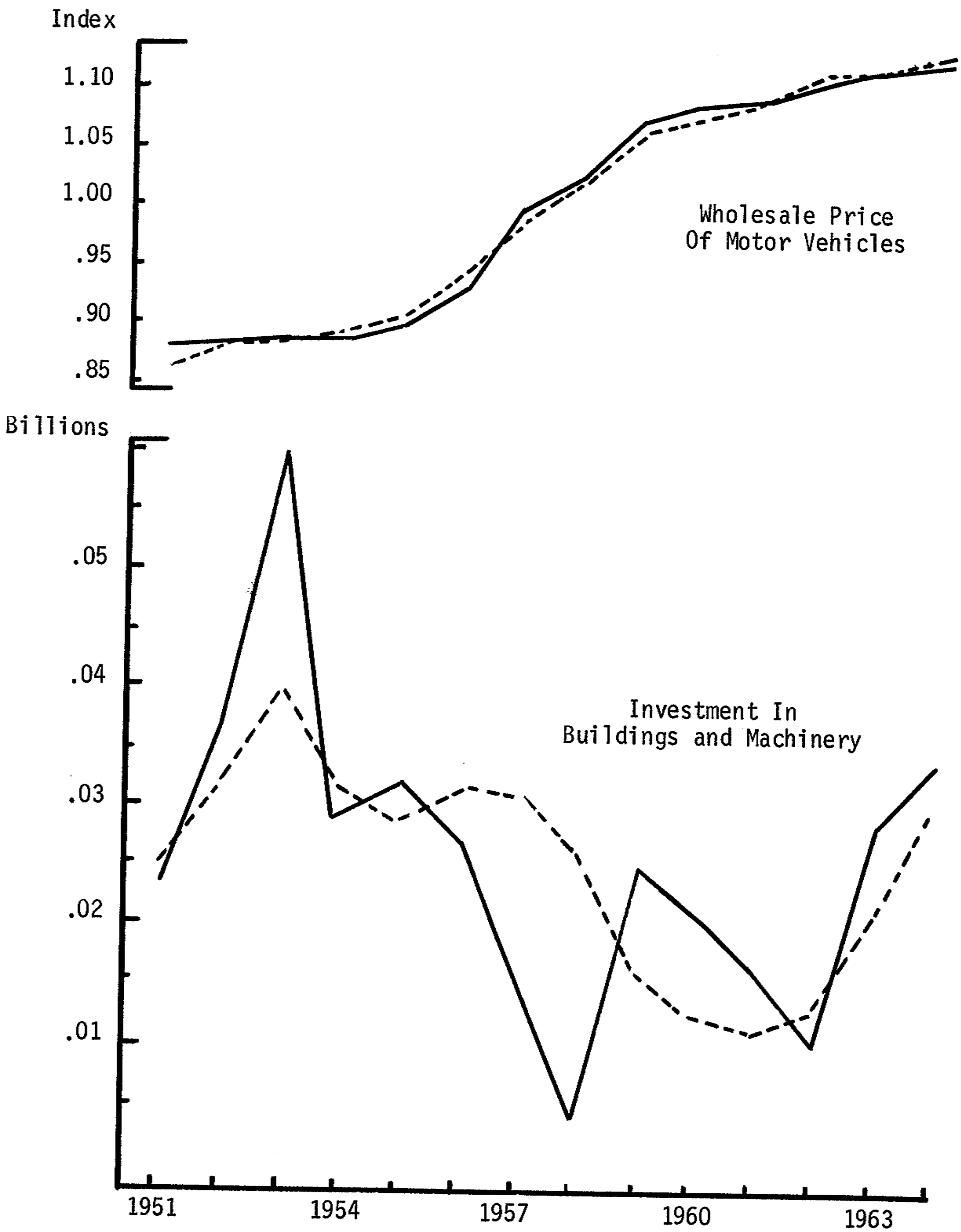

CHART 2

(continued)

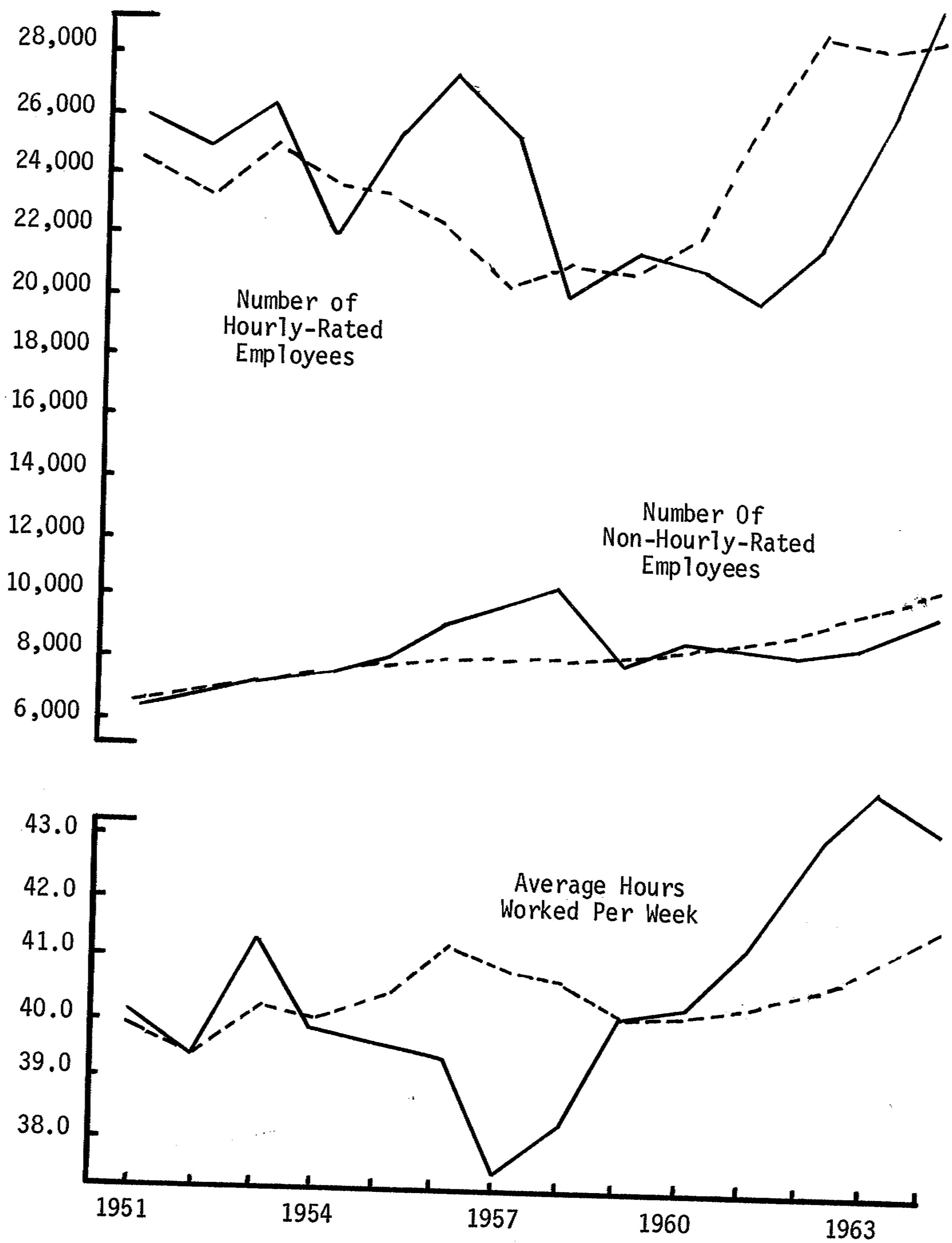

CHART 2

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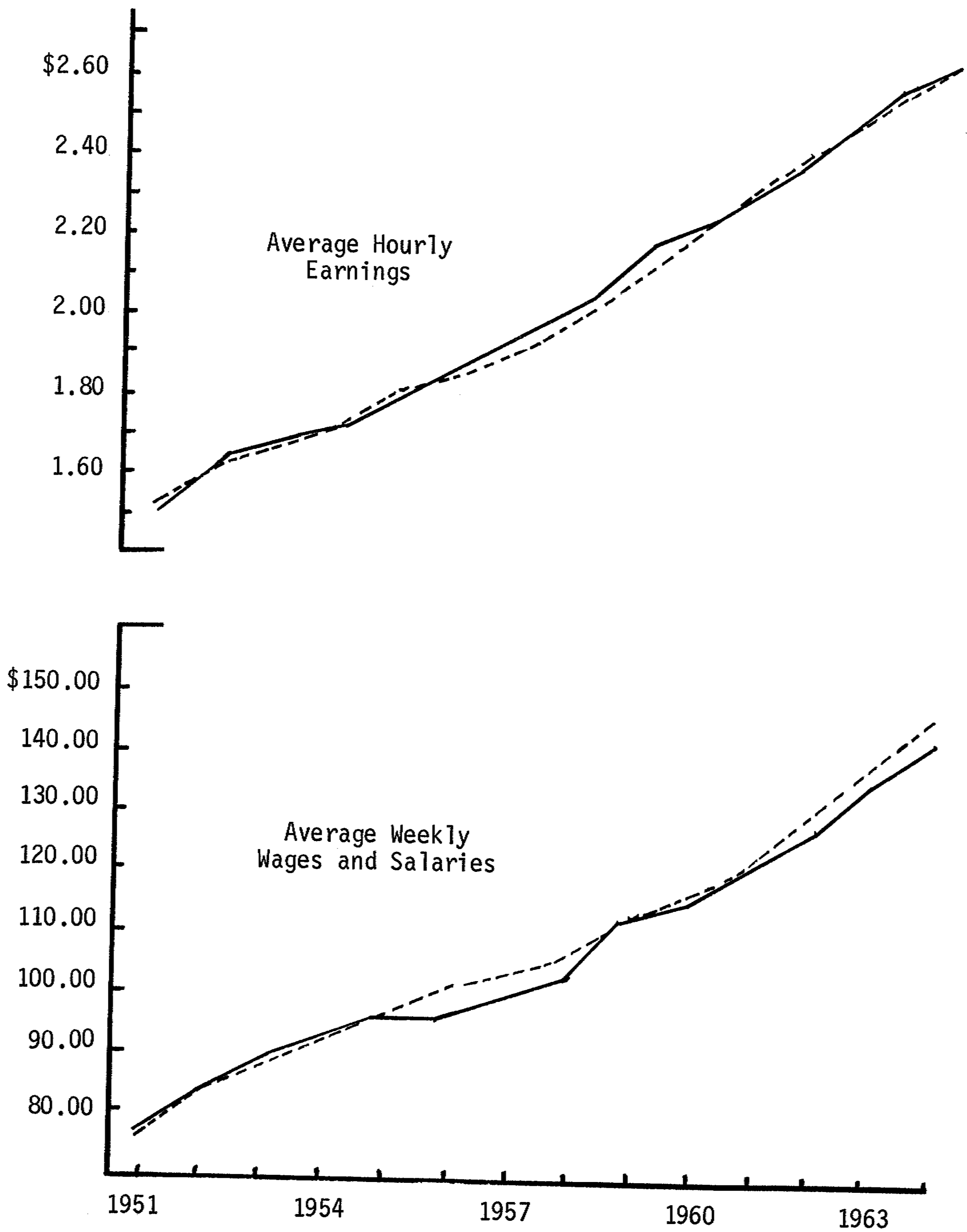

In general, this control simulation demonstrates that the dynamic and structural characteristics of the model tend to keep the endogenous variables relatively closely on track. Even though there are individual discrepancies, R.M.S. errors are reasonably similar to the S.E.E. from PC2SLS.[68] Perhaps even more important, particularly in view of the cyclical nature of the industry and the varying economic conditions over this sample period, about three quarters of all turning points in the individual data series are predicted in the simulation control run.

More specifically, simulation results for prices, wages, and dealer value-added track extremely well. Turning to the demand variables, retail automobile sales predictions simulate the first three year cycle very precisely (an average error well under 1%), as well as the rapid upturn in 1955-56. The major problems would appear to be an over prediction in 1958 and 1961, and a general tendency to smooth out the very pronounced cycle.[69] Commercial vehicle sales exhibit roughly the same general characteristics with discrepancies being somewhat smaller.

Import predictions are not as accurate, although they do follow the general path of actual imports. Recall that the import equations are specified in "share" form in order that relative price effects and differeniating factors could be examined more closely. Consequently, relatively small errors in retail demand and other equations will feed directly into the predictions of import levels. The two major problems in the simulation

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68. Given the differences in time periods (PC2SLS usually runs over the 1948-1964 period), these two error statistics cannot be compared directly.

69. However, a rough calculation for the S.E.E. in the PC2SLS automobile equation reveals a value of approximately $75 million dollars, very close to the R.M.S. error presented in Table 2.

results for United States imports are an underprediction in 1956 and an overprediction in 1962. The mammoth 148 day strike at General Motors of Canada, running well into 1956, may partially account for the upward surge of automotive imports in 1955 and 1956. European import predictions tend to smooth out the highly cyclical pattern, overpredicting prior to the European car boom of the late fifties and underpredicting during this historical phenomenon. I will return to this problem shortly.

Domestic shipments are defined as total retail sales (in current dollars) less imports and dealer value-added. Thus, errors in this series can be traced directly back to the previous stochastic equations. For a tabular presentation of percentage errors in domestic shipments, see Table 3. Employment predictions are characterized by the largest discrepancies of all industry variables with average percentage errors of approximately 10% (again see Table 3). The poorest hourly-rated employment predictions are in 1955-56 and 1961-62, two periods of large errors in domestic shipments prediction. Non-hourly-rated employment predictions tend to reflect these errors with a slight lag, as expected in view of the equation specification.

Given the tremendous volatility in investment expenditures, simulated investment values tend to smooth out the peaks and troughs. Nonetheless, the R.M.S. error is directly comparable to the S.E.E. from PC2SLS. The failure to pick up the minor cycle in the late fifties is the most prominent shortcoming in the investment simulation.

<u>Control Simulation Experiment II</u>

Thus, the major simulation problems are found in the import and employment sectors of the model, with the latter relationships appearing to be quite sensitive to errors in real output prediction. Two modifications are suggested to examine these problems to a further degree. First, the capacity correction variable, previously considered as exogenous to the system, may be contributing to the employment errors. For example, given an over-prediction in real output, a simulated capacity utilization correction factor will be higher than the exogenous (actual) value and thus offer, via the capital stock variable, a partial offset to the employment over-predictions (ignoring feedbacks). An iteration technique is employed to generate an "endogenous" capacity utilization rate. Capacity estimates are constructed on the basis of the initial control simulation run and then inserted as an external factor into a second simulation run from which a third capacity estimate is obtained, etc. These capacity utilization rate estimates converged rapidly, and only two iterations are employed.[70]

The second modification concerns the role of European imports and, in particular, the substantial boom in such imports in the late fifties. This phenomenon can largely be attributed to a change in consumer tastes toward smaller cars and the failure of the North American industry to anticipate such a taste change. While the above estimates predict an increase in these import boom years, they fall well short of the actual level of European imports. Since this historical phenomenon is largely a product of changing consumer tastes and factors outside the scope of this model, one would like to remove its effects (mostly unfavourable) from the model. One way of handling this problem, without removing competitive import effects from the system, is to employ the residuals from the PC2SLS

70. As expected, the new capacity series constructed from the simulation results differs most noticeably for those years in which output predictions are subject to the largest error. For example, in 1962 (an overprediction year) the simulated capacity series increased by about 10%.

European import equation as a proxy for unmeasurable changes in consumer preferences, thus providing a correction for this unique historical event.

Given the fairly accurate predictions for the early part of the simulation period, the second set of control simulations commence in 1956, the first major problem year. Since the major effects of these two modifications are largely confined to the employment-output sector of the model, only these variables are presented in Chart 3. In addition, the previous simulation results are also presented to permit a straight-forward examination of any reduction in error discrepancies.

The results from these two corrections are a definite improvement. Errors in domestic shipments are reduced for every year, particularly for 1956, 1958 and the early 1960's (see Table 3). The effects of these improvements show up even more dramatically in hourly-rated employment

TABLE 3

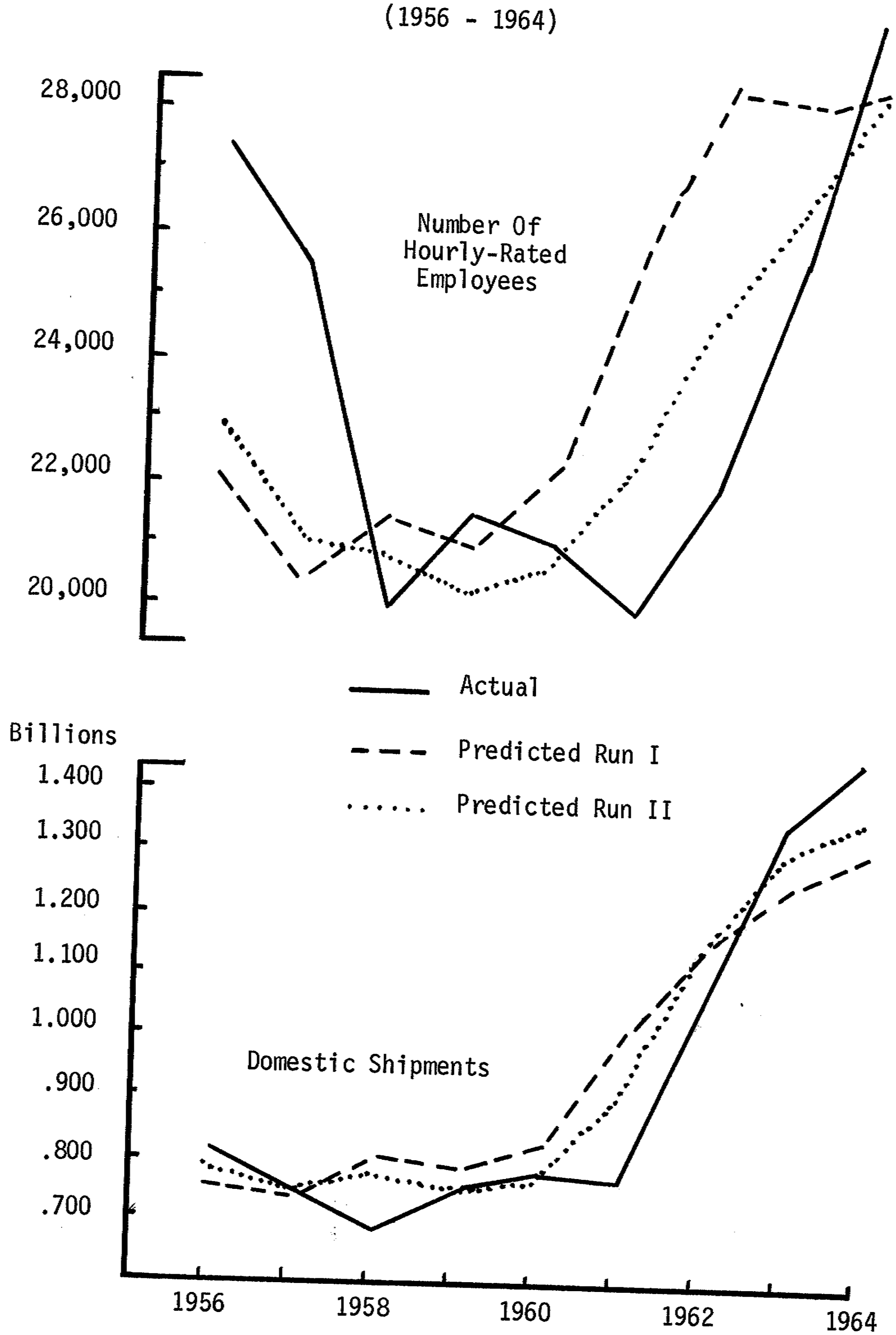
Percentage Predictive Errors in
Simulation Control Runs

	Domestic Shipments		Hourly-Rated Employment	
	Run I	Run II	Run I	Run II
1956	- 6.6 %	- 2.8 %	- 19.2 %	- 16.1 %
1957	3.0	1.6	19.9	17.3
1958	14.3	12.4	6.4	3.6
1959	3.1	- .8	- 2.3	- 6.0
1960	3.8	- .9	5.4	- 1.1
1961	22.0	14.8	31.1	11.0
1962	8.5	7.8	31.3	13.7
1963	- 7.1	- 3.4	10.7	4.9
1964	- 8.5	- 5.9	- 3.2	- 3

CHART 3

Control Simulation II

(1956 - 1964)



predictions, as is evident by the more than 50% reduction of the error discrepancies in the 1960's. If one recalls that the standard error of estimate for hourly-rated employment is in excess of 1500 men (slightly greater than a 6% error), these errors are generally in line with expectations, the exceptions being 1956-57 and 1961-62.[71] Furthermore, these two corrections also substantially reduce the errors in non-hourly employment which previously entered via the hourly-rated employment variable.

Summary

In conclusion, a system of behavioural, technological and definitional equations is hypothesized to quantify the economic behaviour of the Canadian automotive manufacturing industry. In essence, this dynamic demand-supply model focusses on the determination of industry output from both the expenditure (sales) and factor payment sides. As portrayed in Chart 1, two fundamental demand and supply relationships completely unify the entire industry system. While the construction of the model draws heavily on traditional macroeconomic theory and macro model building tools, explicit attempts have been made to incorporate basic institutional and industrial features into the system. Nonetheless, the model still falls short of an ideal economic quantification of industry behaviour, particularly with respect to foreign ownership considerations, oligopolistic features, and the basic industry production technology.

In spite of these limitations, most of which arise from the basic

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71. Given the role of domestic shipments and the lagged dependent variable in this equation, most of these exceptions can be traced back to errors in simulating domestic shipments.

orientation of the model, the total system performs quite satisfactorily. Control simulations demonstrate that the model tracks the actual data relatively closely over the sample period, a period of vastly different economic conditions. Nearly all data turning points are predicted and predictive errors are generally of a tolerable magnitude. In view of the relative scarcity of econometric work examining complete industry systems, it is hoped that such a model will provide useful information concerning sectoral differences and supply/production disaggregation for future economy model building.

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