A Path Analysis of the Relationship of Selected Economic Indicators and Australian Domestic Air Freight

Peter Gilmour & John L. Gattorna

ABSTRACT

Growth of domestic air freight in Australia over recent years has not lived up to industry expectations. It is possible that air freight as a 'product' has passed the introductory and growth stages of the product life cycle and as an established mode exists in the maturity stage. If this is the case then air freight activity will tend to be related to economic conditions, as a buoyant economy generates high customer service demands which are more than proportionately met by air freight.

This paper establishes a causal model and examines the relationships, both direct and indirect, through other variables, of a set of economic indicators and domestic air freight performance in terms of total tonnes embarked.

For the 15 year period examined the causal model exhibited an ability to predict domestic air freight activity. This finding tends to confirm the view that product value/weight and modal price differentials have stabilized in terms of their effect on modal split and that air freight movements are now primarily responsive to general economic conditions.

INTRODUCTION

Growth of domestic air freight in Australia over recent years has not lived up to expectations. Gattorna (1974a) points out that during the five year period to December 1972, domestic air freight tonnes embarked has risen from 81 thousand to 91 thousand, an increase of 12.1 per cent or an average annual groth rate of 2.4 per cent. Tonne-kilometres performed during the same period increased 20.7 per cent from 68.5 million to 82.7 million, or 4.2 per cent per year. This situation represents a considerable downturn from the rosy predictions made during the 1960s of the competitive strength of air as a freight carrying mode.[1]

In another study Gattorna (1974b) established a strong direct relationship between domestic air freight and several macroeconomic indicators. These findings also have a strong appeal of face validity. When economic conditions are buoyant, industrial competition is keen and the service level to customers becomes more important. In order to provide a superior level of customer service manufacturers and wholesalers have more need for air freight.

This paper sets up a causal model and examines the relationships, both direct and indirect through other variables, of a set of indicators of economic well-being and domestic air freight performance in terms of tonnes embarked.

THE CAUSAL MODEL

Causal modelling or path analysis has been developed in biology[2] and extended in the social sciences.[3] The method

1. See, for example, Watkins (1968), Regan (1973) and Fairweather (1971).
2. See, for example, Wright (1934).
3. See, for example, Duncan (1966), Land (1969) and Anderson (1973).

provides a means of constructing a mathematical statement of the causal relationships which exist between the interrelated variables of a hypothesized system. Figure 1 shows the hypothesized causal model. All relationships are linear, additive and asymmetric. One-way arrows lead from each independent to each dependent variable. All except the first three variables are endogenous variables and are assumed to be determined mainly by a combination of the other variables in the system. Double-headed curved lines connecting Gross Domestic Product (GDP) total imports and total exports show unanalyzed correlations among these three exogenous variables. This variation is assumed to be caused by variables outside the system.

In the hypothesized system shown in Figure 1, Gross Domestic Product was not related to the endogenous variables because it was not easy to establish a unidirectional causality flow. For example, does an increase in retail sales cause an increase in GDP? For this reason GDP was omitted from the final model. Exports, imports, retail sales and new car registrations were anticipated to have the strongest direct effect on domestic air freight tonnes uplifted. Savings banks deposits are taken as an example to show the manner of construction of the hypothesized model. Total exports indicate a general level of activity which is related to retail sales. Total imports more directly influence retail sales. Retail sales in turn have an inverse relationship on savings bank deposits. Exports and retail sales both generate factory overtime which is inversely related to job vacancies. Job vacancies in turn are directly related to savings bank deposits negatively and indirectly related through building approvals in a sequential negative and positive relationship. Savings bank deposits are hypothesized to have a relatively weak negative relationship to new car registrations which in turn are positively related to domestic air freight tonnes.

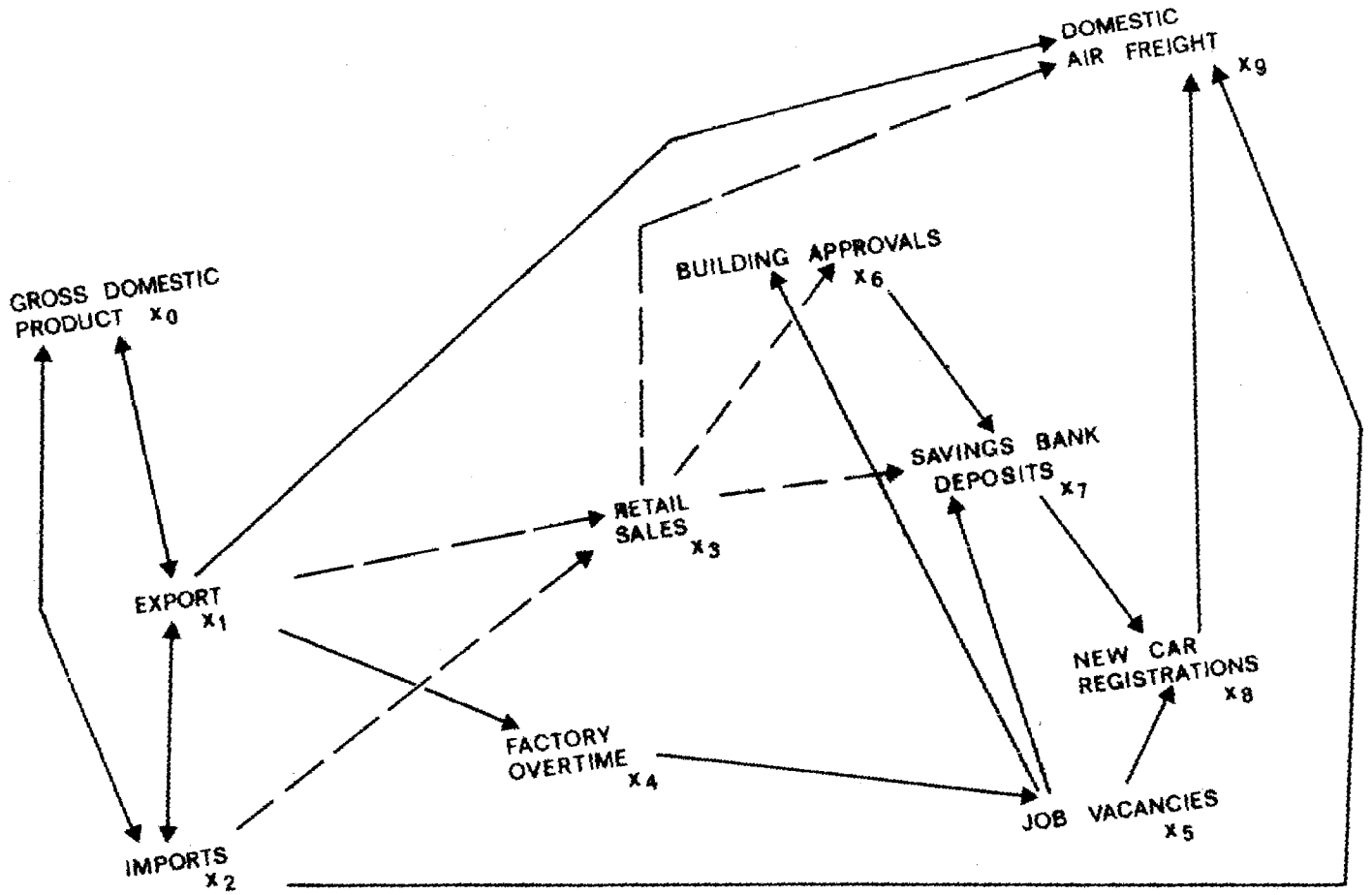


FIGURE 1
HYPOTHESIZED CAUSAL MODEL

The causal model can be expressed in the form of a set of structural equations which depict these relationships. This set of structural equations is:

$$X_3 = p_{32} X_2 + p_{31} X_1 + p_{3a} R_a$$

$$X_4 = p_{43} X_3 + p_{42} X_2 + p_{41} X_1 + p_{4b} R_b$$

$$X_5 = p_{54} X_4 + p_{53} X_3 + p_{52} X_2 + p_{51} X_1 + p_{5c} R_c$$

$$X_6 = p_{65} X_5 + p_{64} X_4 + p_{63} X_3 + p_{62} X_2 + p_{61} X_1 + p_{6d} R_d$$

$$X_7 = p_{76} X_6 + p_{75} X_5 + p_{74} X_4 + p_{73} X_3 + p_{72} X_2 + p_{71} X_1 + p_{7e} R_e$$

$$X_8 = p_{87} X_7 + p_{86} X_6 + p_{85} X_5 + p_{84} X_4 + p_{83} X_3 + p_{82} X_2 + p_{81} X_1 + p_{8f} R_f$$

$$X_9 = p_{98} X_8 + p_{97} X_7 + p_{96} X_6 + p_{95} X_5 + p_{94} X_4 + p_{93} X_3 + p_{92} X_2 + p_{91} X_1 + p_{9g} R_g$$

where the p_{ij} are the path coefficients and the R are residual variables. The residual variable is assumed uncorrelated with the endogenous variable and accounts for the variation in each endogenous variable which is not accounted for by its relationship with other variables in the system. The path coefficient is the fraction of the standard deviation of the endogenous variable for which the particular variable under consideration is directly responsible. Given the assumptions employed in the model developed here, the path coefficients are the standardized partial regression coefficients.

Monthly data for the 15 year period from 1959 to 1973 were used for the nine variables included in the hypothesized system. From this data standardized partial regression coefficients (path coefficients) and residual path coefficients were calculated (see Table 1) and the path model reconstructed including only those path coefficients greater than $\pm$ 0.15. This path model is shown in Figure 2 with the residuals being the square root of one minus the multiple coefficient of determination.

TABLE 1: MULTIPLE CORRELATION COEFFICIENTS AND PARTIAL REGRESSION COEFFICIENTS

Dependent Variable	Independent Variables	Multiple Correlation Coefficient	Standardized Partial Regression Coefficients	Unstandardized Partial Regression Coefficients
Domestic air freight	New car registrations	0.9172	-0.110	-0.023
	Savings Bank deposits		-0.022	-0.016
	Private dwellings approved		0.265	0.146
	Job vacancies registered		-0.200	-0.022
	Factory overtime		0.295	816.545
	Retail sales		0.336	2.580
	Total imports		0.305	5.742
	Total exports		0.057	0.744
New car registrations	Savings bank deposits	0.9305	-0.042	-0.141
	Private dwellings approved		0.222	0.580
	Job vacancies registered		-0.189	-0.098
	Factory overtime		0.450	5927.128
	Retail sales		0.008	0.279
	Total imports		0.380	33.965
	Total exports		0.120	7.440
Savings bank deposits	Private dwellings approved	0.9747	0.073	0.056
	Job vacancies registered		-0.020	-0.003
	Factory overtime		0.039	150.081
	Retail sales		0.238	2.563
	Total imports		0.276	7.265
	Total exports		0.413	7.535
Private dwellings approved	Job vacancies registered	0.9101	-0.218	-0.043
	Factory overtime		0.440	2216.079
	Retail sales		-0.149	-2.079
	Total imports		0.240	8.218
	Total exports		0.597	14.158
Job vacancies registered	Factory overtime	0.7546	0.653	16539.140
	Retail sales		0.135	9.513
	Total imports		0.222	38.154
	Total exports		-0.263	-31.355
Factory overtime	Retail sales	0.7918	0.362	0.001
	Total imports		0.786	0.005
	Total exports		-0.363	-0.002
Retail sales	Total imports	0.9177	0.253	0.621
	Total exports		0.686	1.166

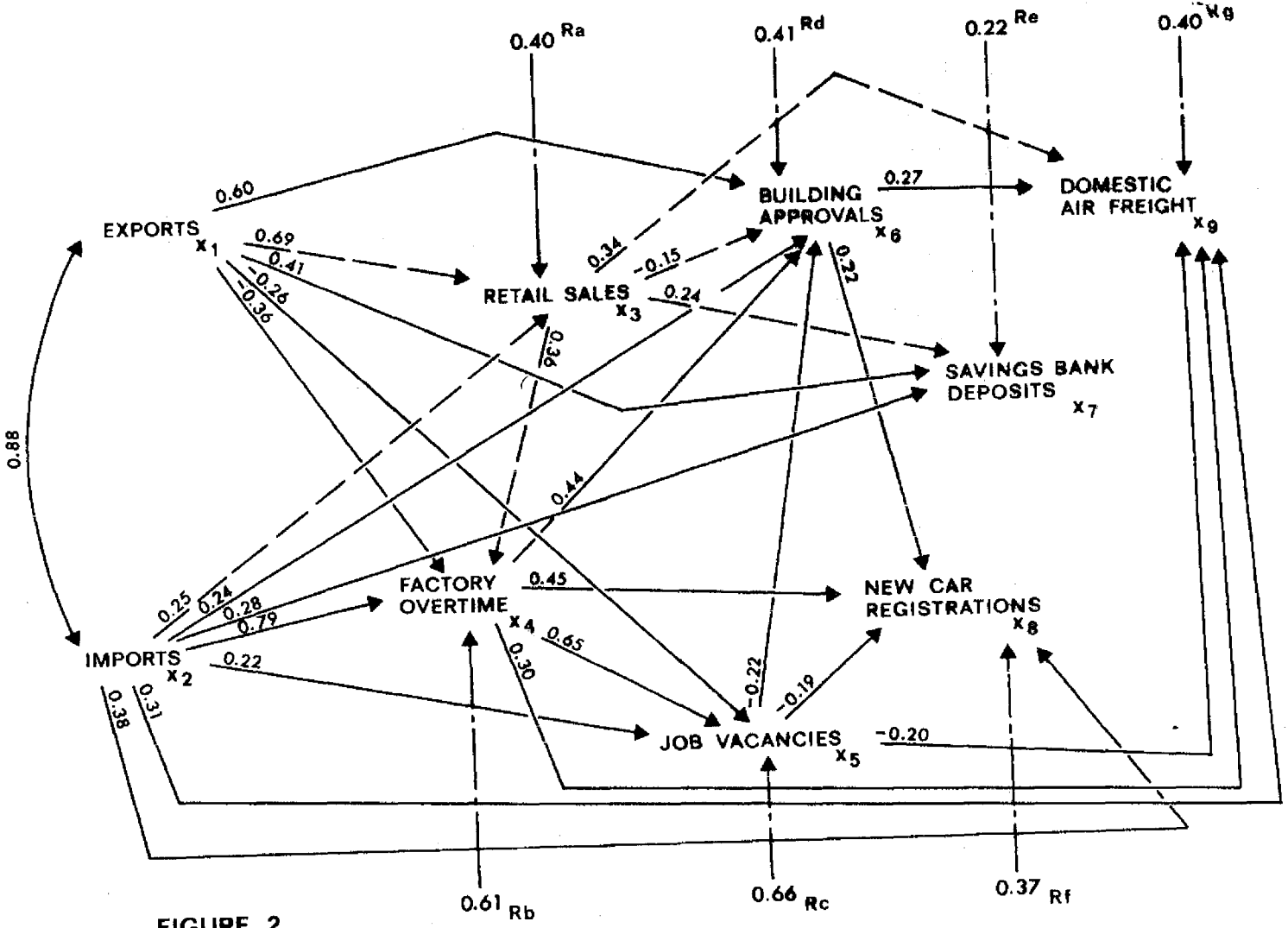


FIGURE 2
PATH MODEL

The basic theorem of path analysis

$$r_{ij} = \sum_k p_{ik} r_{kj}$$

allows the correlation between any two variables in the model to be expressed in terms of the direct path between the two and also in terms of paths between the two leading through other variables.

The total effect of one variable on another is the zero order correlation between the two shown in Table 2. This total effect is split into a direct effect, p_{ij} and an indirect effect, $r_{ij} - p_{ij}$ The total indirect effect is the sum of the indirect effect through other variables in the causal chain and a spurious indirect effect due to the mutual correlation of both variables with other variables in the system. Dynamic programming provides a method to calculate the indirect effect through other variables. The system is decomposed into stages and the calculations required are shown in Table 3 and illustrated for Stage 6 in Figure 3.

The spurious indirect effect of each endogenous variable and the joint indirect effect of each exogenous variable is then established as the residual of the total effect after the removal of the direct effect and the indirect effect through other variables. Direct and indirect effects of each variable on domestic air freight tonnes uplifted are shown in Table 4.

ANALYSIS

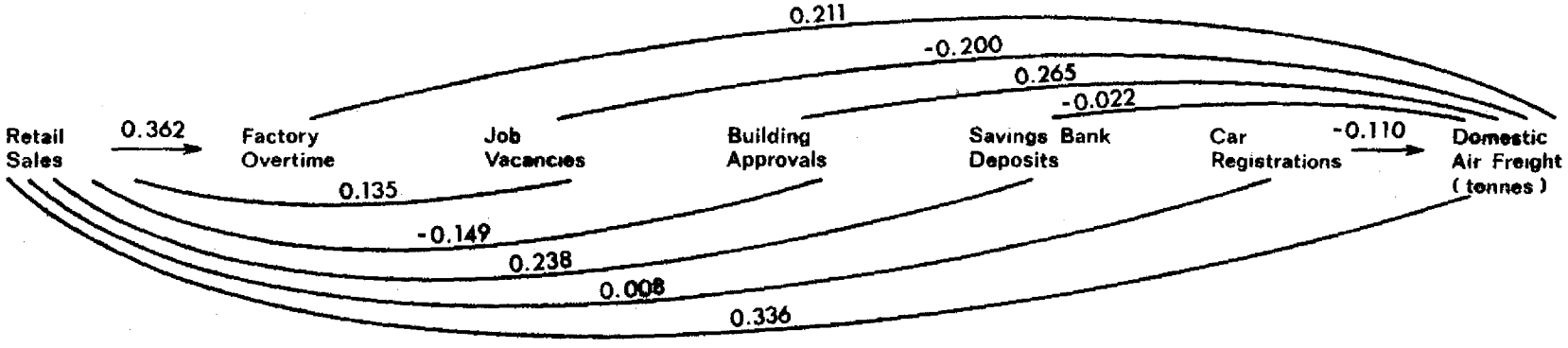
As already indicated, the zero order correlations indicate the total effect that an independent variable has upon a dependent variable. Significance for 180 observations, eight predictor variables and a 95 per cent level of confidence is given by a t value of just under two. Exports, savings bank

deposits and new car registrations have a computed t value less than two even though their zero order correlations are very high, hence their total effect on domestic air freight tonnes is not significant. Private building approvals, retail s les and total imports all have large positive correlations with domestic air freight. Slightly behind these variables is job vacancies registered; the remaining variable, factory overtime, also has a strong positive correlation with domestic tonnes of air freight. These eight predictor variables, taken together, account for 84 per cent of the total variation in domestic air freight tonnes uplifted.

Now each variable is examined in terms of its direct and indirect influence on domestic air freight tonnes.

New car registrations is the variable in the model most proximate to domestic air freight. An increase of one new car registration results in a decrease of 0.02 tonnes of air freight. This is hard to explain although there is no need as new car registrations have already been established as a nonsignificant variable, and the path coefficient itself is also insignificant. This is the case as well for savings bank deposits and total exports - also confirming the above analysis. Continuing with the examination of the path coefficients of Table 2, private dwellings approved, factory overtime, retail sales and total imports all have a relatively large direct effect on domestic air freight. As an illustration, an increase of an average of one hour of overtime worked will result in an increase of 817 tonnes of air freight per month. The remaining variable, job vacancies registered, as expected, has a moderate negative effect on domestic air freight.

Factory overtime and total imports have a strong positive effect on new car registrations. Large amounts of factory



Calculations :

(0.362)(0.211)	=	0.076
(0.135)(-0.200)	=	-0.027
(-0.149)(0.265)	=	-0.039
(0.238)(-0.022)	=	-0.005
(0.008)(-0.110)	=	-0.001
		0.336
		0.340

FIGURE 3
ILLUSTRATION OF DYNAMIC PROGRAMMING PROCEDURE
STAGE 6 , RETAIL SALES

TABLE 2: INTERCORRELATION MATRIX

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9
x_1	1.00	0.88	0.91	0.66	0.49	0.86	0.95	0.82	0.85
x_2		1.00	0.86	0.78	0.61	0.85	0.93	0.88	0.86
x_3			1.00	0.71	0.55	0.79	0.93	0.80	0.85
x_4				1.00	0.75	0.75	0.74	0.82	0.75
x_5					1.00	0.47	0.54	0.52	0.47
x_6						1.00	0.87	0.87	0.85
x_7							1.00	0.85	0.87
x_8								1.00	0.82
x_9									1.00
Mean	275.59	253.76	624.23	2.86	39333.00	9252.82	5550.92	27662.91	6179.91
Standard Deviation	117.11	81.20	199.00	0.55	13986.00	2777.90	2139.30	7267.00	1527.50

x_1 = Total exports ($ million)
x_2 = Total imports ($ million)
x_3 = Retail sales ($ million)
x_4 = Factory overtime (average hours per employee per week)
x_5 = Job vacancies registered (total number)
x_6 = Private dwellings approved (total number)
x_7 = Savings bank deposits ($ million)
x_8 = New car registrations (total number)
x_9 = Domestic air freight (tonnes)

TABLE 3: CALCULATION OF INDIRECT EFFECTS USING DYNAMIC PROGRAMMING

STAGE 1

x_i \ x_j	x_9	$f(x_8)$
x_8	-0.110	-0.110

STAGE 2

x_i \ x_j	x_8	x_9	$f(x_7)$
x_7	0.005	-0.022	-0.017

STAGE 3

x_i \ x_j	x_7	x_8	x_9	$f(x_6)$
x_6	-0.001	-0.025	0.265	0.239

STAGE 4

x_i \ x_j	x_6	x_7	x_8	x_9	$f(x_5)$
x_5	-0.052	0.000	0.021	-0.200	-0.231

STAGE 5

x_i \ x_j	x_5	x_6	x_7	x_8	x_9	$f(x_4)$
x_4	-0.150	0.117	-0.001	-0.050	0.295	0.211

STAGE 6

x_i \ x_j	x_4	x_5	x_6	x_7	x_8	x_9	$f(x_3)$
x_3	0.076	-0.027	-0.039	-0.005	-0.001	0.336	0.340

STAGE 7

x_i \ x_j	x_3	x_4	x_5	x_6	x_7	x_8	x_9	$f(x_i)$
x_1	0.086	0.232	-0.044	0.063	-0.006	-0.042	0.305	0.594
x_2	0.233	-0.107	0.053	0.158	0.009	0.013	0.057	0.390

TABLE 4: CONTRIBUTIONS TO DOMESTIC AIR FREIGHT

Variable	Total Effect	Direct Effect	Indirect Effect Through Other Variables	Joint or Spurious Effect
New car registrations	0.82	-0.11	-	0.93
Savings bank deposits	0.87	-0.02	0.01	0.88
Private dwellings approved	0.85	0.27	-0.03	0.61
Job vacancies registered	0.47	-0.20	-0.03	0.70
Factory overtime	0.75	0.30	-0.08	0.53
Retail sales	0.85	0.34	0.00	0.51
Total imports	0.86	0.31	0.29	0.26
Total exports	0.85	0.06	0.33	0.46

overtime worked reflects a general buoyancy in the economy and a strong import position normally indicates increased car imports. Job vacancies registered again has a moderate negative effect.

Savings bank deposits confirms its unsuitability as a variable for inclusion in this analysis by being insignificantly influenced by all variables except for a moderate positive correlation with retail sales and imports, and a large positive correlation with exports.

Factory overtime and exports have strong positive effects on private dwelling approvals. Job vacancies and retail sales have moderate negative effects, and imports has a moderate positive effect. The negative relationship of retail sales and housing approvals may be caused by a slight cut-back on nondurable consumer goods expenditure when a large drain on family income is expected during housing construction. All the other relationships are variations on the general positive relationship of housing approvals and construction to overall economic health.

Factory overtime has a very strong positive effect on job vacancies registered. Retail sales and imports have a smaller positive effect and exports has a moderate negative effect. If a large number of hours of overtime is being worked, it is only natural for companies to seek additional full-time employees to do this work at a lower overall cost.

A rather surprising relationship is the very large positive effect that total imports has on factory overtime. This relationship suggests that the volume of imports does not increase significantly until hourly workers have income which is in excess of that normally earned. Factory overtime also is relatively strongly effected positively by retail sales, and negatively by total exports. The negative relationship of

exports and factory overtime might reflect an added effort by manufacturers to export products during periods of local downturn.

Total exports have a strong positive effect on retail sales while total imports have a moderate effect, also positive.

The two exogenous variables of the system, total imports and total exports, can be analyzed using the information from Stage 7 of Table 3. Exports has a moderately strong positive influence on domestic air freight directly and through factory overtime. Imports effect air freight positively through retail sales and private dwellings approved and negatively through factory overtime.

SUMMARY

The hypothesized causal model describes a system of interrelated variables which does permit the anticipation of the effect of changes in these variables on the number of tonnes of Australian domestic air freight uplifted.

Some further refinement of the model may be justified. Total exports, savings bank deposits and new car registrations could be replaced by other variables, or their position in the causal sequence altered and the analysis rerun. If the model as presented in this paper is acceptable, or if it is acceptable after some modification, then predictions of future domestic air freight levels can be made from estimations of the future behaviour of these economic indicators. This will lead to a more rational basis for expectations of future development in this segment of Australia's freight transportation network, and materially assist the domestic airlines to make long term decisions related to aircraft and ancillary equipment requirements to meet the projected demand levels.

REFERENCES

Anderson, J.G. (1973). "Social indicators and second-order consequences of health care delivery", AIIE Transactions, Vol. 5, No. 1, March, pp.49-59.

Duncan, O.D. (1966). "Path analysis: Sociological examples", American Journal of Sociology, Vol. 72, pp.1-16.

Fairweather, R.E. (1971). "Air freight gains", Traffic Management, Vol. 10, No. 10, October, pp. 40-42.

Gattorna, J.L. (1974a). "Air freight in Australia", in P. Gilmour (ed.), Physical Distribution Management in Australia, (Melbourne: Cheshire) p. 88.

Gattorna, J.L. (1974b). "The air freight element in Australia's total physical distribution system", Master of Administration Thesis, Monash University, Chapter IV.

Land, K.C. (1969). "Principles of path analysis", in E.F. Borgatta (ed.), Sociological Methodology (San Francisco: Jossey-Bass). pp. 3-37.

Regan, D. (1973). "The future of air cargo", address delivered to the Air Cargo Club of Australia, Essendon, 25 January.

Watkins, J.L. (1968). "The role of air transport in the next decade", Australian Transport, April-June, pp.5-12.

Wright, S. (1934). "The method of path coefficients", Annals of Mathematical Statistics, Vol. 5, pp.161-215.

R75/1441