A THEORY

OF

THE IMPACT OF

TRANSPORTATION INFRASTRUCTURE

ON INVENTORY, PRICE AND CONSUMPTION

WITH AN EMPIRICAL STUDY OF

CANADA AND AUSTRALIA

by

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ABSTRACT

Investment in transportation infrastructure is an externality to the firm, yet the impact of that investment affects both the customer and the factors of the firm. The literature on investment in transportation infrastructure is extensive. There is an emerging literature on the effects of inventories on prices and outputs of the firm. Yet nowhere in either literature is found an analysis of the impact of transportation infrastructure investment upon the firm's inventories. This dissertation examines the variables affecting the inventory of the firm and analyses the impact of investment in transportation infrastructure on that inventory and resulting consumption.

A simple, dynamic inventory model under uncertainty was developed as part of a cost function for the firm. The lead time component of the inventory model was postulated to be a function of the capital invested in transportation infrastructure. The capital investment was segregated into two parts, capital in place and current capital investments in transportation infrastructure. The resulting cost function of the firm was then related to the firm's market under the assumption that the firm

minimizes costs as a price-taker in a competitive environment.

The comparative static analysis demonstrated that increased capital in transportation infrastructure will provide a positive return to consumption, as evidenced by increased sales to the firm. The analysis showed that during the periods of investment the firm's costs -hence prices and consumption - will oscillate, finally resulting in lower costs to the firm. It was assumed that the derived cost equation represented the aggregate firm in a city and it was hypothesized that any investment in a transportation infrastructure in the region would impact on the firm and be evident as a change in consumption in the city.

The cost equation of the firm was then linearized. Two independent data sets were used to test the hypothesis. Canadian data, 1960 to 1979, and Australian data, 1972 to 1981, were obtained by transport mode on a regional basis. The linear equation using these data and income and consumption data for major cities in each region was then estimated for each city using multiple regression. All cities in each data set were regressed together using a Zellner seemingly unrelated regression procedure.

Statistically significant results were obtained from the regressions on each data set which show that investment in a regional transportation infrastructure produces oscillations in consumption (i.e., a business cycle) and permanent changes in levels of consumption.

The results demonstrated that capital in transportation infrastructure has provided negative returns, lower consumption, to some Canadian and Australian cities and that a condition exists where firms may enhance profit through a quantity adjustment rule.

Dedication:

To Margaret G. Reid and Mildred M. Reid,

whose scholarship, integrity and patience provide

the criteria in the pursuit of excellence.

Quotation:

"Good roads, canals, and navigable rivers.... They are... the greatest of all improvements."

Adam Smith, 'Wealth of Nations'.

"One small step for man, one giant leap for mankind."

Neil Armstrong, On the occasion of the first lunar landing.

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1.0 INTRODUCTION

In the analysis of economic activities, transportation has frequently been recognised as the "tie that binds": between production and market in micro-economics; between areas or regions in geography and regional economics; between home and work in urban planning. The tie--transportation--has usually been a secondary consideration in most areas of study. When research has been done the focus on transportation has been mainly on the efficiency or cost-reducing effect it has on the major components of the particular study area. Therefore, any search of the literature on transportation and its effects is found fragmented throughout many disciplines, assuming many guises: an investment, a cost, a search, a distance, a time. Transportation, and its effects, is so pervasive throughout so many study areas that its role in economic analysis must be fundamental. The objective of this dissertation is to examine the impact of investment in transportation infrastructure on economic activity in general.

The real world is not a singular point in space, without transportation, as is so often assumed in economic analysis. Resources are dispersed over a two-dimensional world. Populations usually congregate about these resources in a un-uniform fashion. For any economic interaction to occur distance must be overcome, therefore transportation must exist. Transportation is usually viewed simply as the movement of goods through space. But just as money is valued differently when it is then versus now, so goods have a different value as they are there or here. Thus transportation, the conversion of economic units through space, would appear to be an essential ingredient to the understanding and analysis of economic relationships. This dissertation will examine this question.

Economic analysis has approached this question in diverse ways. International trade does not discuss the question. Neoclassical microeconomics groups each mode into a market, yet ignores the infrastructure and labels transport as a cost of production or a cost of acquisition. Regional economics has attempted to deal with transportation by focussing on the distance-cost aspect of the problem. Macroeconomics views transportation infrastructure investment as just another investment.

Transportation has been treated in this manner because its analysis has appeared to be very complex. The conversion of economic units through distance will require the expenditure of time. So the examination of transportation will require the application of dynamic relationships, or a very well-defined comparative statics analysis, when attempting to explain the interaction amongst variables. By themselves the inclusion of time and distance increase the complexity of any analysis. But these two variables, time and distance, are not the only factors that have acted against the examination of transportation as a primary factor in each discipline. Any transportation mode (rail, air, sea, road), save shank's pony, requires the existence of an infrastructure before individual transport units can become operational. These infrastructures (railbeds and marshalling yards, airports and guidance systems, locks and ports, roads and parking lots) are frequently very large. This presents complications to an economic analysis. The infrastructure is external to the firm and to the customer. The required capital to construct the infrastructure is, sometimes, of a macroeconomic magnitude. The investment decision to build or to improve an infrastructure is, many times, an issue of political economics. To correlate all these effects in any one problem formulation, or even any one discipline, appears to be a complex task.

This dissertation will address this task and will show there is an important link between investment in transportation infrastructure and economic activity through a direct sequence of cause and effect. Moreover, the theory expounded in this dissertation is that transportation and investment in transportation infrastructure are integral components of the economic system: or, in mathematical terms, necessary conditions for the understanding of a general equilibrium economic system. At the macroeconomic level, nations or regions <u>cannot</u> trade without a transportation infrastructure. The assertion here is that the reciprocal benefits received by trading nations or regions are possible only through the effects of investment in transportation infrastructure, and to have an understanding of the reciprocal trade benefits ascribed by trade and regional theories requires a more complete understanding of the effects of investment in transportation infrastructure. At the microeconomic level, individuals and firms, set amongst a dispersion of resources and markets, <u>cannot</u> exist without a transportation infrastructure. It is asserted that the utilities and profits realized by individuals and firms are possible only through the existence of a transportation infrastructure, and to have an understanding of the interactions amongst individuals and firms as described by current microeconomic theories requires an understanding of the impacts of investment in transportation infrastructure on those individuals and firms.

Since the trade of a nation or a region is the aggregation of the outputs and the inputs of the firms in those nations or regions, it is at the level of the firm, with the theory of the firm, that this analysis was begun.

For the firm to provide output to a customer, or to manage input to the production process, the firm must have the relevant commodity or factor instantly on hand for the process to proceed. This is possible to do in either of two ways: to be in receipt of the unit immediately when it is required, or to have the unit in an inventory, i.e. immediate or past transportation of commodity. A re-adjustment of transportation will necessitate a re-evaluation of this choice.

In a world of certainty the analysis of this process is a relatively easy task. If it is assumed that output is provided in the specific quantities desired by known customers arriving at determined intervals, and factors are inventoried at such levels that minimize the costs of storage, search and procurement, then transportation as it affects the arrival of the customer or the factor is a known parameter and inconsequential, except as a known cost or a known time. In particular, a change in transportation cost or transportation time may be precalculated without any undue effects upon the firm.

This assumption of a certain world is not realistic. Uncertainty exists. While the nominal costs of transportation may remain known, the real costs are now imprecise. The uncertainty of travel time for both the arriving customer and the arriving factor may now be known only in terms of averages and variances of probability distributions. If these travel time probability distributions are disturbed, then even these averages and variances of travel time and travel cost can no longer be used precisely by the firm. Indeed, this is exactly what an investment in transportation infrastructure will do. However, the improvement that the infrastructure provides may not be immediately apparent. The reduced average or variance of the travel time must be learned by all the affected economic participants in the system: the firms, the transport carriers and the customers, so that they may readjust their behaviours. If there is an improvement in a region affected by an investment in a transportation infrastructure, then the costs of the affected system should be reduced. This would suggest a change in market prices or a change in the number of market participants.

An improvement in, or facilitated by, a fixed location transportation infrastructure will have distributional effects as well. The improvement may be a benefit for some market participants, but it may prove to be fatal for others. One has only to consider the plight of the gasoline dealer located on the old highway to see one result of an investment in transportation infrastructure. Many firms in a region will view a new highway as access to a new market in an adjacent region, but that highway has the innate peculiarity of going both ways and inviting new competitors.

It can be seen that investment in transportation infrastructure will have diverse effects on firms. It is assumed that the net effect of the investment in transportation infrastructure will be to reduce the average and variance of travel time and travel cost which should reduce costs to the firm, directly and through inventories, and should yield an increase in demand and output through lower prices and increased competition. It is assumed, as well, that firms will face a period of readjustment, perhaps protracted, as all elements of the market system adapt to the change in the transportation infrastructure.

This sequence of cause and effect, between investment in transportation infrastructure and economic activity, will be examined by an empirical test on a model of the firm. The model will be developed by including inventory as a major component in the cost equation of the firm showing a direct relationship between that inventory and transportation infrastructures. This cost equation will be related to consumption and income through a traditional market mechanism. This model will then represent the aggregate firm of a city and a series of empirical tests will be done for a large number of Canadian cities to establish the significance of the relationship between investment in transportation infrastructure and economic activity at a macroeconomic level.

Chapter II will review the literature in both the area of transportation infrastructure investment and the behaviour of inventories. Chapter III will develop a model of the firm that combines the cost components of the firm with investment in transportation infrastructure through inventory under uncertainty. The firm will then be related to a market under the assumption that the firm is a price taker in a competitive environment. Chapter IV will examine the stability and dynamics of the model. Chapter V will develop the empirical model, describe the characteristics of the data and outline the regression procedures. Chapter VI will summarize and analyze the regression results and Chapter VII will discuss the proposition that investment in transportation infrastructure is a critical component of the theory of the firm and an important link in the micro-foundations of macroeconomics.

2.0 LITERATURE SURVEY

The literature has been reviewed with the intent of isolating the various approaches taken by researchers in their examination of transportation investment benefits and the effects of inventories. The span of this literature ranges widely; from transport engineering to welfare economics; from project analysis to political science. It encompasses measurement techniques which range from a zero-effect assumption in trade theory to integrated optimization techniques in multi-regional, multi-industry computer models.

The literature search was conducted with a dual objective; to find studies on investment in transportation infrastructure that examined the effects of that investment on the firm, the firm's inventories and the firm's environment and to find studies that examined inventories and the effects those inventories had on the firm and its environment when the variables affecting inventory were altered. Very few of the articles surveyed examined the factors of investment in transportation infrastructure, inventories and economic activity in any juxtaposition. With the exception of a faint glimmering in the Baumol and Vinod [8] study and a brief hope in a working paper by Tulken and Kiabantu [69] the literature search did not uncover any study that examined the links from investment in transportation infrastructure to the inventory of the firm and then to the firm's environment, at any level of aggregation. The ensuing description of those articles bearing on the interrelationships within this sequence in economic activity will reveal the gaps that exist in the current literature.

These gaps in the literature provided the impetus for this dissertation. The objective of this dissertation is to extend the current research in inventories, evident in the recent literature, by examining the interconnected relationship between investment in transportation infrastructure and the inventories of the firm and to pursue the effect of that relationship out into the economic activity that surrounds the firm.

2.1 The Transportation Literature

The breadth of search is necessitated by the fundamental way in which the simple link of distance and time affects the structure of society. A most lucid exposition of this simple link, time and distance, was given by Voight [70, p7] at an address to the 1979 Annual International Transport convention:

> Human activities are distributed in space, ... transportation, the bridging of space, is necessary. This, in turn, demands an expenditure of time, so that the two categories of space bridging and time expenditure are, within limits, substituteable. A national regional policy always seeks the most productive assignment of important economic activities to particular places and locations. Without transportation as a limiting factor, however, no economic development of a given space is conceivable ... Depending on the way they are brought about and on external conditions, changes in the transport system, autonomous or induced, will have different and differentiating effects on the opportunities for building and exploiting the economic development opportunities of a given area. Thus, in addition to examining changes in the transport system, one must also analyse the external situation.

This essential bridging of space--transportation--has been recognised as an important, but sometimes incidental, variable in many fields of economics.

The view that Voight presents is a restatement, or re-affirmation, of Adam Smith [63, p251]:

> Good roads, canals, and navigable rivers, by diminishing the expense of carriage, put the remote parts of the country more nearly upon a level with those in the neighbourhood of the town. They are upon that account the greatest of all improvements. They encourage the cultivation of the remote .... They are advantageous to the town, by breaking down the monopoly of the country in the neighbourhood. They are advantageous even to that part of the country. Though they introduce some rival commodities into the

> old market, they open many new markets to its produce.

But Voight's restatement is explicit, not only in the statement that transportation is essential for the development of a market, but also in the recognition that transportation will have external effects and that transportation is a dynamic process. A list of the scope of transportation effects is given by Klaassen [40]:

1. size, growth, composition of population;
2. education system;
3. labour market;
4. economic activity;
5. demand and supply for energy;
6. transportation infrastructure and traffic and transport system;
7. social infrastructure;
8. living conditions and ecological system;
9. land use possibilities.

The range of issues and problems raised in an evaluation of an investment in transportation infrastructure has been clearly described by Wilson [74]. He outlines two divergent cases resulting from an increase in transport capacity, a positive case where the increased transport capacity enhances economic efficiency enabling the expansion of output and a negative case where the increased transport capacity in an underdeveloped economy causes the backwash effects to overcome the spread effects. Wilson describes the quagmire that exists in the application of user charges and regulation and the need to specify carefully the affected regions on a disaggregated basis. Wilson's description maintains the view that an investment in transportation infrastructure has a pervasive effect on a region's development but that such an investment should be evaluated strictly in terms of relative net benefits.

These insights into the importance of the transportation variable have been examined at a variety of levels of aggregation.

2.1.1 Location and Regional Analysis

The initial addition of transportation into economics was as a price weight-distance variable by Von Thunen and Weber as described in Paelinck and Nijkamp [52].

Von Thunen's model demonstrated that the unit rents of land from agricultural products diminished inversely to the transport costs of bringing those products to market in a city. This resulted, under a maximization of rents hypothesis, in concentric cultivation of the various products around the city.

Weber's model examined the location decision of a one product firm, given the location of all other firms. His model selects a location for this firm by minimizing the transportation costs of the output and inputs. Subsequent introduction of wage costs permits the minimization of both costs through comparison of each cost change resulting from a location change.

Harris and Hopkins [33, p15], in a location analysis study, indicated the dynamic nature of the problem by stating:

> The optimal profit maximization location site will only rarely coincide with the transportation minimum cost site. Indeed, today's optimal site depends on yesterday's actual location and tomorrow's demand and prices.

The continued development of the Weberian model, with its transportation cost emphasis, has, in Heffley [35], uncovered the illusive Giffen good. This result comes from the analysis of a full-price transportation cost relationship combined with an exponential decay population density assumption for urban centres.

The analysis of this Weberian location problem is mathematically complex. The location problem has been generalised and only recently, using modern day mathematics, has a more general comparative statics solution been developed (see Heaps [34]).

The analysis of larger locations of economic activity, regions, has resulted in a proliferation of regional theories. Most of these implicitly assume transportation as a constraint. A few, such as the Staple Theory (See Watkins [73]), view transportation as a specific causal agent in the economic process. The analytic modelling of this process, explicitly incorporating transportation costs, has been relatively limited and can become complex. An example of regional analysis is a study by Paelinck and Wagenaar [53]. They examined the impact of large transportation projects, airports, on the supply side of regions and developed a regional input-output impact matrix which was estimated for the Dutch Provinces. They constructed a quantity multiplier based on transportation infrastructure investment and related this multiplier to backward and forward linkages in regional economies.

In an attempt to relate areal employment rates to transport costs, Dodgson [23] formulated a gravity model which he utilized to compare a northern area of England with other areas. Neither this test nor his assessment of the effect of the M-62 motorway revealed much effect of transportation costs.

Methods other than theoretical construction have been developed to examine regions by the computer modellers. Here hundreds, or thousands, of simple linear equations are stirred together at great speed with vast quantities of data. Numerous descriptions of the models are reported: Bolton [14], Ballard and Wendling [7], Harris [30,31,32], Treyz [68], to list a few. Some of the modellers, such as Harris, explicitly specify transport costs as a variable. But the main emphasis appears to be on the refinement of the model's forecasting ability with little reporting, or explanation, of the economic relationships in the systems which these models purport to represent.

In an urban context Klaassen and Wagenaar [40] developed a model to examine the allocation of funds for public transport. Using a consumer surplus approach they modelled the net benefits in service levels to cities in the provision of public transit. They developed a demand equation and a linear cost equation based on the concept of level of service. Their model assumed a given infrastructure. The model related the contribution to the net social welfare of each city under both a subsidy and a zero-deficit budget allocation assumption.

Politics is an important factor in many regions. Munro [50] examined the allocation of British Columbia highway expenditures and concluded that they were allocated among electoral districts according to a mixture of economic and political considerations.

Governments apply theory to policy as is evidenced by this statement, in 1980, of Canadian Government Transport Policy [28, pB1]:

> That the fundamental principle of federal transportation policy be to encourage and support economic development through the provision of effective and sensible transportation services across Canada and that when the objectives of commercial viability and regional development conflict, regional development will take precedence.

This policy follows Heymann's [36] statements on the objectives of transportation policy. He calls for diverse objectives in the establishment of policy: economic objectives being the exploitation of natural resources, the increase of industrial output, and the enhancement of per capita consumption; noneconomic objectives being the promotion of social cohesion, the strengthening of a country's defences, and the establishment of desirable locational patterns.

However, he notes:

> How much transportation cannot be answered on the basis of any objective principle. [36, p19]..

and,

> The decision of total resource allocation must emerge as a result of evaluating individually, and in combination, the various transportation uses to which resources can be put in the quest for economic growth. [36, p29]

In response to a statement such as Heymann's, "evaluating (uses) individually", project analysis has altered the examination of transportation from the analysis of transportation costs to the analysis of investment in transportation.

2.1.2 Project Analysis

Two approaches have evolved which attempt to measure the impact of investment in transportation projects on economic units. These are the cost-benefit approach and the consumer surplus approach. Large numbers of studies have been done utilizing each approach.

The cost-benefit approach, a bottom-up approach, entails the complete listing of all the measureable costs and benefits associated with the project. Some recent studies which illustrate the approach are reported.

Shneerson [62] used dynamic programming to evaluate the effects of investment in public ports in Nigeria. Initially, he related the queuing costs at these ports to projected demand. He examined the expected revenue against the expected costs to evaluate the investment in capacity expansion. The objective function was then expanded to include the queuing cost of the ships, the investment cost and inland transport costs. He then evaluated the expansion of the Nigerian public port system.

A review of the state of the United States highway system by Rao and Larson [55] suggested a relationship between the decline in highway investment, including maintenance, and the decline in service levels as measured by congestion, safety and riding comfort. They then provided some suggestions for pricing options.

The alternate approach to project evaluation is that of the consumer surplus approach, a top-down approach. A measure of consumer surplus, hence consumer benefit, is calculated in order to maintain some congruency with economic welfare theory. An example of this approach is the work done by Jara-Diaz and Friesz [37]. They reviewed the problems associated with the application of this approach to the measurement of benefit derived from reduced transport costs resulting from an improvement in a transport mode. They showed that the demand and supply structure associated with each of two spatially separated markets of a common commodity generated a stable aggregate transportation demand curve. The total flow between the markets was obtained from the intersection of the aggregate transportation demand and supply curves. A modal investment or improvement resulting in the reduction in transport costs shown by reference to the aggregate demand, was shown to cause the demand function for the improved mode to shift outward, while the demand curve for the competing mode shifts inward. They examined the traditional method of benefit measurement, line integrals, and showed that consumer surplus may be evaluated utilizing well-defined ordinary integrals.

A restricted view of the benefit from investment in transportation infrastructure was examined by Borins. His first paper [16] developed an airport simulation model which examined the effect of various pricing policies: user fees, constant or diminishing over the life of the project. The model examined the nature and extent of deviation of price from marginal cost pricing under a variety of elasticity and magnitude of demand assumptions and various sizes of increments to capacity. Borin's later empirical work [15] on the Toronto airport used marginal cost pricing in a systems model of peakload congestion where the concept of a transport facility was expanded to include terminals, runways and access roads. The exogenous variables were the growth of demand and the level of aircraft noise abatement technology.

Proponents of each approach provide critiques of the others approach. Advocates of consumer surplus, Lesourne [42], Mohring and Williamson [49], and others, refer to Klaassen's view of the overall impact of large scale projects and, therefore, use the market equilibrium concept of consumer surplus to capture all the effects. They criticize the bottom-up approach: effects on the environment and ecology go unmeasured, nonuser benefits are not taken into account, and therefore, costs and benefits are understated.

Critiques of the consumer surplus approach are available: also Adler [1], Allen [2], Dodgson [22], Stanley and Nash [65], and Stopher and Mayburg [66]. They point out that there exist many special problems with the market assumption. Some markets are oligopolistic; those in transportation are, in the main, regulated. The Hicks-Kaldor criterion assumes prices elsewhere do not change, but this is a strong assumption for a project that may have far-reaching effects. This can be seen when analyzing transportation costs, which change as a result of the project, as a factor input into intermediate goods. The price change will induce factor substitution and the number of markets to be considered, in the consumer surplus approach, multiplies.

Reciprocal criticism revolves around the measurement concepts. Some benefits accrue to large projects that are not currently measureable, e.g. cultural benefits, comfort benefits. To measure all markets and to capture all effects may be an over-extension of the effects of the project. For example, in the development of a road to a mining project which benefits are counted? Expanded mine activity? Expanded town activity? Expanded supplier activity? Expanded national activity? Or, if the reduction in accident rates is measured by a discounted cash flow of the victim's wage, then the retired and unemployed populations have a zero value.

What is lacking in either approach is a well-defined economic relationship among the affected variables. Scott [61, p145] comments:

> The benefit-cost approach is usually in a frame-work of fairly static assumptions about economic growth. However, huge projects (like the St. Lawrence Seaway or the provision of transport for the opening of the north) are not merely inputs but also have a catalytic effect in opening up whole regions. ... - a cost-benefit study might still be made. But it is obvious that a routine study is impossible ..... Beyond a certain point, the routine economic analysis of costs and benefits may be jejune and unduly cautious. But up to that point, it is certain that better development gambles could be based upon clear knowledge of costs and their possible benefits rather than upon the sort of instinctive persistence that for years has saddled Canada with wasted resources in the form of premature or unprofitable canals, railways, roads and ports.

2.1.3 Equilibrium Models

A limited number of models have examined transportation costs or transportation investment in a general equilibrium setting.

A general equilibrium model which incorporated transport costs was developed by Bos and Koyck [17]. They examined the interactions of three locations. Location A is an inland agricultural area which transports product A, along a poor road, to location B, a port. Industry 2, located at B, transforms product A into consumer goods; consumed at B, transported to A for consumption and exported to location C, offshore, when in excess supply. Industry 3, located at B, imports raw materials from C and transforms these to consumer goods which are consumed at B and transported to A for consumption. Economic relationships, demand and supply curves, were postulated which included prices, elasticities, incomes and transport costs for the three locations. The model was perturbated by a reduction in transport costs between location A and B. Under alternate assumptions, constant profit or price, the model exhibited substantial increases in real income and consumption, with some instances of inflation, at all locations.

A theoretical model of equilibrium, incorporating both transport cost and investment in transportation infrastructure, is being developed by Tulken and Kiabantu [69]. They are developing a spatial Arrow-Debreu model with regions and with four types of agents; consumers, private commodity firms, transport carriers and a transportation infrastructure construction agent. While this model is not complete, their analysis shows the conditions required for the existence of an efficient Pareto-optimal solution.

2.1.4 Transport Costs and the Firm

At the level of the firm, analyses of transportation costs are sparse. A model to explain the choice of transport mode by shippers was developed by Baumol and Vinod [8]. They showed that the optimal choice of mode involves a trade-off among freight rates, speed, dependability (variance in speed) and en route loss. The model utilized a cost function for the shipper which included direct shipping cost, total in-transit carrying cost, order cost and receiver's carrying cost. This cost function was optimized by the selection of an order quantity that minimized cost. This order quantity was introduced into the cost function to produce a minimum cost condition. This minimum cost condition was set equal to a constant and the condition rewritten in terms of the variables, shipping cost/unit, average time to complete a shipment and carrying cost in transit/unit. The shipping cost/unit variable was incorporated into the constant to yield cost indifference curves for two parameters, economy and speed. Baumol and Vinod showed that inventory theory makes possible a direct comparison of the four attributes on which a mode selection is based. This model was then restructured by adding a safety stock, equal to a number of standard deviations of a Poisson distribution calculated on the basis of a fixed interval reorder inventory system, to the original cost function. A profit function was proposed where the revenue function was equal to the price difference between the origin and the destination multiplied by the volume shipped. Profit was maximized with respect to the total quantity shipped. The resulting equation was a nonlinear equation in demand quantity and the square root of demand quantity. The analysis was not pursued beyond simplifying the equation using an ad hoc estimation and concluding that inventory policy is an integral component in the procedure of profit maximization.

Rimmer [58] commented on the Baumol and Vinod approach by reference to the integral part inventory plays in the systems of the firm and the other objectives of the firm. The complexity of this approach, referring to their restructured model, is further compounded by its dynamic nature which exhibits multiple lags.

The key role that inventories play in the costs of the firm was highlighted in this section. All firms carry inventories and the costs of inventories and the results of decisions in inventory policy should then be reflected at the macroeconomic level.

2.2 The Inventory Literature

The analysis of those effects of inventories on economic variables has not been a heavily researched area. Arrow [4, p1] comments on the role of inventories in economics:

> It must be stated immediately that economic theory has had remarkably little to say about inventories. This neglect is partly due to the emphasis on equilibrium situations, in which the holding of inventories in anticipation of price changes is ruled out by hypothesis. But even under static conditions it is usually agreed that inventories will be held in most circumstances in spite of storage costs and the tying-up of capital that could be invested elsewhere. There must therefore be utilities derived form the holding of inventories which outweigh the cost. Nevertheless, the usual treatise or textbook has only the most scattered references to the motives for the holding of inventories.

In addition to references on transportation, Adam Smith [63, p372] discussed inventories and the motives for inventories, e.g.:

> ... As the division of labour increases, therefore, in order to give constant employment to an equal number of workmen, an equal stock of provisions, and a greater stock of materials and tools than what would have been necessary in a ruder state of things, must be accumulated beforehand.

What we see here is the acknowledgement that stocks, inventories, of all factors are essential for the firm.

2.2.1 Macroeconomic Studies

Metzler's classic article [47] was the first major examination of the role of inventories in the economy. Following the introduction of the Keynesian behavioural postulates, Metzler developed a basic macroeconomic model with two assumptions:

1. Consumer demand responded immediately (in the same period) to a change in income;
2. A lag of one period occurred in the output of consumer goods behind a change in revenue from sales.

His model assumed that adequate inventories existed such that the discrepancy between output and demand was met by inventory flows rather than price changes. A number of alternate assumptions, hence model variations, were examined. Inventories were first allowed to vary and then brought to a constant level by additional production. A second variation was introduced into the production decision by assuming that a sales trend exhibited in the current period would continue, i.e. an expectations model. All models were perturbated by a non-induced, non-recurring investment in the macroeconomic equations.

Metzler's basic model, the inventory replenishment model, exhibited what he called a 'pure inventory cycle'. This cycle is of a two-period duration, oscillating and returning to equilibrium. The expanded model, the sales expectation model, exhibited a similar cycle with greater amplitudes and extended duration.

Bridge [13] reports a number of significant empirical studies of inventories. Lovell used quarterly U.S. data to investigate inventory functions based on a buffer stock motive. Raw material and goods in progress inventories at the beginning of the period, S_t, were assumed to have an equilibrium level determined by current output, Q_t, expected price changes, the change in output, dQ_t, and unfilled orders, U_t. Lovell used actual proportionate price changes as a proxy for expected price changes. His regression results for a number of industries have the expected signs. Ball and Drake (see Bridge [13]) did a similar evaluation utilizing U.K. national accounts to explain the changes in physical stocks and work in progress. A variety of models with differing expectations assumptions were regressed on the data. For one set of models a quadratic expression resulted which has imaginary roots, implying cyclical behaviour.

Blinder and Fischer [12] studied the mechanism of the gradual adjustment of inventory stocks that could be used to make neoclassical models produce business cycles. They used the inventory adjustment policies of the firm to demonstrate that economic shocks, which perturb inventories, cause a persistent real effect (even when the market clears instantaneously) since firms respond to these perturbations through gradual output adjustments. They reached two principal conclusions. Disturbances such as unanticipated changes in money will set in motion serially correlated deviations of output from trend. As well, if desired inventories are sensitive to the real interest rate, then even fully anticipated changes in money can effect real variables. Excess inventories are worked off slowly over time, in part by reducing levels of output, and inventory adjustment leads to business cycles.

The dynamic consequences of several different behavioural rules involving price or quantity adjustments in a temporary equilibrium, macroeconomic framework were examined by Day and Fan [21]. They developed a model which incorporated a cost mark-up pricing rule and contrasted its dynamics with a quantity adjustment rule. These rules were examined in imperfectly competitive (administered) and purely competitive environments. Both cases yielded temporary equilibrium except at stationary points of the dynamic process. In the case of the imperfectly competitive environment, a full employment equilibrium was unstable and a permanent Keynesian unemployment equilibrium was stable. In the case of the perfectly competitive environment, a permanent Keynesian equilibrium was unstable. These rules were then contrasted with adaptive, monopolistically competitive price or quantity adjustment rules. Both rules were stable around a Keynesian permanent equilibrium in the monopolistically competitive environment. For the price adjustment rule, the equilibrium was approached asymptotically while for the quantity rule it was approached cyclically.

This model was extended by Fan [27] who introduced inventories explicitly into the framework. Two different inventory adjustment processes were coupled with two behavioural rules of price-output determination. The inventory processes examined were, first, the coordination of sales, production and inventory by the producers so that inventory could be adjusted to the desired level through intra-firm transfers and, second, the traditional approach of inventory as part of investment demand. The two behavioural rules were full cost pricing and perceived profit maximization. Both models with inventory treated as investment demand were found to be inherently unstable, whereas the coordinated inventory model under both behavioural rules exhibited damped cycles.

2.2.2 Microeconomic Studies

Following the development of inventory theory in the late 1950's a number of models of the firm were developed and empirical studies carried out at the level of the firm and the product market. These examined a variety of aspects and effects of inventories.

Mills [48] developed a model of a one-product, profit-maximizing firm producing goods to stock, and examined the effect of maintaining a finished goods inventory. A buffer stock model assuming stochastic demand and quadratic costs was developed and one-period changes in the behaviour of the model were analyzed. Belsley [9] and Childs [18] expanded the analysis of inventories. Each developed cost minimizing firms with quadratic cost functions that could produce to order or produce to stock. Belsley viewed the firm as being unable to have unfilled orders when inventory existed, whereas Childs viewed the hetereogeneous product firm as holding both a backlog of orders and finished goods as order cancellations exist and the firm may hold goods until an optimal shipping quantity is reached. Both models were solved on a one-period lag basis utilizing dynamic programming. Both models were estimated in a variety of product markets. A similar model was developed by Courchene [20] but without an explicit decision process. The variety of inventories was expanded to include goods in process and raw materials inventories and the concept of a multi-period lag was introduced, but these complexities were not analyzed.

An empirical examination of Belsey's model was made by Duffy and Lewis [24]. The general solution to the model suggested that variables in the inventory component can assume oscillating behaviour from three sources: complex roots associated with the solution; cyclical or periodic demand; and cyclic behaviour in the stochastic sense. Empirical results showed that cyclical behaviour existed and that the process was stable.

A model of the representative firm in a deterministic environment producing solely to stock, a finished goods inventory, and explicitly setting prices was developed by Maccini [44]. He assumed the firm's demand was a proportion of expected new market orders and that the firm's costs included inventory costs. Two stable equilibria resulted for prices and output, the output equilibrium being approached cyclically.

A model where inventories and stockouts were substitutes for a central market was developed by Gould [29] to examine equilibrium models of the profit maximizing firm facing stochastic demand. The model assumed perishable inventory in a one-period analysis.

Firms chose inventory in each period to maximize expected profit. With an increasing cost function and discriminating consumers choosing firms with equal probability, a multiple price equilibrium was demonstrated.

The contrasting roles of price adjustment and quantity adjustment were modelled by Reagan and Weitzman [57] by examination of the role of inventory carry-overs. The model utilized general functional demand and cost relationships with a one-period lag between the production decision and availability for sale. The model exhibited asymmetrical cyclic fluctuations: when demand was low, output contracted while price held at a fixed level; when demand was high, price increased as output was constrained. This model was expanded by Reagan [56] to examine a monopolist facing stochastic demand. More explicit relationships were specified, including a discount factor and constant marginal costs. The optimal policy of the dynamic programming model provided results similar to the preceding model.

Amihud and Mendelson [3] developed a model of the representative firm which led in the aggregate to a macroeconomic expectations-adjusted supply model. The expected-profit-maximizing firm was assumed to face demand and output uncertainties. The assumptions were that the firm set prices and production at the beginning of each period and the realization of demand and output shocks determined inventories which, in turn, affected prices and production in the next period. An optimal price and production policy was determined using dynamic programming over an infinite horizon. Marginal costs were assumed to be constant and the inventory cost function was assumed to be non-negative and convex. The rate of change in optimal output with respect to the rate of change in the optimal price was determined to be positive. An aggregate relationship was developed, linearized and tested empirically. The results supported the hypothesis that the inventory adjustment behaviour of firms and industries contributes to the explanation of the expectations-adjusted supply function.

A model of a value-maximizing monopolist was developed by Blinder [11]. He assumed that the firm faced a linear, stochastic demand curve and had a quadratic production cost function as well as a quadratic inventory cost function. The resulting one-period lag expectations equation was solved, which resulted in a single second-order nonhomogeneous difference equation. The result was shown to hold for a competitive industry. Blinder demonstrated that the model was, in most instances, a generalization of the models proposed by Reagan and Amihud and Mendelson. Extensive relationships were developed from the principal results; that both price and output responses become smaller as demand shocks become less persistent and output becomes more "inventoriable" (see Blinder [11, p340]). Blinder goes on to observe "that inventories are not the only vehicle for enhancing flexibility ... inventories of labour may be partial substitutes for inventories of goods." [11, p347]

2.3 Conclusions from the Literature

The transportation literature surveyed attempted to relate transportation or investment in transportation infrastructure directly to the surrounding economy. Only in the Baumol and Vinod study was transportation, and a number of transportation effects, linked directly to the firm with a variable affecting the operation of the firm through the firm's inventory.

The inventory literature surveyed, both at microeconomic and macroeconomic levels, viewed inventory as a feedback mechanism between the firm and the firm's market. This literature assumed that inventory policy decisions by a representative firm were determined on the basis of variables within the firm and from the firm's market. The exception to this was the Blinder article incorporating the interest rate variable.

The gap between the two literature surveys is apparent. No study traces the cause and effect sequence from investment in transportation infrastructure to transportation, from transportation to the firm's inventory, from inventory to costs, from costs to prices and from prices to consumption.

A cursory review of inventory theory reveals that there are two variables in the determination of the mechanics of the firm's inventory levels; the rate of sale, the variable that links the market and the firm, and lead time, the variable that links the firm and transportation infrastructure. The evaluation of this sequence should be possible with appropriate assumptions.

A transportation infrastructure is an element of a network of fixed location capital investments. Each element of that network services one region in a nation. The individual firm is connected to that network, usually in one region. Therefore an examination of consumption, the end process of the sequence of cause and effect, must be done at the level where the interactions may be localized, at the region. This was seen in a number of the articles surveyed. National consumption is then the sum of consumption over the network of regions.

In order to examine this sequence of cause and effect, investment in transportation infrastructure and consumption, the linking device, the inventory of the firm, must be examined. Firms have well-specified inventory models with a well-defined rationale for holding inventories. A model will be developed in the following section which will link investment in transportation infrastructure through the inventory of the firm to consumption.

3.0 DEVELOPMENT OF THE MODEL

The literature surveyed disclosed that transportation investment and inventories are important variables to be considered in economic analysis. However, none of the studies constructed a causal relationship between these variables. In this section a model based on the firm examines the effects of a change in the transportation infrastructure. This approach is in keeping with the recent literature but differs in three significant points: the model develops an explicit cost specification derived from inventory theory; the model views the economic system not as a national economy or a product market but as an aggregate of locations; and the model introduces a significant externality, investment in transportation infrastructure, directly into the operating environment of the firm.

3.1 The Role of Inventories

This section is composed largely of material from Arrow [4], Love [43] and Petersen and Silver [54]. The intention here is to provide an exposition on the rationale for the firm's holding inventories and a description of some inventory models, using the terminology of inventory theory.

There are three essential questions in inventory theory;

1. Why should the firm hold inventories?
2. If held, when should the firm replenish?
3. When replenished, in what quantities should inventories be replenished?

Firms hold factor inventories for the same reasons that they, and individuals, hold inventories of money: a transactions motive; a precautionary motive; and a speculative motive. There is extensive literature on the demand for money and so only the outline of these motives as they apply to factors and output will be sketched here.

Transactions motives have three cost components. The first cost component is the procurement cost, which is composed of two elements; the set-up cost involved in the preparation required to obtain the factor, and the acquisition cost of each unit factor. An additional cost is incurred by holding factors in inventory. This cost is the sum of space costs, insurance costs and management costs. The third cost component is an opportunity cost. The acquisition of factors in volume, or on special occasions, can provide the purchaser with substantial discounts. These transactions costs are applicable in both the deterministic world and the uncertain world, whereas the speculative and precautionary motives result only in an uncertain world.

The precautionary motive results in inventories being held in excess of the known rates of demand. Either a change in the rate of demand or in the rate of supply could produce a shortage in the factor. In an uncertain world either of these rate changes is probable and excess inventories are held, at a cost, to decrease the probability of a shortage. The cost of these excess inventories is calculated to be equal to the expected cost of the shortage at the margin.

The use of the speculative motive, speculation in price changes or demand rate changes, in a particular product market is well-defined for a large number of commodities, as is evidenced by the existence of well structured futures markets. These markets diminish the firm's requirement to hold (or sell) the actual commodity in the current period. But it can not be assumed that these futures markets totally satisfy the motive for actually holding these commodities themselves. In product markets without existing futures markets it must be assumed that the speculative motive, with its attendant costs, is met via inventories. It can be seen then that all firms dealing in goods will have the motivation to hold inventories.[1]

3.2 Types of Inventory Models

A simple classification of goods inventories is given in Love [43].

1. raw materials,
2. work-in-process,
3. finished goods,
4. wholesale,
5. retail.

It is the rare firm that will inventory one, or even a small number, of goods. While it might appear, under the above classification scheme, that some firms will have, at the most, three inventories, that view would be naive. Rather it is the usual practice for each commodity in the firm to be inventoried according to commodity

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1 While the literature and this paper focus on goods inventories it is probable that inventories of all factors are held by the firm. Extensive labour literature exists on implied contracts, search and the uncertainty of labour availability. Extensive literature on finance, money and investment exists which discusses the foregoing motivations. This analogy will not be pursued in this paper, but as observed by Blinder [11] the similarity of motivations for all the factors of the firm is intriguing.

classification, size, model, style, grade, colour, brand, etc., to a level designated as a stock-keeping unit (SKU). Many firms will have multiple inventories of the same SKU at different locations. This illustrates the breadth of the inventory problem for the firm. Any casual review of a firm's balance sheet and profit and loss statement will reveal the extent of inventories in the operation of the firm.

Firms which keep inventories will require an inventory policy; i.e., when and how much does it replenish? To determine the inventory policy to be followed the firm develops an inventory model. An inventory model is a mathematical model describing the behaviour of an inventory under the class of policies allowed for in the model. The user of the model is then in a position to derive an optimal inventory policy with respect to the model.

Inventory models can be exceedingly complex. Non-stationary demand distributions coupled with uncertain cost structures viewed over lengthy time horizons make some inventory models mathematically intractable. A series of studies, Arrow et al [4, 5, 6], as well as continuing research published in the journals, have reviewed and answered some of the problems in this field.

Of the inventory models possible, four common models, from Petersen and Silver [54], are shown here.

3.2.1 (s,Q) Model

This is a simple model involving the continuous review of the SKU. A quantity, Q, is ordered whenever the current inventory level is equal to, or less than, an order point, s.

3.2.2 (s,S) Model

The SKU is continuously reviewed. An order is placed whenever the current inventory level is equal to, or less than, an order point, s. The order quantity is variable; being the amount equal to the difference between an order level, S, and the current inventory level. This model generates a total cost no larger than the (s,Q) model, but the computational requirements for s and S, while solveable (see Scarf [60]), are extensive.

3.2.3 (R,S) Model

On a periodic basis, R units of time, the SKU is reviewed. An order is placed which will bring the current inventory level up to a pre-determined level, S. This model, while enabling a frequent readjustment of S, has high management costs and high carrying costs compared to the other models.

3.2.4 (R,s,S) Model

On a periodic basis, R units of time, the SKU is reviewed. An order is placed whenever the current inventory level is equal to, or less than, an order point, s. The order quantity is variable; being an amount equal to the difference between an order level, S, and the current inventory level. Like the (s,S) model the computational requirements are extensive.

3.3 A Model of the Firm

3.3.1 The Cost Function

An inventory model of the (s,Q) variety was used to develop an analytic cost function for the firm which was tractable for empirical purposes while remaining consistent with economic practice. A few simplifying assumptions were made; however none of the assumptions detract from the realism of the model of the firm or deviate from inventory models found in the literature. The model is a simplified variation of a (s,Q) model from Wagner [71].

Assume a stochastic demand rate, $m(t)$, for the firm's product. Assume also that if $t_1 < t_2$ then $m(t_1)$ and $m(t_2)$ are independent and identically distributed with mean $\bar{m}$.

Then;

$$M(t) = \sum_{a=0}^{t} m(a),\ 0 \leq t \leq T, \quad \ldots\ldots 1$$

where T is the planning horizon and $M(t)$ represents cumulative demand.

Let $Q(t)$ be the quantity received at time t, then;

$$q(t) = \sum_{a=0}^{t} Q(a)\ \ 0 \leq t \leq T, \quad \ldots\ldots 2$$

where $q(t)$ represents cumulative orders.

Then $y(t)$, the inventory level at time t, will be;

$$y(t) = y(0) + q(t) - M(t),\ 0 \leq t \leq T, \quad \ldots\ldots 3$$

It is assumed that if there is unsatisfied demand that it is lost and, for the purposes of exposition only, that the value of lost sales is not calculable and the firm incurs zero cost. However, to minimize lost sales a safety stock (buffer stock) is maintained. The amount of safety stock is determined, following Wagner [71], as a number of standard deviations from the expected demand during the lead time, L.

Lead time, L, is the time between the ordering of goods and their availability for sale (use) and encompasses a number of diverse activities; internal processing by the firm, communication to a supplier, delivery of goods over distance and the preparation of goods for sale.[2] Therefore the safety stock, SS, for the firm is given by;

$$SS = K_2(\bar{m}L)^{\frac{1}{2}}, \qquad \ldots 4$$

where the demand distribution is assumed to be Poisson, where $(\bar{m}L)^{\frac{1}{2}}$ is the standard deviation of the expected demand during the lead time, L, and K_2 represents the number of standard deviations chosen.[3]

The order point, s, is at a level to cover average demand during the lead time plus the safety stock;

$$s = SS + \bar{m}L, \qquad \ldots 5$$

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2 This sequence could be viewed equivalently as a completely internal process; internal order processing by the firm, set-up of production, production, delivery and preparation of goods for sale.

3 The selection of an appropriate K_2 by the firm for the SKU usually involves an assessment of the importance of the SKU in the particular process involved.

Consider Figure 1:

Typical Inventory Profile

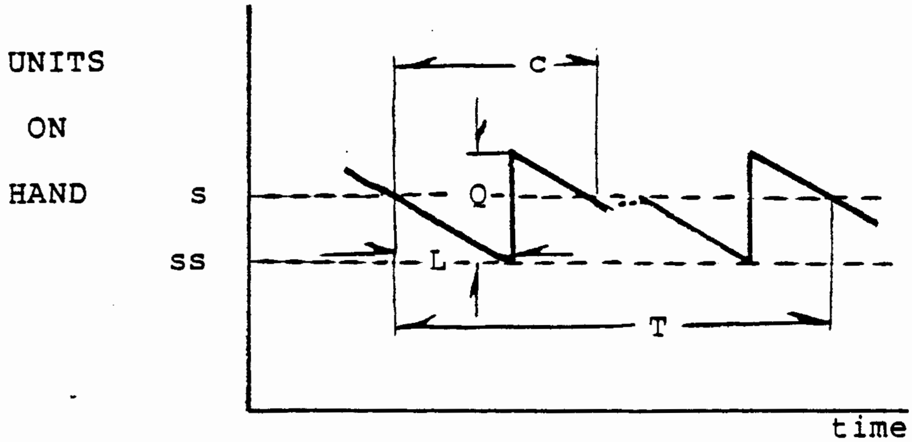

Figure 1.

where: L is lead time;

c is expected cycle time,

T is the planning horizon,

and where $c = Q(t)/\bar{m}$.

Let $\bar{y}_1(t)$ be the expected average inventory during the period spent waiting for an order to arrive. Since inventory is s at the order time, average sales during the waiting period are $\bar{m}L$,[4] and given that the firm has a safety stock, we assume that the probability of a stockout is zero.

4 This is a simplification. In reality there will exist a distribution of the parameter L, which is usually assumed to be a normal distribution, and therefore the actual distribution will be a multivariate distribution. A search of the literature has not disclosed a solution that is useful for this model.

Therefore;

$$\bar{y}_1(t) = \tfrac{1}{2}\,(s + s - \bar{m}L), \quad \ldots\ldots 6$$

Expected average inventory during the period from when an order is received to when a new order is sent out is;

$$\bar{y}_2(t) = \tfrac{1}{2}(s - \bar{m}L + Q + s), \quad \ldots\ldots 7$$

because at the beginning of the period inventory is;

$$y(t) = s - \bar{m}L + Q, \quad \ldots\ldots 8$$

and at the end of the period inventory is;

$$y(t) = s, \quad \ldots\ldots 9$$

Expected average inventory is then given by[5];

$$\bar{y}(t) = \bar{y}_1(t)L/c + \bar{y}_2(t)(1 - L/c), \quad \ldots\ldots 10$$

since L/c is the fraction of the cycle period, c, prior to an order being received and (1-L/c) is the fraction of the cycle period after an order is received.

Or;

$$\bar{y}(t) = \tfrac{1}{2}[2K_2(\bar{m}L)^{\frac{1}{2}} + \bar{m}L]\ nL/T + \tfrac{1}{2}[2K_2(\bar{m}L)^{\frac{1}{2}} + \bar{m}L + Q]\ (1-nL/T), \quad \ldots\ldots 11$$

where $nc = T$, and n is the number of cycles during the planning period.

Therefore;

$$\bar{y}(t) = K_2(\bar{m}L)^{\frac{1}{2}} + \bar{m}L/2 + (Q/2)(1-nL/T), \quad \ldots\ldots 12$$

Let the costs of the system be;

holding costs, \$h/ unit held /unit time;

ordering costs $\$K_1$/ each order placed;

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5 This is a variation from Wagner [71]. He uses the fractions $\bar{m}L/Q$ and $(1-\bar{m}L/Q)$. Since c has been defined as $Q/\bar{m}$, it is seen that the fractions are equivalent.

unit landed cost,[6] $D/ unit ordered;

all other costs/unit time of the firm during the planning horizon, $B.

Then the expected average costs/unit time of the firm during the planning horizon will be;

$$C(n,Q) = (K_1 + DQ)n/T + h[K_2(\bar{m}L)^{\frac{1}{2}} + \bar{m}L/2 + (Q/2)(1 - nL/T)] + B, \qquad 13$$

It is assumed that the planning period for the firm is long enough so that the firm expects

$$\bar{m}T = Qn, \qquad 14$$

and since $\bar{m}$ and T are predetermined, n is replaced in equation 13 by $\bar{m}T/Q$ as;

$$C(Q) = K_1\bar{m}/Q + D\bar{m} + h[K_2(\bar{m}L)^{\frac{1}{2}} + Q/2] + B, \qquad 15$$

3.3.2. The Market

It was assumed that the firm operated in a competitive industry. This means that the firm acts as a profit maximizer and takes the price of its sales as given. It also takes its sales distribution as given. Therefore maximizing profits is equivalent to minimizing costs. As well, it was assumed that the product offered on this market was the composite good so that the price elasticity of demand was equal to unity. The market was

---

6 Unit landed cost is the supplier price/unit plus the transport cost/unit.

assumed to come to an equilibrium instantly at the beginning of each planning period upon presentation of the product's price in the market and the resulting demand rate persisted during the planning period. Consumption of the good is exogeneously determined such that consumers spend a constant proportion of their income on the good.

$$\bar{m}P = AY, \qquad \text{16}$$

where, A is an arbitrary constant,

Y is income (assuming demand is homogeneous in income), and

P is the commodity price,

While the firm may wish to optimize its net revenues over an infinite planning horizon it is able to make its ordering (production) decision at the beginning of each planning horizon upon realization of the past period's performance (see Blinder [11]). Assuming that the firm has naive expectations, that $\bar{m}$ during the current planning horizon will be as in the previous planning horizon, then it is sufficient for the firm to optimize over the current period alone. Then the firm will maximize expected profit as;

$$\text{PROFIT} = P\,\bar{m} - C(Q), \qquad \text{17}$$

and an unconstrained profit maximization (cost minimization) yields;

$$Q = (2K_1\bar{m}/h)^{\frac{1}{2}}, \qquad 18$$

as the optimal order (production) quantity.

It should be noted that the result obtained for the order quantity, Q, as expressed in equation 18, is consistent with both the simple Wilson lot-size formulation used here (see Wagner [71]) and with complex (s,S) model solutions as derived by Roberts [59].

Substituting (18) into (15) yields;

$$C(\bar{m}) = D\bar{m} + [hK_2L^{\frac{1}{2}} + (2hK_1)^{\frac{1}{2}}]\bar{m}^{\frac{1}{2}} + B, \qquad 19$$

This formulation leads to an expected average cost function which will be shown to have economically appealing properties with respect to the exogeneous variables. In the competitive market of the firm the equilibrium expected profit position will be a zero (non-excess) profit position and, for the firm, expected average revenue will equal expected average cost, as,

$$AY = D\bar{m} + [hK_2L^{\frac{1}{2}} + (2hK_1)^{\frac{1}{2}}]\bar{m}^{\frac{1}{2}} + B, \qquad 20$$

Where the expected average revenue, $\bar{m}P$, is related through the market clearing condition (16) to the expected average cost shown in equation 19.

3.3.2.1 Nature of the Expected Average Cost Function

The expected average cost equation of the firm is depicted in Figure 2;

Expected Average Cost and Orders

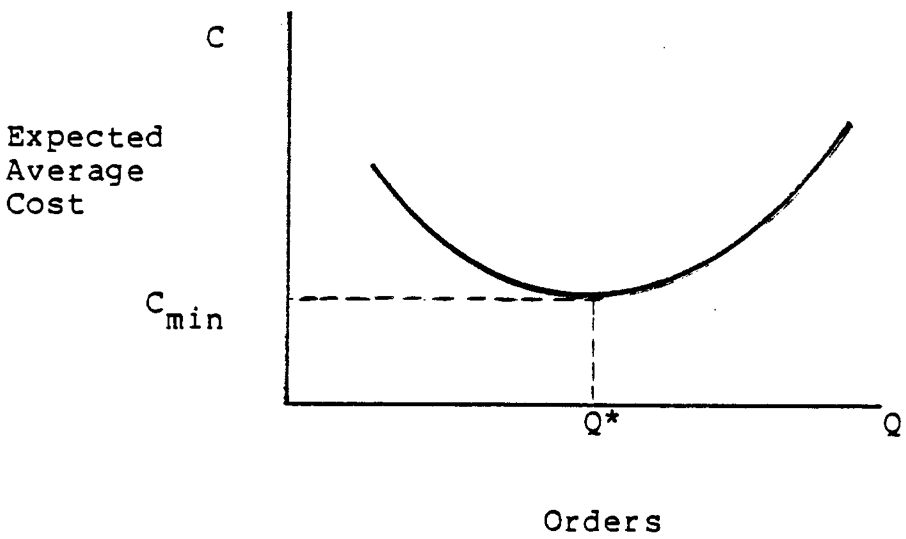

Figure 2.

and;

$$C_Q = -K_1\bar{m}/Q^2 + h/2, \qquad \text{21}$$

$$C_{QQ} = 2K_1\bar{m}/Q^3 > 0, \qquad \text{22}$$

and where C_{min} is given by equation 19 and Q* is as defined in equation 18.

This figure clearly illustrates the optimization of expected average cost by the selection of an appropriate value for orders (production).

Expected average cost as a function of expected average demand is shown in Figure 3.

<u>Expected Average Cost and Expected Average Demand</u>

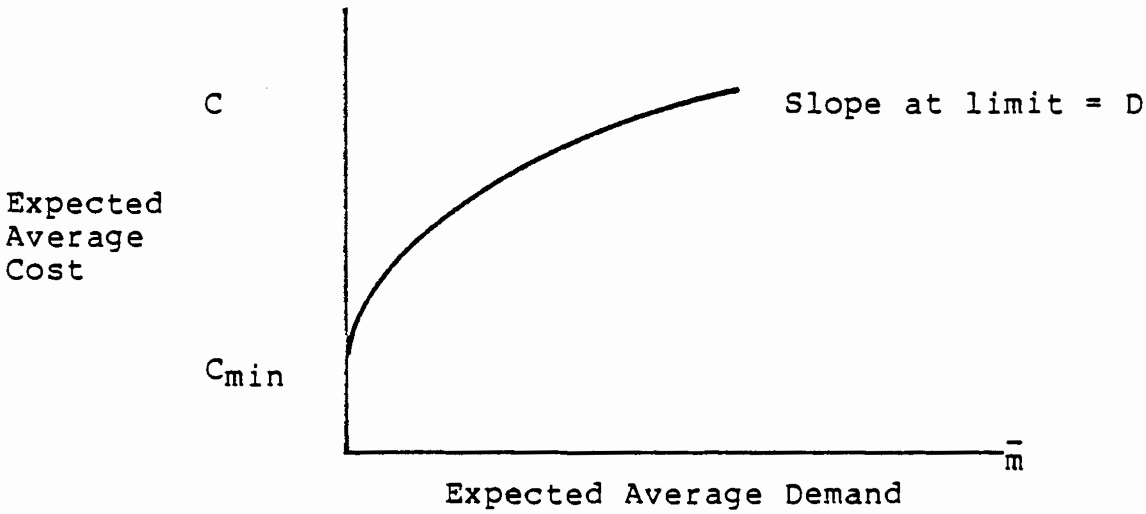

Figure 3.

where,

$$C_{min} = B, \qquad (23)$$

and,

$$C_{\bar{m}}(\bar{m}) = D + \tfrac{1}{2}[hK_2L^{\frac{1}{2}} + (2hK_1)^{\frac{1}{2}}]/\bar{m}^{\frac{1}{2}}, \qquad (24)$$

and where we assume that the expression $[hK_2L^{\frac{1}{2}} + (2hK_1)^{\frac{1}{2}}]$ is always positive.

When expected average demand is zero, the expected fixed costs to the firm remain. As expected average demand increases, the expected average cost increases but at a diminishing rate due to increasing returns to scale.

Expected average cost as a function of unit cost is shown in Figure 4.

Expected Average Cost and Unit Landed Cost

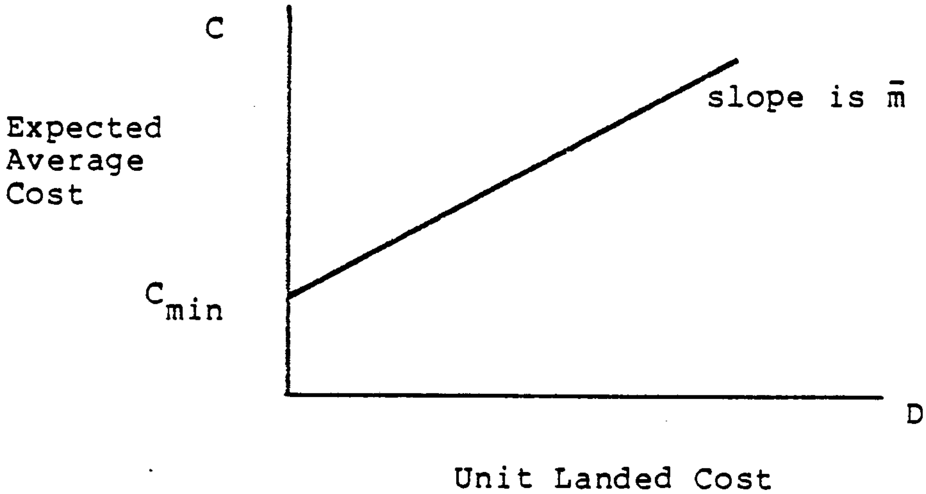

Figure 4.

where

$$C_{min} = [hK_2L^{\frac{1}{2}} + (2hK_1)^{\frac{1}{2}}]\bar{m}^{\frac{1}{2}} + B, \qquad (25)$$

and,

$$C_D = \bar{m}. \qquad (26)$$

The simplistic assumptions that the supplier's market is perfectly elastic for orders or that there are constant returns to scale in production are shown in this figure. The figure shows that expected average costs will be positive even if the unit landed cost is zero. This positive cost reflects the value-added costs of inventory and fixed costs. As well the figure shows the increase to expected average cost if the transport price component of unit landed cost rises.

Expected average cost as a function of lead time is shown in Figure 5.

Expected Average Cost and Lead Time

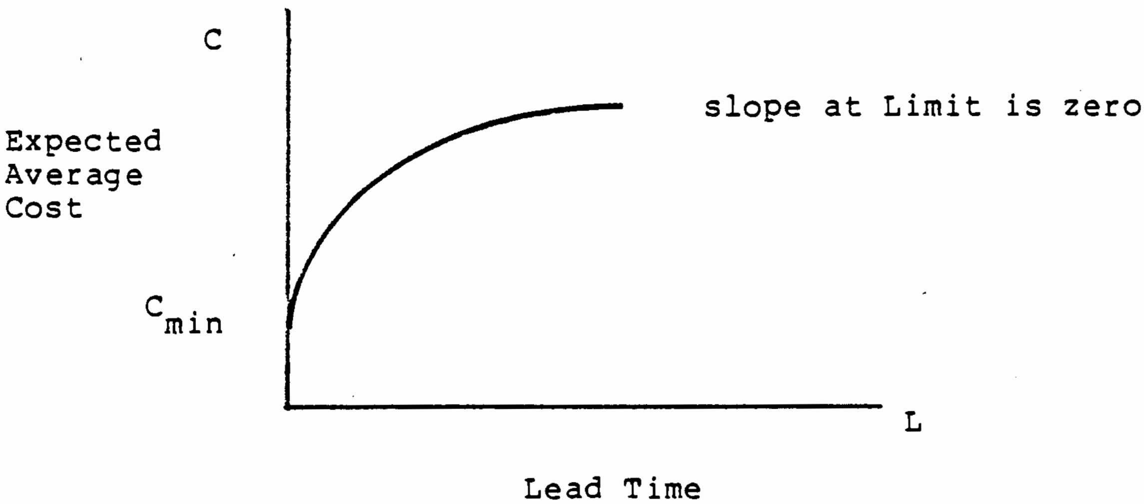

Figure 5.

where;

$$C_{min} = D\bar{m} + (2hK_1\bar{m})^{\frac{1}{2}} + B, \quad \ldots\ldots 27$$

and;

$$C_L = \tfrac{1}{2}hK_2\bar{m}^{\frac{1}{2}}/L^{\frac{1}{2}}, \quad \ldots\ldots 28$$

This figure clearly illustrates the impact on expected average cost by lead time. Most significant is the illustrated change in this cost when lead times are small and apparently inconsequential.

3.3.2.2 Market Equilibrium

Following from the description of the market (§3.3.2) the expected revenue-expected cost relationship for the firm was given by equation 20.

The nature of the market equilibrium is examined in the following figures.

Expected Average Demand and Income

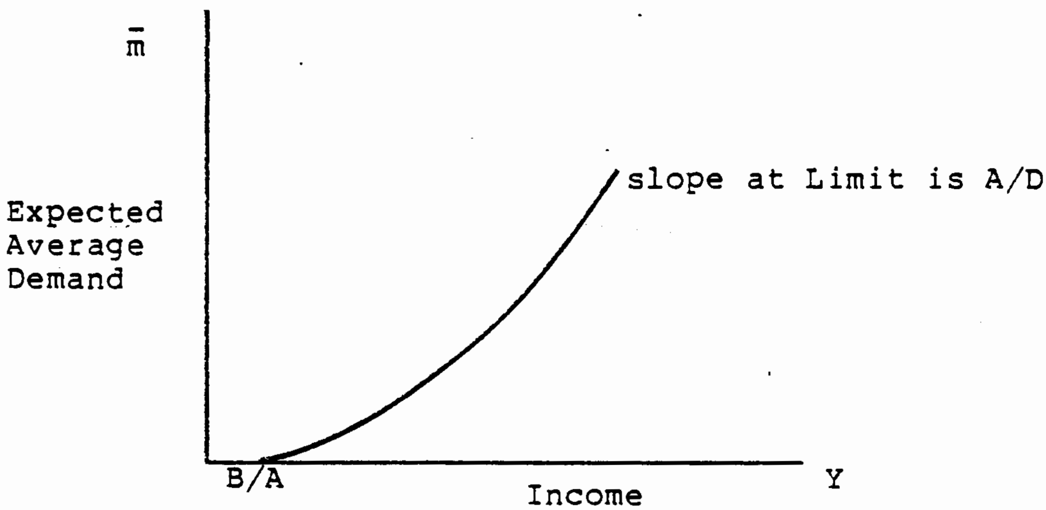

Figure 6.

where $d\bar{m}/dY = A/(D+[hK_2L^{\frac{1}{2}}+(2hK_1)^{\frac{1}{2}}]/2\bar{m}^{\frac{1}{2}}) > o$ 29

From Figure 6 it can be seen that the firm will satisfy average demand at levels above that which covers their fixed costs. The rate of increase in expected average demand is in excess of the rate of increase in income as the reduced average cost associated with the increased average demand is passed on to the consumer through lower prices.

The relationship between $\bar{m}$ and D is shown in Figure 7.

<u>Expected Average Demand and Unit Landed Cost</u>

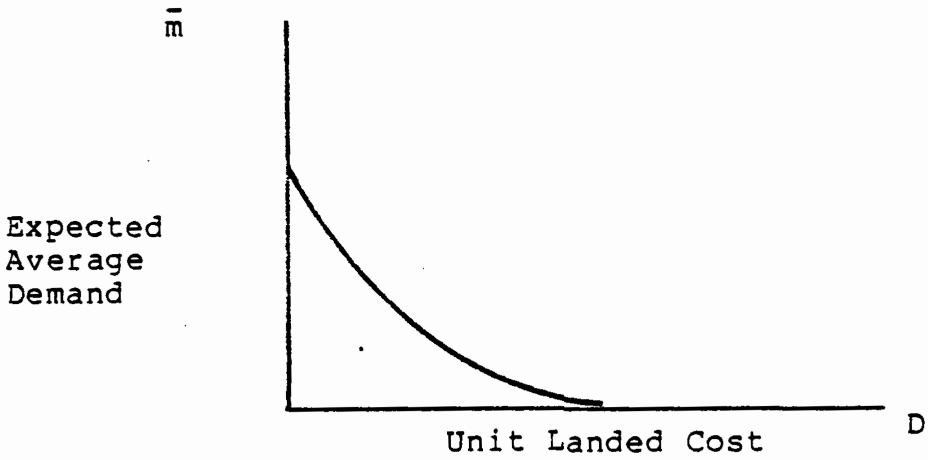

Figure 7.

where $d\bar{m}/dD = -\bar{m}/(D+[hK_2L^{\frac{1}{2}}+(2hK_1)^{\frac{1}{2}}]/2\bar{m}^{\frac{1}{2}})$, ...30

This figure clearly demonstrates the value-added costs of the firm. Even when the unit landed cost of the good is zero, the average demand will be constrained as the firm will price the fixed and inventory costs into the good. As the unit landed cost to the firm increases and is passed directly through to the customer, this will diminish average demand. This decrease in average demand will further increase average cost thus exacerbating the decline in average demand.

The relationship between $\bar{m}$ and L is shown in Figure 8.

Expected Average Demand and Lead Time

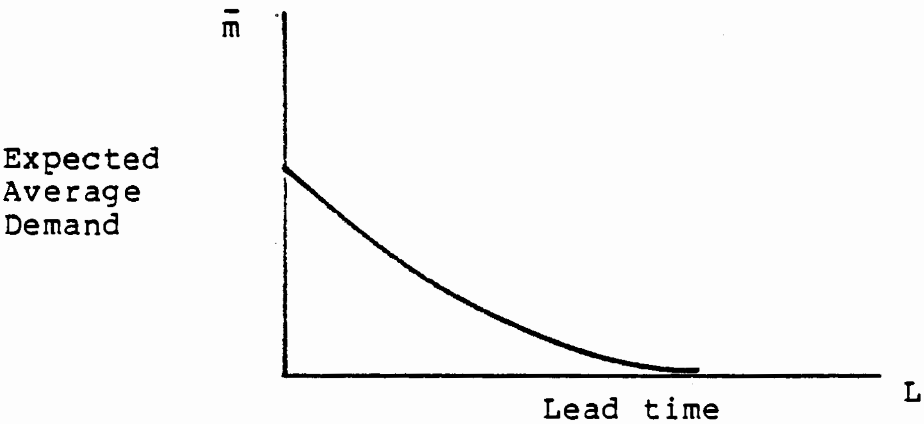

Figure 8.

where $d\bar{m}/dL = - hK_2\bar{m}/[2D(mL)^{\frac{1}{2}} + (2hK_1L)^{\frac{1}{2}} + hK_2L]$, ...31

The economic interpretation of this figure is similar to the previous figure. Lead time is a component of average cost and in the absence of lead time, average demand will be determined by the other components of average cost. An increase in lead time will cause an increase in average cost, which will diminish average demand. This decrease in average demand will further increase average cost per unit, which will further diminish average demand. Conversely, a decrease in lead time will decrease average cost causing an increase in average demand. This increase in average demand will diminish the average cost per unit, causing a further increase in average demand. It is this lead time-demand relationship that will be exploited in the following section.

3.3.3 The Impact of Investment in Transportation Infrastructure

Lead time, as viewed by the firm, is an important time period internal to the firm. But lead time is influenced, as well, by variables external to the firm. The distance between the firm and the supplier is a space to be bridged which can be viewed as a barrier to be reduced by the application of some technological device.[7] The time, lead time, to surmount this barrier, distance, is costly as was seen in Figure 5. The effective reduction of the barrier should enhance demand, as was indicated in Figure 8. The underlying relationship is assumed to be;

$$L = f(K), \qquad \text{.....32}$$

where K represents the capital stock in place in the transportation infrastructure, and where $f' \leq 0$; the equality exists under the assumption that some minimum requirement for dK/dt may exist.

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7 The following analysis could equally apply to the communication process, e.g. development of electronic document/photo transmission devices, electronic conferences etc.

More specifically, the relationship was assumed to interact as;

$$L(t) = f(K(t-e)), \qquad \ldots 33$$

since there may exist a delay of e units of time between the completion of investment in a transportation infrastructure project and the resultant change in L.

The capital in transportation infrastructure may be seen as having two components, as,

$$K(t-e) = K(i) + \sum_{u=i+1}^{t-e} I(u), \qquad \ldots 34$$

where K(i) represents some previous state in equilibrium at period i and the second term represents additions to that state. It was assumed that the depreciation of capital in transportation infrastructures is negligible for short and intermediate time horizons.

Then equation 33 becomes,

$$L(t) = f\left(K(i) + \sum_{u=i+1}^{t-e} I(u)\right), \qquad \ldots 35$$

This equation is linearized, to simplify algebra, as

$$L(t)^{\frac{1}{2}} = a - b \sum_{u=i+1}^{t-e} I(u), \qquad \ldots 36$$

This relationship will be used to capture the effect of the stock of transportation investment on lead time.

Inserting (36) into (20) yields;

$$AY = D\bar{m} + [hK_2(a-b \sum_{u=i+1}^{t-e} I(u)) + (2hK_1)^{\frac{1}{2}}]\bar{m}^{-\frac{1}{2}} + B, \ldots\ldots\ldots\ldots 37$$

Equation 37 provides an expression to describe consumption in a market where that consumption is a function of income and capital and investment in transportation infrastructure.

The relationship among variables as described in equation 37 expresses a real link between investment external to the firm and consumption. The sequence of effects is straightforward. Investment in transportation infrastructure to improve that infrastructure will increase the capital in place. The improved infrastructure will effectively change the lead time by facilitating the reduction of its mean or variance and this will reduce inventory held by the firm. The reduced inventory, in relation to current demand, should reduce costs for the firm. In a competitive environment these reduced costs will be reflected as reduced prices to the firm's market. This market, faced with reduced prices and assuming no changes in income, will increase consumption.

This sequence of effects is shown in the following comparative statics analysis.

3.3.4 Comparative Statics

To preserve the mathematical integrity of the functional relationship between lead time and capital in transportation infrastructure, equation 19 was modified to include the functional relationship, equation 33, to yield;

$$C(\bar{m}) = D\bar{m} + hK_2[f(K(t-e))]^{\frac{1}{2}}\bar{m}^{-\frac{1}{2}} + (2hk_1)^{\frac{1}{2}}\bar{m}^{\frac{1}{2}} + B, \ldots\ldots 38$$

Expected Average Cost and Capital

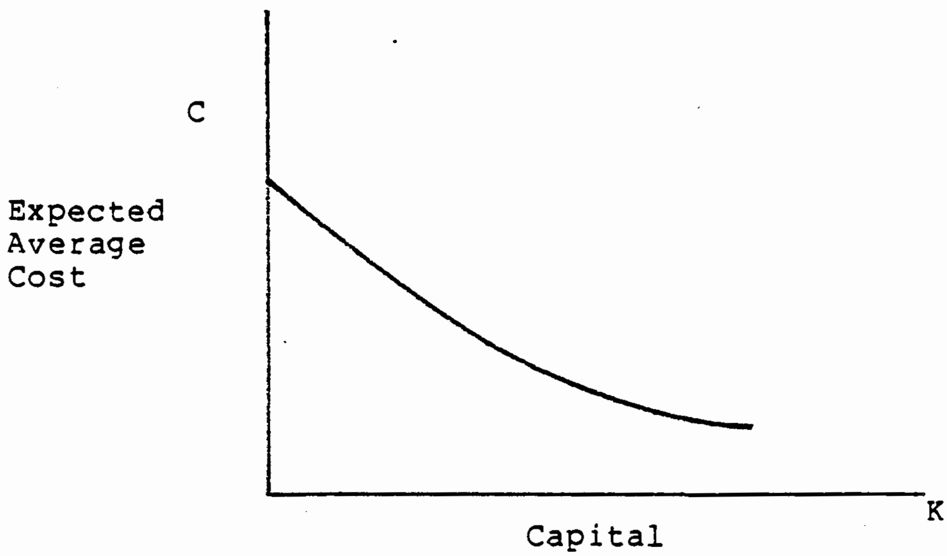

Figure 9

where,

$$C_K(\bar{m}) = hK_2\bar{m}^{-\frac{1}{2}}\ f'(K(t-e))/2[f(K(t-e))]^{\frac{1}{2}} < 0, \ldots\ldots\ldots 39$$

The relationship shows that the increase in capital in transportation infrastructure will facilitate the reduction of lead time which will reduce expected average cost. This figure is a mirror-image of Figure 5, the expected average cost and lead time relationship.

The relationship between expected average cost and demand has not changed and is portrayed in Figure 3.

The relationship between demand and capital in transportation infrastructure is shown as;

<u>Expected Average Demand and Capital</u>

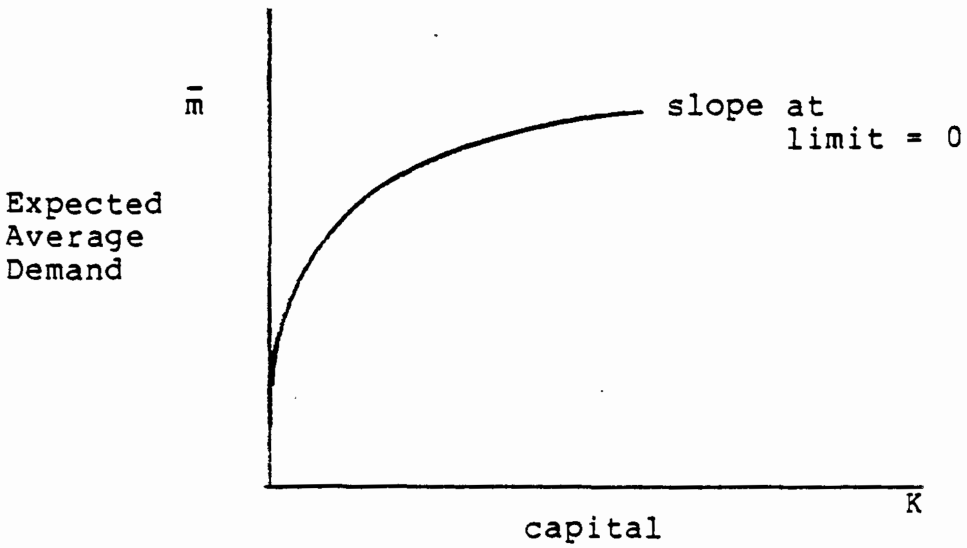

Figure 10

where,

$$d\bar{m}/dK = -hK_2\bar{m}f'(K(t-e))/(2D\bar{m}^{\frac{1}{2}}f^{\frac{1}{2}} + hK_2f + (2hK_1)^{\frac{1}{2}}f^{\frac{1}{2}}),40$$

The increase in capital in transportation infrastructure effectively reduces lead time which in turn reduces average inventory. This reduction in average inventory reduces costs. These reduced costs, in a competitive environment, are passed on to the consumer as reduced prices and demand increases.

4.0 THE TRANSITORY IMPACTS OF THE MODEL

4.1 An Exposition

The model developed in Chapter 3 clearly shows that an increase in the capital in place in a transportation infrastructure will have a variety of effects upon the firm. However the process of putting capital into these infrastructures is usually a protracted process. Some major transportation projects take years to complete. Upon completion of the revised infrastructure it is assumed that the users must experience the new benefits before these new benefits become part of a market equilibrium. To this point these transition effects have not been examined, rather they have been implied by the use of subscripts, t, e, i, to reflect events occurring at different points in time. These dynamics will be analyzed with more precision.

These transitory effects may be illustrated by using a simple series of cause and effect. Assume that two economic agents, the ordering agent and the supplying agent, are at some distance from each other connected by an inefficient transportation infrastructure. Consequently, goods procured by the ordering agent, either by movement to the supplier to pick them up or by their delivery via a transport carrier, will take a considerable period of time, a large L, before they are made available for sale (use) by the ordering agent. In the initial state it is assumed they are at equilibrium. As is known (see Petersen and Silver, [54]) an ordering firm will have an inventory on hand greatly in excess of the current rate of demand.[8] This equilibrium is depicted in Figure 11 where both firms are shown side by side in order to more easily compare the effects on the firms. Both the rate of sale and the level of inventory for each firm are shown on the figure to portray more clearly the interaction between these two variables.

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8 For example, non-food retailers have an annual turnover of about four times average inventory levels. Thus for most commodities reviewed on a biweekly basis the ratio of stock to demand is about six.

Initial Equilibrium

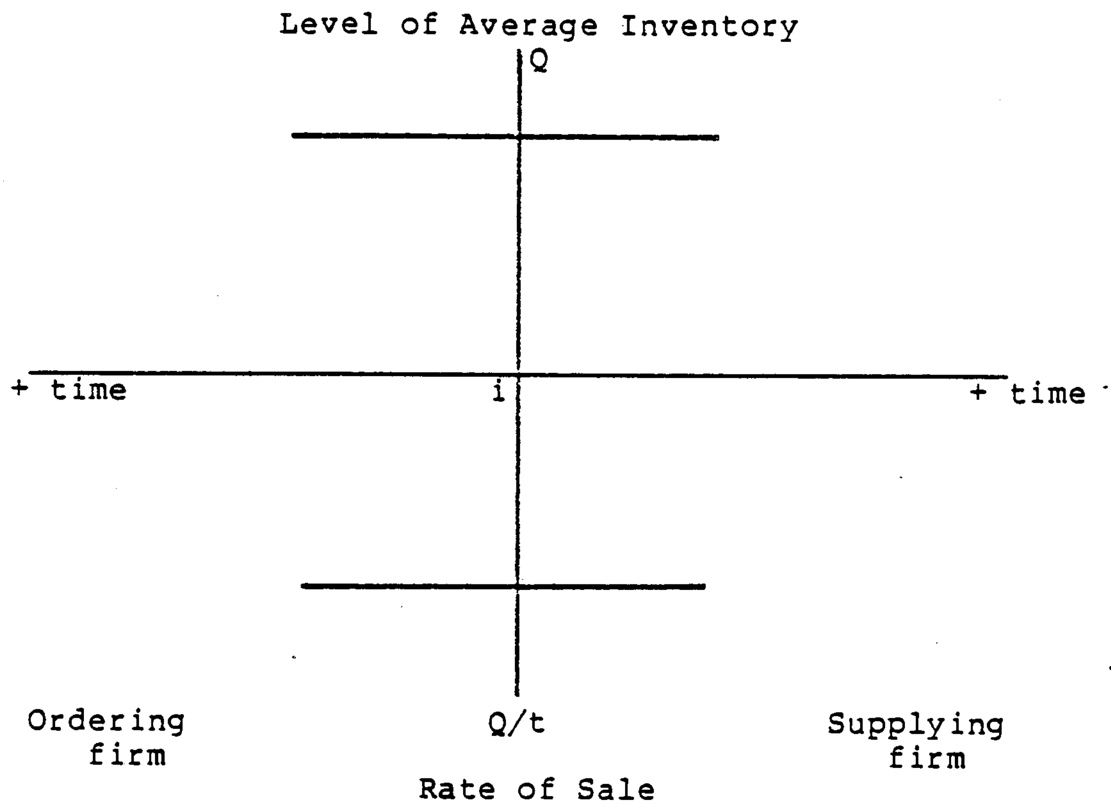

Figure 11

Since the agents are in equilibrium their sales rates are equal. For exposition purposes, so are the inventories. Now assume that a major transportation infrastructure project is undertaken adjacent to the ordering agent at time t=i. Ignoring the effects of the infusion of funds into the region and other such effects, consider the effect when the project is complete at time t-e. Assuming instant adjustment in the transport carrier market, we let the lead time between the two agents diminish significantly. The ordering agent is now able to have rapid replenishment, and any requirement for safety stock is reduced substantially. Therefore the ordering agent will have excess stocks on hand in his safety stock and average order point stock. The first indication of this change to the supplier agent will be when his sales rate, at t-e, drops to zero. This is depicted in Figure 12.

New Lead Time

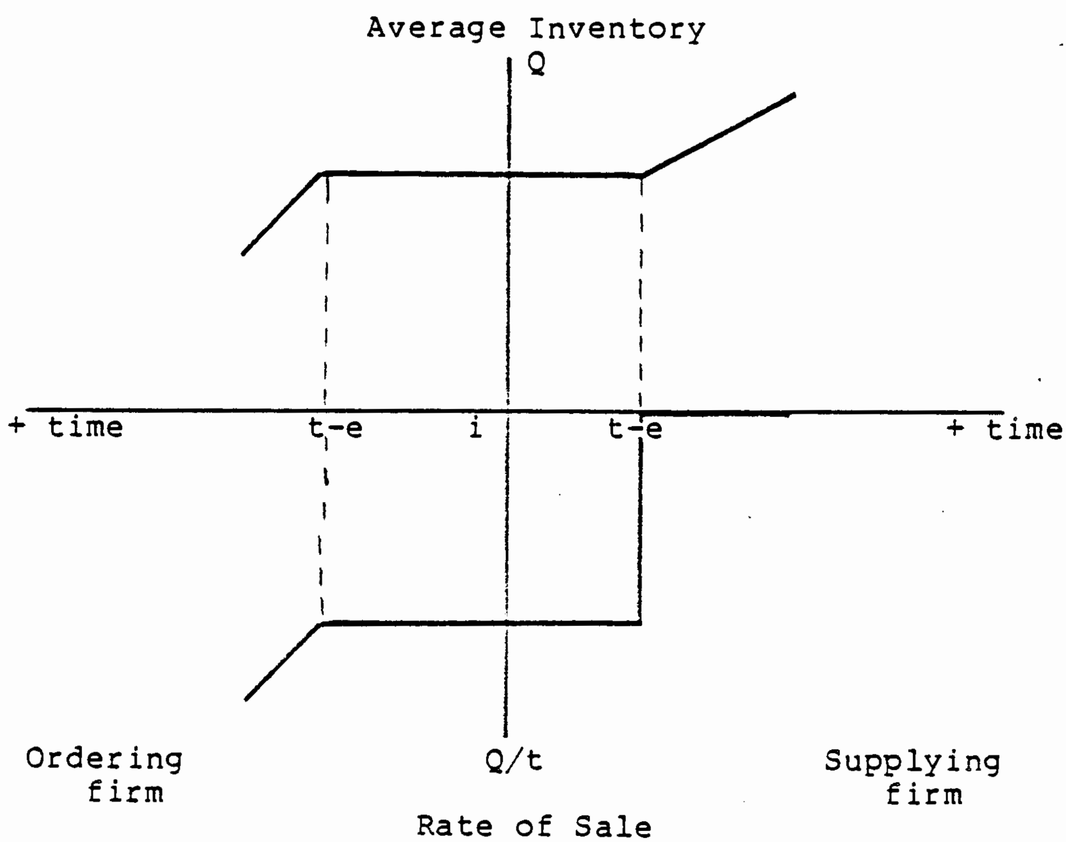

Figure 12

Two secondary results will become effective. The supplier agent, having experienced a significant variability in his sales rate, will increase his safety stocks accordingly. This will increase his costs, thus his prices. The ordering agent, having reduced his order point, s, and his levels of safety stock, will have reduced his costs, thus his prices. The tertiary effect of resultant variability in sales will further increase the level of safety stocks in the supplying firm. To anticipate the exact sequence of these effects as they interact between the firms and the market, particularly as the lag effects are unknown and complicate the sequence, would be presumptuous. However, at some point in time, t, a stable equilibrium will be re-established where the sales in the system will be higher as the costs are lower, i.e. safety stocks and lead time stocks (and storage space and insurance for them) in the ordering firm are much lower. If we assume that the ordering firm initiates the price changes then an approximation of the process is shown in Figure 13.[9]

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9 This simple exposition could be augmented by the entry or exit of firms to ensure 'normal' profits.

Equilibrium Process

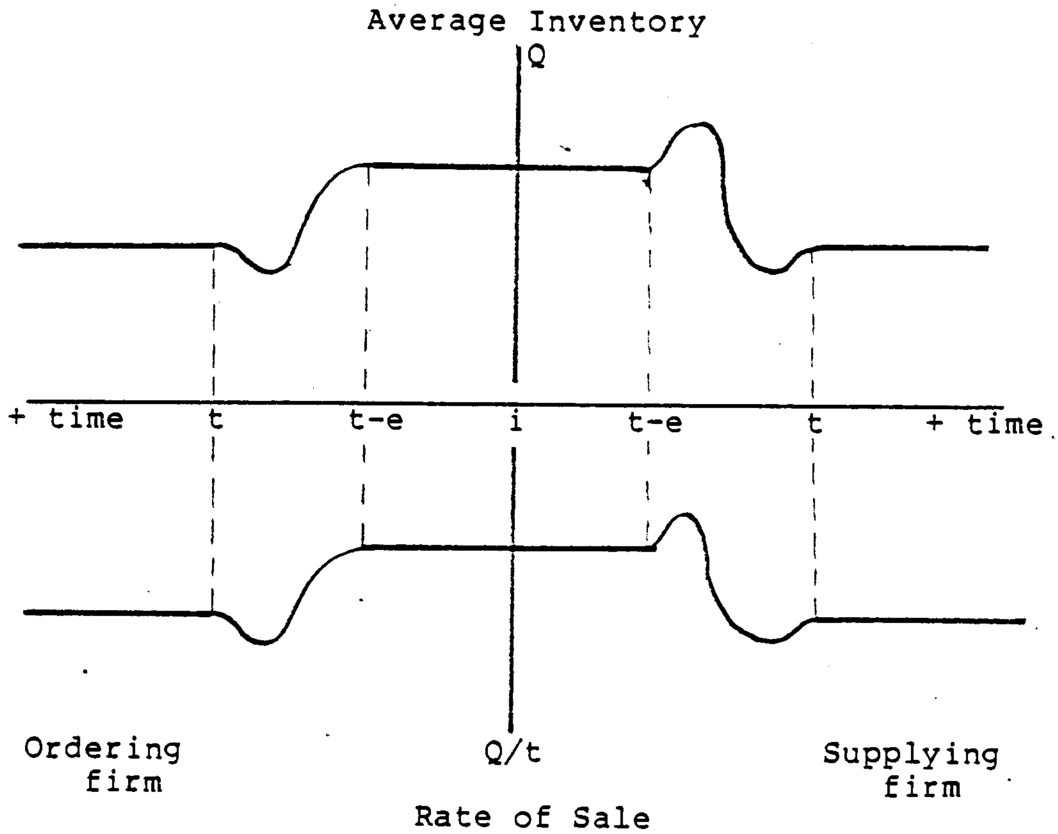

Figure 13

The exposition is expanded by considering the regional case, when the ordering agent is in City A and supplying agents are in nearby cities B and C, as compared to the city case, when the consuming (ordering) agent is in a city at location A and the selling (supplying) agents are in the same city at locations B and C.

Consider Figure 14.

A Simple Network

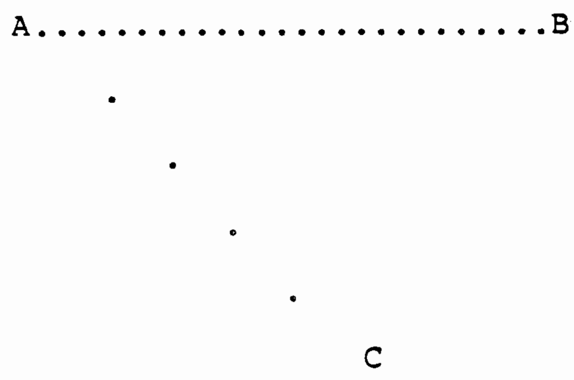

Figure 14

Let the ordering agent be located at A and the suppliers be located at B and C. If we assume an improvement in the transportation infrastructure between A and B, then the net effect should be a reduction of costs and prices at A and a shift of source of supply from C to B. If the case under consideration is within a city then the inter-firm results may be very small unless large metropolitan areas, large projects and unlimited numbers of firms are considered. However, if we re-cast the ordering firm as a consuming agent electing to travel from his household at A to firms at either B or C, then the prior discussion is relevant. An improvement in transportation infrastructure in the segment (network) AB will shift demand from C to B. Travel time and cost to A will be reduced, thus allowing these savings to be utilized elsewhere. The net benefit to the city as a whole should be positive through the reduction of travel cost and time to a number of agents A who are now in a position to increase consumption. The intra-city redistributional effects are clearly seen. The inter-city case will be tested in this paper.

4.2 Stability and Dynamics

The preceding explanation provides an intuitive view into the sequence of events between the infusion of capital into transportation infrastructures and the resulting increase in demand to a firm. However intuition needs to be substantiated by an analysis of the elements of the specific model under consideration. Assuming the economic environment is stable a model of an economic process needs to be examined for its own stability, if it is to be realistic. The model under consideration proposes that a sequence of events occur at different periods in time. The dynamics, interrelated events, need to be clearly portrayed in order to view the impact of the capital in transportation infrastructure and the effect of the period by period changes to that capital on the demand to the firm.

The stability of the model is reviewed using a two-period price comparison under the assumption that prices adjust to changes in costs only after a lag of one period. An expected average cost equation, equation 41, is obtained by inserting the linearized lead time and capital in transportation infrastructure relationship, equation 36, into the expected average cost equation 19.

$$C(m) = Dm + [b_1 - a_2 I(t-e)]m^{\frac{1}{2}} + B, \ldots\ldots\ldots\ldots 41$$

where,

$$m = \bar{m}; \ldots\ldots\ldots\ldots 41(a)$$

$$b_1 = hK_2 a + (2hK_1)^{\frac{1}{2}}; \ldots\ldots\ldots\ldots 41(b)$$

$$a_2 I(t-e) = hK_2 b \sum_{u=i+1}^{t-e} I(u); \ldots\ldots\ldots\ldots 41(c)$$

Then the two-period price comparison which assumes that the expected average cost equation, equation 41, represents the aggregate firm's price in a competitive industry, is;

$$P(t+1) = C(m(t))/m(t), \ldots\ldots\ldots\ldots 42$$

Making the equilibrium condition price assumption that price/unit in the next period will be;

$$P(t+1) = D + b_1/m(t)^{\frac{1}{2}} - (a_2 I(t-e)/m(t)^{\frac{1}{2}} + B/m(t), \ldots\ldots\ldots 43$$

and recalling;

$$AY(t) = P(t)m(t), \quad \text{......44}$$

then,

$$P(t+1) = D + b_1P(t)^{\frac{1}{2}}/U^{\frac{1}{2}} - [a_2I(t-e)]P(t)^{\frac{1}{2}}/U^{\frac{1}{2}}$$

$$+ BP(t)/U = f(P(t)), \quad \text{......45}$$

where U = AY(t).

A stable price, P*, will exist, at the limit, if and only if;

$$B < AY, \quad \text{......46}$$

i.e. all other costs of the firm are less than average revenue, and P* will be approached if and only if;

$$m^{\frac{1}{2}}(b_1 - [a_2I(t-e)])/2 + B < AY, \quad \text{......47}$$

Then;

$$\lim_{P(t) \to 0} f(P(t)) \to D, \quad \text{......48}$$

$$\lim_{P(t) \to \text{inf.}} f(P(t)) \to \text{infinity}, \quad \text{......49}$$

$$\lim_{P(t) \to 0} f'(P(t)) \to \text{infinity}, \quad \text{......50}$$

$$\lim_{P(t) \to \inf.} f'(P(t)) \to B/AY(t), \qquad \ldots 51$$

This is depicted in Figure 15;

Price Stability

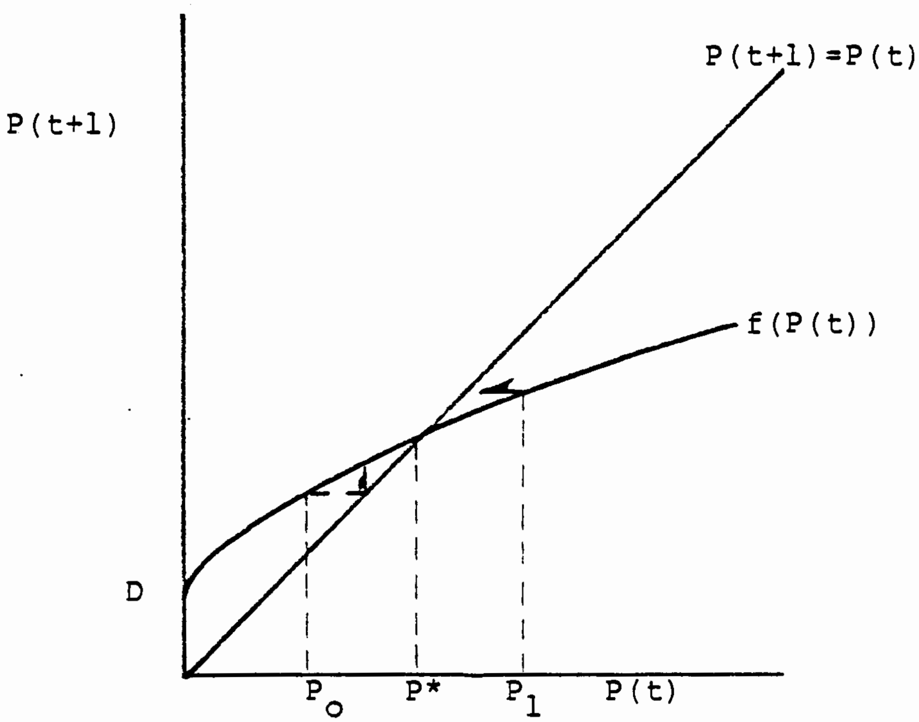

Figure 15

A stable price, P*, was obtained as a solution of equation 45 as;

$$P^* = \left(\frac{AY}{AY-B}\right)\left(\frac{Z^2}{2(AY-B)} + D \pm Z\left[\frac{Z^2}{4AY(AY-B)} + \frac{D}{AY-B}\right]^{\frac{1}{2}}\right), \qquad \ldots 52$$

where; $Z = b_1-[a_2I(t-e)]$.

Market stability was developed similarly where;

$$m(t+1) = AY[D+(b_1-[a_2I(t-e)])\ m(t)^{-\frac{1}{2}}+Bm(t)^{-1}]^{-1}$$

$$= f(m(t)), \qquad \ldots 53$$

and depicted in Figure 16 as;

Consumption Stability

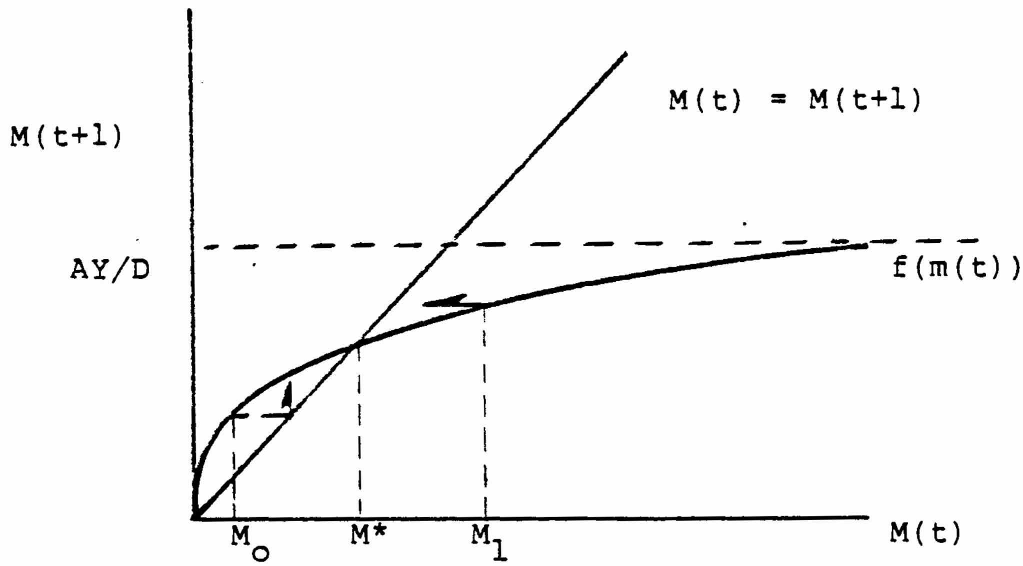

Figure 16

and the stable consumption point is;

$$M^* = \frac{1}{D}\left(\frac{Z^2}{2D} + AY-B \pm Z\left[\frac{Z^2}{4D^2} + \frac{(AY-B)}{D}\right]^{\frac{1}{2}}\right), \qquad \ldots 54$$

This analysis has shown that the model exhibits a stable price. The model shows that if a price is altered from the stable price by any transitory effect, without components of equation 41 being altered, then the price will return to the stable price in a diminishing cyclical fashion.

Investment in transportation infrastructure will reduce the expected average cost. But the effect of that transportation investment will not be apparent as a reduction in expected average cost immediately. There will be some interval, e periods, until the effect is learned by all participants, transport carriers and firms, in the market system. As the infrastructure is being improved substantial investments will be impacting into the market environment. Firms and transport carriers will form expectations as to the possible state of the market when the infrastructure is complete. Prior to and after completion firms may enter or exit the market dependent on their ability to cope with a revised market environment. From the period of the initialization of the change in the transportation infrastructure until e periods after its completion the market will be in a state of disequilibrium, i.e. moving from one stable equilibrium position to another stable equilibrium position. In the new equilibrium position the expected average cost of the firm will be lower, thus prices will be lower and consumption will be higher. This sequence of movement from the original equilibrium position to the new equilibrium position is shown in the following figures.

New Equilibrium

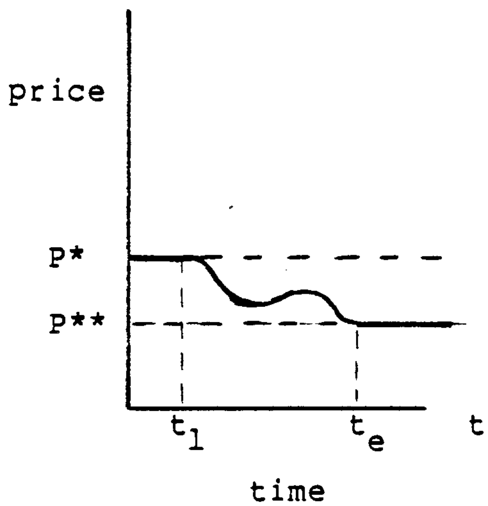

Figure 17

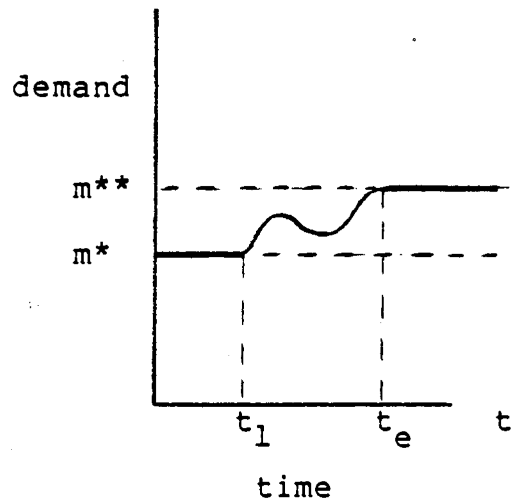

Figure 18

It can be seen that consumption and prices will be altered in this model by a reduction in lead time through an investment in transportation infrastructure.

Furthermore it can be seen that both the investment and capital components will produce effects on price and demand. Therefore both these effects need to be incorporated in any estimation process.

4.3 Spatial Aggregation

4.3.1 The Representative Firm in a City

The model developed has been for a single firm, a price-taker in a competitive environment. While cities are large with many firms, it is not realistic to assume the city meets all of the assumptions of the theoretical competitive environment. However, given the number of competing firms within cities and the wide range of substituteable goods sold by these firms, it appears reasonable to assume that the competitive environment within a city is an approximation to the theoretical construct. As well, given the range of products offered and consumed in cities, it is reasonable to assume that, in the aggregate, consumption in a city is of a composite good.

The equation developed to describe the interaction among the market, firm and transportation infrastructure was for a single firm. Not all firms use an (s,Q) inventory model. Retail firms tend to use (R,S) or (R,s,S) models. Major firms are adopting (S,s) models as they acquire large computers. Many small firms still utilize eyeball or ad hoc models. However, all inventories exhibit the profile shown in Figure 1, and the behaviour of all inventory models is dependant on the lead time variable. The (s,Q) model yields, of the four inventory models, one of the lowest levels of inventory.

While the model developed was based on the assumption of an individual firm, the data available are for the city and the region. To assume that the model will aggregate firm by firm to specify the city is unrealistic. The use of differing inventory models by individual firms, each ordering and supplying differing assortments of goods and services, could not conceivably be aggregated by any mathematical technique. Thus the (s,Q) model used is an approximation to the inventory behaviour in a city rather than a well-defined aggregated inventory model. But the components of the model are still applicable. The city is a market with income. The city has a well-specified price index.[10] The aggregate of goods sold in a city may be viewed as a composite good which is inventoried and should, therefore, exhibit an inventory profile. More clearly, the capital and investment in the transportation infrastructures in the transport networks impinging on the city should affect the level of economic activity in the city.

4.3.2 Cities and Regions

The dynamics (§ 4.2) illustrated have been developed with reference to an ordering firm. It can be assumed that the output of a supplying firm will be that of the ordering firm at both the initial and final equilibria.

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10 Statistics Canada, Consumer Prices for Regional Cities, 62-009.

Firms, ordering and supplying, do not co-exist at singular points. Either a hierarchical or nodal concept of spatial aggregation hypothesizes that firms, consumers and workers congregate together for benefits. These congregations result in a network of nodes of activity over geographic space. At any one of these nodes of economic activity there will exist a proportion of ordering and supplying firms. Any nodal pair that trades between itself will be affected by an investment in the transportation infrastructure that links the nodal pair. For example, assume city A and city B are exclusive trading partners. An investment is made in the transportation infrastructure linking city A and city B. If city A has a higher proportion, on a demand-weighted basis, of ordering firms, i.e. is a net importer, then city A's aggregate consumption pattern should be as exhibited in Figure 18, and city B, a net exporter, should initially exhibit a reduction in demand, but at a final equilibrium exhibit an increase in demand.

A more relevant situation is that of a city and its surrounding hinterland, much like von Thunen's model. It is typical that the city contains the majority of the population in the region. The city usually contains many firms whose output is predominantly consumer or industrial finished goods. These goods are sold within the city, to other cities and to the outlying hinterland. The balance of the regional population is dispersed throughout the hinterland, usually at localities adjacent to natural resources. Each locality has few firms; some servicing the locality with consumer goods brought from the city, and a small number of firms engaged in a primary industry exporting their output to or through the city. In sum, each locality would appear to be a net exporter. This scenario does not explicitly consider the ownership and resulting monetary flow for the firms described, but it is assumed that in the aggregate the level of economic activity throughout the region will flow through to the relevant locality and the city. The sole vehicle of exchange between the hinterland and the city is the transportation infrastructure. A network of transportation nodes is developed from the city to service the localities and to receive their exports. This network will be interconnected with the transport network among cities.

It is clear that the city is critically dependent on these two transportation networks with their transportation infrastructures. Consider Figure 19.

CONTINGENT REGIONS

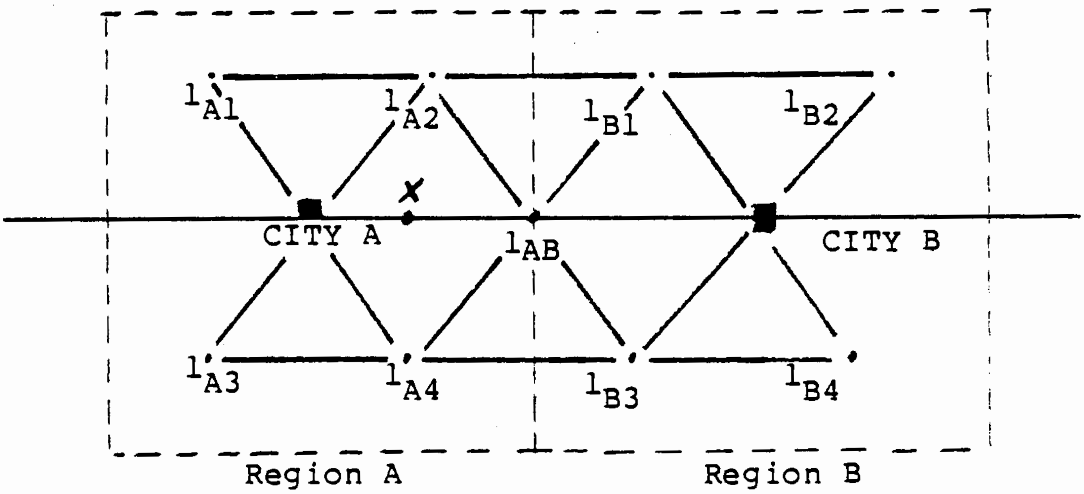

Figure 19

The city and its localities, l_i represent a city and its hinterland. Together they define a region. The city is the focus of a transportation network, composed of transportation infrastructures and transport carriers, servicing the city and the hinterland localities. As well the city is a node in an inter-city transportation network, serviced by transportation infrastructures, any one of which may or may not be identical with a transportation infrastructure servicing the region (Edmonton municipal airport services only intra-provincial flights, Edmonton international airport services only inter-provincial flights, Winnipeg international airport services both). A city is a net importer with respect to its localities l. Consider an investment in transportation infrastructure servicing only the segment $C_A l_{AB}$. The improvement in the transportation infrastructure will result in a consumption change in city A as portrayed in Figure 18, an initial rise in consumption, followed by oscillations in consumption, and finally a new, higher consumption equilibrium as a result of cost reductions. Next consider an investment in a transportation infrastructure at X servicing only the segment AB. If city A is a net importer with respect to city B, then the results at city A should be similar to the preceding example. If city A is a net exporter with respect to city B then the initial consumption at city A should fall, but the remainder of the sequence of cause and effect should remain the same as the preceding examples.

Consider now that the transportation infrastructure at X services both network segments, AB and l_{AB}. If city A is a net importer with respect to city B, then the effect of an improvement in the transportation infrastructure at X will have a dual impact on city A, from the relationships between city A and l_{AB} and between city A and city B. However, if city A is a net exporter with respect to city B, the initial changes in consumption in city A will be indeterminate. The final level at consumption at city A will be higher. Observe that an improvement in transportation infrastructure of X, servicing segment AB alone or in conjunction with Al_{AB}, will have an impact on city B in region B. Therefore any estimation of the cause and effect sequence, investment in transportation infrastructure and consumption, within a region will have contemporaneous effects from investments in transportation infrastructures in every other region in the transportation network.

Whether either city is a net importer or net exporter with respect to the other city is indeterminate. Any change in either of these two networks will alter the flow of goods to, from or through the city. Therefore any change in these networks will alter the level of economic activity within the city.

Thus the hypothesis generated is that investment in the transportation infrastructures of transport networks in a region about a city will result in increased consumption in that city above and beyond any increased consumption due to increases in income. To test this hypothesis, a regression of the independent variables income, capital and investment in transportation infrastructure was done against the dependant variable, consumption, in a relationship indicated by the model developed.

It would be necessary to reject the hypothesis if the coefficients for the key variables were not statistically significant. It would be sufficient to reject the hypothesis, as well, if, excluding income, the coefficients of the investment variables alone were statistically significant and exhibited a pattern of declining positive values. This result could more readily be attributable to a simple investment multiplier theory.

Equation 37 was used to test the hypothesis.

5.0 ESTIMATION

5.1 The Econometric Model

The equilibrium formulation, equation 37, is a quadratic equation in $m^{\frac{1}{2}}$. It was solved to yield;

$$m(t)^{\frac{1}{2}} = -\left(b_1 - a_3 \sum_{u=i+1}^{t-e} I(u)\right) / 2D$$

$$\pm \left[b_1 - a_3 \sum_{u=i+1}^{t-e} I(u)\right)^2 - 4D(B-AY)]^{\frac{1}{2}}/2D, \ldots\ldots\ldots\ldots\ldots 55$$

where substitutions 41(a), 41(b) and $a_3 = hK_2b$, apply.

This expression is non-linear and not amenable to estimation. Application of either a linearization technique (see Christ [19]) to equation 37 or a full function first-order Taylor expansion to equation 55 at equilibrium yielded;

$$m(t)^{\frac{1}{2}} = a_o + a_I \sum_{u=i+1}^{t-e} I(u) + a_{k+1}\ y(t) \ldots\ldots\ldots\ldots\ldots\ldots 56$$

However, as argued previously (§4.0), m(t) will also be effected by the transitory investment. To try to capture these effects, the equation is modified to,

$$m(t)^{\frac{1}{2}} = a_o + a_I \sum_{u=i+1}^{t-e} I(u) + a_1\ I(t-1) + \ldots + a_k\ I(t-k) +$$

$$+ a_{k+1}\ Y\ (t), \ldots\ldots 57$$

Thus the linear estimating equation becomes,

$$m(t)^{\frac{1}{2}} = a_o + a_I \sum_{u=i+1}^{t-e} I(u) + a_1\ I(t-1) \ldots + a_k\ I(t-k)$$

$$+ a_{k+1}\ Y(t) + a_{k+2}\ DUMM + error \ldots\ldots 58$$

where DUMM is appended to capture the effects of changes in the accounting of data; e, the lag between the current period and the period of completion is to be determined and t-k, the duration of the transitory adjustment effects, is to be determined. The a's are the coefficients to be estimated for each mode, I, of transport investment. The formulation in equation 58 assumes only one mode of transportation. When more than one mode is considered equation 58 should include one set of capital and investment terms, like the above, for each different mode, as capital and investment in different modes will, presumably, have different impacts on m.

The capital variable, $\sum_{u=i+1}^{t-e} I(u)$, was initialized with a value of zero in the period prior to the first period of data used. The value of this variable then increased monotonically. As there existed investment in transportation infrastructure for all modes and regions in the initial year, the capital variable was never equal to zero. However the capital variable was always understated by an amount equal to the actual, unknown amount of capital in place in the initial period. This constant discrepancy multiplied by the capital coefficient will be reflected in the intercept term.

The process of data accumulation for the regressions highlighted a wide dispersion of unknowns and presumptions that are implicit in the model. The theory presented in this dissertation proposes that an investment in transportation infrastructure will change a real variable, the mean and variance of lead time. This change in a real variable will then result in changes to another real variable, inventory. The change in inventory will result in a reduced cost, in dollars, to firms and that these reduced costs will flow through, via reduced prices, to consumers. These reduced prices will enhance consumption in units which is reflected in increased consumption expenditure in dollars, assuming unitary elasticity. A strict measurement of this sequence of causes and effects would entail measurement of dollar investment versus unit volume changes at infrastructure locations, unit volume changes at infrastructure locations versus average inventory holdings in regional firms, average inventory holdings in firms versus consumer prices and consumer prices versus consumer expenditure. The model bypasses a number of steps in this sequence. Thus the dollar investment in infrastructure versus dollar consumption expenditure measurement ignores vast quantities of data which could possibly be used to test the theory proposed.

5.2 Canadian Data

The allocation of dollars spent on transportation infrastructure is a decision made by governments at Provincial and Federal levels. How this allocation is made is not known. Funds could be allocated to regions on the basis of cost-benefit analyses. However studies have been done which suggest that a measure of political concern enters into the allocation decision (see Munro [50]). This political concern suggests that the allocation decision will change when governments change. The allocation of funds among the modes has also been a contentious issue. Dollars spent on Hamilton harbours and Pickering airports clearly illustrate the non-use of cost-benefit analysis. The use of dollars masks other problems. The cost to build one mile of road in British Columbia is substantially more than that required to build one mile of road in Saskatchewan. While data on regional highway construction price indices were available, and used, to mitigate this problem, it was felt that the indices themselves were highly dependent on the size and stability of the construction industry. Another concern with investments in roads is the determination of the location of benefit. Which end of the road? This is extremely difficult to isolate and would require a direct matching of investment dollars to specific road projects. This dual relationship is exacerbated for airports where the dual terminus relationship becomes a multi-terminus relationship. Therefore the data collected for a region was considered to be applicable only within the region.

An improvement in the infrastructure does not necessarily mean the benefits of the improvement will flow on to consumers. The transportation infrastructure is a device primarily for transport carriers and unless these carriers are willing and able to make use of the new or improved facility the possible benefits may remain, unavailable to the consumer. Most transport carrier markets are stringently regulated in the use of the infrastructure facilities and the time between the infrastructure improvement and subsequent change in the transport carrier market could be protracted. This regulation problem differs substantially between modes. Data on the use of infrastructures, for most modes, is available in such terms as vehicles per day, tons handled per day etc. However, there is no dollar value attached to these statistics and, usually, no indication of their origin and destination. Therefore to pinpoint the location of a dollar benefit, with that data, is not possible.

The firms who receive the benefit of the reduced mean and variance of lead time will initially reduce inventory levels. Here, again, data are available on inventory levels maintained by firms. However, these data are not available on a regional basis. They are accumulated on an industrial sector basis. Assuming that the resulting price reduction increases sales to the firm, with increasing returns to scale, the firm may make personnel, plant and warehouse changes. Data are available on employment rates, average wage rates, land purchases and industrial construction. They were not used. The costs of these changes are not directly comparable between regions. While interest rates, as a constituent part of holding costs, may be uniform throughout the country, wages, land and building costs are not. This will be reflected, for a comparable commodity, in different costs and prices per unit consumed. These differing regional characteristics are illustrated by comparing a retail sales per square foot statistic[11] for two cities; $4.50 retail sales per square foot in Toronto versus $6.20 retail sales per square foot in Calgary. These types of significant data, available on a regional basis, were not included. It was assumed that the effects of these differences would be reflected in the consumer price indices published for the major cities.

11 Data are periodically published in the Financial Post. The source given is the National Retail Merchants Association. The example reflects the case for the year 1969.

The end user in this sequence is the consumer. A reduction in prices, with the assumptions in the model, would result in a proportional increase in consumption. The constant proportion of income assumption is embedded in the planning horizon assumption. This planning horizon for firms is, usually, a fraction of a fiscal year - the time base for the data collected. The amount of the constant proportion could change between planning horizons. Consumers spend an appreciable amount of dollars on services. Infrastructure changes will reflect directly on goods alone, with the exception of travel. Conceivably the allocation of expenditure between goods and services could be isolated and relative elasticity of demand values utilized. However data for consumption expenditure, by region, were not available. A proxy had to be used that related goods and services to goods alone.

Consumers spend out of income. Consumers travel. With the dispersion of branch outlets throughout many regions the increased consumption in one region may be reflected as increased income in some other region. This provides some measure of independence for the regional income variable. The consumption expenditure dependence is similar in its open region implications. Improved infrastructure, coupled with a region's attractive features, may draw tourists which increases consumption expenditure, but through an entirely different series of cause and effect. Indeed, the improved infrastructure could induce residents to consume elsewhere. Data for tourist volumes, in and out of each region, together with average expenditures at destinations, are sampled by government agencies. These data were not used.

The model was restricted in its use of data to that which could be specified in dollar amounts allocated for infrastructure investment and available as disposable income. These dollars, weighted by appropriate regional annual indices, were the data used to reflect a proposed series of cause and effect relationships: investment in transportation infrastructure reduces costs to the firm, this reduces unit prices and consumers therefore increase consumption of units.

Twenty years of data were obtained, 1960-1979. Records and price indices prior to that time were not consistently available.

5.2.1 City Selection

Nader [51] has shown that a number of cities in Canada act as nodes for surrounding regions. However data for all those cities referenced were not available. Therefore only major cities for which data were available were included.

5.2.2 Consumer Spending

Data for consumer spending by major cities, the variable m, were not available. Neither consumption expenditure nor retail goods expenditure data were available on a city basis. Neither goods only expenditure nor goods only price indexes were directly available.

The lack of Canadian data [12] means that the theory above cannot be tested directly. However, the discussion on page 89 indicates that m rises because of a fall in the price of transportable goods relative to other goods. This can be seen by noting that in a competitive market profits will be zero so that, from equation 17,

$$P.m = CPI.C(m) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad 59$$

where C(m) is the real cost of selling m and CPI is the consumer price index. This equation shows that an increase in transportation infrastructure which increases m (and hence lowers C(m)m) does so by decreasing P/CPI. The theory will be tested for the Canadian data by using the comparative price index P/CPI as the dependent variable.

The price of transportable goods, P, data was not available directly. However, as consumer prices may be

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12 These data were, however, available for Australian cities (see 5.3) so that a direct test of the theory was available for that country.

represented using the consumer price index, it was sufficient to represent goods only prices using a goods only prices index.

A goods only price index was constructed. Market basket expenditure weights from expenditure surveys for food (without restaurant meals), clothing, housing and shelter along with the companion price indexes were obtained[13] for the major cities. A household goods price index and market basket expenditure weight was constructed for each city from the housing and shelter data series. A goods only price index was then constructed from the food, clothing and household goods data. These resulting price indexes for the cities were thus composed of predominantly goods, containing only small amounts of services expenditures from the clothing series - dry cleaning and laundry services - and from the resultant household goods series - household operation services. These resulting goods only price indexes for each city for the period 1961 to 1979 were then related to the consumer price index for each city to form a comparative price index, CPG (consumer price index, goods only) to CPI, for each city for the relevant period.

13 The market basket expenditure weights for each expenditure survey along with the price index series were provided by the Information and Current Analysis Unit, Consumer Prices Section, Prices Division, Statistics Canada.

5.2.3 Income

Since a comparative price index was used as the dependent variable, m, in the Canadian regressions, there was no need to include the income independent variable in these regressions.

5.2.4 Infrastructure Investment

5.2.4.1 Mode Aggregation

Data for capital investment in transportation infrastructure were compiled for the period 1960 to 1979, inclusive, from the Federal public accounts[14] and the Provincial public accounts[15].

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14 Public Accounts of Canada, Volume II, Details of Expenditure and Revenues, Minister of Supply and Services, Canada.
15 Public Accounts of the Province of Alberta, Alberta Treasury Department;
Public Accounts, Department of Finance, Province of British Columbia;
Public Accounts, Manitoba Treasury Department, Queen's Printer for the Province of Manitoba;
Public Accounts, Department of Finance, Government of Newfoundland;
Public Accounts, Province of New Brunswick;
Public Accounts, Department of Finance, Nova Scotia;
Public Accounts, Department of Finance, Prince Edward Island;
Public Accounts of Ontario, Provincial Auditors Office, Queen's Printer, Ontario.
Public Accounts, Department of Finance, Quebec.
Public Accounts, Department of Finance, Province of Saskatchewan;
Public Accounts, Saskatchewan Treasury Department.

Data were allocated by mode category to geographic regions. The region was defined as the province unless the item was specifically designated as investment in or adjacent to a city in which case it was allocated to that specific city and not included in the larger geographic region. The provincial investments and the city specific investments were then aggregated for each city by category (see §5.2.5). The categories included: road investment included road construction and upgrading, highway bridge construction and railroad grade crossing improvements; harbour investment included harbour construction, ferry terminal construction, canals, locks and waterways construction; air investment included airport runway construction, air-tower equipment and air-terminal construction. Transportation capital investment of an infrastructure character alone was used, where infrastructure has been defined as an immobile facility constructed to service or to be utilized by mobile transport carriers. For example, ferry terminal construction was used whereas new ferry purchases were not used; road construction and upgrading was used whereas road maintenance was not used. The data were taken directly from published public accounts and converted to constant 1961 dollars using government provincial price indices[16] for highway construction.

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16 Statistics Canada, Prices and Price Indices, 62-002.

5.2.4.2 Federal Data

5.2.4.2.1 Roads

Federal expenditures on highways were listed in the Public Accounts under a variety of categories and programs. A grade-crossing subsidization program has existed for a number of years which provides capital to provinces for the improvement of railroad highway crossings. National Parks and territory highway construction and upgrading were shown as well as bridge construction over navigable waterways and at international boundaries. Federal-Provincial agreements, which included funds for highway construction, were listed under a variety of programs: Trans-Canada highway construction, grants for northern Provincial development, and DREE and FRED programs. While the Federal accounts clearly show the capital nature of the grants, it was not clear in all of the Provincial accounts that these monies had not been used, at least partially, for right-of-way appropriation.

5.2.4.2.2 Harbours

The accounts clearly distinguished categories of expenditure with descriptions, e.g. acquisition of land, consulting fees, etc. and only construction expenditures were used. An exception was made for dredging. This category was included as the dredging process enlarges harbour and waterway capacity as well as maintaining the facility. The distinction between the enlargement and maintenance purposes was not given in the accounts. However, this data set was the least accurate of all data sets. Harbour data, since the establishment of the National Harbours Board as an independent authority, have became much less accessible. Prior to the Board becoming relatively autonomous, harbour expenditures were listed by type, category and location. During the transition period and since the Board has become autonomous, capital expenditure items were not listed individually. The exceptions were for mega-projects where Parliament had explicitly approved specific funds. But even here the timing of the expenditure of the approved funds was not published. Authorized expenditures were not utilized, only recorded actual expenditures.

5.2.4.2.3 Airports

These data were not consistently defined in the Public accounts. Expenditures on appropriation of right-of-way were not consistently isolated. As well, large expenditures for electronic and navigation purposes, which make substantial differences to the capacity and operation of an airport facility were, mostly, appropriated to a head-office account which did not allow for allocation on the basis of location.

Municipal subsidies for annual operating expenditures were clearly shown, but no municipal grants for municipal airport construction or expansion were found. It was not reasonable to assume that municipal authorities did not ask for and receive Federal assistance.

5.2.4.2.4 Urban Transit

Recently, Federal funds have been available to municipalities for the development of major urban transportation systems. For the purposes of this study these funds were allocated to the road classification.

5.2.4.3 Provincial Data

Most Provincial accounts have changed radically over the past twenty-five years: in the manner of accounting - from financial accounting to planned program budget systems; in the manner of departmentalization - from road construction being done in a number of departments (public works, highways, forests) to the creation of a transportation department; in the manner of politicization - from a responsible government department where each and every expenditure was listed for public scrutiny to the creation of crown corporations, agencies, boards and authorities where expenditures are lumped together without description and are not available for public review.

Most certainly, many items were missed where they were not clearly or consistently reported. Some provinces do not report right-of-way appropriation separately from construction, thus these provinces appear to have higher expenditures. Where provinces have created crown corporations, boards or agencies or, in some cases, have purchased or expropriated private transport companies, the capital expenditures on infrastructure were obscured. By and large, the Provincial capital grants to municipalities for urban transit or major highway access were vague. Usually the recipient city was not named and the mode was not specified. Therefore the investment data from Provincial accounts were understated.

5.2.4.4 City Data

Numerous attempts were made to obtain access to city data on transportation infrastructure investment made by cities. While data sources are, no doubt, in the National Library, no data set was readily available for all, or even most, of the cities selected. Requests to municipal clerks of these cities for copies of the data were rejected by all except two, on the grounds of cost of reproduction. Therefore no investment data for specific cities were used except where it was specifically labelled in federal or provincial sources.

5.2.5 Data Aggregation

Data files were constructed for each city by mode. Each city was viewed as a regional node and it was assumed that any modal investment within that city's region would impact on the city (see Nader [51]). Therefore each city data file was the sum of provincial and federal investments plus city investments. Where there existed more than one selected city within the same province, each city data file would reflect similar investments. For example, in road investment the Calgary road sum equalled Calgary municipal expenditure plus provincial Alberta expenditure less explicit Edmonton expenditure plus Federal Alberta expenditure less explicit Edmonton expenditure, and the Edmonton sum equalled Edmonton municipal expenditure, plus provincial Alberta expenditure less explicit Calgary expenditure, plus Federal Alberta expenditure less explicit Calgary expenditure. That is, each city was considered the node for the entire provincial region.

Apparently anomalous situations resulted. Substantial harbour investments are shown for Manitoba, Quebec and for the Ottawa-Hull area. Aside from Lockport, Manitoba and flood avoidance investment on the Red River, it was assumed and frequently stated in the accounts that the harbour investment was in Churchill, Manitoba. Churchill is within the Winnipeg hierarchical region and, therefore, the impact of the investment was assumed to be felt at the regional node, Winnipeg. The assumption was that the city region was comprised of a network of transportation and that investment within the network would impact on the city. This was very evident in the case of Ottawa-Hull. Substantial harbour investments were catalogued for that city, yet no harbour, per se, exists.

As the nation is a network of interconnected regions, where a region may be defined on a variety of community of interest criteria, investment in one region may very well affect a city node in an adjacent region or, indeed, a city node in a far distant region. The number of permutations and combinations of investment and city node were too extensive to estimate beyond the individual pairing of investment and impact within the provincial geographic region.

5.2.6 Omissions and Errors

5.2.6.1 Omissions

The rail mode was not included in this data set. While data were at hand for the capital investment by the two major operators for the period, no reasonable assumption could be made to allocate these sums to the provinces or cities under consideration. Its omission introduced those errors ascribed to missing regressor variables.

The interest rate was assumed to be a component of the holding cost, h, in the analysis. However this variable was assumed to be the same for each city in any one time period. Its omission also introduced those errors ascribed to missing regressor variables.

The assumption was made that the depreciation of transportation infrastructures was negligible for short and intermediate time horizons. This is incorrect. These facilities do deteriorate with time and use. This deterioration will have an effect on the users of the facilities. However, these facilities are maintained. If it is assumed that the amounts allocated for maintenance of the facilities is sufficient to maintain them at their original service levels, then the original capital investment in the facility will reflect that service level. No maintenance data were used in this study. It is assumed that these two omissions will offset each other. If maintenance exceeded depreciation of service then the capital and investment variables are understated and the coefficients for these variables will be overstated in magnitude. If maintenance was insufficient to maintain the service level of the facilities, then the variables are overstated and the coefficients for these variables will be understated in magnitude.

There is no question that the data for investment in harbour infrastructures is understated for a number of recent periods when the National Harbours Board produced financial reports separate from the Federal Department of Public Works. Therefore the variables for those regressions will be understated and the coefficients for these variables will be overstated in magnitude.

5.2.6.2 Errors

All efforts were made to transcribe data correctly. Errors in the data exist where expenditures on the transfer of ownership were not isolated in the accounts. This introduced an overstatement into the investment data. This overstatement was diminished by the data unavailable from crown corporations, agencies and boards. Funds from senior governments allocated to junior governments may not have been consistently utilized on specified mode infrastructure.

5.2.7 Dummy Variable

The number of census tracts defining a metropolitan city was changed by Statistics Canada on two occasions. The changes were not uniformly carried out in the same time periods for each city. As well, some cities were unaffected. A dummy variable with arbitrary scales (see Dutta [25]) was introduced for the affected cities to capture these changes. This method was used to minimize the number of regressor variables.

Table 1.

City Dummy Variable Values

Period	Value of Dummy variable
initial period until first change	0
from first change until second change	1
from second change until terminal period	2

Major changes were made to the Consumer Price index midway during the period selected. A second dummy variable; valued at 0 before the change and 1 after the change was introduced to try to capture any effect.

5.3 Australian Data

The difficulties encountered in the compilation of the Canadian data set did not occur for the Australian data set. This meant that it was possible to directly estimate equation 58 for Australia, unlike the Canadian case where it was necessary instead to test an implication of this equation.

The Australian economic structure is very similar to the Canadian structure. Both economies are primarily export-led economies. Both economies display widely dispersed urban areas supporting and supported by large hinterlands. The allocation of public resources in each country is determined by similar government structures operating under very comparable conditions (see Sproule-Jones [64]). However, the Australian constitution differs from the Canadian in that the transportation responsibility is a State responsibility in Australia. As a result of this difference and a differing data collection history of the Australian Bureau of Statistics, an Australian data set could be related more directly to the variables in the model. A data set was compiled for the period 1971-1972 to 1980-1981 inclusive. Goods only price indexes prior to this interval were not available.

5.3.1 City Selection

Data for only the six Australian State capital cities were available.

5.3.2 Consumer Spending

Private Final Consumption Expenditure data on goods, the variable m, were available for each State capital city.[17] As well, the Australian Bureau of Statistics has,

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17 The Private Final Consumption Expenditure data is available explicitly stating expenditures for; Food, Cigarettes and tobacco, Alcoholic drinks, Clothing etc., Health, Dwelling rent, Gas, Electricity and fuel, Household durables, Books, papers, artist's goods, All other goods, Travel and communication and All other services. Health, Dwelling rents, Travel and communication and all other services were not included in the total utilized. The data is published in: Australian National Accounts, National Income and Expenditure, catalogue 5204.0, Australian Bureau of Statistics, Canberra, Australia.

since September 1974, compiled a consumer goods-only price index for each State capital city.[18] These data were used to obtain a deflated consumer goods expenditure dependent variable, m, for the periods 1973-1974 to 1980-1981 inclusive.

5.3.3 Income

Household disposable income for each State capital city for the relevant period was obtained[19] and converted to constant 1980-1981 dollars using the consumer price index.[20]

5.3.4 Infrastructure Investment

Data for capital investment in transportation infrastructure were available[21] for the rail, road, inter-urban and sea (harbour) modes for the relevant periods. Data were available by mode and by State and classified as expenditure on new fixed assets. These data were not comparable to the Canadian infrastructure data. In the Australian case the expenditure applies only to the public sector and includes maintenance and acquisition of large transport carriers.

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18 Unpublished data, Australian Bureau of Statistics, Perth, Australia.
19 Op. cit.
20 Op. cit.
21 State and Local Government Finance in Australia, catalogue 5504.0, Australian Bureau of Statistics, Canberra, Australia.

The capital investment data were deflated to a 1980-81 base using a variety of price indexes; the road investment data were deflated using a specific road construction price index,[22] the harbour investment data were deflated using the national implicit price deflator[23] and the rail and inter-urban investment data were deflated using a special series construction index.[24]

5.3.5 Data Aggregation

As all Australian data were published by city or state, no aggregation of data was required. All data sources stated that the appropriate Federal, State and/or municipal data had been included.

5.3.6 Omissions and Errors

5.3.6.1 Omissions

The air mode was not included in this data set. While data were available for the economy as a whole, no reasonable method was readily available to allocate the expenditure by region.

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22 BTE Road Construction Price Indexes: 1973-74 to 1983-84, Information Paper 12, Bureau of Transport Economics, Australian Government Publicity Service, Canberra.
23 Australian National Accounts, op. cit.
24 Price Indexes of Materials used in Building other than Housing, catalogue 6407.0, Australian Bureau of Statistics, Canberra Australia.

The majority of infrastructures are in the public domain. However there exist numerous facilities, for all modes, that are in private hands. These data were available for the whole economy but, again, no method was available to disaggregate these data.

5.3.6.2 Errors

There exists an error within each investment data set. While the transportation function is constitutionally a State responsibility, the Federal government has recognised the benefits accruing to the transportation network by the addition and upgrading of regional portions of that network. Consequently the Federal government has partially funded numerous State transportation infrastructures. However the method of funding has been in the form of a long-term loan to the particular state. While the appropriate annual expenditure is clearly included for the mode investment in the relevant time period, the reported expenditure is on a net basis, i.e. minus the required annual loan repayments for previous Federally funded projects. There existed no method to capture the amounts of all such repayments.

5.4 Estimation Procedures

5.4.1 OLS Procedure

While the Canadian data set of twenty years appeared to be large, the number of coefficients (8 to 12) plus the lagged variables (2 or 3) reduced the degrees of freedom to a minimal level (5 to 10). This restriction limits the usefulness of an OLS procedure except for the purposes of obtaining a residual matrix as data for a GLS procedure and for a preliminary check on the possibility of reasonable results. The lack of degrees of freedom limited the choice of the number of investment periods to a maximum of two. The Australian data set of ten years exacerbated the degrees of freedom restriction. This necessitated that each mode be regressed individually for the Australian data set.

The number of periods of lag, e, and the initial period, i, were unknowns to be determined by experimentation. Because of the lack of degrees of freedom, little leeway existed for that experimentation. Therefore two intervals were used. The first lag interval tried was no lag at all; i.e. e=o, this was designated as Level A. The second lag chosen was that of a one-period lag, e=1, this was designated as Level B.

There existed two choices in the introduction of the transitory investment effect. The first option was to assume that the transitory effect would occur after the capital variable effect. This formulation was designated as case 2. However this choice appeared to specify the capital variable as being related to an old infrastructure with investments being made later in time. It did not relate directly to any 'new' infrastructure variable. Therefore the second choice, the transitory effect occurring before the capital variable effect, was formulated as case 1. These cases are summarized as:

Table 2.

CLASSIFICATION OF REGRESSIONS

CLASSIFICATION	VARIABLE	
	most recent	extended
Case 1, Level A	I(t) I(t-1)	$\sum_{1960}^{t-2}$ (SUM)
Case 1, Level B	I(t-1) I(t-2)	$\sum_{1960}^{t-3}$ (SUM)
Case 2, Level A	$\sum_{1960}^{t}$ (SUM)	I(t-1) I(t-2)
Case 2, Level B	$\sum_{1960}^{t-1}$ (SUM)	I(t-2) I(t-3)

Therefore a typical Case 1, Level B regression for the Canadian data set will encompass the periods as shown in Table 3.

Table 3

REGRESSION PERIODS

variable	PERIODS initial	final
$m(t)^{\frac{1}{2}}$	1963	1979
y(t)	1963	1979
I(t-1)	1962	1978
I(t-2)	1961	1977
$\sum_{1960}^{t-3}$ (SUM)	1960	sum 1960 to 1976

A single equation OLS regression was performed on each set of city data for each mode, each case and each level.

The dependent variable, m, in the Canadian data set was regressed as (CPG/CPI). Thus the expectation of a positive relationship between investment in transportation infrastructure and consumer expenditure in the Australian data regressions could be constrasted with the expectation of a negative relationship between investment in transportation infrastructure and the constructed comparative price index, goods-only price index to consumer price index, in the Canadian data regressions.

5.4.2 Zellner Procedure

Maddala [46] and Judge et al. [38] provide descriptions of a variety of regression techniques which may be used when there exist a number of similar equations. Two appropriate models are the variance-component model and the Zellner seemingly unrelated regression model. The variance-components model assumes the intercepts of the equations are random variables and that the expected value of all the intercepts will be zero. The type of correlation that would arise in this model is one where each cross-section unit has a specific time invariant variable omitted from the equation. The use of this model is inappropriate if an examination of the OLS regression for the single equations shows a systematic pattern in the values for the intercepts. As the intercept term for each equation in this study will include the effect of the value of the capital in place in infrastructure prior to the regression period, the use of the variance-component model is inappropriate. In the Zellner seemingly unrelated regression model, the residuals are uncorrelated over time but correlated across equations. This type of correlation would arise if there are some omitted variables that are common to all equations. This method is appropriate only if the residuals are generated by a true multivariate distribution. Footnote 4 (page 47), that the demand distribution during lead time is really a multivariate distribution, is now relevant. The assumptions of the Zellner model are appropriate for this study and in this case, in addition to the omitted interest rate variable, there existed any number of macroeconomic variables that could affect the dependent variable. Malinvaud (see Theil [67]) recommends a Zellner seemingly unrelated regressions procedure for investigation of the same relation over different units for which observations relating to a series of periods are available. He also notes that there exist no a priori restrictions on the coefficients with the procedure. Zellner [75, p349] visualized a number of applications of the procedure including; "a fourth application is to regression equations in which each equation refers to a particular classification category and the observations refer to different points in space".

The Zellner procedure involved the grouping of equations to be estimated simultaneously. The procedure obtains its gain in efficiency by the utilization of an Aitken's GLS procedure (see Zellner [75]) which takes into account the fact that cross-equation error correlation may not be zero. The procedure enhances the degrees of freedom by the stacking of the equations. Thus the degrees of freedom for the system of equations is the sum at the degrees of freedom from each equation. The procedure is a two-stage estimation procedure. OLS is applied to each equation and the computed residuals are utilized to estimate the contemporaneous variance-covariance matrix of the error vector in the system of equations. If the cross-equation residuals are uncorrelated, then the estimation reduces to an OLS estimation of each equation. In this study equations for each city for the same case and level were grouped together for estimation. A computer econometric package, TROLL (see Belsley [10]), was used to perform the estimations.

The number of equations used in the GLS procedure was twelve for the Canadian data set and six for the Australian data set.

6.0 ANALYSIS OF RESULTS

6.1 OLS Regressions

The residuals of the OLS regressions were utilized by the computer package only as input for the GLS routine. Therefore the OLS regressions are not reported here.

6.2 GLS (Zellner) Regressions

The GLS regressions were done with the two independent data sets. The results of the GLS regressions on the Canadian data set are shown in Appendix 1 and those of the Australian data set in Appendix 2. The results of each set of GLS regressions were analyzed separately.

6.3 GLS Statistical Results

The statistical results appearing in the appendices show 't' values beneath each coefficient. The 't' values may be used in two-tailed tests, different from zero, for one level of significance or in one-tailed tests, greater or less than zero, at a higher level of significance.

As in evident from a review of the Appendices a large number of statistically significant results (at the 5% level) were obtained. While the primary objective of the regressions was to examine the relationship between investment in transportation infrastructure and consumption, there exist a number of categories within the individual country data sets that are of interest. It could be postulated, from a variety of sources, that the relationship between investment in transportation infrastructure and consumption should vary by mode, by region, by learning (lag-level) or by the state of the existing infrastructure. In order to examine the regression results obtained within these categories a simple chi-square statistical test was done. Using the observed frequency of statistically significiant results, these results were aggregated by category and a contingency test was done. The null hypothesis, Ho, was made that the observed sign of the coefficient on the regressor variable was independent of the category (mode, region, case, level). The results of the regressions are shown in the following sections as well as the results of the contingency tests on the statistically significant results.

6.4 Intercept Coefficient

The significance test results for the Canadian data set are not shown as all regressions yielded significant positive values for the intercept coefficient. The Australian data set regression results are shown in Table 4.

Table 4

NUMBER OF GLS, INTERCEPT

SIGNIFICANT RESULTS : AUSTRALIAN DATA

	CASE AND LEVEL				SUM
Road Mode	1A	2A	1B	2B	
positive sign	3	2	4	5	14
negative sign	2	2	1	1	6
Total	5	4	5	6	20
Harbour Mode					
positive sign	3	2	5	6	16
negative sign	1	2	0	0	3
Total	4	4	5	6	19
Urban Mode					
positive sign	1	2	6	5	14
negative sign	1	1	0	0	2
Total	2	3	6	5	16
Rail Mode					
positive sign	5	4	6	6	21
negative sign	1	2	0	0	3
Total	6	6	6	6	24
All Modes					
positive sign	12	10	21	22	65
negative sign	5	7	1	1	14
Total	17	17	22	23	79

The intercept coefficient was statistically significant (at the 5% level) in all of the forty-eight instances in the Canadian GLS regressions and in seventy-nine of the ninety-six instances (82.3%) in the Australian GLS regressions.

The expectation for the Canadian GLS regressions was that the intercept coefficient would be positive and equal to one. The dependent variable, m, in these regressions was the comparative price index (CPG/CPI) and in the absence of any regression is positive and equal to one. Two factors were expected to contribute to any variation in this value. The capital variable was initially set to zero and was expected to be understated by the value of the existing capital and the value of the intercept coefficient was expected to be modified by this unknown capital amount multiplied by the value of the capital coefficient. But this modification of the value of the intercept coefficient was expected to be compensated by the depreciation of the infrastructure which was not quantified in the data. This expectation was realized.

The expectation for the Australian GLS regressions was that the intercept coefficent would be positive. In these regressions the dependent variable, m, was consumer expenditure. The two uncaptured capital amounts, initial value and depreciation, were expected to compensate each other resulting in a zero net effect. The Australian regression equation could be viewed as an augmented consumption function and, therefore, the intercept coefficient was expected to be positive. This expectation was not realized.

The Australian GLS regressions exhibited both positive and negative values for the intercept coefficient. A contingency test was done on these results to determine if the observed frequency of the number of negative sign occurrences on the intercept coefficient was independent of the level (lag) of regression. That is by aggregating the sign counts by level A; the regressions where the current period is used for the stock and flow independent regressors versus level B, a one-period lag for these regressors, the contingency test showed (at a level greater than 1%) that the null hypothesis, of sign and level being independent, cannot be accepted.

The Australian data set was limited to ten years, one-half the length of time of the Canadian data set. Assuming that transportation infrastructures are viable over long periods of time and given the result of the contingency test on the regressions of different time intervals it is concluded that the incidence (14/79) of statistically significant negative values for the intercept coefficient is not meaningful and simply reflects the combination effect of the uncaptured initial values of capital in place and the uncaptured depreciation.

6.5 Income Coefficient

As indicated (§5.2.3) the income regressor was not used in the Canadian data regressions.

The income coefficient was significant in seventy of the ninety-six instances (72.9%) in the Australian results. The expectation for this coefficient was to observe a positive sign, as postulated by economic theory. The significant results of the regression on the Australian data set are shown in the following table.

Table 5

NUMBER OF GLS, INCOME

SIGNIFICANT RESULTS : AUSTRALIAN DATA

	CASE AND LEVEL				SUM
Road Mode	1A	2A	1B	2B	
positive sign	6	6	1	1	14
negative sign	0	0	1	2	3
Total	6	6	2	3	17
Harbour Mode					
positive sign	6	6	1	2	15
negative sign	0	0	2	2	4
Total	6	6	3	4	19
Urban Mode					
positive sign	6	6	2	2	16
negative sign	0	0	0	0	0
Total	6	6	2	2	16
Rail Mode					
positive sign	6	6	2	2	16
negative sign	0	0	1	1	2
Total	6	6	3	3	18
All Modes					
positive sign	24	24	6	7	61
negative sign	0	0	4	5	9
Total	24	24	10	12	70

Most coefficient signs (61/70) on the income variable were positive. However all of the statistically significant negative signs occurred in regression levels B. A contingency test of the null hypothesis, that the observed frequency of sign was independent of level of regression, cannot be accepted at a level greater than 1%.

6.6 Dummy Coefficients

6.6.1 City Dummy Coefficient

The coefficient on the city dummy variable was significant in twenty-five of thirty-two instances (78.1%) in the Canadian data regressions. In three instances mixed signs were displayed among the regressions; Vancouver, Toronto and Montreal.

6.6.2 Consumer Price Coefficient

The coefficient on the consumer price dummy variable was significant in twenty-nine of forty-eight instances (60.4%) in the Canadian data regressions. In three instances mixed signs were displayed among the regressions; Toronto, Montreal and St. John N.B.

6.7 Infrastructure Coefficients

6.7.1 Capital Coefficient

For the Canadian data regressions the expectation was formed that the sign on the capital coefficient would be negative. Increased capital in transportation infrastructure would lower lead time, lower lead time would reduce costs to firms and reduced costs to firms would result in lower prices. The frequency and sign of significant coefficients on the capital variable in the Canadian results are shown in Table 6.

Table 6

NUMBER OF GLS, INFRASTRUCTURE

SIGNIFICANT RESULTS : CANADIAN DATA

	CASE AND LEVEL				SUM
Road Mode	1A	2A	1B	2B	
positive sign	5	5	6	4	20
negative sign	5	3	4	4	16
Total	10	8	10	8	36
Harbour Mode					
positive sign	4	5	5	5	19
negative sign	3	3	2	2	10
Total	7	8	7	7	29
Air Mode					
positive sign	2	1	1	3	7
negative sign	5	6	4	6	21
Total	7	7	5	9	28
All Modes					
positive sign	11	11	12	12	46
negative sign	13	12	10	12	47
Total	24	23	22	24	93

A number of contingency tests were completed among a variety of subsets from Table 6 and the tests and results are shown in Table 7.

Table 7

CONTINGENCY TEST RESULTS

CANADIAN INFRASTRUCTURE

(Ho : independence between variables)

TEST	RESULT
Sign and Case	cannot reject Ho
Sign and Level	cannot reject Ho
Sign and Mode	reject Ho at 1% level
Sign and Mode	
by Case 1	reject Ho at 10% level
by Case 2	reject Ho at 10% level
Sign and Mode	
by Level A	reject Ho at 10% level
by Level B	reject Ho at 10% level
CENTRAL REGION (Toronto, Ottawa, Montreal)	
Sign and Case	cannot reject Ho
Sign and Level	cannot reject Ho
Sign and Mode	reject Ho at 2½% level
HINTERLAND REGION (all others)	
Sign and Case	cannot reject Ho
Sign and Level	cannot reject Ho
Sign and Mode	cannot reject Ho

For the Australian data set the expectation was formed that the sign of the capital coefficient would be positive. Increased capital in transportation infrastructure would lower lead time, lower lead time would reduce cost to firms, reduced cost to firms would result in lower prices and lower prices would increase consumption. The frequency and sign of significant coefficients on the capital variable in the Australian results are shown in Table 8.

Table 8

NUMBER OF GLS, INFRASTRUCTURE

SIGNIFICANT RESULTS : AUSTRALIAN DATA

	CASE AND LEVEL				SUM
Road Mode	1A	2A	1B	2B	
positive sign	0	0	3	3	6
negative sign	4	6	1	1	12
Total	4	6	4	4	18
Harbour Mode					
positive sign	1	1	3	4	9
negative sign	4	4	0	0	8
Total	5	5	4	4	17
Urban Mode					
positive sign	1	0	3	3	7
negative sign	4	4	1	1	10
Total	5	4	4	4	17
Rail Mode					
positive sign	2	1	5	5	13
negative sign	4	4	1	1	10
Total	6	5	6	6	23
All Modes					
positive sign	4	2	14	15	35
negative sign	16	18	3	3	40
Total	20	20	17	18	75

A number of contingency tests were completed among a variety of the results from Table 8 and those tests and results are shown in Table 9.

Table 9

CONTINGENCY TEST RESULTS

AUSTRALIAN INFRASTRUCTURE

(Ho : independence between variables)

TEST	RESULT
Sign and Case	cannot reject Ho
Sign and Level	reject Ho at 1% level
Sign and Mode	cannot reject Ho
Sign and Mode	
by Case 1	cannot reject Ho
by Case 2	cannot reject Ho
Sign and mode	
by Level A	cannot reject Ho
by Level B	cannot reject Ho
EASTERN SEABOARD REGION	(Sydney, Melbourne, Brisbane, Hobart)
Sign and Case	reject Ho at 1% level
Sign and Level	cannot reject Ho
Sign and Mode	cannot reject Ho
HINTERLAND REGION (Adelaide, Perth)	
Sign and Case	reject Ho at 1% level
Sign and Level	cannot reject Ho
Sign and Mode	reject Ho at 5% level

The sign expectation for the coefficient on the capital variable was not realized. The GLS regressions on both the Canadian and Australian data yielded a number of statistically significant signs on the capital coefficient that were the reverse of that postulated. The reversed coefficient implies that $dm/dk < 0$ ($dp/dk > 0$) exists as a significant relationship between consumption (price of goods) and change in capital in transportation infrastructure. That is, for a large number of major cities in both Canada and Australia the investment in transportation infrastructure is providing a negative return in the form of reduced consumption (Australia) or higher prices (Canada).

These results, of a significant number of contra-indicated signs on the coefficient of the capital variable, require exploration. Three possible characteristics are evident from the regression results and the model: a characteristic common to certain cities, a characteristic common to each regression type or a characteristic of the underlying model. Each of these will be examined.

In the Canadian results the sign on the capital coefficient may be segregated by city and is illustrated in the following table.

Table 10

SIGNIFICANT CAPITAL COEFFICIENT SIGN:

CANADIAN CITIES, BY MODE

(NUMBER OF SIGNIFICANT INSTANCES)

CITY	ROAD	HARBOUR	AIR
Vancouver	+(3)	-(3)	+(2)
Montreal	+(4)	-(4)	-(4)
Halifax	+(3),-(1)	+(4)	-(3),+(1)
St. John's	+(3)	+(1),-(2)	-(4)
Winnipeg	-(3)	+(1),-(1)	+(2),-(1)
Toronto	-(4)	+(4)	-(1)
Ottawa	-(3)	+(4)	-(3)
St. John N.B.	-(4)	+(4)	+(2)
Edmonton	-(1)		+(1)
Calgary	+(4)		-(3)
Saskatoon	+(3)		-(2)

With few exceptions, the case and level regressions were consistent for each city. Aggregating cities using a variety of available criteria; central region versus hinterland, deepsea port versus inland port versus no port, failed to yield statistical significant differences using the contingency analysis technique. The remaining explanation, within the scope of this model and data analysis, is to postulate that the different cities reflect their individual positions as demanders or suppliers of goods as outlined in previous sections (S4.1). Their positions in this respect could provide an explanation for the results obtained in the Canadian data regressions. However, this explanation does not follow through to explain the similar sign disparity in the Australian data regression results.

The contingency test by level and sign on the Australian regression results clearly indicates that when the independent capital or investment regressor variable was of the current period then the sign on that regressor variable coefficient was negative. Conversely when the independent regressor was lagged one period the sign on the regressor variable coefficient was positive. This would suggest that there exists a one period lag between capital or investment in transportation infrastructure and benefits becoming apparent. The negative sign in the current period regressions could imply either a disruptive influence in the goods-transportation network or a reduction of available consumption dollars in the case of investment in transportation infrastructure in the current period. Both these explanations would support the regression results but the explanations do not follow through to explain the similar sign disparity in the Canadian data regression results.

A third explanation for the number of reversed sign results in the regressions on both data sets requires a re-examination of the underlying model. Consider the differentiation of the equation obtained from the substitution of equation 33 into equation 20.

$$dm/dK = - \frac{[mdD/dK + (hK_2 m^{\frac{1}{2}} f'(K(t-e))/2[f(K(t-e))]^{\frac{1}{2}})]}{[D + (hK_2[f(K(t-e))]^{\frac{1}{2}} + (2hK_1)^{\frac{1}{2}})/2m^{\frac{1}{2}}]} \quad .....60$$

Then dm/dK > 0 if and only if,

$$dD/dK < - hK_2 \; f'(K(t-e))/2m^{\frac{1}{2}} \; [f(K(t-e))]^{\frac{1}{2}}, \quad .....61$$

dm/dK = 0 if and only if,

$$dD/dK = - hK_2 \; f'(K(t-e))/2m^{\frac{1}{2}} \; [f(K(t-e))]^{\frac{1}{2}}, \quad .....62$$

and dm/dK < 0 if and only if,

$$dD/dK > - hK_2 \; f'(K(t-e))/2m^{\frac{1}{2}} \; [f(K(t-e))]^{\frac{1}{2}}, \quad .....63$$

It is seen that the sign on the capital coefficient, when regressed against consumption expenditure, can be negative only if the ratio of the increase in unit landed cost to the increase in transportation investment exceeds a parameter $S_t E_K$, where,

$$S_t = hSS/2mL, \quad .....64$$

and $$E_K = -f'(K(t-e)), \quad .....65$$

Since it is assumed that any investment in transportation infrastructure will enhance the efficiency of the infrastructure, E_K will be positive and lead time will be reduced, resulting in reduced costs to the firm. As holding costs, safety stocks and mL are positive, S_t

will be positive. Since dm/dK has been seen to be predominantly negative in the Australian data regression results and inferred to be negative in a large number of cases in the Canadian data regression results it should be inferred that unit landed cost has increased by such an amount as to increase the expected average costs to the firm more than the decrease in those expected average costs resulting from the reduction in lead time. This is interpreted as meaning that the benefits obtained from the improvement in transportation infrastructure have resulted in increased prices either to or from the transport carriers which are passed through to the firm and then to consumers. Thus a change to the capital in transportation infrastructure has two effects. The first effect is the lead time effect. The second effect is the transport price effect. The change in capital in transportation infrastructure has induced a price increase either to the transport carrier as a user fee or from the transport carrier to the firm as a value-added fee.

The result of $dm/dK < 0$ and $dD/dK > 0$ has a significant impact and implication for the firm. Differentiation of the expected average cost equation of the firm yields,

$$C_K(m) = (D + (hK_2[f(K(t-e))]^{\frac{1}{2}} + (2hK_1)^{\frac{1}{2}})/2m^{\frac{1}{2}})\,dm/dK$$
$$+ m\, dD/dK$$
$$+ hK_2 m^{\frac{1}{2}}\, f'(K(t-e))/[f(K(t-e))]^{\frac{1}{2}}2, \qquad \text{.............66}$$

Since $dm/dK < 0$ and $dD/dK > 0$ then

$$C_K(m) = 0, \qquad \text{......67}$$

which has a solution with $m>o$

and therefore the expected average cost equation of the firm exhibits a minimum. Thus the firm is able to enhance its profit position in a competitive environment by the use of a quantity adjustment rule.

It can be seen that equation 66 is a cubic equation in $m^{\frac{1}{2}}$ and is illustrated in the following figure.

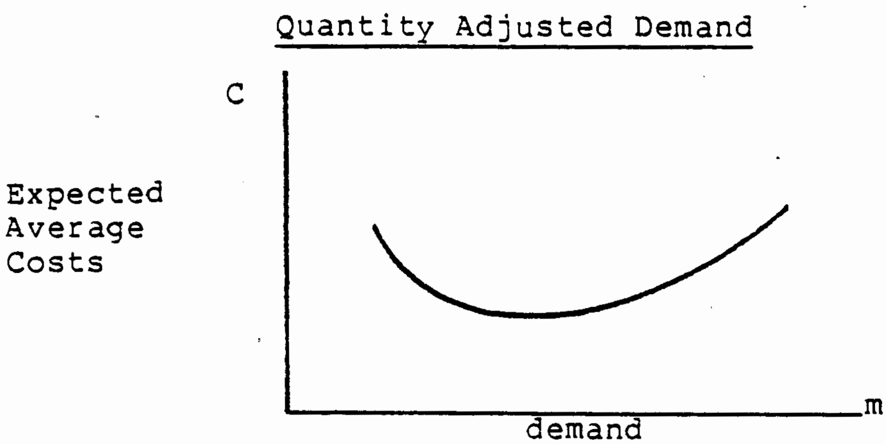

Figure 20

Not only is investment in transportation infrastructure providing a negative effect on consumption, $dm/dK < 0$, but the condition required for this to occur, $dD/dK > S_t \, E_K$, while maintaining credibility in service level improvement, $f'(K) < 0$, results in a situation where firms in a number of Canadian and Australian cities may profitably employ a quantity adjustment rule.

6.7.2 Investment Coefficient

The coefficient of the investment variable in the Canadian data regressions was significant in one hundred and fifty-two of the two hundred and fifty-six instances (59.4%) and significant in the Australian data regressions in one hundred and thirty-seven of one hundred and ninety-two instances (71.4%).

An attempt was made to find patterns of consistency among; the two data sets, five modes, eighteen cities and four regressions. As each regression restricted the number of investment variables to two per mode - the degree of freedom restriction - the capital variable coefficient was utilized to obtain three successive points in time for a graphical analysis of the coefficients. Given the disparate results of the signs between level A and level B in the Australian data regressions, each regression was reviewed separately. As well the Australian data regressions were done separately by mode. This introduced a bias not found in the Canadian data regressions. Therefore the graphical evaluation of the coefficients was done on a mode basis. The graphical evaluation revealed five consistent patterns. Pattern one was a 'zero effect' pattern where the coefficients differed minimally from zero and plotted as a straight line. Pattern two was an inverted 'V' and pattern three was a 'V'. Pattern four exhibited increasing values for the sequential coefficients in prior time, an upward rising pattern. This pattern suggests that the most current regressor provides the least positive effect on the dependent variable. The last pattern, pattern five, portrayed a downward falling sequence of coefficient values. The last coefficient value could be positive or negative as there was no constraint on this pattern to conform to a 'diminishing to zero' criteria.

6.7.2.1 Road

All five patterns were exhibited when the three regressor coefficients were graphed for this mode. The cities exhibiting this pattern are shown, by regression, in the following table. Underlined cities indicate that all three coefficients were significant, the bracketed value indicates the number of significant coefficients (maximum 3).

Table 11

PATTERN 1 - STRAIGHT LINE

CASE AND LEVEL

1 A	2 A	1 B	2 B
Sydney	Perth	Toronto	Melbourne
Vancouver (2)	Melbourne	Brisbane	Toronto
Toronto(2)	Sydney (2)	Montreal (1)	Montreal
Montreal (2)	Toronto(2)	Ottawa (1)	Ottawa
Ottawa (1)	Montreal (2)	Melbourne (1)	Brisbane
	Ottawa (2)	Sydney (0)	Sydney (0)
	Vancouver (1)		
	Edmonton (0)		

It is noticeable that this table contains, almost exclusively, the largest metropolitan areas.

The next two patterns noticeable were those of an inverted 'V' and 'V' shapes. Those cities exhibiting those patterns are shown in the following two tables.

Table 12

PATTERN 2 - INVERTED 'V'

CASE AND LEVEL

1	2	1	2
A	A	B	B
Saskatoon	Adelaide	Winnipeg	
Winnipeg	St John NB	Hobart	
Calgary(2)		Perth	
Edmonton(2)		Halifax(2)	
Perth(1)		Regina(2)	
Regina(0)		Saskatoon(2)	
		St John NB(2)	

Table 13

PATTERN 3 - 'V'

CASE AND LEVEL

1	2	1	2
A	A	B	B
Halifax	Brisbane	St John's Nfld(2)	Adelaide(2)
Hobart	St John's Nfld	Calgary(1)	Edmonton(1)
Brisbane(2)	Halifax(2)	Edmonton(1)	
	Regina(2)	Adelaide(0)	
	Saskatoon(2)		
	Calgary(1)		

With the exception of Pattern 4, Regression Case 2 level B, these two patterns contain the balance of the cities in the data sample. The remaining two patterns are shown in the next two tables.

Table 14

PATTERN 4 - UPWARD RISING

CASE AND LEVEL

1 A	2 A	1 B	2 B
Melbourne	Hobart(2)	Vancouver	Vancouver
St John's Nfld	Winnipeg(1)		Halifax
			St John NB
			Hobart(2)
			Perth(2)
			Saskatoon(2)
			Regina(1)
			Winnipeg(1)

Table 15

PATTERN 5 - DOWNWARD FALLING

CASE AND LEVEL

1 A	2 A	1 B	2 B
St John NB(2)			Calgary(2)
Adelaide(2)			St John's Nfld(2)

Both Halifax and St. John N.B. exhibited coefficient values greatly in excess of any other cities, yet maintaining the observed pattern.

6.7.2.2 Harbour

Only four of the patterns were exhibited in the harbour mode regression coefficient results. The straight line pattern was absent. The following tables show the patterns with the significant coefficients presented as before.

Table 16

PATTERN 2 - INVERTED 'V'

CASE AND LEVEL

1 A	2 A	1 B	2 B
Melbourne	Montreal(2)	Melbourne	Montreal
Adelaide	Brisbane(2)	Sydney(2)	Sydney(2)
Halifax	St John's Nfld(2)	Hobart(2)	Adelaide(2)
Brisbane(2)	Adelaide(1)	Perth(2)	
Perth(0)	Melbourne(1)	St John's Nfld(1)	

Table 17

PATTERN 3 - 'V'

CASE AND LEVEL

1 A	2 A	1 B	2 B
Hobart	St John NB	Adelaide	Melbourne
Ottawa	Sydney	Brisbane(0)	St John NB
St John NB(2)			Halifax(2)
Toronto(1)			Brisbane(2)
			Toronto(2)
			Ottawa(2)
			Winnipeg(0)

Table 18

PATTERN 4 - UPWARD RISING

CASE AND LEVEL

1 A	2 A	1 B	2 B
St John's NFld	Hobart	Winnipeg	
			Perth
Sydney(2)	Vancouver(2)	Toronto(2)	Vancouver(2)
Winnipeg(1)	Perth(2)	Ottawa(2)	Hobart(0)
	Winnipeg(2)	St John NB(2)	

Table 19

PATTERN 5 - DOWNWARD FALLING

CASE AND LEVEL

1 A	2 A	1 B	2 B
Montreal(2)	Toronto	Halifax	St John's Nfld(2)
Vancouver(1)	Ottawa(2)	Montreal(2)	
	Halifax(2)	Vancouver(2)	

Again, both Halifax and St. John N.B. exhibited coefficient values much in excess of other cities. As well, for the harbour series, Winnipeg exhibited similar high values.

6.7.2.3 Air

Only three of the patterns appear to any substantial degree within the Canadian data regression coefficients. Again, the zero effect pattern is absent. The tables outlining the patterns follow.

Table 20

PATTERN 2 - INVERTED 'V'

CASE AND LEVEL

1 A	2 A	1 B	2 B
Calgary(2)	Calgary	Halifax	Saskatoon
Saskatoon(2)	Regina(1)	Edmonton(1)	Halifax
St John's Nfld(2)	Saskatoon(0)	St John's Nfld(1)	St John's Nfld
Winnipeg(1)			Calgary(2)
			Edmonton(0)

Table 21

PATTERN 3 - 'V'

CASE AND LEVEL

1 A	2 A	1 B	2 B
Montreal	Vancouver(2)	Montreal	St John NB
Vancouver(1)	Winnipeg(2)	Saskatoon(1)	Winnipeg(2)
Toronto(0)	Edmonton(1)	Ottawa(0)	
	St John NB(1)		

Table 22

PATTERN 4 - UPWARD RISING

CASE AND LEVEL

1 A	2 A	1 B	2 B
Ottawa	Toronto	Vancouver	Montreal
Halifax	St John's Nfld	Winnipeg	Vancouver
Edmonton(2)	Halifax (2)	Calgary(2)	Ottawa
Regina(0)	Montreal(2)	St John NB(2)	Toronto(0)
	Ottawa(2)	Regina(1)	
		Toronto(0)	

Table 23

PATTERN 5 - DOWNWARD FALLING

CASE AND LEVEL

1 A	2 A	1 B	2 B
St John's NB(0)			Regina(1)

The dominant pattern is Pattern 4 - upward rising - exhibiting nine fully significant cities across the four regressions. Halifax and St. John N.B. continue to have coefficient values in excess of other cities.

6.7.2.4 Urban

The results of the Australian urban data regression coefficients are portrayed in the following tables.

Table 24

PATTERN 2 - INVERTED 'V'

CASE AND LEVEL

1 A	2 A	1 B	2 B
Hobart	Adelaide	Sydney(2)	Hobart
Perth	Brisbane(2)		Melbourne
Sydney	Perth(2)		Sydney(1)
Brisbane(2)			

Table 25

PATTERN 3 - 'V'

CASE AND LEVEL

1 A	2 A	1 B	2 B
	Melbourne(2)	Brisbane	Adelaide(1)
		Melbourne(2)	
		Perth(1)	

Table 26

PATTERN 4 - UPWARD RISING

CASE AND LEVEL

1 A	2 A	1 B	2 B
Melbourne(2)	Hobart	Hobart(0)	
	Sydney(2)		

Table 27

PATTERN 5 - DOWNWARD FALLING

CASE AND LEVEL

1 A	2 A	1 B	2 B
Adelaide		Adelaide(2)	Perth Brisbane(2)

The dominant pattern emerging is that of the inverted 'V' with both the greatest number of fully significant patterns and the greatest number of cities.

6.7.2.5 Rail

The Australian rail regression coefficients exhibit all five patterns with the zero effect or straight line pattern being exhibited in major cities.

Table 28

PATTERN 1 - STRAIGHT LINE

CASE AND LEVEL

1 A	2 A	1 B	2 B
	Sydney(2)	Melbourne(1) Brisbane(1)	Brisbane(2)

Table 29

PATTERN 2 - INVERTED 'V'

CASE AND LEVEL

1 A	2 A	1 B	2 B
Adelaide	Brisbane(2)		Hobart
Hobart			
Melbourne			
Sydney			

Table 30

PATTERN 3 - 'V'

CASE AND LEVEL

1 A	2 A	1 B	2 B
Perth	Melbourne	Sydney	Melbourne
Brisbane(2)	Adelaide(2)	Hobart	Perth(2)
		Adelaide(2)	Adelaide(2)

Table 31

PATTERN 4 - UPWARD RISING

CASE 2, LEVEL A

Hobart, Perth(1)

Table 32

PATTERN 5 - DOWNWARD FALLING

Case 1, level B; Perth
Case 2, level B; Sydney

6.7.3 Infrastructure Coefficient Synopsis

The number of significant coefficients among the variety of modal variables in each data set was very high. The attempt to isolate consistent characteristics among the significant coefficients was hampered by the number of combinations of regressions, data sets, modes and cities. However a number of consistent patterns were discernible.

The return on investment in transportation infrastructure, as indicated by the sign on the capital coefficient, was more negative than positive in both data set regressions.

Within the Australian data regression the case B regression, a one period lag between the capital and transitory regressors, indicated a positive return on investment.

Five separate patterns emerged from the combined capital and investment coefficients graphical analysis. The first pattern, the straight line pattern, dominated the road mode. Each of the last four patterns appeared in both data sets for most of the other modes. The second, third and fourth patterns predominated with the last pattern, downward falling, appearing in only two instances, an Adelaide road and a Perth rail regression, where the downward falling pattern was a decline towards a zero value.

The emergent patterns showed a tendency towards a straight line - zero effect - pattern for the road mode for the large metropolitan cities. There appeared to be some significant difference for the smaller cities, which tended to exhibit the 'V' and inverted 'V' patterns, with their coefficients increasing in absolute value as the distance from the major cities increased, however this observation was not quantified.

For the rail mode the predominant patterns were the 'V' and inverted 'V' patterns for both large and small cities.

The urban mode displayed the inverted 'V' pattern more frequently than any other pattern with little distinction between large and small cities.

Only three patterns; 'V', inverted 'V' and upward rising were observed to any extent in the air mode tables. These patterns were exhibited, predominantly, by the smaller cities.

Both large and small cities exhibited all patterns, except the straight line pattern, for the harbour mode.

For all modes, except the road mode, the predominant patterns that emerged were the 'V', the inverted 'V' and the upward rising. There appeared to be no prevalence of city size among the patterns.

7.0 DISCUSSION AND CONCLUSIONS

7.1 Methodology

The data bases used were restrictive. The Canadian data base was sufficient to include all mode regressors for a city in a single equation but the acquisition of the investment data was difficult as there was no source reporting this data in a consistent manner. The Australian data base was restricted by the number of years of data available. This required the regressions to be completed on an individual mode base, thus introducing a bias into the regression results. An extension of the data bases would relieve both these problems.

All regressions done using the TROLL computer package utilized a Zellner procedure, a two-stage estimation procedure, wherein all regressions converged. However in order to obtain convergence the convergence criteria was set for a 0.1% relative change at each iteration for each coefficient. Even at this broad setting the number of iterations required for convergence was substantial. The use of the GLS procedure produced many more significant coefficients than did an OLS procedure. This is consistent with the observations of a variety of authors who recommend the technique for estimating spatially separated similar relationships. As well the improvement of the GLS regression results over the OLS regression results strongly support the existence of contemporaneous correlations among the regression residuals.

7.2 Discussion of Results

7.2.1 Similar Literature Findings

Some results of the consumption, income and investment relationship as specified in equation 20 were similar to the papers reviewed in the literature.

The behavioural assumptions in this dissertation were similar to those in Metzler's model and the results, as indicated in tables 11-32, show that investment in transportation infrastructure has a transitory effect which is cyclical as time passes. This cyclical consumption behaviour is consistent, as well, with the Ball and Drake model, which also utilized a quadratic expression. The cyclical behaviour seen is consistent with the Blinder and Fischer model where inventories were subjected to real shocks. The cyclical consumption behaviour is consistent with Fan's coordinated inventory model. The cyclical phenomenon is consistent with the Duffy and Lewis empirical examination of the Belsley model and with the results of Blinder's general model. The investment coefficients are similar to the quantity multipliers developed by Paelinck and Wagenaar in their examination of the impact of transportation projects on regions. The results shown are consistent with the Bos and Koyck model which exhibited consumption changes at specific locations when affected by transportation cost changes.

To some extent the differing consumption behaviour for each city implies that each location is unique, which would confirm the relevance of a Weberian location decision model.

The differing effects of each mode are consistent with the Jara-Diaz and Friesz model which imply asymmetrical inter-modal relationships.

The pattern 1 graph, straight line with the coefficient values statistically significant but very close to zero, which was exhibited in the road regressions for both Australia and Canada is consistent with Keeler's [39] recent study (1986) of the trucking industry and highway investments in the United States.

7.2.2 New Findings

A number of results were evident which had not been specifically examined in the literature.

The evidence of a small number (9) of significant negative income coefficients, in the Australian data regressions, is at variance with most macroeconomic and microeconomic theory. It is only within regional economics and the theory of Central Places (see Eaton and Lipsey [26]) that there is an implicit argument that consumption at a specific location, usually a small region, will fall when income at that location rises. That is, as income at the location rises, the firms at that location do not or are not able to accommodate the increased income with a supply of goods, and retail sales are increased at another location.

The effect of the change in the measurement in the boundaries of cities was not compared to other studies as this was tangential to this study. This dummy variable was used as a statistical correction device. Any reasoning to support or explain the sign on this significant coefficient would be speculative.

The significant results found for the capital variable, representing capital investment in transportation infrastructure, have not been reported in this form in the literature. The following table condenses the frequency and dominance of the sign of the capital variable coefficient.

Table 33.

Sign of Capital Variable Coefficient.

Mode Sign	Canadian Data +	Canadian Data -	Australian Data +	Australian Data -
ROAD	20	16	6	12
HARBOUR	19	10	9	8
AIR	7	21	-	-
URBAN	-	-	7	10
RAIL	-	-	13	10
	46	47	35	40

The analysis of the sign on the coefficient of the capital variable in the preceding section (§6.7.1) has shown that a negative sign in the Australian case and a positive sign in the Canadian case might represent a negative return, as evidenced by a reduction (increase) in consumption (goods prices), in major cities from investments in transportation infrastructures in those cities or the regions surrounding those cities. It has been assumed that the cities and the firms in those cities received increased service levels in the form of reduced lead time from these investments. To assume otherwise is not reasonable as it is unlikely that investment in transportation infrastructures would have continued over such a length of time at so many locations had the results of such investments been detrimental and without some form of cost-benefit analysis indicating net benefits. It appears, however, that cost benefit studies have not have extended to include the impact on the level of consumption expenditure (goods prices) in the cities.

This result, that the continued investment in Canadian and Australian transportation infrastructure can provide a negative return is confirmation of Scott's (intuitive) comment [61, p145] on Canada's "wasted resources". Wilson [74] describes a situation where an increase in transport capacity may lead to a decline in per capita output. In this situation, in an under-developed economy, "the backwash effects swamp the spread effects" and the expansion in one region adversely affects other regions.

The analysis of the signs on the capital variable revealed that these signs were significantly different among the mode categories. In the Canadian regressions the road and harbour infrastructure coefficients were positive and the air coefficient was predominantly negative. As was noted in §5.2.6.1 the data recorded for the investments in harbour infrastructure became very difficult to access midway through the period of analysis. This suggests that the values used for this variable may have been understated and that the true value of investment in harbour infrastructure is much higher. If this is the case, then the frequency of the positive sign in the regression results, indicating the negative return on investment, for harbour infrastructure may be overstated. In the Australian regressions the harbour coefficient was more frequently positive (9 positive versus 8 negative) as was the rail coefficient (13 positive versus 10 negative). The urban coefficient was predominantly negative. The road coefficient, in both regressions, indicated a negative return.

The technique employed to evaluate the return on the investment compared the end of a sequence, consumption expenditure (Australia) and price of goods (Canada), with the beginning of that sequence, investment in transportation infrastructure. Only the market structure in the last stage of that sequence was specified, a competitive market for firms in the consumer market. If the investment in transportation infrastructure was providing real benefits or facilitating real benefits available from the transport carriers during the period, and the return to the consumer was negative, then the real return has been dissipated or appropriated.

An examination of this situation reveals there are only two candidates left in the sequence, governments who control the infrastructures and transport carriers who use the infrastructures. Governments hold a near-monopoly on transportation infrastructures. Not only is the price charged for use of the infrastructure administered, but access to and use of the infrastructures is rigidly controlled. Whether any real benefit is passed through this system of administered prices and quantity rationing to the transport carriers is unknown. The transport carrier industry is not necessarily competitive. Entry to the industry is regulated by governments. Prices are regulated by governments. Services provided by transport carriers to their customers, consumers and firms, are regulated by government. Whether the transport carriers have acted to cause, to mitigate or to exacerbate the dissipation of the real benefit to the consumer is unknown. What remains is that a real benefit, reduction in the mean and variance of lead time, resulting from an investment in transportation infrastructure whose purpose was to provide or facilitate that benefit, has become a negative return, a reduction (increase) in consumer expenditure (goods prices), to the end user of the transportation system.

The reduced lead time most certainly reduced the average costs to the firm. However if the impact of transportation investment on consumption was negative then under the assumptions of the model an increase in the transport carrier price, imbedded in the cost parameter D, must have occurred. In this case the expected average cost equation for the firm exhibits a minimum for a positive value of expected average demand. This would enable a firm in a competitive market to enhance profit through quantity adjustments. As this quantity adjustment implication is a finding from the regressions and the assumptions of the model it has not been compared to any of the variety of studies that exist in the literature on this contentious issue.

7.3 Conclusions

The theory has been developed in this dissertation that time is an essential ingredient in the determination of costs, and that time and space are related. This has been illustrated using the vehicle of the materials inventory of the firm. The holding of inventory by the firm provides benefits and costs to the firm. A major variable in the assessment of the quantity of materials held in inventory has been assumed to be the time required to replenish the inventory, the lead time. The control of this lead time variable is, by and large, beyond the control of the firm. It is external to the firm and largely dependent upon transportation infrastructures and transportation technology. Therefore it was assumed that improvements in these transportation infrastructures, by increases in the capital allocated to them, would improve or facilitate improvement in lead time. This improvement in lead time was shown to be capable of reducing costs to the firm and, in a competitive market, result in reduced prices and increased consumption. The isolation of these effects was accomplished by the assumption that goods flow between cities and between a city and its hinterland. Each city and its hinterland comprised a trading region that is interdependent with other trading regions and is serviced by a network of interconnected transportation infrastructures. Therefore a change to one particular infrastructure would have repercussions throughout the transportation network. These repercussions have been illustrated to have effects on the firm over a duration of several time periods. This was assumed to be a result of a learning and market adjustment process in the several inter-related markets. The regression of the independent variable, capital in infrastructure, against the dependent variable, consumption (Australian data) and price of goods (Canadian data), was done on a regional-city basis -with two independent data sets from two different countries spanning two separate time intervals - but the regression equations for the individual cities were grouped and estimated simultaneously for each data set, by a Zellner regression technique with technical characteristics that were consistent with the assumptions of the model. The majority of these regressions results were statistically significant and a number of conclusions may be made with confidence.

The first set of conclusions is made with respect to the capital in place in transportation infrastructures. The coefficients on the capital variable were found to be statistically significant for a large number of cities in both samples. From this is drawn the conclusion that the capital in place in transportation infrastructures in a region has a significant impact on the consumption expenditure (Australia) or price of goods (Canada) of cities in that region. The second conclusion with respect to this capital variable is in regard to the persistence of its effect. Four separate sets of regressions were performed where this capital variable was regressed with no lag, a one-period lag, a two-period lag and a three-period lag between it and the dependent variable, consumption expenditure (Australia) or price of goods (Canada). In each set of regressions in both data sets the coefficient on this capital variable was usually statistically significant. A chi-square analysis on the counts of significance among these regressions could not reject the null hypothesis that there was no difference across the sets in the frequency of counts observed. From this is drawn the conclusion that the amount of capital in place in transportation infrastructures in a region has a persistent, consistent impact on consumption expenditure (price of goods) in a city.

The principal conclusion is with respect to the type of impact this capital variable had on the dependent variable. In over one half of the significant cases in the Australian data regressions the coefficient on this capital variable had a negative sign and in just under one half of the significant cases in the Canadian data regresssions the coefficient on this capital variable had a positive sign. From this is drawn the conclusion that the capital in place in transportation infrastructures in cities and regions can have and does have a significant negative (positive) impact on consumption expenditure (price of goods) in some cities.

The next set of conclusions is made with respect to the investments made in those transportation infrastructures. Transportation infrastructures are large and may take considerable periods of time to improve or to construct. A transport carrier acts as a middleman between the government which controls the transportation infrastructure and the firms which require goods to be transported. Therefore any effect of an investment in a long-term transportation infrastructure project in a region must progress through a number of markets and market participants before impacting upon the price of goods and consumption expenditure in a city. The investents for each of two sequential periods were used as the independent regressors. A number of conclusions may be drawn from the tabular analysis of the statistically significant coefficients on these variables. The first two conclusions are that the investment variables have a varying influence on consumption expenditure and price of goods in a city, and that this influence extends over several periods in time. The main observation was, with the exception of the road mode, that the transitory impact of investment in transportation infrastructure on consumption and prices produced predominantly oscillatory effects or effects consistent with the effects produced by the capital variable. These effects appeared to be independent of the size of the city. This leads to the conclusion that investment in transportation infrastructure in a region can lead to a cyclical consumption (price of goods) pattern in a city, i.e., a business cycle.

The model presented in this paper internalized an external investment variable, capital and investment in transportation infrastructures, into the firm as a causal variable, lead time, effecting the costs of the firm through the firm's inventory. The regressions show that the price of goods and consumption in a city react to a change in transportation investment and the corresponding capital in transportation infrastructure.

In summary, the dynamics of the model, formulated on explicit inventory behaviour, produced a number of effects suggested, but not tested, by other inventory models: oscillatory output and lagged effects. As well, the significant impact of investment and capital in transportation infrastructure on the firm has been shown by changes in consumption and the price of goods at specific locations. The hypothesis cannot be rejected that the flow of economic goods through space can be analyzed in conjunction with the stocks (inventories) of those economic goods and that this relationship between stocks and flows is influenced, significantly, by investment in transportation infrastructure.

7.4 Implications and Future Research

The development of this model and the results obtained open a number of issues in economic theory and may warrant further study.

The model and the regressions clearly demonstrated the role externalities could have in affecting the behaviour of the firm which enriches the analysis of the theory of the firm. Other externalities exist which impact directly on the firm. The developments in the telecommunications infrastructure should make signficiant changes in the time relationship within a firm, among firms and between the firm and its markets.

A number of the regression results seem to have imnplications for economic theory. These were not tested explicity. The appearance of significant negative income coefficients for some cities has some qualitative support in location theory. This result, in conjunction with the distinctly different cyclical consumption patterns and the differing impacts of the capital variable among modes suggests specific differences between cities. This study, or a variation, could be repeated for a regional model where the sample cities are in close proximity, vary in size and form a region, such as a Province or a State. A study with a reduced number of cities but incorporating all transport modes might more clearly isolate the effectiveness of all variables, but particularly the differences among modes.

Two controversial issues arise out of the findings of this dissertation. First, the sign on the coefficient of the capital variable indicates that the substantial amounts of capital allocated to transportation infrastructures have not returned a benefit to the consumers in most of the major cities in Canada or Australia. The rationale for that allocation of capital must have been based on the expectation of positive benefits. How and where were those benefits dissipated or not passed on to consumers? If cities represent competitive markets for firms, then there are only two other participants in the process, the government and the transport carriers, who could capture benefits from the investments. Two possible options are that the government has over-constructed the infra-structure or is managing it in an inefficient manner. Another option is that the transport carrier sector is absorbing the benefit more than totally. A fourth option is that the benefit is being shared by both parties. The assumption in this paper that the firm was a price-taker in a competitive market should be reviewed and tested. Volumes of data exist that might be used to examine any of the other options presented here.

The second contentious issue that arises flows from the required inference that the transport carriers may have raised their prices in conjunction with the change in capital in transportation infrastructures. This price change leads to the result that a price-taking firm in a competitive environment may enhance its profit position through the use of a quantity adjustment rule. This inference may be tested. Congestion theory (see Walters [72]) postulates increasing costs to transport users past a specific point. Investment in transportation infrastructure should relieve that congestion and reduce costs. That cost reduction should be seen in the transport carrier market as reduced prices. A model could be developed with these assumptions which might show results similar to those presented here.

The major implication of this dissertation has been the demonstrated relationship between microeconomic and macroeconomics. The development of this model and the results obtained provide evidence of the importance of the firm's inventories and the concept of time in the economic process. The model has shown that inventory in a firm is a vital link between external investment and external consumption.

APPENDIX 1

Canadian Regression Results

Dependent Variable

Consumer Goods Price Index / Consumer Price Index

Table Heading Symbol Key

Symbol	Regression Variable
Intercept	Constant
Dummy 1	City Boundary Change Dummy
Common Dummy	Consumer Price Change Dummy
K (t)	Capital Variable, e=o
K (t-1)	Capital Variable, e=1
K (t-2)	Capital Variable, e=2
K (t-3)	Capital Variable, e=3
I (t)	Transitory effect, current period
I (t-1)	Transitory effect, one-period lag
I (t-2)	Transitory effect, two-period lag
I (t-3)	Transitory effect, three-period lag

TABLE 34

CANADIAN DATA :

GLS REGRESSIONS : VANCOUVER

	CASE AND LEVEL			
COEFFICIENTS	1	2	1	2
('t' VALUE)	A	A	B	B
INTERCEPT	0.9837 (116.1380)	0.9809 (83.4934)	0.9670 (179.2090)	0.9449 (97.8521)
DUMMY 1	0.0040 (0.8191)	0.0125 (1.7127)	-0.0023 (0.4386)	-0.0132 (2.4048)
COMMON DUMMY	0.0004 (0.0440)	-0.0114 (1.4367)	0.0015 (0.2749)	-0.0258 (3.7492)
ROAD				
K(t)		-0.0 (0.1782)		
K(t-1)				0.0001 (3.0879)
K(t-2)	0.0004 (2.2392)			
K(t-3)			0.0005 (5.7074)	
I(t)	-0.0 (1.4328)			
I(t-1)	0.0002 (2.0745)	0.0002 (2.3491)	0.0002 (5.1370)	
I(t-2)		+0.0 (0.1845)	0.0004 (3.9203)	0.0004 (5.7447)
I(t-3)				0.0004 (5.8108)

TABLE 34 (cont'd)

CANADIAN DATA :

GLS REGRESSIONS : VANCOUVER

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
HARBOUR				
K(t)		-0.0003 (1.2437)		
K(t-1)				-0.0009 (4.7425)
K(t-2)	-0.0020 (2.8264)			
K(t-3)			-0.0027 (6.7988)	
I(t)	-0.0002 (0.4578)			
I(t-1)	-0.0010 (1.3155)	0.0009 (1.9065)	-0.0006 (1.3676)	
I(t-2)		0.0011 (2.5799)	-0.0020 (3.8506)	-0.0006 (1.8111)
I(t-3)				0.0001 (0.3711)

TABLE 34 (cont'd)

CANADIAN DATA :

GLS REGRESSIONS : VANCOUVER

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
AIR				
K(t)		0.0015 (4.3549)		
K(t-1)				0.0001 (3.0879)
K(t-2)	0.0002 (0.2788)			
K(t-3)			0.0005 (5.7074)	
I(t)	0.0015 (2.6508)			
I(t-1)	-0.0011 (1.5976)	-0.0022 (2.4482)	0.0002 (5.1370)	
I(t-2)		0.0009 (1.2894)	0.0004 (3.9203)	0.0004 (5.7447)
I(t-3)				0.0004 (5.8108)

TABLE 35

CANADIAN DATA :

GLS REGRESSIONS : EDMONTON

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
INTERCEPT	0.9436 (38.2629)	1.0442 (64.8752)	1.0257 (39.3011)	1.0300 (44.9233)
DUMMY 1	0.0185 (2.6429)	0.0051 (0.6625)	0.0109 (1.4089)	0.0110 (1.4140)
COMMON DUMMY	0.0302 (3.4617)	0.0141 (1.5339)	0.0213 (2.3498)	0.0256 (2.9242)
ROAD				
K(t)		+0.0 (0.9534)		
K(t-1)				-0.0 (1.1094)
K(t-2)	-0.0001 (2.5684)			
K(t-3)			-0.0 (0.6711)	
I(t)	-0.0002 (0.5892)			
I(t-1)	0.0007 (2.3421)	-0.0003 (0.9045)	0.0002 (0.5660)	
I(t-2)		-0.0003 (1.1162)	-0.0006 (1.8294)	-0.0007 (1.9031)
I(t-3)				-0.0003 (0.7157)

TABLE 35 (cont'd)

CANADIAN DATA :

GLS REGRESSIONS : EDMONTON

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
AIR				
K(t)		-0.0014 (1.2448)		
K(t-1)				0.0010 (0.6782)
K(t-2)	0.0037 (2.8297)			
K(t-3)			0.0002 (0.1691)	
I(t)	-0.0046 (2.9661)			
I(t-1)	0.0017 (1.1558)	-0.0019 (1.2005)	-0.0036 (2.1303)	
I(t-2)		0.0029 (2.4871)	0.0014 (0.9989)	0.0019 (1.2306)
I(t-3)				-0.0004 (0.2544)

TABLE 36

CANADIAN DATA :

GLS REGRESSIONS : CALGARY

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
INTERCEPT	0.9590 (92.2237)	0.9560 (67.4384)	0.9932 (57.3159)	1.0643 (62.1731)
DUMMY 1	-0.0290 (4.6708)	-0.0306 (4.7006)	-0.0273 (2.5902)	-0.0234 (2.9900)
COMMON DUMMY	0.0179 (2.5932)	0.0069 (0.8872)	0.0228 (1.8007)	0.0358 (3.6187)
ROAD				
K(t)		0.0004 (8.0539)		
K(t-1)				0.0002 (3.5384)
K(t-2)	0.0003 (8.8637)			
K(t-3)			0.0002 (3.4045)	
I(t)	0.0002 (0.6560)			
I(t-1)	0.0008 (3.1359)	0.0 (0.1703)	0.0003 (0.5043)	
I(t-2)		0.0002 (0.4980)	-0.0001 (0.2110)	-0.0003 (1.1042)
I(t-3)				-0.0014 (3.6507)

TABLE 36 (cont'd)

CANADIAN DATA :

GLS REGRESSIONS : CALGARY

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
AIR				
K(t)		-0.0043 (6.0209)		
K(t-1)				-0.0024 (3.1598)
K(t-2)	-0.0026 (6.1097)			
K(t-3)			-0.0010 (1.0368)	
I(t)	-0.0044 (6.8002)			
I(t-1)	-0.0003 (0.5189)	0.0032 (3.1369)	-0.0022 (2.3925)	
I(t-2)		0.0020 (2.7561)	-0.0017 (1.9269)	0.0046 (3.4559)
I(t-3)				0.0009 (1.1529)

TABLE 37

CANADIAN DATA :

GLS REGRESSIONS : SASKATOON

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
INTERCEPT	1.0108 (155.9990)	0.9963 (141.5180)	1.0011 (104.9240)	0.9851 (114.0460)
DUMMY 1	0.0212 (3.6671)	0.0191 (2.1540)	0.0065 (0.3068)	0.0334 (4.6748)
COMMON DUMMY	-0.0192 (2.2632)	-0.0202 (2.3281)	-0.0181 (2.0796)	-0.0244 (2.6157)
ROAD				
K(t)		0.0001 (2.1469)		
K(t-1)				0.0 (1.4646)
K(t-2)	0.0002 (2.8118)			
K(t-3)			0.0 (1.7929)	
I(t)	-0.0008 (2.0096)			
I(t-1)	0.0009 (2.3840)	-0.0003 (0.7218)	0.0001 (0.2406)	
I(t-2)		0.0011 (2.6617)	0.0009 (1.7373)	0.0007 (2.0126)
I(t-3)				0.0009 (1.8426)

TABLE 37 (cont'd)

CANADIAN DATA :

GLS REGRESSIONS : SASKATOON

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
AIR				
K(t)		-0.0055 (1.6175)		
K(t-1)				-0.0053 (1.9978)
K(t-2)	-0.0057 (2.1269)			
K(t-3)			0.0013 (0.1951)	
I(t)	-0.0123 (3.0376)			
I(t-1)	-0.0034 (0.8820)	0.0051 (1.0673)	-0.0008 (2.4697)	
I(t-2)		-0.0028 (0.4591)	-0.0093 (0.9791)	0.0128 (2.3384)
I(t-3)				-0.0086 (3.4716)

TABLE 38

CANADIAN DATA :

GLS REGRESSIONS : REGINA

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
INTERCEPT	0.9662 (13.8426)	1.0120 (19.5594)	0.9997 (15.9720)	0.9703 (27.5286)
COMMON DUMMY	0.0144 (1.2660)	-0.0017 (0.1681)	-0.0104 (1.1230)	-0.0188 (2.1254)
ROAD				
K(t)		0.0 (1.0693)		
K(t-1)				0.0 (1.3959)
K(t-2)	0.0 (0.3019)			
K(t-3)			0.0 (1.5263)	
I(t)	-0.0007 (1.6687)			
I(t-1)	0.0002 (0.4329)	-0.0010 (2.4592)	-0.0013 (3.0407)	
I(t-2)		0.0020 (4.1445)	0.0027 (5.4785)	0.0005 (1.4066)
I(t-3)				0.0021 (4.9464)

TABLE 38 (cont'd)

CANADIAN DATA :

GLS REGRESSIONS : REGINA

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
AIR				
K(t)		-0.0021 (0.4146)		
K(t-1)				0.0001 (0.0340)
K(t-2)	0.0044 (0.6561)			
K(t-3)			-0.0010 (0.1590)	
I(t)	-0.0071 (0.9717)			
I(t-1)	0.0029 (0.4204)	0.0002 (0.2561)	-0.0129 (1.9993)	
I(t-2)		-0.0013 (1.9371)	-0.0028 (0.4536)	-0.0005 (1.1289)
I(t-3)				-0.0014 (3.7997)

TABLE 39

CANADIAN DATA :

GLS REGRESSIONS : WINNIPEG

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
INTERCEPT	1.0280 (23.7152)	1.0746 (26.9908)	0.8236 (26.9503)	0.9770 (18.1640)
COMMON DUMMY	0.0655 (4.1698)	0.0872 (3.8978)	0.0089 (1.7195)	0.0338 (1.4978)
ROAD				
K(t)		-0.0002 (1.6382)		
K(t-1)				-0.0008 (3.1191)
K(t-2)	-0.0005 (3.7547)			
K(t-3)			-0.0012 (16.2591)	
I(t)	0.0008 (2.1278)			
I(t-1)	0.0025 (4.6623)	0.0006 (1.0855)	0.0021 (7.1364)	
I(t-2)		0.0017 (2.3880)	0.0025 (7.4849)	-0.0001 (0.1910)
I(t-3)				0.0005 (0.3699)

TABLE 39 (cont'd)

CANADIAN DATA :

GLS REGRESSIONS : WINNIPEG

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
HARBOUR				
K(t)		-0.0875 (2.5711)		
K(t-1)				0.0265 (1.3903)
K(t-2)	0.0031 (0.1091)			
K(t-3)			0.1525 (13.7542)	
I(t)	-0.0856 (3.3800)			
I(t-1)	-0.0125 (0.5205)	-0.0343 (2.0169)	0.0240 (2.8444)	
I(t-2)		0.0145 (1.1985)	0.1064 (11.5960)	-0.0066 (0.3342)
I(t-3)				0.0231 (1.4844)

TABLE 39 (cont'd)

CANADIAN DATA :

GLS REGRESSIONS : WINNIPEG

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
AIR				
K(t)		0.0078 (1.9216)		
K(t-1)				0.0061 (2.0104)
K(t-2)	0.0002 (0.0562)			
K(t-3)			-0.0028 (2.0643)	
I(t)	-0.0088 (1.9263)			
I(t-1)	0.0014 (0.4281)	-0.0072 (2.6632)	-0.0055 (2.0320)	
I(t-2)		0.0 (0.0436)	-0.0048 (2.9934)	-0.0084 (2.2575)
I(t-3)				-0.0015 (0.4926)

TABLE 40

CANADIAN DATA :

GLS REGRESSIONS : TORONTO

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
INTERCEPT	1.0340 (24.6703)	1.0309 (82.0060)	1.0071 (62.9011)	0.9396 (65.920)
DUMMY 1	0.0015 (0.1936)	-0.0056 (1.6172)	-0.0071 (2.4818)	0.0054 (2.2985)
COMMON DUMMY	0.0081 (1.0355)	0.0053 (2.4529)	-0.0015 (0.5836)	-0.0073 (1.7317)
ROAD				
K(t)		-0.0 (12.4258)		
K(t-1)				-0.0 (11.2165)
K(t-2)	-0.0 (6.6579)			
K(t-3)			-0.0 (15.3317)	
I(t)	-0.0001 (2.2091)			
I(t-1)	-0.0 (1.5610)	0.0 (1.1201)	-0.0 (2.3191)	
I(t-2)		0.0 (3.3646)	0.0 (2.0304)	0.0001 (3.4917)
I(t-3)				0.0 (2.1315)

TABLE 40 (cont'd)

CANADIAN DATA :

GLS REGRESSIONS : TORONTO

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
HARBOUR				
K(t)		0.0020 (8.8417)		
K(t-1)				0.0022 (4.5665)
K(t-2)	0.0012 (5.7185)			
K(t-3)			0.0014 (10.1678)	
I(t)	-0.0004 (0.2781)			
I(t-1)	-0.0008 (0.5545)	-0.0013 (2.0069)	-0.0008 (1.6182)	
I(t-2)		-0.0014 (4.9465)	-0.0006 (1.8685)	-0.0014 (3.0991)
I(t-3)				0.0006 (1.5960)

TABLE 40 (cont'd)

CANADIAN DATA :

GLS REGRESSIONS : TORONTO

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
AIR				
K(t)		-0.0018 (5.3302)		
K(t-1)				-0.0006 (0.9795)
K(t-2)	-0.0001 (0.2125)			
K(t-3)			-0.0 (0.2923)	
I(t)	-0.0 (0.0554)			
I(t-1)	-0.0005 (1.1980)	-0.0009 (5.5838)	-0.0005 (0.9026)	
I(t-2)		0.0016 (3.7708)	-0.0 (0.2230)	0.0 (0.3281)
I(t-3)				0.0010 (1.4043)

TABLE 41

CANADIAN DATA :

GLS REGRESSIONS : OTTAWA

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
INTERCEPT	1.1191 (22.2502)	1.1035 (45.7885)	0.9161 (14.7002)	1.0551 (50.5812)
DUMMY 1	-0.0197 (5.4894)	-0.0336 (7.3533)	-0.0198 (3.9629)	0.0005 (0.0718)
COMMON DUMMY	0.0085 (1.3409)	-0.0085 (1.7212)	-0.0098 (1.3283)	-0.0222 (3.5816)
ROAD				
K(t)		-0.0 (2.8336)		
K(t-1)				-0.0 (2.2329)
K(t-2)	0.0 (0.0803)			
K(t-3)			-0.0 (3.4324)	
I(t)	-0.0 (1.9843)			
I(t-1)	-0.0 (0.7092)	-0.0 (0.7642)	-0.0 (0.1015)	
I(t-2)		-0.0001 (2.5668)	0.0 (0.2057)	0.0001 (2.8890)
I(t-3)				0.0 (2.8086)

TABLE 41 (cont'd)

CANADIAN DATA :

GLS REGRESSIONS : OTTAWA

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
HARBOUR				
K(t)		0.0007 (5.3749)		
K(t-1)				0.0004 (3.6840)
K(t-2)	0.0004 (4.1885)			
K(t-3)			0.0005 (4.5408)	
I(t)	0.0011 (4.8874)			
I(t-1)	-0.0004 (2.5045)	-0.0003 (1.3106)	-0.0001 (0.4699)	
I(t-2)		-0.0009 (3.256)	0.0003 (1.7717)	-0.0003 (1.1110)
I(t-3)				0.0008 (2.8030)

TABLE 41 (cont'd)

CANADIAN DATA :

GLS REGRESSIONS : OTTAWA

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
AIR				
K(t)		-0.0011 (5.1128)		
K(t-1)				-0.0015 (5.6368)
K(t-2)	-0.0011 (2.3382)			
K(t-3)			0.0009 (1.4911)	
I(t)	-0.0022 (2.9225)			
I(t-1)	-0.0012 (2.0617)	-0.0001 (0.5206)	0.0014 (1.5966)	
I(t-2)		0.0005 (2.7281)	0.0007 (1.0098)	-0.0015 (4.6764)
I(t-3)				0.0012 (3.9813)

TABLE 42

CANADIAN DATA :

GLS REGRESSIONS : MONTREAL

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
INTERCEPT	1.1625 (43.8863)	1.0386 (92.6902)	1.1454 (30.6538)	1.0775 (139.0850)
DUMMY 1	0.0019 (0.6954)	0.0004 (0.1667)	0.0 (3.4393)	-0.0143 (8.2092)
COMMON DUMMY	0.0077 (1.7700)	0.0029 (0.7684)	-0.0097 (1.7537)	-0.0030 (1.1962)
ROAD				
K(t)		0.0 (3.0653)		
K(t-1)				0.0 (7.0675)
K(t-2)	0.0001 (5.6652)			
K(t-3)			0.0 (3.4393)	
I(t)	0.0 (0.2644)			
I(t-1)	0.0 (2.1210)	0.0 (0.5508)	0.0 (0.6928)	
I(t-2)		0.0 (3.2896)	-0.0 (0.5628)	-0.0 (4.4925)
I(t-3)				0.0001 (8.0842)

TABLE 42 (cont'd)

CANADIAN DATA :

GLS REGRESSIONS : MONTREAL

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
HARBOUR				
K(t)		-0.0003 (2.1952)		
K(t-1)				-0.0004 (4.7924)
K(t-2)	-0.0010 (4.8327)			
K(t-3)			-0.0005 (2.2579)	
I(t)	0.0004 (2.4652)			
I(t-1)	0.0 (0.1402)	0.0003 (1.9965)	0.0006 (3.1964)	
I(t-2)		0.0 (0.5464)	-0.0002 (1.5008)	0.0006 (5.1833)
I(t-3)				-0.0008 (5.9064)

TABLE 42 (cont'd)

CANADIAN DATA :

GLS REGRESSIONS : MONTREAL

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
AIR				
K(t)		-0.0008 (3.0595)		
K(t-1)				-0.0016 (8.4822)
K(t-2)	-0.0032 (6.0761)			
K(t-3)			-0.0030 (4.0060)	
I(t)	-0.0033 (6.0513)			
I(t-1)	-0.0050 (7.1654)	-0.0008 (4.8426)	-0.0032 (4.7917)	
I(t-2)		-0.0 (0.4072)	-0.0039 (3.8442)	-0.0010 (9.7499)
I(t-3)				0.0007 (6.6635)

TABLE 43

CANADIAN DATA :

GLS REGRESSIONS : ST. JOHN N.B.

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
INTERCEPT	0.9537 (72.1594)	0.9966 (69.8572)	0.9930 (64.5979)	0.9380 (57.1402)
COMMON DUMMY	0.0902 (8.6436)	0.0003 (0.0132)	0.0271 (1.6313)	-0.0822 (4.5090)
ROAD				
K(t)		-0.0030 (3.2974)		
K(t-1)				-0.0068 (7.5210)
K(t-2)	-0.0034 (4.1390)			
K(t-3)			-0.0042 (4.0765)	
I(t)	0.0012 (2.8392)			
I(t-1)	0.0006 (0.9126)	0.0025 (3.9678)	-0.0 (0.0670)	
I(t-2)		0.0022 (2.8559)	-0.0022 (2.0693)	0.0027 (5.0014)
I(t-3)				0.0034 (5.5793)

TABLE 43 (cont'd)

CANADIAN DATA :

GLS REGRESSIONS : ST. JOHN N.B.

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
HARBOUR				
K(t)		0.0076 (2.9691)		
K(t-1)				0.0172 (7.1731)
K(t-2)	0.0082 (3.5338)			
K(t-3)			0.0100 (3.4919)	
I(t)	0.0036 (2.6574)			
I(t-1)	0.0022 (1.1404)	-0.0035 (1.9695)	0.0027 (1.3723)	
I(t-2)		-0.0028 (1.8293)	0.0053 (2.0497)	-0.0119 (5.0952)
I(t-3)				0.0061 (3.6634)

TABLE 43 (cont'd)

CANADIAN DATA :

GLS REGRESSIONS : ST. JOHN N.B.

	CASE AND LEVEL			
COEFFICIENTS	1	2	1	2
('t' VALUE)	A	A	B	B
AIR				
K(t)		0.0036 (0.8226)		
K(t-1)				0.0248 (4.9387)
K(t-2)	-0.0010 (0.4056)			
K(t-3)			0.0106 (2.0754)	
I(t)	0.0048 (1.2599)			
I(t-1)	0.0017 (0.4903)	-0.0227 (3.9255)	-0.0050 (1.0876)	
I(t-2)		-0.0036 (0.5922)	0.0080 (1.7221)	-0.0462 (6.9234)
(5.0952)				
I(t-3)				-0.0203 (3.7144)

TABLE 44

CANADIAN DATA :

GLS REGRESSIONS : HALIFAX

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
INTERCEPT	0.8202 (3.6706)	3.2687 (10.3385)	3.3086 (8.6084)	3.0839 (18.9734)
DUMMY 1	0.2044 (6.6849)	0.3555 (4.1159)	0.3031 (4.1672)	0.5037 (17.2967)
COMMON DUMMY	-0.2782 (4.6615)	-0.8072 (6.0207)	-0.8297 (8.1838)	-1.5174 (21.3137)
ROAD				
K(t)		0.0073 (4.0182)		
K(t-1)				0.0074 (6.5959)
K(t-2)	-0.0126 (7.2666)			
K(t-3)			0.0119 (2.7202)	
I(t)	-0.0187 (8.6074)			
I(t-1)	-0.0306 (11.1031)	-0.0155 (3.5122)	-0.0056 (0.8026)	
I(t-2)		-0.0039 (0.9676)	0.0209 (2.9621)	0.0072 (2.8031)
I(t-3)				0.0327 (13.0255)

TABLE 44 (cont'd)

CANADIAN DATA :

GLS REGRESSIONS : HALIFAX

	CASE AND LEVEL			
COEFFICIENTS	1	2	1	2
('t' VALUE)	A	A	B	B
HARBOUR				
K(t)		0.0522 (3.9955)		
K(t-1)				0.0516 (13.2832)
K(t-2)	0.0417 (11.2835)			
K(t-3)			0.0375 (3.8819)	
I(t)	-0.0839 (9.0385)			
I(t-1)	0.0512 (11.5438)	0.0443 (3.1502)	0.1012 (9.0588)	
I(t-2)		-0.0034 (0.3104)	0.0686 (7.0926)	-0.0708 (11.1226)
I(t-3)				-0.0078 (1.5105)

TABLE 44 (cont'd)

CANADIAN DATA :

GLS REGRESSIONS : HALIFAX

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
AIR				
K(t)		-0.5160 (7.4904)		
K(t-1)				-0.5472 (16.2468)
K(t-2)	0.1441 (2.5718)			
K(t-3)			-0.5712 (5.9649)	
I(t)	0.1091 (2.4461)			
I(t-1)	0.1434 (2.9720)	0.0233 (0.3339)	-0.5771 (8.6267)	
I(t-2)		0.0793 (1.9122)	-0.4133 (3.8459)	0.5241 (10.2736)
I(t-3)				-0.1172 (4.4445)

TABLE 45

CANADIAN DATA :

GLS REGRESSIONS : ST. JOHN'S NFLD.

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
INTERCEPT	1.0368 (156.9340)	1.0180 (328.9370)	1.0312 (136.2310)	1.0068 (259.8470)
DUMMY 1	-0.0336 (8.5671)	-0.0324 (14.4894)	-0.0225 (6.0724)	-0.0295 (16.4240)
COMMON DUMMY	0.0076 (0.8760)	0.0178 (4.3234)	0.0096 (1.1214)	0.0253 (7.8294)
ROAD				
K(t)		0.0004 (6.6508)		
K(t-1)				-0.0 (1.3938)
K(t-2)	0.0005 (4.7108)			
K(t-3)			0.0004 (3.0385)	
I(t)	0.0002 (1.7895)			
I(t-1)	0.0002 (1.8531)	-0.0003 (4.3525)	0.0002 (1.8898)	
I(t-2)		-0.0002 (4.2153)	-0.0 (0.7223)	-0.0001 (2.1832)
I(t-3)				-0.0003 (5.4066)

TABLE 45 (cont'd)

CANADIAN DATA :

GLS REGRESSIONS : ST. JOHN'S NFLD.

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
HARBOUR				
K(t)		-0.0008 (2.7351)		
K(t-1)				0.0012 (4.9896)
K(t-2)	-0.0015 (3.0219)			
K(t-3)			-0.0005 (0.9175)	
I(t)	-0.0021 (3.5994)			
I(t-1)	-0.0018 (4.0982)	-0.0001 (0.2608)	-0.0017 (2.2487)	
I(t-2)		-0.0009 (3.6733)	-0.0005 (1.0814)	-0.0005 (1.4804)
I(t-3)				-0.0014 (6.4520)

TABLE 45 (cont'd)

CANADIAN DATA :

GLS REGRESSIONS : ST. JOHN'S NFLD.

	CASE AND LEVEL			
COEFFICIENTS	1	2	1	2
('t' VALUE)	A	A	B	B
AIR				
K(t)		-0.0044 (9.6457)		
K(t-1)				-0.0013 (1.8279)
K(t-2)	-0.0047 (2.5366)			
K(t-3)			-0.0089 (3.9748)	
I(t)	-0.0026 (2.5137)			
I(t-1)	-0.0023 (1.2582)	0.0060 (4.6946)	-0.0013 (0.7371)	
I(t-2)		0.0073 (5.8207)	-0.0004 (0.1658)	0.0036 (3.3055)
I(t-3)				-0.0031 (2.3950)

APPENDIX 2

Australian Regression Results

Dependent Variable

Consumer Expenditure on Goods

Table Heading Symbol Key

Symbol	Regression Variable
Intercept	Constant
K (t)	Capital Variable, e=o
K (t-1)	Capital Variable, e=1
K (t-2)	Capital Variable, e=2
K (t-3)	Capital Variable, e=3
I (t)	Transitory effect, current period
I (t-1)	Transitory effect, one-period lag
I (t-2)	Transitory effect, two-period lag
I (t-3)	Transitory effect, three-period lag

TABLE 46

AUSTRALIAN DATA : ROAD MODE

GLS REGRESSIONS : PERTH

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL			
	1 A	2 A	1 B	2 B
INTERCEPT	-1.620 (0.828)	5.078 (6.890)	6.111 (1.395)	4.978 (5.116)
INCOME	0.086 (26.371)	0.084 (57.579)	-0.011 (1.139)	-0.074 (1.958)
K(t)		-0.0004 (5.118)		
K(t-1)				0.001 (2.473)
K(t-2)	0.0 (0.079)			
K(t-3)			0.0004 (4.589)	
I(t)	-0.005 (1.057)			
I(t-1)	0.012 (2.488)	-0.005 (2.553)	-0.002 (2.226)	
I(t-2)		-0.015 (10.259)	0.003 (1.727)	0.006 (1.246)
I(t-3)				0.015 (1.856)

TABLE 47

AUSTRALIAN DATA : HARBOUR MODE

GLS REGRESSIONS : PERTH

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
INTERCEPT	-0.315 (1.021)	-1.120 (2.440)	4.789 (10.968)	3.414 (20.988)
INCOME	0.082 (24.356)	0.084 (31.810)	0.008 (1.402)	0.022 (9.508)
K(t)		0.003 (1.711)		
K(t-1)				0.004 (22.627)
K(t-2)	0.002 (0.793)			
K(t-3)			0.003 (9.291)	
I(t)	0.006 (1.058)			
I(t-1)	0.007 (0.884)	0.010 (1.444)	-0.001 (0.359)	
I(t-2)		0.021 (2.530)	0.011 (4.706)	0.007 (13.005)
I(t-3)				0.010 (16.955)

TABLE 48

AUSTRALIAN DATA : URBAN MODE

GLS REGRESSIONS : PERTH

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL			
	1 A	2 A	1 B	2 B
INTERCEPT	-0.749 (5.342)	-0.536 (2.179)	6.457 (9.987)	6.235 (12.948)
INCOME	0.080 (58.536)	-0.084 (33.043)	-0.011 (1.219)	-0.007 (1.040)
K(t)		0.0 (0.014)		
K(t-1)				0.016 (9.085)
K(t-2)	0.007 (2.518)			
K(t-3)			0.016 (7.224)	
I(t)	0.076 (6.177)			
I(t-1)	0.104 (5.905)	0.058 (2.882)	0.003 (0.453)	
I(t-2)		0.057 (2.462)	-0.014 (1.462)	-0.021 (2.282)
I(t-3)				-0.035 (3.851)

TABLE 49

AUSTRALIAN DATA : RAIL MODE

GLS REGRESSIONS : PERTH

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
INTERCEPT	0.516 (3.587)	-0.898 (2.274)	4.438 (22.917)	5.336 (16.847)
INCOME	0.088 (70.071)	0.085 (29.018)	0.009 (3.377)	0.005 (1.259)
K(t)		0.001 (1.400)		
K(t-1)				0.002 (6.780)
K(t-2)	-0.001 (2.086)			
K(t-3)			0.003 (18.507)	
I(t)	0.008 (2.784)			
I(t-1)	-0.029 (13.235)	0.001 (0.139)	0.008 (13.822)	
I(t-2)		0.016 (4.002)	0.007 (7.500)	-0.005 (5.949)
I(t-3)				0.001 (0.646)

TABLE 50

AUSTRALIAN DATA : ROAD MODE

GLS REGRESSIONS : ADELAIDE

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
INTERCEPT	-1.994 (6.339)	0.100 (0.315)	4.993 (3.186)	6.406 (6.395)
INCOME	0.080 (57.597)	0.081 (62.905)	0.014 (0.851)	0.026 (1.487)
K(t)		-0.0002 (2.303)		
K(t-1)				-0.0 (0.430)
K(t-2)	-0.0 (0.433)			
K(t-3)			0.0001 (1.450)	
I(t)	0.007 (3.816)			
I(t-1)	0.003 (2.143)	0.009 (14.470)	0.004 (1.615)	
I(t-2)		-0.009 (8.377)	-0.003 (1.549)	-0.007 (2.063)
I(t-3)				-0.005 (2.387)

TABLE 51

AUSTRALIAN DATA : HARBOUR MODE

GLS REGRESSIONS : ADELAIDE

	CASE AND LEVEL			
COEFFICIENTS ('t' VALUE)	1 A	2 A	1 B	2 B
INTERCEPT	-1.154 (5.018)	-0.638 (1.178)	6.900 (18.460)	7.976 (9.098)
INCOME	0.077 (61.158)	0.079 (33.310)	-0.008 (1.756)	-0.024 (2.079)
K(t)		0.0004 (0.121)		
K(t-1)				0.004 (2.676)
K(t-2)	0.005 (2.965)			
K(t-3)			0.003 (2.911)	
I(t)	0.026 (2.999)			
I(t-1)	0.056 (6.949)	0.040 (1.901)	0.021 (3.024)	
I(t-2)		0.001 (0.040)	-0.028 (2.931)	0.023 (1.503)
I(t-3)				-0.023 (2.937)

TABLE 52

AUSTRALIAN DATA : URBAN MODE

GLS REGRESSIONS : ADELAIDE

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
INTERCEPT	0.069 (0.853)	-0.049 (0.508)	2.864 (2.075)	5.142 (0.571)
INCOME	0.078 (62.655)	0.081 (50.237)	0.043 (2.450)	0.014 (1.258)
K(t)		-0.016 (4.225)		
K(t-1)				0.002 (1.344)
K(t-2)	-0.010 (9.111)			
K(t-3)			-0.010 (2.135)	
I(t)	0.020 (5.885)			
I(t-1)	-0.004 (2.008)	0.040 (3.825)	0.011 (2.652)	
I(t-2)		0.019 (2.517)	0.002 (0.795)	-0.017 (4.081)
I(t-3)				0.004 (0.713)

TABLE 53

AUSTRALIAN DATA : RAIL MODE

GLS REGRESSIONS : ADELAIDE

	CASE AND LEVEL			
COEFFICIENTS ('t' VALUE)	1 A	2 A	1 B	2 B
INTERCEPT	-1.950 (5.906)	-0.969 (5.609)	5.783 (6.732)	2.445 (2.732)
INCOME	0.068 (36.504)	0.080 (39.618)	-0.006 (0.561)	0.039 (3.796)
K(t)		0.004 (1.426)		
K(t-1)				0.005 (6.609)
K(t-2)	0.022 (6.026)			
K(t-3)			0.010 (7.669)	
I(t)	0.038 (9.170)			
I(t-1)	0.039 (4.216)	-0.009 (1.897)	0.029 (5.340)	
I(t-2)		0.031 (9.690)	-0.001 (0.227)	0.004 (1.390)
I(t-3)				0.012 (4.176)

TABLE 54

AUSTRALIAN DATA : ROAD MODE

GLS REGRESSIONS : HOBART

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
INTERCEPT	0.116 (4.484)	-0.046 (3.427)	-0.573 (3.104)	-1.329 (2.367)
INCOME	0.164 (178.667)	0.162 (301.470)	0.184 (21.071)	0.219 (8.159)
K(t)		-0.001 (29.289)		
K(t-1)				-0.001 (6.797)
K(t-2)	-0.001 (18.889)			
K(t-3)			-0.001 (15.708)	
I(t)	0.002 (6.152)			
I(t-1)	-0.0033 (17.099)	0.0 (0.656)	-0.001 (6.199)	
I(t-2)		0.002 (8.563)	0.003 (12.067)	-0.0 (1.189)
I(t-3)				0.004 (7.840)

TABLE 55

AUSTRALIAN DATA : HARBOUR MODE

GLS REGRESSIONS : HOBART

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
INTERCEPT	0.199 (4.544)	-0.196 (2.099)	0.955 (1.466)	1.520 (1.912)
INCOME	0.165 (98.175)	0.163 (129.996)	0.105 (3.819)	0.077 (2.226)
K(t)		-0.003 (3.045)		
K(t-1)				0.001 (0.560)
K(t-2)	-0.006 (9.263)			
K(t-3)			-0.0 (0.351)	
I(t)	0.007 (3.119)			
I(t-1)	-0.016 (5.220)	0.008 (2.838)	0.006 (1.670)	
I(t-2)		0.011 (3.789)	0.008 (2.073)	0.005 (1.184)
I(t-3)				0.006 (1.539)

TABLE 56

AUSTRALIAN DATA : URBAN MODE

GLS REGRESSIONS : HOBART

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL			
	1 A	2 A	1 B	2 B
INTERCEPT	0.030 (1.191)	0.030 (1.439)	3.245 (4.449)	1.587 (5.317)
INCOME	0.163 (100.036)	0.164 (115.175)	0.006 (0.160)	0.084 (5.924)
K(t)		-0.029 (12.052)		
K(t-1)				-0.011 (3.663)
K(t-2)	-0.026 (10.063)			
K(t-3)			0.009 (1.139)	
I(t)	-0.030 (6.376)			
I(t-1)	-0.017 (4.061)	-0.007 (1.826)	-0.002 (0.484)	
I(t-2)		0.013 (2.687)	0.002 (0.402)	0.011 (6.008)
I(t-3)				0.007 (2.247)

TABLE 57

AUSTRALIAN DATA : RAIL MODE

GLS REGRESSIONS : HOBART

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL			
	1 A	2 A	1 B	2 B
INTERCEPT	6.662 (4.089)	5.128 (4.264)	3.832 (13.335)	4.348 (13.194)
INCOME	0.190 (23.410)	0.176 (24.200)	0.065 (9.502)	0.086 (6.797)
K(t)		-0.078 (4.406)		
K(t-1)				-0.039 (5.336)
K(t-2)	-0.103 (4.270)			
K(t-3)			-0.026 (5.680)	
I(t)	-0.113 (4.023)			
I(t-1)	-0.087 (3.695)	-0.009 (1.706)	-0.024 (5.736)	
I(t-2)		0.006 (3.564)	-0.032 (5.488)	0.002 (2.634)
I(t-3)				-0.011 (5.035)

TABLE 58

AUSTRALIAN DATA : ROAD MODE

GLS REGRESSIONS : MELBOURNE

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
INTERCEPT	3.743 (4.160)	3.651 (4.761)	12.000 (16.970)	13.627 (38.997)
INCOME	0.051 (57.580)	0.050 (66.031)	-0.006 (1.422)	-0.014 (9.630)
K(t)		-0.0004 (6.091)		
K(t-1)				0.0002 (21.364)
K(t-2)	-0.001 (4.740)			
K(t-3)			0.0002 (3.264)	
I(t)	-0.006 (9.101)		0.0001 (0.196)	
I(t-1)	-0.001 (0.587)	-0.003 (4.379)	-0.001 (0.967)	
I(t-2)		-0.003 (2.446)		-0.002 (8.205)
I(t-3)				0.001 (5.426)

TABLE 59

AUSTRALIAN DATA : HARBOUR MODE

GLS REGRESSIONS : MELBOURNE

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
INTERCEPT	0.333 (0.878)	0.922 (1.349)	13.880 (24.708)	13.537 (35.068)
INCOME	0.051 (68.237)	0.049 (37.236)	-0.021 (6.132)	-0.018 (8.217)
K(t)		-0.004 (2.108)		
K(t-1)				0.005 (14.118)
K(t-2)	-0.005 (5.124)			
K(t-3)			0.006 (8.625)	
I(t)	-0.029 (3.137)			
I(t-1)	0.019 (7.167)	-0.001 (0.043)	0.009 (2.870)	
I(t-2)		-0.014 (1.256)	0.012 (4.949)	-0.004 (3.103)
I(t-3)				0.008 (6.329)

TABLE 60

AUSTRALIAN DATA : URBAN MODE

GLS REGRESSIONS : MELBOURNE

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
INTERCEPT	0.178 (1.431)	0.126 (1.147)	11.416 (14.260)	9.358 (13.226)
INCOME	0.050 (51.565)	0.049 (73.458)	-0.005 (1.287)	0.005 (1.448)
K(t)		0.001 (0.416)		
K(t-1)				0.003 (2.978)
K(t-2)	-0.001 (0.472)			
K(t-3)			0.006 (10.495)	
I(t)	-0.038 (5.494)			
I(t-1)	-0.023 (2.167)	-0.026 (4.127)	0.009 (3.281)	
I(t-2)		-0.018 (2.928)	0.001 (0.415)	0.008 (2.255)
I(t-3)				-0.008 (3.174)

TABLE 61

AUSTRALIAN DATA : RAIL MODE

GLS REGRESSIONS : MELBOURNE

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
INTERCEPT	0.715 (3.264)	1.152 (5.747)	10.763 (14.114)	11.560 (16.480)
INCOME	0.049 (62.977)	0.050 (70.970)	-0.001 (0.368)	-0.006 (1.590)
K(t)		0.001 (2.481)		
K(t-1)				0.001 (6.752)
K(t-2)	0.001 (3.165)			
K(t-3)			0.001 (6.823)	
I(t)	-0.019 (12.273)			
I(t-1)	0.007 (2.415)	-0.012 (5.020)	-0.001 (1.268)	
I(t-2)		-0.010 (1.865)	0.0 (0.263)	-0.005 (4.552)
I(t-3)				0.002 (1.731)

TABLE 62

AUSTRALIAN DATA : ROAD MODE

GLS REGRESSIONS : SYDNEY

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
INTERCEPT	-4.330 (6.821)	-0.145 (0.423)	10.172 (4.550)	9.810 (3.598)
INCOME	0.039 (140.865)	0.039 (95.636)	0.008 (1.005)	0.008 (0.882)
K(t)		-0.0002 (5.591)		
K(t-1)				0.0 (0.547)
K(t-2)	-0.0002 (12.375)			
K(t-3)			0.0 (0.569)	
I(t)	0.003 (7.388)			
I(t-1)	0.003 (6.777)	0.001 (5.239)	-0.0 (0.632)	
I(t-2)		-0.0003 (1.485)	-0.0 (0.665)	-0.001 (0.936)
I(t-3)				0.0 (0.344)

TABLE 63

AUSTRALIAN DATA : HARBOUR MODE

GLS REGRESSIONS : SYDNEY

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL			
	1 A	2 A	1 B	2 B
INTERCEPT	0.754 (4.515)	0.452 (5.298)	9.506 (5.992)	9.159 (4.177)
INCOME	0.038 (76.105)	0.039 (172.409)	0.008 (1.571)	0.009 (1.229)
K(t)		-0.002 (10.190)		
K(t-1)				0.001 (1.087)
K(t-2)	-0.002 (3.101)			
K(t-3)			0.001 (1.509)	
I(t)	-0.007 (2.318)			
I(t-1)	-0.002 (0.648)	-0.010 (5.464)	-0.005 (3.282)	
I(t-2)		0.008 (7.357)	0.005 (3.575)	0.005 (2.573)
I(t-3)				-0.004 (1.928)

TABLE 64

AUSTRALIAN DATA : URBAN MODE

GLS REGRESSIONS : SYDNEY

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL			
	1 A	2 A	1 B	2 B
INTERCEPT	1.614 (9.602)	1.093 (6.044)	8.793 (6.532)	6.896 (5.990)
INCOME	0.040 (105.245)	0.040 (106.516)	0.010 (2.027)	0.015 (3.680)
K(t)		-0.056 (11.576)		
K(t-1)				0.009 (1.069)
K(t-2)	-0.071 (12.914)			
K(t-3)			0.009 (0.761)	
I(t)	-0.099 (7.010)			
I(t-1)	-0.046 (8.263)	-0.026 (0.058)	0.001 (2.312)	
I(t-2)		0.045 (4.276)	0.022 (1.798)	0.038 (5.134)
I(t-3)				0.003 (0.578)

TABLE 65

AUSTRALIAN DATA : RAIL MODE

GLS REGRESSIONS : SYDNEY

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
INTERCEPT	0.203 (2.919)	0.488 (4.620)	14.957 (8.019)	15.141 (11.360)
INCOME	0.038 (196.267)	0.039 (109.941)	-0.008 (1.397)	-0.009 (2.011)
K(t)		-0.001 (6.385)		
K(t-1)				0.001 (6.894)
K(t-2)	-0.001 (17.529)			
K(t-3)			0.001 (4.418)	
I(t)	-0.003 (8.714)			
I(t-1)	0.003 (10.431)	-0.0 (0.719)	0.001 (2.492)	
I(t-2)		-0.001 (2.075)	-0.002 (6.741)	-0.001 (2.222)
I(t-3)				-0.004 (10.284)

TABLE 66

AUSTRALIAN DATA : ROAD MODE

GLS REGRESSIONS : BRISBANE

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
INTERCEPT	3.131 (3.162)	-2.666 (4.770)	7.326 (292.821)	7.199 (292.588)
INCOME	0.068 (45.859)	0.062 (60.246)	-0.001 (4.586)	-0.0002 (1.430)
K(t)		-0.0001 (1.920)		
K(t-1)				0.0003 (358.481)
K(t-2)	-0.001 (6.272)			
K(t-3)			0.0003 (145.687)	
I(t)	-0.006 (3.004)			
I(t-1)	-0.001 (0.510)	-0.006 (4.014)	0.0004 (11.390)	
I(t-2)		0.014 (8.210)	-0.001 (9.196)	-0.0002 (15.400)
I(t-3)				-0.0003 (10.60)

TABLE 67

AUSTRALIAN DATA : HARBOUR MODE

GLS REGRESSIONS : BRISBANE

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
INTERCEPT	0.228 (3.161)	0.570 (7.158)	5.310 (4.046)	8.378 (9.180)
INCOME	0.068 (83.955)	0.063 (84.483)	0.018 (1.414)	-0.011 (1.278)
K(t)		-0.001 (3.856)		
K(t-1)				0.004 (5.443)
K(t-2)	-0.009 (7.708)			
K(t-3)			0.001 (0.810)	
I(t)	0.003 (1.378)			
I(t-1)	0.007 (3.558)	-0.0004 (0.368)	0.002 (1.128)	
I(t-2)		-0.011 (7.861)	-0.002 (0.569)	-0.003 (4.292)
I(t-3)				0.0001 (0.084)

TABLE 68

AUSTRALIAN DATA : URBAN MODE

GLS REGRESSIONS : BRISBANE

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
INTERCEPT	0.088 (0.979)	0.388 (2.001)	7.405 (17.848)	6.481 (13.136)
INCOME	0.067 (72.485)	0.066 (34.299)	-0.003 (0.737)	0.006 (1.196)
K(t)		-0.032 (3.737)		
K(t-1)				0.019 (4.467)
K(t-2)	-0.030 (7.329)			
K(t-3)			0.027 (7.290)	
I(t)	-0.006 (1.494)			
I(t-1)	0.030 (4.263)	0.049 (4.941)	0.016 (5.434)	
I(t-2)		-0.019 (1.501)	0.013 (4.571)	0.005 (1.068)
I(t-3)				-0.014 (3.753)

TABLE 69

AUSTRALIAN DATA : RAIL MODE

GLS REGRESSIONS : BRISBANE

COEFFICIENTS ('t' VALUE)	CASE AND LEVEL 1 A	2 A	1 B	2 B
INTERCEPT	0.318 (1.834)	0.410 (2.291)	7.692 (64.120)	7.555 (25.590)
INCOME	0.067 (51.640)	0.066 (46.564)	-0.005 (4.172)	-0.004 (1.431)
K(t)		-0.001 (4.112)		
K(t-1)				0.001 (9.981)
K(t-2)	-0.001 (4.916)			
K(t-3)			0.001 (23.692)	
I(t)	0.001 (0.355)			
I(t-1)	-0.002 (1.925)	0.002 (1.721)	-0.0 (0.374)	
I(t-2)		-0.002 (1.580)	-0.0 (1.142)	0.0 (0.180)
I(t-3)				-0.001 (2.236)

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