A Benefit Costs Analysis
Of
Twinning Highway #3
Revised and Updated
May 7. 2004

I. Introduction

In late 2000 discussions began, involving the Highway #3 Association, the Van Horne Institute at the University of Calgary, and Frank Atkins, from the Department of Economics of the University of Calgary, towards producing a study of the costs and benefits of twinning Highway #3 in southern Alberta. A final proposal was submitted in mid 2001 and the final report was completed in February, 2002. This report was completed under the guidance of a steering committee composed of representatives from the Highway #3 Association, the Provincial Government, the Van Horne Institute, as well as Frank Atkins. The purpose of this May, 2004 paper is to summarize the methodology and results from the most recent update of this ongoing project. As such, this update should be read in conjunction with the original report.

The conclusion of the first report was that the infrastructure investment involved in the twining of Highway #3 should be undertaken. This conclusion was reached based on econometric estimation of the benefits to the region from the infrastructure investment. These benefits would accrue in the form of growth in economic activity, *beyond the normal growth forecast for this region*, which would be in excess of the total cost of the infrastructure investment. The results of the study were presented to a *Standing Committee* of the provincial government.

The conclusion from this update of the original Highway #3 study, is essentially unchanged from that of the original study: twinning Highway 3 will bring about economic benefits to the region of Southern Alberta which exceed the costs of building the highway. Thus, according to the results in this study, twinning Highway 3 is an economically viable infrastructure project.

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Chapter 1
Introduction and Summary

1.1 Introduction

The purpose of this project is to undertake a benefit cost analysis of twinning of Highway 3 from the British Columbia border to Medicine Hat. In this chapter we briefly outline the methodology used, and the major results obtained. In Chapter 2 we present a review of the relevant literature from existing Canadian and U.S. studies. In Chapter 3 we describe in detail the data manipulation that was necessary before an econometric model could be estimated. In Chapter 4 we describe the various econometric models that were estimated in order to arrive at a final acceptable model. In Chapter 5 we calculate the benefit cost ratio, and Chapter 6 provides conclusions.

1.2 Outline of Benefit Cost Methodology

A benefit cost analysis is a general methodology, which provides a decision rule for whether or not capital projects are viable. The basis of a benefit cost study is to attach dollar values to all benefits and all costs that result from undertaking a project. Once all dollar values are ascertained, a benefit cost ratio (BCR) is then calculated as

(1.1) BCR = Dollar Value of All Benefits/Dollar Value of all Costs

The decision criterion is that a project is economically viable if the benefits exceed the costs. Therefore the decision rule is:

(1.2) If BCR > 1, project is viable

(1.3) If BCR < 1, project is not viable

Of course, in the case of projects competing for limited investment resources, the project with the highest BCR provides the best return.

1.3 Estimated Benefits of Twinning Highway 3

The benefits to twinning Highway 3 accrue in (at least) two areas: safety improvements and increases in economic activity.

Safety Improvements

The literature on the relationship between road improvements and accidents shows that lane widening and road improvements generally decrease accidents by 13-49%.[1] These percentage decreases can be translated into dollar amounts by placing a dollar value on the losses attributable to accidents. It is well known that highway accidents cause dollar losses in three areas: wage and productivity loss; increased medical expenses; and vehicle damage. Although there is no general consensus on the dollar value of these costs, some estimates state that a highway death costs approximately $980,000 and an injury costs approximately $35,600.[2] A very rough estimate of the dollar value of these safety improvements could be calculated by multiplying the dollar costs of injuries and fatalities by the expected reduction in accidents brought about by twinning Highway 3.

However, any estimate of the dollar value of these safety improvements would justifiably be subject to a great deal of skepticism, as there is no strong consensus in the literature surrounding the figures that were quoted above. In addition, as we show below, this Highway 3 project is economically viable (i.e. the BCR>1) without including the dollar value of these benefits in the final calculations. Therefore, we provide no exact dollar estimate of these benefits, and note that any calculation of these benefits would simply serve to increase any calculated benefit cost ratio.

[1] Source: http://www.tc.gc.ca/pol/en/report/Highway_Infrastructure_Road_Safety/Table_of_Content.htm .

[2] Source: http://www.nsc.org/lrs/statinfo/estcost8.htm. In addition to the above, there is also the decrease in quality of life associated with an injury or fatality. There is even less consensus on the dollar cost in this category, with some estimates as high as $3,000,000 per fatal accident.

Benefits from increases in Economic Activity

The benefits accruing to increases in economic activity from twinning Highway 3 can be categorized as direct and indirect. Direct benefits are immediate and temporary, and are related to the spending surrounding the highway construction process. These benefits vanish very quickly upon completion of the construction. Therefore, they do not have any lasting benefit, and we do not calculate them.[3]

Indirect benefits accrue in the future. These are the benefits that come from increased economic activity related to the increase in infrastructure expenditure. These indirect benefits are by far the largest benefit and must be estimated via an econometric model. An econometric model is simply an equation, or set of equations, that is estimated through statistical techniques. The goal of constructing an econometric model is to describe economic activity in some region. For the purposes of this project, it was our goal to build an econometric model of economic activity in Southern Alberta. This model could then be used to forecast local gross domestic product (GDP) under two assumptions. First, the model could be used to forecast local GDP, assuming that there is no change in infrastructure investment in the future. Second, the model could be used to forecast local GDP under the assumption that infrastructure investment is increased, in the form of twinning Highway 3. The difference between these two forecasts of local GDP is a measure of the economic benefits from twinning Highway 3.

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[3] These benefits are sometimes called multiplier benefits. That is, a one time $1.00 expenditure in an area may lead to an increase in economic activity greater than $1.00. However, this cannot be permanent, or, for instance, a one time increase in government spending in the economy would lead to a permanent increase in economic activity. This idea has been thoroughly dismissed in the economics literature.

1.4 Estimated Costs of Twinning Highway 3

It is our understanding that twinning Highway 3 will cost approximately $1,000,000 per kilometer, and there are approximately 220 kilometers to be twinned. In addition, structures will cost approximately $25 million, for a total direct cost of $245 million. In addition, ongoing maintenance will cost approximately $1,000,000 per year.[4]

1.5 A Summary of the General Econometric Methodology

In order to estimate the economic impact of an increase in investment on highway capital, researchers almost universally have applied some variant of production function analysis. This type of analysis assumes that economic activity (i.e. GDP) is determined by inputs to the production process, called factors of production. Generally speaking these inputs are in the form of capital and labour. The most general form of a production function is given by the following equation:

$$Y = AF(K,L) \tag{1.4}$$

Where output is denoted by Y, capital by K and labour by L. The term A is designed to catch other factors such as technological progress or increases in factor productivity. For the purposes of this study, we wish to know how much a change in capital (K) will change output (Y). More specifically, however, we are interested in how a change in the highway component of the capital stock will affect output. Thus, we can change equation (1.4) to split K into two components:

$$Y = AF(K^h, K^o, L) \tag{1.5}$$

Thus the total capital stock is composed of that portion attributable to highways (K^h) and that portion attributable to other capital (K^o), such as machinery, factories, etc.

[4] That is, maintenance costs are estimated to be approximately $5,000 per kilometer per year. Recall that there are 220 kilometers of new highway under consideration in this project. This excludes other investments to maintain and improve the existing highway network.

In order to ascertain how the factors of production are related to output, a statistical model must be estimated. This requires assuming a functional form for equation (1.5). One very common functional form is the log linear production function:

(1.6) $$y = \beta_0 + \beta_1 k^h + \beta_2 k^o + \beta_3 l + \mu$$

Where lower case letters represent variables measured in natural logarithms, i.e. $y = lnY$, etc. The term β_0 captures the technology/factor productivity effects (A from equation (1.4)), while β_1, β_2 and β_3 are elasticities. These elasticities measure the percentage response of output to a change in one of the inputs. Of importance for this study is β_1 which measures how much output changes in response to an increase in highway capital.

In this study we faced two problems in estimating equation (1.6). First there is no existing data on the relevant variables for the southern Alberta region, and, second, we faced the statistical problem that all of the variables in equation (1.6) do not conform to normal stationarity requirements. The latter problem refers to the question of whether the data varies in a manner that is compatible with standard estimation. This will be explained more fully in Chapter 4.

1.6 Gathering the Data

In order to estimate equation (1.6), we required data that pertains to a measure of real GDP, capital stock with highway capital separated out, and labour, all for the *southern* region of Alberta. Unfortunately, this data did not exist when we began this project. Data had to be collected from many existing sources and the relevant data for estimation was then constructed for the southern region of Alberta. Due to data constraints, the final data set was comprised of annual observations for the years 1961 to 1997. All dollar measures are in millions of constant 1992 and labour is measured in thousands.

1.7 Statistical Properties of the Data

Initial estimation of various standard forms of equation (1.6) produced results that were *statistically* anomalous. The nature of these statistical anomalies led us to suspect that the underlying data was not amenable to traditional regression analysis. In statistics parlance, the data was shown to be non-stationary. In simple terms, one manner in which to understand this problem is that the mean and variance of the data are not constant over time. It must be stressed that this was not a problem with the underlying production function methodology from economic theory, but rather the data did not have standard statistical properties.

In the macroeconomic time series literature, there is a very large, very recent contribution on statistical methods of dealing with non stationarity problems. This literature falls under the broad title of Integrated and Co-integrated variables and Error Correction Methodology. This is the methodology that we have applied in estimating the production function model for this study.

It should be noted that a search of the production function literature showed that, although some researchers have mentioned that non stationarity may be a problem, there are no published papers using Canadian data that we are aware of that have actually dealt with this problem. Thus, in applying this methodology in this study, we believe that we are producing the seminal study.

1.8 The Final Model

As a result of a tremendous amount of estimation and testing using the advanced techniques outlined above, a final form for the econometric model was chosen. This form is a variant of equation (1.6) known as an error correction model. This model is of the general form:

$$\Delta y = \beta_0 + \beta_1 \Delta k^h + \beta_2 \Delta k^o + \beta_3 \Delta l + \gamma EC + \mu \tag{1.7}$$

This model is a combination of short and long run effects. The long run effects are captured in the term EC.[5] Embedded in the EC term are the elasticites that are required in order to calculate the estimated long run increase in GDP due to an increase in expenditure on highway capital. The short run ealsticites are captured in the other terms in the equation, and are required that the forecasting exercise properly takes into account both short run and long run effects. From our final model, the important estimated long-run elasticity is 0.505 for highway capital. This elasticity indicates that a 1% increase in highway investment will produce a 0.505% increase in GDP in the long run. Given the range of elasticities reported in the literature for highway capital and other forms of capital (see Chapter 2) this elasticity can be considered to be in a 'reasonable' range.

[5] Please be aware that equation (1.7) is a very over simplified representation of the actual error correction model, and is presented for illustration purposes only. See Chapter 4 for details.

1.8 Forecasting With the Final Model

The above error correction model was used to forecast GDP under two scenarios. First, the model was used to forecast base line values of GDP in Southern Alberta, based on the assumption that highway capital, all other capital, and labour would all grow in the future according to a linear time trend, estimated from the past behaviour of these variables. Second, the model was used to forecast GDP in southern Alberta based on the assumption that labour and all capital other than highway capital would grow in the future according to a linear time trend, and highway capital would increase by the amount of the construction cost.[6] The accumulated difference in GDP over the forecast horizon is an estimate of the economic benefit to the southern Alberta region from twinning Highway 3.

1.9 Calculating the Benefit Cost Ratio

Once the forecasting exercise was completed, the benefit cost ratio could be calculated. The benefits to the Southern Alberta region are the accumulated increases in GDP as a result of twinning Highway 3. As the benefits to twinning Highway 3 accrue in the future, they must be discounted to the present. In addition, the costs of construction were spread over 5 years, and these, along with the future maintenance cost also had to be discounted to the present. Therefore, the BCR will vary depending on the discount rate chosen. In Table 1-1 below, reports a summary of the benefit cost ratios for a representative sample from the models that were estimated.[7] The benefits and costs are discounted assuming different discount rates, and a BCR is calculated for each different discount rate.

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[6] The gross amount of construction cost is added to the value of the highway capital stock, and then highway depreciation, for the new section only, is factored into this amount.

[7] As will be shown below, there is no unique final model that can be said to be superior to all other models. In the end we chose ten of the 'best' models. The details are explained in Chapter 4.

Table 1-1
Benefit Cost Ratio Calculations
Different Real Discount Rates

Real Discount Rate	Present Value of Future GDP ($millions)	Cost ($millions)	BCR
3.00%	$899,000	$238,500	3.76
4.00%	848,000	232,100	3.65
5.00%	801,000	226,100	3.54
6.00%	757,000	220,400	3.43
10.00%	607,000	200,300	3.03

The most important feature of Table 1-1 is that the BCR is greater than 1 for all reasonable discount rates. Notice that the BCR is also greater than 1 for a real discount rate of 10 percent, which, by economic theory standards, should be considered to be quite high.

Recall that the estimated benefits for the calculations on Table 1-1 do not include any benefits that accrue to safety improvements from twinning Highway 3. Including these benefits would only serve to increase any of the BCR shown on Table 1.

At the end of Chapter 5 we test the sensitivity of the BCR estimates to errors in the estimation of the long run highway elasticity.

1.10 Conclusions

In this chapter we have outlined the methodology used to estimate the benefit cost ratio for the capital project of twinning Highway 3 from the British Columbia border to Medicine Hat. In calculating the BCR, we have applied the advanced methodology of integrated and co-integrated variables and error correction modeling. We believe that this study is the first of its type in Canada, and as such, it can serve as a template for further benefit cost studies in this area.

The conclusion from this introductory chapter, which is also the conclusion of this study, is that twinning Highway 3 will bring about economic benefits to the region of Southern Alberta which exceed the costs of building the highway. Thus, according to the results in this study, twinning Highway 3 is an economically viable infrastructure project.

Chapter 2
Review of the Literature

2.1 Introduction

As outlined in Chapter 1, the goal of this study is provide a benefit cost analysis of twinning Highway 3. In economics, the question of the benefits of highway construction compared to the costs is part of the larger, and somewhat more complex, question concerning whether any public expenditures are beneficial to an economy. In this study, and in the literature that is reviewed, we restrict our attention to the more narrow question of how can public infrastructure investment may benefit an economy.

The literature on the benefits of public investment in highway infrastructure can be divided into two broad areas. The first strand of the literature attempts to quantify benefits using what might broadly be called engineering studies. By this we mean any study that is related to traffic congestion and the benefits that accrue when traffic congestion is alleviated through road improvement (eg. widening of a highway). In this literature, the benefits to infrastructure investment are generally measured as transportation cost reductions, and savings due to the reduction in accidents that inevitably result from road building or improvement.

The second broad area of the literature concentrates on the set of benefits that derive from the general improvement in economic activity resulting from improved infrastructure. For example, with road improvements, and the resultant reduction in transportation costs, firms become more profitable, and are more likely to expand their business, this will attract more population to an area, and inevitably result in more spending, and higher output in a region.

Of course, these two categories of benefits are not mutually exclusive. In fact, most of the recent studies in this area implicitly assume that any reduced transportation cost and safety improvements are implicitly captured in any measure of increased economic activity. For this reason, and given that benefits from the first category are notoriously difficult to measure, most benefit cost studies estimate the benefits from increased economic activity, assuming that this captures the implicit engineering benefits.

This higher output resulting from increased infrastructure expenditure is generally estimated through an economic model called a production function. Before proceeding we first introduce the production function.

The Production Function

In order to estimate the economic impact of an increase in investment on highway capital, researchers almost universally have applied some variant of production function analysis. This type of analysis assumes that economic activity (i.e. GDP) is determined by inputs to the production process, called factor of production. Generally speaking these inputs are in the form of capital and labour. The most general form of a production function is given by the following equation:

(2.1) $$Y = AF(K, L)$$

Where output is denoted by Y, capital by K and labour by L. The term A is designed to catch other factors such as technological progress or increases in factor productivity.

Of course, within the broad category of capital, there are several components. Generally speaking, we wish to think of capital as including public capital (highways, bridges, etc) and private capital (factories, machines, etc.). Therefore, we can use the production function to think of how a change in public capital (such as building a new road) will change economic activity, as measured by GDP. Thus, we can extend equation (2.1) to split K into two components:

(2.2) $$Y = AF(K^h, K^o, L)$$

Thus the total capital stock is composed of that portion attributable to highways (K^h) and that portion attributable to other capital (K^o), such as machinery, factories, etc.

The production function assumes that any changes in GDP in a region can be explained by change in capital or by a change in labour in that region. In order to ascertain how the factors of production are related to output, a statistical model must be estimated. This requires assuming a functional form for equation (2.2). One very common functional form is the log linear production function:

$$y = \beta_0 + \beta_1 k^h + \beta_2 k^o + \beta_3 l + \mu \tag{2.3}$$

Where lower case letters represent variables measured in natural logarithms, i.e. $y = \ln Y$, etc. The term β_0 captures the technology/factor productivity effects (A from equation (2.4)), while β_1, β_2 and β_3 are elasticities. These elasticities measure the percentage response of output to a change in one of the inputs. Of importance for this study is β_1 which measures how much output changes in response to an increase in highway capital. For instance, if β_1 is measured to be 0.5, then a 1 percent increase in investment in highways, will lead to 0.5 percent increase in GDP. This can then be used to calculate the economic benefits to a region from building or expanding highways in that region.

Although the log linear specification of the production function given by equation (2.3) is the simplest and most widely used form of the production function, many other variants exist. Most of these variants are extremely complicated, and impose restrictions on equation (2.3). For instance, a constant returns to scale (CRS) production function estimates equation (2.3) with the restriction that $\beta_1 + \beta_2 + \beta_3 = 1$. As we will see below, increasing the complexity of equation (2.3) does not appear to have a large effect on the elasticity estimates.

2.2 A Review of Canadian Studies

There are relatively few Canadian studies which attempt to quantify the effects of highway expenditure on the economy. These Canadian studies broadly fall into the two categories summarized above: those that have estimated the benefits to highway construction by calculating the reduction in transportation costs due to highway improvements or new highway construction; and those that have estimated the benefits to highway construction by estimating elasticites from a production function.

Studies that Consider Reductions in Transportation Costs

In 1995 Transport Canada produced a report carefully outlining the role of transportation costs in the goods producing industries in Canada.[1] This study estimates and examines the importance of transportation costs and savings in the production and distribution of commodities by Canadian industries. The general finding from this study was that with a more efficient highway system, transportation costs decrease, which is beneficial to business users as well as consumers. The transportation sector's importance can be seen by three indicators: the contribution to total Gross National Product; transportation as an intermediate input to goods-producing industries; and transportation margins as a percent of industrial output and of commodity value. This study used estimated transportation cost data from Statistics Canada's Input-Output models, and the costs are calculated from production costs or prices and are by industry and commodity groups.

In the cost structure of the goods producing sector, the average transportation cost share was found to be about 2.4 percent, and added on average 4.6 percent to the producer's prices of commodities. The ratio was found to be much higher in the primary sector than in the manufacturing industry, about 10% versus 3.3%. Of primary

[1] "The Importance of Transportation Costs in Goods-Producing Industries", *Transport Canada, TP 12673E*, Canada, December 1995.

importance to the Alberta economy are export goods, which were found to generally bear higher transportation cost ratios.[2] These ratios average 6 percent, somewhat higher than the average of 4 percent for domestically consumed goods. Table 2 in the Appendix lists the industry costs produced by Statistics Canada.

This study concluded that transportation is a strategic factor in the competitiveness of Canadian shippers, and that a decrease of transportation costs from a more efficient highway system contributed to the growth of rate of output over the past decade. Finally, the authors suggested that initiatives aimed at improving the efficiency of the transportation sector are essential.

A 1996 Transport Canada study concerning national highway policy reviewed 145 projects in Canada and summarized the benefit-cost analysis results.[3] Most of the studies were conducted with Transport Canada's HUBAM model, used to calculate the dollar amounts of costs and benefits. In this study benefits included the dollar value of the reduction in time and vehicle operating costs, as well as the benefits from reduction in accidents. Costs considered were the future operating and management costs and the initial investment.

This study concluded that overall, the benefit cost ratio was in the neighborhood of 3. As well, time and vehicle operating cost savings accounted for over 70% of the benefits. The range in values of time, life and estimated speed of vehicles produced inconsistencies in the reviewed projects. This study also concluded that benefit-cost analysis is an important success indicator of a proposed project, and cost-beneficial improvements would promote growth and standard of living improvement. In the list of projects that were reviewed, twinning in Alberta was identified as one of the possible better projects in Canada.

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[2] That is, transportation cost over output.

[3] "Highway Benefit-Cost Analysis: Review of Evidence", *Transport Canada, TP 12790 E*, Canada, June 1996.

Canadian Studies Using the Production Function

There is very little published Canadian research using a production function methodology to estimate the benefits from building or expanding highways. The major published work was undertaken by Transport Canada.[4] This study estimated the output elasticity of highway investment (that is β_1 from equation (2.3)) for Canada using different assumptions. The elasticity results of this study vary depending on several factors. The most important consideration was whether the production function was estimated using national time series data, or using pooled data. National time series data considers the Canadian economy measured over time, while the pooled data consider each province "pooled" together to form one time series.

The elasticity results from this study are summarized on Table 2-1.

[4] Khanam, Bilkis. "Highway Infrastructure Capital and Productivity Growth: Evidence from the Canadian Goods Producing Sector", Canadian Transportation Research Forum Proceedings, May, 1996 and "Macroeconomic Performance and Public Highway Infrastructure", *Transport Canada/Economic Analysis, Special Infrastructure Project*, Canada, June 1996.

Table 2-1
Summary of Output Elastcities from Transport Canada[5]

	Functional Form	Restrictions	Elasticity
Time Series			
	Cobb-Douglas	CRS	0.24
	Cobb-Douglas	CRS	0.33
	Cobb-Douglas	None	0.46
	Cobb-Douglas	Delayed	0.60
	Translog	None	0.47
Pooled			
	Cobb-Douglas	GLS	0.12
	Cobb-Douglas	Fixed Time	0.10*
	Cobb-Douglas	Fixed Time Delayed	0.15*
	Cobb-Douglas	Fixed Province/Time	0.14
	Cobb-Douglas	First Difference	0.09*
	Translog	None	0.13*
	Translog	Fixed Time	0.17
	Translog	Fixed Province/Time	0.36*

Note:

- Denotes an estimate that is *not* statistically significant at 95%. That is, the estimate is indistinguishable from 0.0.
- CRS denotes a constant returns to scale restriction.
- GLS is estimated by generalized least squares.

It can be seen on Table 2-1 that the estimated output elasticities vary from 0.24 – 0.60 for national time series data and from 0.09 – 0.36 for pooled data. However, many of the elasticities estimated from the pooled data are not statistically significant. Generally speaking, it appears that the type of data used (eg. time series vs. pooled) matters much more than the specification of the production function (eg. Cobb-Douglas vs. Translog).

[5] This Table is adapted from "Macroeconomic Performance and Public Highway Infrastructure", *Transport Canada/Economic Analysis, Special Infrastructure Project*, Canada, June 1996, Tables 1 and 2.

This study concludes:

> "The output elasticities of public highway capital suggest that the benefit cost ratio of investments that are not made at the margin is in the order of 3. Hence, the benefit cost ratios of those investments that are made should be higher. There is substantial evidence that many highway projects undertaken have much lower benefit cost ratios".

The fact that the time series estimates are larger than the pooled estimates is thought by the authors of the Transport Canada study to be a result of spurious regression, a statistical anomaly that results when two or more series appear to be related over time, but actually are not. In Chapter 4, below, we deal explicitly with this spurious regression problem.

2.2 A Review of United States Studies

In a seminal study, D.A. Aschauer[6] concluded that the slowdown in productivity in the U.S. economy in the 1970s was attributable to the decline in the rate of public infrastructure investment. Although this sort of grand sweeping conclusion is beyond the scope of this study, Aschauer did estimate that the output elasticity of public expenditure ranged from 0.39 – 0.56, using national time series data.

Not surprisingly, the Aschauer results lead to responses from several authors. The elasticity results from the Aschauer study, and those that followed are summarized in Table 2-2.

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[6] D.A. Aschauer, "Is Public Expenditure Productive? Journal of Monetary Economics, 23, 1989, 177-200.

Table 2-2
A Summary of U.S. Elasticity Results

Study	Data	Functional Form	Infrastructure	Output Elasticity
Aschauer (1989)	Time Series	C-D,	Public Capital	0.39 – 0.56
Munnell (1990c)	Time Series	C-D, Translog	Public Capital	0.33 *
Lynde and Richmond (1991)	Time Series	C-D	Public Captial	0.20
Munnell (1990a)	Pooled	C-D, CRS, Translog	Public Capital	0.15
Munnell (1990b)	Pooled	C-D, Translog	Highway Capital	0.06
Moomaw & Williams (1991)	Pooled	Translog	Highway Capital	0.25
Garcia-Mila & McGuire (1988)	Pooled	C-D	Highway Capital	0.04
Garcia-Mila & McGuire (1992a)	Pooled	C-D	Highway Capital	0.13
Garcia-Mila & McGuire (1992b)	Pooled	C-D	Highway Capital	0.12
Nadiri & Mamuneas (1996)	Industrial	Cost Function	Highway Capital	0.04 - 0.17**

Note:

- *denotes labour productivity elasticity
- ** The cost function is a variant of the production function approach, which requires more detailed data. Technically, this is known as the dual of the production function.

Table 2-2 shows that, as with the Canadian results, the estimated elasticities are somewhat higher when time series data is used. Once again, the authors of these studies warn of the statistical problems associated with the use of time series data. However, none of these studies attempt to correct for these potential problems.

2.3 *Summary of the Literature*

The most important result from this literature is that changes in highway capital are estimated to have a significant, positive effect on output, both in Canada and in the United States. The benefit cost ratios from the above studies are all greater than 1, and have been estimated to be as high as 3. However, a great deal of caution is warranted in summarizing this literature. It is very clear that the estimated output elasticities, and, therefore, the calculated benefit cost ratios, are sensitive to the methodology employed. Interestingly, the results do not appear to be overly sensitive to restrictions imposed on the standard Cobb-Douglas production function given by equation (2.3). However, the results are sensitive to whether time series or pooled data is used. It appears that time series estimates give a higher output elasticity and, therefore, a higher benefit cost ratio.

Chapter 3
Gathering Data

3.1 Introduction

In order to estimate an econometric model, data is required. Generally speaking, data comes in two forms: time series and cross section. The distinction between these two forms of data is important. Suppose that, as in this study, we wish to model the relationship between output and capital in the Canadian economy. Time series data would be composed of observations on output and capital for, say, the Canadian economy, over some specified period of time. Cross section data would be composed of observations on output and capital at one point in time, but over different provinces. Thus time series data holds location constant and varies time, while cross section data holds time constant and varies location. If we were to combine measures of GDP over time, and for different provinces, the result would be a third type of data, called pooled data.

In the studies reviewed in the previous chapter, researchers were primarily interested in estimating the output elasticity in response to a change in highway capital. These studies used either time series data or pooled data. This output elasticity was shown to be sensitive to the data used in the estimation, in that the estimated elasticity appeared to be somewhat higher when time series data was used, as opposed to when pooled data was used. Most studies concluded that this higher elasticity was quite likely a spurious result, due to the statistical problems associated with conventional analysis using time series data. The implication is that statistical analysis undertaken with pooled data is somehow superior.

This conclusion is somewhat suspect, and likely stems from a lack of understanding of potential problems associated with time series data. It should be understood that pooled data is a form of time series. In order to see this, assume that you had at your disposal observations on GDP in Canada over the period 1961 – 2001. This is time series data. If, in addition, you had time series data on GDP for each of the provinces, you could pool this data with the Canadian GDP. This pooled data would still have time series properties, which would not disappear in the pooling process. The fact that there are differences in the time series and pooled elasticities is more likely due to the improper statistical techniques which did not adequately account for potential time series problems. In this study we explicitly recognize that there are statistical problems associated with the use of time series techniques, and we apply advanced techniques which control for these problems. (See chapter 4).

In this study, we restrict ourselves to the question of the economic effects of twinning highway 3. Thus, any output response that we wish to measure is the response of output in the areas surrounding the highway 3 region. This is in contrast to the studies reviewed in the previous chapter, most of which were concerned with the effects of highway expenditure on the national economy as a whole. In that framework, the use of pooled data was feasible, in that data existed for the national economies as well as the provincial or state economies. In order to be able to use pooled data in this study, we would require two sets of economic data: data that pertains to the southern Alberta region; and data that pertained to other sub-regions within southern Alberta. As neither of these data sets exist in a form that is usable for this study, this was judged to be an insurmountable data problem, and the use of pooled data in this study was ruled out.

However, ruling out the feasibility of using pooled data for this study does not obviate the general problem that there exists no useable data pertaining to the southern Alberta region. The data required to estimate the production function were measures of real GDP, capital stock and labour, for the *southern* region of Alberta. In addition, highway capital had to be separated from the measure of the total capital stock. In his chapter we carefully describe how the needed data was created from existing sources.

All final data is graphed in Appendix A.

3.2 Estimation of Data

Alberta Real Gross Domestic Product

Somewhat surprisingly, real gross domestic product for Alberta is not available as a consistent time series from 1961 onwards. Statistics Canada does provide this series from 1981. However, there are various sources which give information concerning nominal GDP, price indices for Alberta GDP, and some industrial level nominal and real GDP. Given this, there are several different conceptual methodologies that could be used to construct real GDP for Alberta from 1961 onwards. In this study, we attempted several different methodologies, and below we describe one methodology that we believe yields a reasonable series.

For the years 1981 to 1999, GDP in constant 1992 dollars is available from Statistics Canada's data base CANSIM (Series D24963). For the years 1971 to 1984, industry level data is available measured in constant 1981 dollars (Matrix 7890). For these years, we summed across the industry categories (agriculture, fishing, logging, manufacturing, construction, forestry and water), which yields provincial GDP, measured in 1981 dollars, for the years 1971 to 1984. In order to convert this series to 1992 dollars, we applied the following procedure. For the year 1981, we calculated the ratio between the series measured in 1992 dollars and the series measured in 1981 dollars. This ratio was then applied to the 1981 dollar series for the period 1971 to 1980, which converts this series to 1992 dollars.[1]

[1] This procedure will also correct any minor discrepancies that may have arisen from adding up the components of GDP. Notice that this procedure changes the level but preserves the percentage change.

Finally, for the years 1961 to 1971, Nominal GDP for Alberta is available from the Bank of Canada published statistics.[2] These series were deflated to 1992 dollars using the Consumer Price Index (CPI) for Canada.[3] Following this procedure, the calculated GDP value for 1971 was slightly different from the value obtained from summing the GDP components. This was most likely due to differences in measurement of particular industries, the collection processes used by CANSIM and the Bank of Canada, or due to using the Canadian CPI to deflate. The series was spliced using an adjustment of 0.858, which is the ratio of the two series.

Figure 3-1
Summary of GDP Creation

1961 - 1970

Nominal GDP from Bank of Canada Review (CANSIM D31656); deflated by Canadian CPI, 1992=100; adjusted by 0.8585 to splice with 1971 data.

1971 – 1980

Gross Domestic Product at Factor Cost by Industry (CANSIM matrix 7890), measured in constant 1981 dollars. Component summed and converted to 1992 dollars.

1981 – 1997

Gross Domestic Product for Alberta (CANSIM D24963) measured in constant 1992 dollars.

[2] We subsequently discovered that this series is available in electronic format as CANSIM D31656.
[3] Alternatively, we could have created a series for the Consumer Price Index for Alberta over the period 1961-1971. This would have involved weighting historical data on the CPI for Calgary and Edmonton. Since the 1960s were a relatively tranquil period for the CPI, we judged that there would be bery little gain in following this procedure.

Southern Alberta Real Gross Domestic Product

The second step in GDP creation is to estimate GDP for the southern Alberta region, based on the time series for Alberta GDP. To accomplish this, we made use of the provincial website *Alberta First*. This source contains household income measures for 11 regions of Alberta, for the census years 1991 and 1996. Household income was the 'closest' measure we could find relating to regional GDP measures. We took the two southwest and southeast regions, added their measures together, and compared the total to the provincial number (all 11 regions added together). It was found that the southeast and southwest regions accounted for 8.445% of the provincial household income total for 1991, and 8.483 for 1996. The 1991 percentage was multiplied with the GDP figures for 1961 to 1991, and the 1996 figure multiplied with the GDP figures for 1992 to 1997, to create real GDP for the southern region of Alberta.

Capital Stocks

Capital stock measures for the province of Alberta, measured in constant 1992 dollars for the period 1961 - 1997 were purchased from Statistics Canada. The capital stock for all of Alberta was available for the following categories: engineering capital, machinery capital and building structures. Highway capital is a sub-component of engineering capital, but Statistics Canada could not provide separate capital stock data for this category. Therefore, the data had to be manipulated in two manners: engineering capital stock had to be divided into highway capital and all other engineering capital; the provincial capital stock measures would have to be broken down to regional capital stock.

In order to divide the engineering capital stock into highway capital and other engineering capital, we made use of expenditure data. Expenditure data is the flow of spending that results in increases in the capital stock. The engineering expenditure data from Statistics Canada can be split into highway expenditure and other engineering expenditure using data available from CANSIM. The following data is available in current dollars: engineering construction expenditure in Alberta (808797) and construction expenditure in Alberta on highways roads and streets (D808807) from 1961 – 1991. These series are also available for 1992 – 1997 as D873325 and D873333 respectively. This allows us to take the ratio of highway construction expenditure to engineering expenditure from 1961 – 1997. This ratio is then applied to the Statistics Canada series on engineering expenditure in constant dollars. The result is a series on highway expenditure in Alberta in constant 1992 dollars.

To construct a highway capital stock measure for Alberta, we need a base year value of the capital stock, and then the expenditure series can be added each year to this base. We assume the base highway capital stock to be $5,641 million in 1961. This is equal to the value of the engineering capital stock in 1961 multiplied by the ratio of highway expenditure to engineering expenditure in 1961. Cumulating the highway capital stock in this manner, lead to an estimate of the 1997 capital stock of approximately $19.4 billion. This is very close to the estimate of $19.2 billion for 1997 provided by Alberta Transportation.

The final step is to estimate a highway capital stock series for the southern region of Alberta. Once again census data was used. The percentage of highway capital stock under the category 'total primary highway capital' for the census years 1991 and 1996 equals approximately 21%. This percentage was applied to the Alberta highway capital stock figures.

Figure 3-2
Creation of Highway Capital Stock

Step 1

Highway construction expenditure in current dollars (D808807 and D873333) divided by engineering construction expenditure in current dollars (D808797 and D873325). This ratio for 1961 to 1997 is applied to engineering construction expenditure in constant 1992 dollars provided by Statistics Canada.

Step 2

Construct a base year highway capital stock of $5.64 billion in 1992 dollars. This is obtained by taking the above ratio for 1961 and applying it to the engineering capital stock provided by Statistics Canada.

Step 3

Cumulate the stock of highway capital using the base year value and adding highway construction expenditure each year, allowing for depreciation. This results in an estimate of highway capital for 1997 of $19.4 billion, corroborated by Alberta Transport.

Step 5

Southern Alberta region capital stock is assumed to be 21 percent of totals Alberta capital stock.

Dividing up the building, machinery and remaining engineering capital stock followed a similar process. From the Municipal Affairs provincial website, capital property stock, measured in engineering, machinery and building categories, was available for the years 1994 to 1999 for each provincial municipality. The main southern municipalities were totaled, along with a provincial total of all cities and towns, and ratios were found for the southern region as percentages of total provincial stocks for each category. The ratios found for 1994 were applied to the previous years 1961 to 1994.

Each Alberta capital stock measure was multiplied with its appropriate ratio, to get southern Alberta capital stock measures, in current 1992 dollars, in millions. The highway capital measure was subtracted from the engineering measure to get a regional capital series for engineering without highway capital.

Labour

Labour force statistics of Alberta were available from CANSIM., series D987395 from matrix 3481. This includes the labour force of Alberta, aged 15 and above, in thousands for the period 1976 to 2000. Labour force figures for previous years were taken from the *Bank of Canada Review*. Again, we made use of information contained in the *Alberta First* website. For the census years 1991 and 1996, labour force for the regions of Alberta were available, and again, ratios for the southern regions against the province were found and multiplied with the provincial labour force series to get a regional labour force series. The ratio 8.7334% from the 1991 census was applied to the years 1961 to 1991, and the ratio 8.86% was applied to the years 1992 to 1997. This series is in thousands.

Figure A3-1
Real GDP Southern Alberta

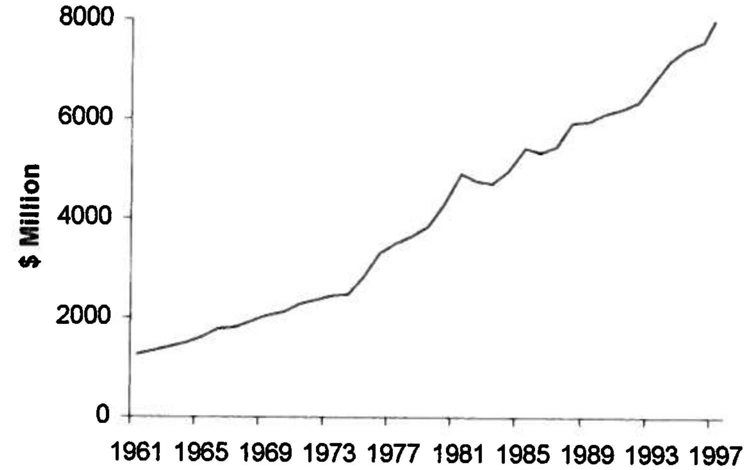


Figure A3-2
Highway Capital in Southern Alberta

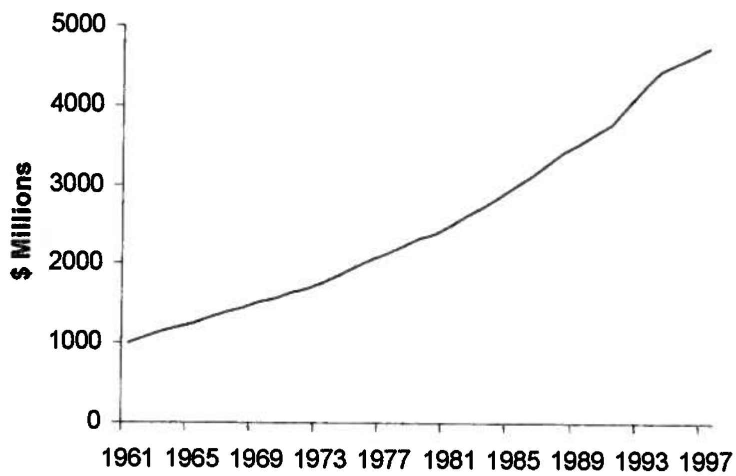


Figure A3-2
Total Other Capital
Southern Alberta

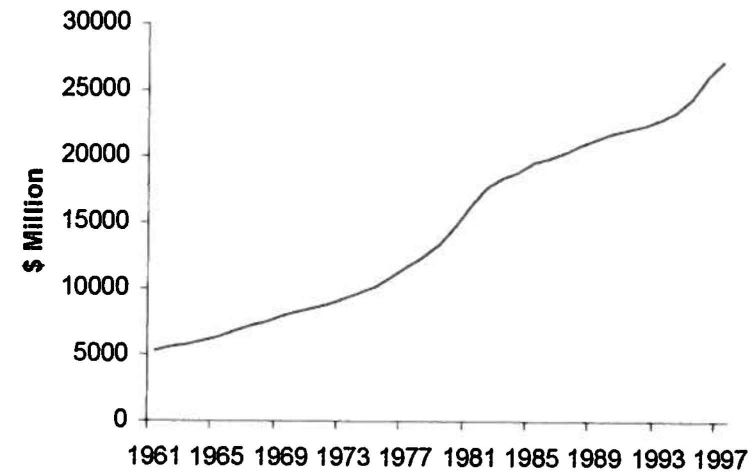
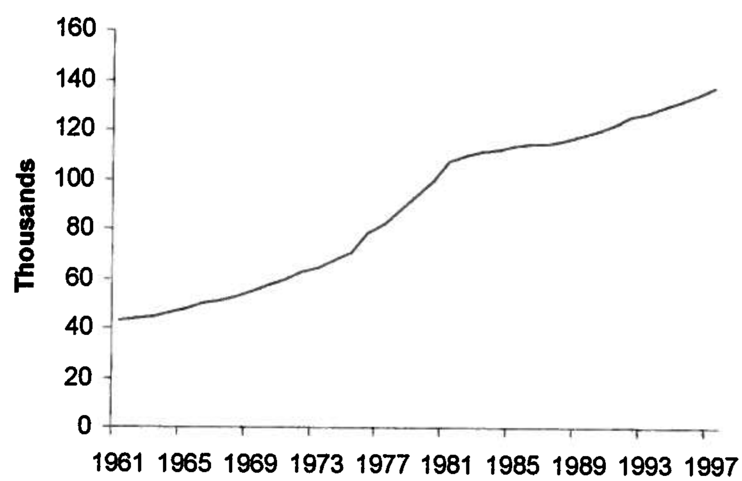


Figure A3-4
Labour Force
Southern Alberta



Chapter 4
Econometric Modeling

4.1 Introduction

In the body of this chapter, we outline the major steps that were undertaken in estimated the production function model. The process is extremely complicated, and required a great deal of estimation and testing. The details have been relegated to appendices for the interested reader.

In the last chapter we described the methodology used a build a data set suitable for estimating a model of economic activity in the southern Alberta region. In this chapter we describe the statistical testing that was undertaken in the process of finding a suitable econometric model. Recall from Chapter 1 that the general form of the model under consideration is a Cobb-Douglas production function of the following form:

(4.1) $$y = \beta_0 + \beta_1 k^h + \beta_2 k^o + \beta_3 l + \mu$$

In equation (4.1) all variables are measured in natural logarithms; y is real GDP, k^h is highway capital, k^o is other capital (engineering, building and machinery), and l is labour. The general goal is to estimate the response of output to changes in any of the inputs. These responses are called elasticities and are measured by β_1, β_2 and β_3 in equation (4.1). Of primary interest in this study is the estimate of β_1, which will tell us how much output changes in response to a change in highway capital.

4.2 Traditional Estimation

At the outset, a great number of simple ordinary least squares (OLS) variants of equation (4.1) were estimated. These estimates are presented in Appendix 1. Many models were tested; with and without certain capital measures, with and without a constant (technology factor) and with and without a time variable to capture the influence over time. As well, some models were restricted, for example, forcing the elasticities to sum to one (constant returns to scale). The results of this regression exercise show that various estimates of β_1 vary over the range 0.44 to 0.65, implying that a 1% increase in highway capital stock is generally associated with an increase in GDP of 0.4% to 0.6%.

As alluded to in earlier chapters, there are potential serious problems associated with this type of time series regression analysis. When variables are continually increasing over time, they may not have conventional statistical properties. Consider, for instance, two standard statistics used to describe variables: mean and variance. In time series econometrics, the mean and variance may not be constant over time. If this is true, then these variables may be "non-stationary", which leads to the problem that OLS regressions, such as those used above, and those used in the studies reviewed in the Literature Review chapter, may not have any traditional statistical properties. Generally speaking, if the variables used in an OLS regression are non-stationary, then the estimates of the elasticities are incorrect. Recall that, as noted in the Literature Review, all previous studies that used time series data alluded to this potential problem. Given the potential seriousness of this problem, we test for non-stationarity in the next section.

4.2. Testing for Stationary Variables

There is a very large, very technical literature on the methodology for testing the stationarity properties of variables. In this study, we applied a series of tests called Dickey-Fuller tests. The results of this exhaustive test procedure are presented in Appendix 2. These results are overwhelmingly consistent with each of the variables from equation (4.1) being non-stationary.

In statistics, a non stationary variable is often called an integrated variable. In order to understand the importance of the result that all of the variables in equation (4.1) are integrated, consider the following. If some variable, X, is non-stationary, it can be made stationary by applying a first difference. A first difference is defined as

$$\Delta X_t = X_t - X_{t-1} \tag{4.2}$$

In equation (4.2) the variable X_t is non-stationary, while the variable ΔX_t is stationary, or in statistical language, X_t is an integrated variable.[1]

Because stationary variables have valid statistical properties, we can re-write equation (4.1) as

$$\Delta y = \beta_0 + \beta_1 \Delta k^h + \beta_2 \Delta k^o + \beta_3 \Delta l + \mu \tag{4.3}$$

Therefore, OLS estimation of equation (4.3) would produce valid estimates of the elasticities that we seek in this study. However, even though equation (4.3) may be statistically correct, as all variables are stationary, it is no longer correct from the perspective of a production function. A production function estimates the equilibrium, or long run, relationship between output (*y*) and capital (k^h, k^o) and labour (*l*). Technically, when variables are differenced, the long run equilibrium component is removed. Therefore, equation (4.3) no longer contains any information concerning the long run equilibrium relationship between inputs and output in a production function framework. Equation (4.3) does, however, contain valuable information concerning the short-run relationship amongst the variables in a production function. In order to be able to combine the short run relationship given in equation (4.3) with the long run relationship given in equation (4.1), we must introduce the concept of cointegration.

[1] To be precisely technically correct, the variable X_t is said to be integrated of order 1, meaning that it must be difference once to become stationary. This is often written as I(1).

4.3. *Testing for Cointegration*

Cointegration is a statistical concept that is very similar to stationarity. Above, we tested for the stationary properties of each of the variables in equation (4.1), one at a time. Cointegration tests for stationarity for the variables in equation (4.1) as a group. We ask the question, given that each of the variables in equation (4.1) are individually non-stationary, is there a linear combination of these variables which itself is stationary. We search for an appropriate linear combination by choosing different combinations of β_1, β_2, and β_3. The results of this technical exercise are found in Appendix 3.

In Appendix 3 we prove that there exists a stationary relationship between all of the variables given in equation (4.1). This relationship is given by the following estimated equation:

$$(4.4) \quad y = 0.505 * k^h + 0.002 * k^o + 0.871 * l$$

Equation (4.4) defines the *long-run* equilibrium relationship between capital (both highway and other), labour, and output. This equation contains the long run elasticites. Thus, for instance, the long run response of output to a change in highway capital equal 0.505. In statistical terminology, equation (4.4) is used to form what is known as the cointegrating vector.[2] This cointegrating vector is then used in conjunction with equation (4.3), which contains the short run relationship between the variables.

[2] This is the term EC from equation (1.7) introduced in Chapter 1.

The next stage in the modeling procedure is to estimate a model which combines the features of equation (4.3) and equation (4.4). This model is known in the literature as an error correction model, and is the following general form:

$$(4.5) \quad \begin{aligned} \Delta y_t &= \gamma_0 + \sum_{i=1}^{k} \gamma_{1,i} \Delta y_{t-i} + \sum_{i=0}^{k} \gamma_{2,i} \Delta k^{k}_{t-i} + \sum_{i=0}^{k} \gamma_{3,i} \Delta k^{o}_{t-i} \\ &+ \sum_{i=0}^{k} \lambda_{4,i} \Delta l_{t-i} + \lambda (y_{t-1} - 0.505 k^{h}_{t-1} - 0.002 k^{o}_{t-1} - 0.871 l_{t-1}) + \mu_t \end{aligned}$$

Where μ_t is a stochastic error with the usual assumed properties.[3]

The modeling problem is then to estimate all of the γ parameters jointly with the λ parameter.[4] The search procedure employed in this stage of the modeling procedure is documented in Appendix 4. As a result of this search procedure, we uncovered ten potential models. It must be understood that there is no one unique model that totally dominates all other models. Appendix 5 lists the statistical properties of the ten "best" models chosen from this exercise.

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[3] That is it is assume to be normally distribute with mean zero and constant variance.

[4] Equation (4.5) is written in somewhat of a restrictive form in that the lag structures on the differenced variables do not have to be identical.

4.4 Forecasting With the Error Correction Model

Recall that the goal of this study is to estimate a benefit cost ratio for twinning highway 3. The production function models that are estimated in this chapter form the basis for estimating the economic benefits to twinning highway 3. For each one of the models, two forecasts are then calculated. First, we forecast GDP in the southern Alberta region for 20 years ahead, under the assumption that all inputs to the production function will simply grow by their historical growth rates.[5] Second, we calculate a second forecast of GDP in the southern Alberta region, where all inputs to the production function grow by the same rates as in the previous forecast, plus we allow highway capital to grow for 5 years, increasing each year by one-fifth of the total twining cots. Therefore, at the end of 5 years, highway capital (k^h in equation (4.5)) has increased by the value of twinning highway 3.[6]

In Appendix 5 there are ten models, listed in descending order of statistical acceptability. The forecasts of the gain in GDP over the twenty year forecast horizon are graphed on Figures 4-1 and 4-2.[7]

[5] This procedure is documented in Appendix 6.

[6] After the five year period of initial construction, the new portion of the highway was depreciated at 15% per year.

[7] Amongst these ten models, models 2 and 3 are virtually indistinguishable, as are models 8 and 9. Therefore, for purposes of Figures 4-1 and 4-2, we have only graphed 8 of the forecasts.

Figure 4-1
Forecast Increase in GDP
Models 1, 2, 6, 7 and 8

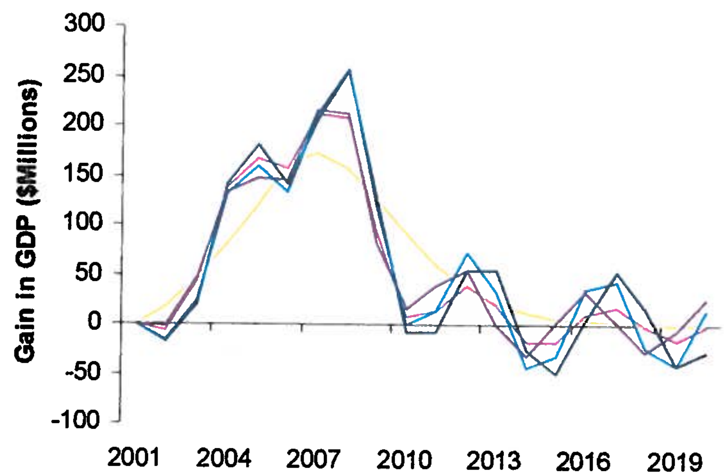
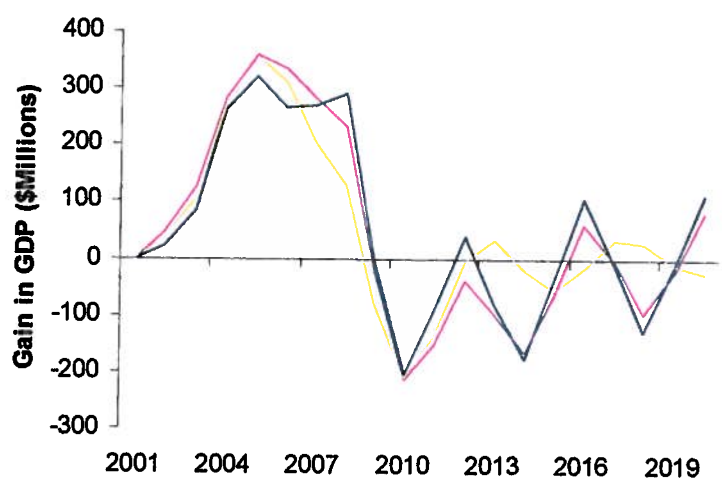


Figure 4-2
Forecast Increase in GDP
Models 4, 5, and 10



It can be seen on these two graphs that the forecasting properties of the models fall broadly into two groups. On Figure 4-2 models 1, 2, 6, 7, and 8 all forecast an increase in GDP that peaks at approximately 9-10 years and then slowly dies out. In contrast, on Figure 4-2, models 4, 5, and 10, all forecast an increase in GDP which is not only larger than those in Figure 4-1, it also occurs several years earlier. However, these latter models have more dynamic structure, and some of the early gains are nullified by decreases in GDP in the last years of the forecast horizon. It appears that the models displayed on Figure 4-2 are over accentuating the business cycle aspects of southern Alberta GDP.

4.5 Summary of the Model

In this chapter we have summarized the procedure undertaken to build an econometric model of the southern Alberta region. This model is unique in two manners. First, generally speaking, we are not aware of any existing econometric model of the southern Alberta region. As such, this is a first. However, more importantly for this study, no existing benefit cost stud of highway expenditure has applied the statistical methodology used in this study. Most of the existing studies in this area alluded to the potential statistical problems associated with time series modeling, but we are the first to correct for these problems, using advanced time series techniques.

The forecasting performance of several variants of this model are summarized on Figures 4-1 and 4-2. Generally speaking, the results are reasonable, in that they show that an increase in public expenditure on highways, leads to an increase in economic activity in a region. In the next chapter, we use the forecasts from this chapter to construct a benefit cost ratio for twinning highway 3.

APPENDIX 1

A simple linear regression, with all variables.

```
|_ols loggdp logbldg logmach logeng loghigh loglab / loglog dwpvalue resid=resid

 DURBIN-WATSON STATISTIC  =   1.33646
 DURBIN-WATSON P-VALUE =    0.001328

 R-SQUARE =    0.9975     R-SQUARE ADJUSTED =    0.9971
 VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.96541E-03
 STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.31071E-01
 SUM OF SQUARED ERRORS-SSE=  0.29928E-01
 MEAN OF DEPENDENT VARIABLE =   8.1624
 LOG OF THE LIKELIHOOD FUNCTION(IF DEPVAR LOG) = -222.791
```

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO 31 DF	P-VALUE	PARTIAL CORR.	STANDARDIZED COEFFICIENT	ELASTICITY AT MEANS
LOGBLDG	-0.27961	0.1438	-1.944	0.061	-0.330	-0.2574	-0.2796
LOGMACH	-0.94669E-01	0.1561	-0.6065	0.549	-0.108	-0.1005	-0.0947
LOGENG	0.31438	0.1911	1.645	0.110	0.283	0.2743	0.3144
LOGHIGH	0.41877	0.1034	4.052	0.000	0.588	0.3367	0.4188
LOGLAB	1.0959	0.2949	3.716	0.001	0.555	0.7499	1.0959
CONSTANT	0.23905	0.2932	0.8153	0.421	0.145	0.0000	0.2390

```
|_test logbldg+logmach+logeng+loghigh+loglab=1

 TEST VALUE =  0.45477      STD. ERROR OF TEST VALUE  0.97469E-01
 T STATISTIC =    4.6657296     WITH   31 D.F.     P-VALUE= 0.00006
 F STATISTIC =    21.769033     WITH    1 AND   31 D.F.  P-VALUE= 0.00006
 WALD CHI-SQUARE STATISTIC =    21.769033      WITH     1 D.F.  P-VALUE= 0.00000
 UPPER BOUND ON P-VALUE BY CHEBYCHEV INEQUALITY = 0.04594

|_plot resid

       37 OBSERVATIONS
                   *=RESID
                   M=MULTIPLE POINT
 0.80000E-01     |
 0.71579E-01     |
 0.63158E-01     |                   *
 0.54737E-01     |
 0.46316E-01     |              *
 0.37895E-01     |                          *
 0.29474E-01     |      *        *
 0.21053E-01     |    ** *               *   *
 0.12632E-01     |         *   *              *
 0.42105E-02     |   *    *         *             **
-0.42105E-02     |                *                  *
-0.12632E-01     |          *         *        * *
-0.21053E-01     | **        *     *      **
-0.29474E-01     |*                     *
-0.37895E-01     |                              *   *
-0.46316E-01     |
-0.54737E-01     |*                    *
-0.63158E-01     |
-0.71579E-01     |            *
-0.80000E-01     |

                  ________________________________________

               0.000     10.000     20.000     30.000     40.000
                                    TIME
```

A simple linear regression, without building capital.

```
|_ols loggdp logmach logeng loghigh loglab / loglog dwpvalue resid=resid

 DURBIN-WATSON STATISTIC  =   1.18848
 DURBIN-WATSON P-VALUE =    0.000447

 R-SQUARE =    0.9972     R-SQUARE ADJUSTED =    0.9969
 VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.10493E-02
 STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.32393E-01
 SUM OF SQUARED ERRORS-SSE=  0.33578E-01
 MEAN OF DEPENDENT VARIABLE =    8.1624
 LOG OF THE LIKELIHOOD FUNCTION(IF DEPVAR LOG) = -224.920

 VARIABLE   ESTIMATED  STANDARD   T-RATIO        PARTIAL STANDARDIZED ELASTICITY
   NAME    COEFFICIENT   ERROR     32 DF    P-VALUE CORR. COEFFICIENT  AT MEANS
 LOGMACH   0.79220E-01 0.1334     0.5940     0.557 0.104     0.0841     0.0792
 LOGENG    0.58462E-01 0.1445     0.4047     0.688 0.071     0.0510     0.0585
 LOGHIGH   0.48371     0.1020      4.744     0.000 0.643     0.3889     0.4837
 LOGLAB    0.70201     0.2234      3.142     0.004 0.486     0.4804     0.7020
 CONSTANT  0.23044     0.3057     0.7539     0.456 0.132     0.0000     0.2304

|_test logmach+logeng+loghigh+loglab=1

 TEST VALUE =  0.32339      STD. ERROR OF TEST VALUE  0.73244E-01
 T STATISTIC =    4.4153326     WITH   32 D.F.    P-VALUE= 0.00011
 F STATISTIC =    19.495162     WITH    1 AND   32 D.F.  P-VALUE= 0.00011
 WALD CHI-SQUARE STATISTIC =    19.495162     WITH     1 D.F.  P-VALUE= 0.00001
 UPPER BOUND ON P-VALUE BY CHEBYCHEV INEQUALITY = 0.05129

 |_plot resid

                   *=RESID
                   M=MULTIPLE POINT
 0.80000E-01     |
 0.71579E-01     |
 0.63158E-01     |                 *
 0.54737E-01     |              *
 0.46316E-01     |
 0.37895E-01     |               *
 0.29474E-01     |         *
 0.21053E-01     |    * **               *  *        *
 0.12632E-01     |     *  *    *    *
 0.42105E-02     |   *      *     *          *
-0.42105E-02     |                            *   **
-0.12632E-01     |           *     *                *
-0.21053E-01     |  *                 *   *    * *
-0.29474E-01     | *                       *
-0.37895E-01     |*                     *
-0.46316E-01     |                              *
-0.54737E-01     |*
-0.63158E-01     |                     *
-0.71579E-01     |            *
-0.80000E-01     |
                  ----------------------------------------

             0.000    10.000    20.000    30.000    40.000
                              TIME
```

A simple linear regression, with building, engineering and highway capitals. No machinery capital.

```
|_ols loggdp logbldg logeng loghigh loglab / loglog dwpvalue resid=resid

 DURBIN-WATSON STATISTIC  =   1.30378
 DURBIN-WATSON P-VALUE =    0.001637

 R-SQUARE =   0.9975      R-SQUARE ADJUSTED =   0.9972
 VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.94634E-03
 STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.30763E-01
 SUM OF SQUARED ERRORS-SSE=  0.30283E-01
 MEAN OF DEPENDENT VARIABLE =   8.1624
 LOG OF THE LIKELIHOOD FUNCTION(IF DEPVAR LOG) = -223.009

 VARIABLE   ESTIMATED  STANDARD   T-RATIO        PARTIAL STANDARDIZED ELASTICITY
   NAME    COEFFICIENT   ERROR      32 DF   P-VALUE CORR. COEFFICIENT  AT MEANS
 LOGBLDG  -0.22964     0.1167      -1.968     0.058-0.329    -0.2114    -0.2296
 LOGENG    0.24647     0.1533       1.607     0.118 0.273     0.2151     0.2465
 LOGHIGH   0.45034     0.8840E-01   5.094     0.000 0.669     0.3621     0.4503
 LOGLAB    0.93216     0.1175       7.934     0.000 0.814     0.6378     0.9322
 CONSTANT  0.24309     0.2902      0.8376     0.408 0.146     0.0000     0.2431

|_test logbldg+logeng+loghigh+loglab=1

 TEST VALUE =  0.39933      STD. ERROR OF TEST VALUE  0.33542E-01
 T STATISTIC =     11.905560     WITH   32 D.F.     P-VALUE= 0.00000
 F STATISTIC =     141.74237     WITH    1 AND   32 D.F.   P-VALUE= 0.00000
 WALD CHI-SQUARE STATISTIC =    141.74237     WITH    1 D.F.   P-VALUE= 0.00000
 UPPER BOUND ON P-VALUE BY CHEBYCHEV INEQUALITY = 0.00706

|_plot resid

                    *=RESID
                    M=MULTIPLE POINT
   0.80000E-01   |
   0.71579E-01   |
   0.63158E-01   |                   *
   0.54737E-01   |
   0.46316E-01   |              *
   0.37895E-01   |                          *
   0.29474E-01   |      *        *
   0.21053E-01   |    *  * *             *   *
   0.12632E-01   |     *  *    *
   0.42105E-02   |   *              *         *   **
  -0.42105E-02   |          *     *                  *
  -0.12632E-01   |           *                 * *
  -0.21053E-01   | **              *  *   **
  -0.29474E-01   |                      *
  -0.37895E-01   |*                             *   *
  -0.46316E-01   |
  -0.54737E-01   |*                    *
  -0.63158E-01   |
  -0.71579E-01   |            *
  -0.80000E-01   |
                  ________________________________________

                0.000    10.000    20.000    30.000    40.000
                                TIME
```

A simple linear regression, with out engineering capital.

```
|_ols loggdp logbldg logmach loghigh loglab / loglog dwpvalue resid=resid

 DURBIN-WATSON STATISTIC  =   1.21405
 DURBIN-WATSON P-VALUE =    0.000573

 R-SQUARE =   0.9973     R-SQUARE ADJUSTED =   0.9970
 VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.10169E-02
 STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.31889E-01
 SUM OF SQUARED ERRORS-SSE=  0.32540E-01
 MEAN OF DEPENDENT VARIABLE =   8.1624
 LOG OF THE LIKELIHOOD FUNCTION(IF DEPVAR LOG) = -224.340
```

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO 32 DF	P-VALUE	PARTIAL CORR.	STANDARDIZED COEFFICIENT	ELASTICITY AT MEANS
LOGBLDG	-0.11669	0.1070	-1.091	0.284	-0.189	-0.1074	-0.1167
LOGMACH	0.55764E-01	0.1298	0.4296	0.670	0.076	0.0592	0.0558
LOGHIGH	0.55353	0.6467E-01	8.559	0.000	0.834	0.4450	0.5535
LOGLAB	0.88795	0.2734	3.248	0.003	0.498	0.6076	0.8879
CONSTANT	0.52174	0.2438	2.140	0.040	0.354	0.0000	0.5217

```
|_test logbldg+logmach+loghigh+loglab=1

 TEST VALUE =  0.38055     STD. ERROR OF TEST VALUE  0.88675E-01
 T STATISTIC =    4.2915467     WITH   32 D.F.     P-VALUE= 0.00015
 F STATISTIC =    18.417373     WITH    1 AND   32 D.F.  P-VALUE= 0.00015
 WALD CHI-SQUARE STATISTIC =   18.417373      WITH     1 D.F.  P-VALUE= 0.00002
 UPPER BOUND ON P-VALUE BY CHEBYCHEV INEQUALITY = 0.05430

|_plot resid

                    *=RESID
                    M=MULTIPLE POINT
  0.80000E-01    |
  0.71579E-01    |
  0.63158E-01    |                   *
  0.54737E-01    |
  0.46316E-01    |
  0.37895E-01    |              *           *
  0.29474E-01    |      *  *             *
  0.21053E-01    |    ** **      *
  0.12632E-01    |                           *       *
  0.42105E-02    |   *      *  *    *         *
 -0.42105E-02    |                                 *
 -0.12632E-01    |           *    *   *   **      *
 -0.21053E-01    |  *                          *    *
 -0.29474E-01    | *               *    *        *
 -0.37895E-01    |*
 -0.46316E-01    |
 -0.54737E-01    |                     *        *
 -0.63158E-01    |*
 -0.71579E-01    |            *
 -0.80000E-01    |
                  ----------------------------------------
               0.000     10.000     20.000     30.000     40.000
                                 TIME
```

A linear regression with all capitals, building, machinery and engineering are added together and then logged as one variable.

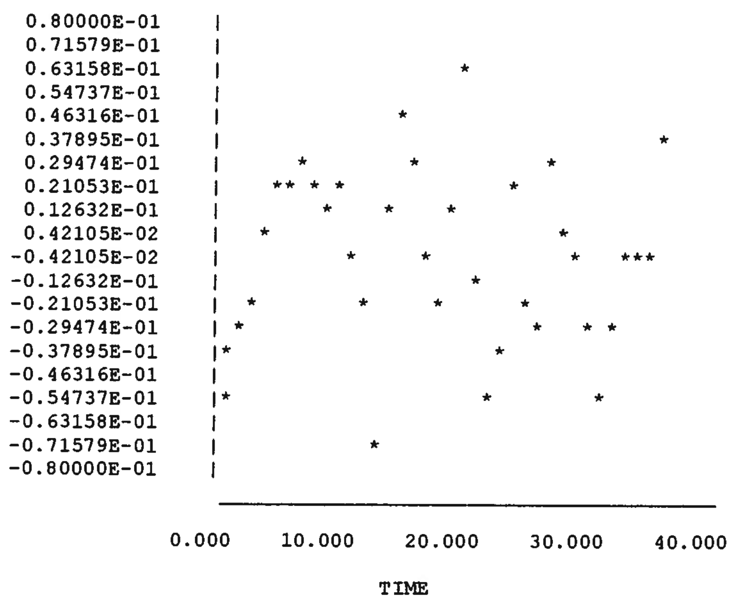
```
|_ols loggdp logbme loghigh loglab / loglog dwpvalue resid=resid

 DURBIN-WATSON STATISTIC  =   1.17695
 DURBIN-WATSON P-VALUE =    0.000658

 R-SQUARE =   0.9971      R-SQUARE ADJUSTED =   0.9969
 VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.10413E-02
 STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.32270E-01
 SUM OF SQUARED ERRORS-SSE=  0.34364E-01
 MEAN OF DEPENDENT VARIABLE =   8.1624
 LOG OF THE LIKELIHOOD FUNCTION(IF DEPVAR LOG) = -225.348
```

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO 33 DF	P-VALUE	PARTIAL CORR.	STANDARDIZED COEFFICIENT	ELASTICITY AT MEANS
LOGBME	0.15656E-02	0.1512	0.1035E-01	0.992	0.002	0.0014	0.0016
LOGHIGH	0.50553	0.8434E-01	5.994	0.000	0.722	0.4064	0.5055
LOGLAB	0.87142	0.1399	6.231	0.000	0.735	0.5963	0.8714
CONSTANT	0.38421	0.4133	0.9296	0.359	0.160	0.0000	0.3842

```
|_plot resid
```

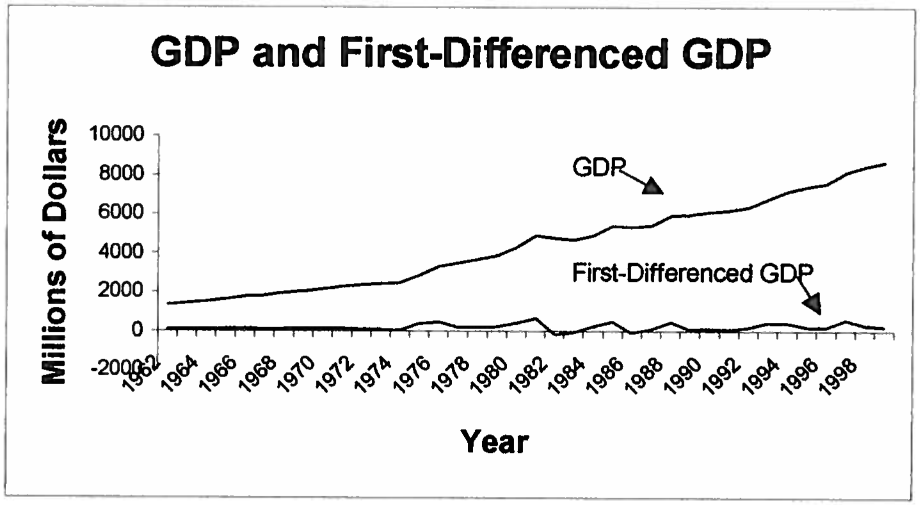


APPENDIX 2

A stationary variable is integrated of order zero, denoted I~(0). If a variable is non-stationary, is a random walk, then the variable is differenced to find a stationary transformation. That is, its value at time t-1 is subtracted from its value at time t, and this first-differenced variable is then tested for stationarity. If its first-difference is stationary, the variable is said to be integrated of order one, I~(1). We tested using the Bayesian Information Criteria (BIC). The differenced variable is regressed on its lag and lags of the difference. For annual data, theory suggests that no more than four lags of the differenced variable are needed. Thus, a regression for each variable was run with zero to four lags, without a constant and trend, with a constant and no trend, and with a constant and trend variable. The results are presented in Appendix 2.

$$BIC = N * Ln(SSR) + K * Ln(N)$$

For each regression, the BIC is calculated, where N is the number of observations, SSR is the sum of squares of the residuals, K is the number of parameters estimated and Ln is the natural log. The BIC calculated from each of the regressions and the test statistic (t-value on the lagged variable, *not* the lags of the difference variables) of the lowest BIC is used as *the* test statistic for that variable, and is compared to the critical BIC t-value, from a simulation procedure by Engle and Granger. If the test statistic is less than the critical value, the null hypothesis of first-difference stationary is rejected and concluded that the variable is stationary. From the results, it was concluded that all the variables, GDP, labour, and the capitals, are I~(1), their first-differences are stationary at a 95% confidence level. As seen from the graph below for GDP, the series is non-stationary. It is trending up, and its mean and variance from one time period is not necessarily the same as for another time period. But its first difference was found to be stationary, its mean and variance over time are significantly constant, first-differenced GDP is time-invariant. As seen in the graph, the mean and variance of first-differenced GDP does not differ between any time period. And so, first-differences are a good predictor for the future. Instead of regressing the time series as is, first-differences are taken and modeled, which don't vary over time, and thus should be applicable to the future of unknown values.



Stationary Tests for All Variables

variable/model	values	0 lags	1 lag	2 lags	3 lags	4 lags	lowest BIC	test stat	critical value	conclusion
GDP										
no constant, no trend	N	32	32	32	32	32	-85.9	6.37	-1.62	do not reject
	k	1	2	3	4	5	(0 lags)			GDP~I(1)
	SSR	0.0612	0.059	0.0518	0.0505	0.0478				
	BIC	-85.930	-83.635	-84.334	-81.682	-79.975				
	test stat	6.366	3.386	4.072	2.691	1.829				
constant, no trend	N	32	32	32	32	32	-85.9	-1.44	-2.57	do not reject
	k	2	3	4	5	6	(0 lags)			GDP~I(1)
	SSR	0.055	0.0544	0.0442	0.0442	0.0434				
	BIC	-85.882	-82.767	-85.946	-82.480	-79.599				
	test stat	-1.439	-1.253	-1.731	-1.595	-1.348				
constant, trend	N	32	32	32	32	32	-85.5	-1.96	-3.13	do not reject
	k	3	4	5	6	7	(0 lags)			GDP~I(1)
	SSR	0.0499	0.0484	0.0406	0.0405	0.0397				
	BIC	-85.530	-83.041	-85.199	-81.812	-78.985				
	test stat	-1.963	-2.068	-1.85	-1.814	-1.771				
LABOUR										
no constant, no trend	N	32	32	32	32	32	-138.9	1.07	-1.62	do not reject
	k	1	2	3	4	5	(2 lags)			LAB~I(1)
	SSR	0.01911	0.01068	0.0094	0.0094	0.0094				
	BIC	-123.176	-138.329	- 138.948	-135.483	-132.02				
	test stat	7.13	1.89	1.07	1.066	1.082				
constant, no trend	N	32	32	32	32	32	-141.6	-1.77	-2.57	do not reject
	k	2	3	4	5	6	(2 lags)			LAB~I(1)
	SSR	0.0211	0.0093	0.008	0.0083	0.0083				
	BIC	-117.034	-140.031	- 141.631	-137.234	-134.01				

	test stat	-2.957	-1.864	-1.774	-1.728	-1.67				
constant, trend	N	32	32	32	32	32	-141.9	-2.66	-3.13	do not reject
	k	3	4	5	6	7	(2 lags)			LAB~I(1)
	SSR	0.0119	0.0081	0.0069	0.0069	0.0069				
	BIC	-131.402	-140.246	-141.911	-138.445	-134.98				
	test stat	-2.387	-2.322	-2.659	-2.62	-2.564				
HIGHWAY										
no constant, no trend	N	32	32	32	32	32	-181.2	2.44	-1.62	do not reject
	k	1	2	3	4	5	(1 lag)			HIGH~I(1)
	SSR	0.0038	0.0028	0.0027	0.0027	0.0027				
	BIC	-174.862	-181.169	-178.867	-175.401	-171.94				
	test stat	21.08	2.445	2.656	1.931	1.637				
constant, no trend	N	32	32	32	32	32	-182.0	-1.57	-2.57	do not reject
	k	2	3	4	5	6	(2 lags)			HIGH~I(1)
	SSR	0.0029	0.0025	0.0022	0.0022	0.0021				
	BIC	-180.046	-181.330	-181.955	-178.489	-176.51				
	test stat	-1.817	-1.377	-1.57	-1.714	-1.98				
constant, trend	N	32	32	32	32	32	-179.2	-1.20	-3.13	do not reject
	k	3	4	5	6	7	(1 lag)			HIGH~I(1)
	SSR	0.0029	0.0024	0.0022	0.0021	0.002				
	BIC	-176.580	-179.170	-178.489	-176.512	-174.61				
	test stat	-1.145	-1.2	-0.9391	-0.6362	-0.0425				
BUILDING										
no constant, no trend	N	32	32	32	32	32	-126.4	-0.20	-1.62	do not reject
	k	1	2	3	4	5	(2 lags)			BLDG~I(1)
	SSR	0.0329	0.0181	0.0139	0.0128	0.0128				
	BIC	-105.791	-121.448	-126.431	-125.603	-122.14				
	test stat	7.115	1.639	-0.1974	0.1756	0.0712				
constant, no trend	N	32	32	32	32	32	-125.1	-2.06	-2.57	do not reject
	k	2	3	4	5	6	(2 lags)			BLDG~I(1)
	SSR	0.0223	0.0156	0.0121	0.0112	0.0112				
	BIC	-113.615	-121.006	-125.093	-123.524	-119.48				
	test stat	-3.285	-2.003	-2.062	-1.89	-1.852				
constant, trend	N	32	32	32	32	32	-126.4	-1.87	-3.13	do not reject
	k	3	4	5	6	7	(2 lags)			BLDG~I(1)
	SSR	0.0216	0.0148	0.0112	0.0108	0.0107				
	BIC	-112.325	-120.957	-126.410	-124.108	-120.94				
	test stat	-1.659	-1.677	-1.871	-1.493	-1.47				
MACHINERY										
no constant, no trend	N	32	32	32	32	32	-105.2	1.56	-1.62	do not reject
	k	1	2	3	4	5	(1 lag)			MACH~I(1)

	SSR	0.0711	0.0301	0.0298	0.0288	0.0283				
	BIC	-81.132	-105.172	-102.027	-99.653	-96.748				
	test stat	6.316	1.562	1.633	1.825	1.932				
constant, no trend	N	32	32	32	32	32	-102.7	-0.75	-2.57	do not reject
	k	2	3	4	5	6	(1 lag)			MACH~I(1)
	SSR	0.0635	0.0292	0.0288	0.028	0.0275				
	BIC	-81.283	-102.678	-99.653	-97.089	-94.200				
	test stat	-1.404	-0.7511	-0.7729	-0.6952	-0.6243				
constant, trend	N	32	32	32	32	32	-105.5	-2.60	-3.13	do not reject
	k	3	4	5	6	7	(1 lag)			MACH~I(1)
	SSR	0.0592	0.024	0.024	0.0237	0.0236				
	BIC	-80.061	-105.488	-102.022	-98.959	-95.628				
	test stat	-1.75	-2.603	-2.47	-2.273	-2.157				
ENGINEERING										
no constant, no trend	N	32	32	32	32	32	-137.4	2.21	-1.62	do not reject
	k	1	2	3	4	5	(1 lag)			ENG~I(1)
	SSR	0.0188	0.011	0.0108	0.0099	0.0096				
	BIC	-123.699	-137.384	-134.505	-133.824	-131.34				
	test stat	10.38	2.205	1.696	2.149	2.272				
consant, no trend	N	32	32	32	32	32	-135.1	-0.71	-2.57	do not reject
	k	2	3	4	5	6	(1 lag)			ENG~I(1)
	SSR	0.0171	0.0106	0.0106	0.0096	0.0093				
	BIC	-123.266	-135.104	-131.638	-131.343	-128.89				
	test stat	-1.232	-0.7082	-0.5249	-0.5911	-0.6702				
constant, trend	N	32	32	32	32	32	-133.8	-1.57	-3.13	do not reject
	k	3	4	5	6	7	(1 lag)			ENG~I(1)
	SSR	0.0167	0.0099	0.0098	0.0091	0.0088				
	BIC	-120.558	-133.824	-130.683	-129.589	-127.20				
	test stat	-1.059	-1.574	-1.559	-1.367	-1.343				
BL+MA+EN										
no constant, no trend	N	32	32	32	32	32	-170.6	1.87	-1.62	do not reject
	k	1	2	3	4	5	(2 lags)			BME~I(1)
	SSR	0.0177	0.0043	0.0035	0.0034	0.0033				
	BIC	-125.628	-167.441	-170.563	-168.024	-165.51				
	test stat	10.62	1.199	1.872	1.443	1.59				
constant, no trend	N	32	32	32	32	32	-170.0	-1.43	-2.57	do not reject
	k	2	3	4	5	6	(2 lags)			BME~I(1)
	SSR	0.0139	0.0041	0.0032	0.0031	0.0031				
	BIC	-129.896	-165.499	-169.964	-167.515	-164.05				
	test stat	-2.334	-1.018	-1.427	-1.372	-1.392				
constant, trend	N	32	32	32	32	32	-170.8	-2.06	-3.13	do not reject
	k	3	4	5	6	7	(2 lags)			BME~I(1)

	SSR	0.013	0.0035	0.0028	0.0028	0.0027				
	BIC	-128.573	-167.097	-170.772	-167.306	-165.00				
	test stat	-1.863	-2.387	-2.056	-2.037	-1.958				
BLDG+ENG										
no constant, no trend	N	32	32	32	32	32	-175.5 (2 lags)	1.76	-1.62	do not reject BE~I(1)
	k	1	2	3	4	5				
	SSR	0.0161	0.0038	0.003	0.003	0.003				
	BIC	-128.660	-171.397	-175.495	-172.030	-168.56				
	test stat	10.91	1.107	1.756	1.39	1.427				
constant, no trend	N	32	32	32	32	32	-174.2 (2 lags)	-1.53	-2.57	do not reject BE~I(1)
	k	2	3	4	5	6				
	SSR	0.0124	0.0036	0.0028	0.0027	0.0027				
	BIC	-133.550	-169.661	-174.237	-171.935	-168.47				
	test stat	-2.431	-1.123	-1.525	-1.462	-1.473				
constant, trend	N	32	32	32	32	32	-174.4 (2 lags)	-1.99	-3.13	do not reject BE~I(1)
	k	3	4	5	6	7				
	SSR	0.0117	0.0031	0.0025	0.0025	0.0025				
	BIC	-131.944	-170.980	-174.398	-170.932	-167.47				
	test stat	-1.807	-2.361	-1.991	-1.967	-1.895				
BLDG+MACH										
no constant, no trend	N	32	32	32	32	32	-136.2 (3 lags)	1.31	-1.62	do not reject BM~I(1)
	k	1	2	3	4	5				
	SSR	0.0287	0.0115	0.0107	0.0092	0.0092				
	BIC	-110.162	-135.962	-134.803	-136.171	-132.70				
	test stat	8.219	1.508	0.813	1.306	1.112				
constant, no trend	N	32	32	32	32	32	-136.8 (3 lags)	-1.72	-2.57	do not reject BM~I(1)
	k	2	3	4	5	6				
	SSR	0.0196	0.0103	0.0095	0.0081	0.0081				
	BIC	-118.900	-136.022	-135.144	-136.780	-133.31				
	test stat	-3.186	-1.676	-1.778	-1.723	-1.69				
constant, trend	N	32	32	32	32	32	-136.2 (3 lags)	-2.01	-3.13	do not reject BM~I(1)
	k	3	4	5	6	7				
	SSR	0.0183	0.0093	0.0083	0.0074	0.0074				
	BIC	-117.630	-135.825	-135.999	-136.206	-132.74				
	test stat	-2.097	-2.077	-2.35	-2.009	-1.98				
MACH+ENG										
no constant, no trend	N	32	32	32	32	32	-137.4 (1 lag)	2.01	-1.62	do not reject ME~I(1)
	k	1	2	3	4	5				
	SSR	0.0213	0.011	0.011	0.0104	0.0106				
	BIC	-119.704	-137.384	-133.918	-132.247	-128.17				
	test stat	9.981	2.008	1.75	2.059	2.129				

constant, no trend	N	32	32	32	32	32	-134.8	-0.68	-2.57	do not reject
	k	2	3	4	5	6	(1 lag)			ME~I(1)
	SSR	0.0192	0.0107	0.0107	0.0101	0.0099				
	BIC	-119.560	-134.803	-131.337	-129.718	-126.89				
	test stat	-1.327	-0.6786	-0.6623	-0.661	-0.7117				
constant, trend	N	32	32	32	32	32	-134.5	-1.77	-3.13	do not reject
	k	3	4	5	6	7	(1 lag)			ME~I(1)
	SSR	0.0186	0.0097	0.0097	0.0093	0.0091				
	BIC	-117.110	-134.477	-131.011	-128.893	-126.12				
	test stat	-1.27	-1.766	-1.735	-1.584	-1.568				

No constant, no trend model: change x = previous x + error (+ lags of change x)

Constant, no trend model: change x = constant + previous x + error (+ lags of change x)

Constant, trend model: change x = constant + time + previous x + error (+ lags of change x)

Variables where null not rejected in all models (test stat=(previous x coef - 0)/se(coef)): ALL VARIABLES

Appendix 3

Cointegration Tests for All Variables										
GDP = Gross Domestic Product										
LAB = Labour Force										
HIGH = Highway Capital Stock										
BLDG = Building Capital Stock										
MACH = Machinery Capital Stock										
ENG = Engineering Capital Stock										
BME = Building + Machinery + Engineering Capital Stock										
Note: All of these variables are logged										
variables	**values**	**0 lags**	**1 lag**	**2 lags**	**3 lags**	**4 lags**	**lowest**	**test**	**critical**	**conclusion**
model							BIC	stat	value	
GDP = LAB										
constant, no	N	32	32	32	32	32	-96.8	-1.29	-3.04	co-
trend	k	2	3	4	5	6	(0 lags)		(m=2)	integrated
	SSR	0.0391	0.0387	0.0376	0.0375	0.0347				
	BIC	-96.801	-93.664	-91.121	-87.741	-86.758				
	test stat	-1.294	-1.383	-0.895	-0.8658	-1.297				
constant, trend	N	32	32	32	32	32	-94.6	-1.23	-3.5	co-
	k	3	4	5	6	7	(0 lags)		(m=2)	integrated
	SSR	0.0376	0.0374	0.0358	0.0358	0.0331				
	BIC	-94.587	-91.292	-89.225	-85.759	-84.803				
	test stat	-1.233	-1.275	-0.7147	-0.6362	-1.603				
GDP = HIGH										
constant,	N	32	32	32	32	32	-85.7	-1.47	-3.04	co-
no trend	k	2	3	4	5	6	(0 lags)		(m=2)	integrated
	SSR	0.0562	0.0524	0.0472	0.0454	0.0417				
	BIC	-85.685	-84.707	-84.832	-82.857	-82.359				
	test stat	-1.468	-1.847	-1.176	-1.415	-1.871				
constant, trend	N	32	32	32	32	32	-82.5	-1.54	-3.5	co-
	k	3	4	5	6	7	(0 lags)		(m=2)	integrated
	SSR	0.0548	0.0518	0.0457	0.0446	0.0415				
	BIC	-82.533	-80.869	-81.412	-78.726	-77.566				
	test stat	-1.535	-1.846	-1.146	-1.318	-1.746				
GDP = BLDG										
constant,	N	32	32	32	32	32	-79.4	-1.07	-3.04	co-
no trend	k	2	3	4	5	6	(0 lags)		(m=2)	integrated
	SSR	0.0674	0.0611	0.0581	0.0532	0.0506				
	BIC	-79.376	-79.051	-77.196	-76.550	-74.687				
	test stat	-1.07	-1.725	-1.093	-1.651	-1.965				
constant, trend	N	32	32	32	32	32	-77.1	-0.91	-3.5	co-
	k	3	4	5	6	7	(0 lags)		(m=2)	integrated
	SSR	0.065	0.06	0.0565	0.0524	0.0499				

	BIC	-77.071	-76.166	-74.624	-73.569	-71.667				
	test stat	-0.9145	-1.52	-0.8592	-1.395	-1.708				
GDP = MACH										
constant,	N	32	32	32	32	32	-86.0	-2.32	-3.04	co-
no trend	k	2	3	4	5	6	(1 lag)		(m=2)	integrated
	SSR	0.0548	0.0466	0.0443	0.0438	0.0419				
	BIC	-84.844	-85.988	-83.564	-79.885	-77.261				
	test stat	-1.639	-2.319	-1.594	-1.657	-1.915				
constant, trend	N	32	32	32	32	32	-84.3	-2.28	-3.5	co-
	k	3	4	5	6	7	(1 lag)		(m=2)	integrated
	SSR	0.0548	0.0466	0.0442	0.0438	0.0418				
	BIC	-82.533	-84.254	-82.480	-79.305	-77.335				
	test stat	-1.612	-2.28	-1.563	-1.623	-1.878				
GDP = ENG										
constant,	N	32	32	32	32	32	-88.6	-2.21	-3.04	co-
no trend	k	2	3	4	5	6	(0 lags)		(m=2)	integrated
	SSR	0.0506	0.0462	0.0444	0.0442	0.0417				
	BIC	-88.550	-87.996	-85.802	-82.480	-80.878				
	test stat	-2.213	-2.759	-1.99	-1.948	-2.273				
constant, trend	N	32	32	32	32	32	-85.6	-2.23	-3.5	co-
	k	3	4	5	6	7	(0 lags)			integrated
	SSR	0.0498	0.0458	0.044	0.0439	0.0414				
	BIC	-85.594	-84.808	-82.625	-79.232	-77.643				
	test stat	-2.226	-2.72	-1.964	-1.916	-2.23				
GDP = BME										
consant,	N	32	32	32	32	32	-93.5	-2.30	-3.04	co-
no trend	k	2	3	4	5	6	(0 lags)		(m=2)	integrated
	SSR	0.0433	0.0393	0.0362	0.0357	0.0337				
	BIC	-93.536	-93.172	-92.335	-89.315	-87.694				
	test stat	-2.3	-2.853	-1.827	-1.916	-2.25				
constant, trend	N	32	32	32	32	32	-90.1	-2.27	-3.5	co-
	k	3	4	5	6	7	(0 lags)		(m=2)	integrated
	SSR	0.0432	0.0392	0.0362	0.0357	0.0336				
	BIC	-90.144	-89.788	-88.870	-85.849	-84.323				
	test stat	-2.272	-2.812	-1.788	-1.878	-2.206				
GDP = LAB + HIGH										
constant,	N	32	32	32	32	32	-112.5	-4.88	-3.45	co-
no trend	k	2	3	4	5	6	(1 lag)		(m=3)	integrated
	SSR	0.0263	0.0215	0.0213	0.0213	0.0204				
	BIC	-109.49	-112.47	-109.31	-105.84	-103.76				
	test stat	-3.837	-4.881	-3.223	-2.766	-2.971				
constant, trend	N	32	32	32	32	32	-112.3	-5.30	-3.84	not
	k	3	4	5	6	7	(1 lag)		(m=3)	co-
	SSR	0.0254	0.0194	0.0194	0.0193	0.0184				integrated
	BIC	-107.14	-112.30	-108.83	-105.53	-103.59				

	test stat	-3.983	-5.302	-3.672	-3.281	-3.483				
GDP = LAB + BLDG										
constant,	N	32	32	32	32	32	-94.8	-1.28	-3.45	co-
no trend	k	2	3	4	5	6	(0 lags)		(m=3)	integrated
	SSR	0.0416	0.0401	0.0372	0.0368	0.0351				
	BIC	-94.817	-92.527	-91.463	-88.344	-86.391				
	test stat	-1.279	-1.598	-0.7734	-0.9021	-1.244				
constant, trend	N	32	32	32	32	32	-92.6	-1.13	-3.84	co-
	k	3	4	5	6	7	(0 lags)		(m=3)	integrated
	SSR	0.04	0.039	0.0352	0.0352	0.0337				
	BIC	-92.607	-89.951	-89.766	-86.300	-84.228				
	test stat	-1.125	-1.376	-0.4316	-0.4888	-0.8266				
GDP = LAB + MACH										
constant,	N	32	32	32	32	32	-93.9	-1.15	-3.45	co-
no trend	k	2	3	4	5	6	(0 lags)		(m=3)	integrated
	SSR	0.0428	0.0424	0.0416	0.0416	0.0393				
	BIC	-93.907	-90.742	-87.886	-84.420	-82.775				
	test stat	-1.147	-1.248	-0.8319	-0.7837	-1.16				
constant,	N	32	32	32	32	32	-92.2	-1.07	-3.84	co-
trend	k	3	4	5	6	7	(0 lags)		(m=3)	integrated
	SSR	0.0405	0.0403	0.0391	0.039	0.0371				
	BIC	-92.209	-88.902	-86.404	-83.020	-81.152				
	test stat	-1.071	-1.096	-0.5867	-0.4683	-0.8392				
GDP = LAB + ENG										
constant,	N	32	32	32	32	32	-100.7	-2.74	-3.45	co-
no trend	k	2	3	4	5	6	(0 lags)		(m=3)	integrated
	SSR	0.0346	0.0323	0.0308	0.0308	0.0287				
	BIC	-100.71	-99.449	-97.505	-94.039	-92.833				
	test stat	-2.736	-3.133	-2.052	-1.813	-2.199				
constant, trend	N	32	32	32	32	32	-97.3	-2.69	-3.84	co-
	k	3	4	5	6	7	(0 lags)		(m=3)	integrated
	SSR	0.0346	0.0323	0.0308	0.0307	0.0287				
	BIC	-97.248	-95.983	-94.039	-90.677	-89.367				
	test stat	-2.69	-3.08	-1.991	-1.75	-2.133				
GDP = LAB + BME										
constant,	N	32	32	32	32	32	-99.2	-2.33	-3.45	co-
no trend	k	2	3	4	5	6	(0 lags)		(m=3)	integrated
	SSR	0.0363	0.034	0.0313	0.0312	0.0294				
	BIC	-99.179	-97.807	-96.989	-93.626	-92.062				
	test stat	-2.328	-2.734	-1.626	-1.568	-1.927				
constant, trend	N	32	32	32	32	32	-95.8	-2.24	-3.84	co-
	k	3	4	5	6	7	(0 lags)		(m=3)	integrated
	SSR	0.0362	0.034	0.0312	0.0311	0.0294				
	BIC	-95.801	-94.342	-93.626	-90.263	-88.596				
	test stat	-2.244	-2.642	-1.498	-1.427	-1.782				

GDP = LAB + HIGH + BLDG										
constant,	N	32	32	32	32	32	-114.0	-5.00	-3.81	not
no trend	k	2	3	4	5	6	(1 lag)		(m=4)	co-
	SSR	0.025	0.0205	0.0205	0.0205	0.0194				integrated
	BIC	-111.11	-114.00	-110.53	-107.07	-105.37				
	test stat	-4.013	-4.995	-3.465	-2.876	-3.146				
constant, trend	N	32	32	32	32	32	-113.8	-5.46	-4.15	not
	k	3	4	5	6	7	(1 lag)		(m=4)	co-
	SSR	0.0239	0.0185	0.0184	0.0184	0.0174				integrated
	BIC	-109.09	-113.82	-110.52	-107.06	-105.38				
	test stat	-4.178	-5.457	-3.99	-3.44	-3.665				
GDP = LAB + HIGH + MACH										
constant,	N	32	32	32	32	32	-114.8	-5.82	-3.81	not
no trend	k	2	3	4	5	6	(1 lag)		(m=4)	co-
	SSR	0.0252	0.02	0.0198	0.0198	0.0193				integrated
	BIC	-110.86	-114.79	-111.64	-108.18	-105.53				
	test stat	-3.992	-5.187	-3.32	-2.776	-2.849				
constant, trend	N	32	32	32	32	32	-116.0	-5.85	-4.15	not
	k	3	4	5	6	7	(1 lag)		(m=4)	co-
	SSR	0.0239	0.0173	0.0173	0.0173	0.0169				integrated
	BIC	-109.09	-115.96	-112.50	-109.03	-106.31				
	test stat	-4.211	-5.849	-3.997	-3.482	-3.527				
GDP = LAB + HIGH + ENG										
constant,	N	32	32	32	32	32	-112.8	-4.88	-3.81	not
no trend	k	2	3	4	5	6	(1 lag)		(m=4)	co-
	SSR	0.026	0.0213	0.0211	0.0211	0.0203				integrated
	BIC	-109.86	-112.77	-109.61	-106.14	-103.91				
	test stat	-3.866	-4.88	-3.17	-2.667	-2.836				
constant, trend	N	32	32	32	32	32	-112.3	-5.27	-4.15	not
	k	3	4	5	6	7	(1 lag)		(m=4)	co-
	SSR	0.0251	0.0194	0.0194	0.0194	0.0187				integrated
	BIC	-107.52	-112.30	-108.83	-105.37	-103.08				
	test stat	-3.981	-5.274	-3.57	-3.109	-3.268				

GDP = LAB + HIGH + BME										
constant,	N	32	32	32	32	32	-112.5	-4.88	-3.81	not
no trend	k	2	3	4	5	6	(1 lag)		(m=4)	co-
	SSR	0.0263	0.0215	0.0213	0.0213	0.0204				integrated
	BIC	-109.49	-112.47	-109.31	-105.84	-103.76				
	test stat	-3.837	-4.881	-3.221	-2.764	-2.968				
constant, trend	N	32	32	32	32	32	-112.3	-5.30	-4.15	not
	k	3	4	5	6	7	(1 lag)		(m=4)	co-

	SSR	0.0254	0.0194	0.0194	0.0193	0.0184				integrated
	BIC	-107.14	-112.30	-108.83	-105.53	-103.59				
	test stat	-3.938	-5.301	-3.669	-3.278	-3.479				
Constant, no trend model: change x = constant + previous x + error (+ lags of change x)										
Constant, trend model: change x = constant + time + previous x + error (+ lags of change x)										
Note: The residuals from the model and the time variable are NOT logged										

APPENDIX 4

ERROR CORRECTION MODEL TESTS

diffgdp = gdp(t) - gdp(t-1)
dif1gdp = gdp(t-1) - gdp(t-2)
dif2gdp = gdp(t-2) - gdp(t-3)
dif3gdp = gdp(t-3) - gdp(t-4)
lagres = lag of residuals from MODEL
lab = labour
high = high
bme = building + machinery + capital

MODEL: GDP = CONSTANT + LABOUR + HIGHWAY
GDP = CONSTANT + LABOUR + HIGHWAY + CAPITALS

GDP = CONSTANT + LABOUR + HIGHWAY	**BIC**
With lagged residual only	
ols diffgdp lagres	-90.483
With laggged residual and one variable with one lag	
ols diffgdp lagres dif1lab	-93.026
ols diffgdp lagres dif1high	-87.075
ols diffgdp lagres dif1gdp	-99.943
ols diffgdp lagres dif2lab	-88.969
ols diffgdp lagres dif2high	-87.362
ols diffgdp lagres dif2gdp	-88.107
ols diffgdp lagres dif3lab	-87.613
ols diffgdp lagres dif3high	-89.951
ols diffgdp lagres dif3gdp	-87.050
With lagged residual and two variables, each with one lag	
ols diffgdp lagres dif1lab dif1high	-89.697
ols diffgdp lagres dif1lab dif1gdp	-98.217
ols diffgdp lagres dif1high dif1gdp	-99.048
ols diffgdp lagres dif2lab dif2high	-86.001
ols diffgdp lagres dif2lab dif2gdp	-90.244
ols diffgdp lagres dif2high dif2gdp	-85.365
ols diffgdp lagres dif3lab dif3high	-87.935
ols diffgdp lagres dif3lab dif3gdp	-84.827
ols diffgdp lagres dif3high dif3gdp	-86.656
ols diffgdp lagres dif1lab dif2high	-90.423
ols diffgdp lagres dif1lab dif2gdp	-94.428
ols diffgdp lagres dif1high dif1gdp	-84.630
ols diffgdp lagres dif2lab dif1high	-85.641

ols diffgdp lagres dif2lab dif1gdp	-99.953
ols diffgdp lagres dif2high dif1gdp	-96.578
ols diffgdp lagres dif1lab dif3high	-94.209
ols diffgdp lagres dif1lab dif3gdp	-89.943
ols diffgdp lagres dif1high dif3gdp	-83.656
ols diffgdp lagres dif3lab dif1high	-84.207
ols diffgdp lagres dif3lab dif1gdp	-96.899
ols diffgdp lagres dif3high dif1gdp	-99.262
ols diffgdp lagres dif2lab dif3high	-90.674
ols diffgdp lagres dif2lab dif3gdp	-86.859
ols diffgdp lagres dif2high dif3gdp	-83.949
ols diffgdp lagres dif3lab dif2high	-84.538
ols diffgdp lagres dif3lab dif2gdp	-85.547
ols diffgdp lagres dif3high dif2gdp	-87.325
With lagged residual and three variables, each with one lag	
ols diffgdp lagres dif1lab dif1high dif1gdp	-97.035
ols diffgdp lagres dif1lab dif1high dif2gdp	-90.941
ols diffgdp lagres dif1lab dif1high dif3gdp	-86.685
ols diffgdp lagres dif1lab dif1gdp dif2high	-95.069
ols diffgdp lagres dif1lab dif1gdp dif3high	-98.588
ols diffgdp lagres dif1high dif1gdp dif2lab	-100.019
ols diffgdp lagres dif1high dif1gdp dif3lab	-96.094
ols diffgdp lagres dif2lab dif2high dif1gdp	-96.697
ols diffgdp lagres dif2lab dif2high dif2gdp	-88.956
ols diffgdp lagres dif2lab dif2high dif3gdp	-84.157
ols diffgdp lagres dif2lab dif2gdp dif1high	-86.755
ols diffgdp lagres dif2lab dif2gdp dif3high	-93.412
ols diffgdp lagres dif2high dif2gdp dif1lab	-93.833
ols diffgdp lagres dif2high dif2gdp dif3lab	-82.951
ols diffgdp lagres dif3lab dif3high dif1gdp	-96.971
ols diffgdp lagres dif3lab dif3high dif2gdp	-85.685
ols diffgdp lagres dif3lab dif3high dif3gdp	-86.748
ols diffgdp lagres dif3lab dif3gdp dif1high	-81.496
ols diffgdp lagres dif3lab dif3gdp dif2high	-81.902
ols diffgdp lagres dif3high dif3gdp dif1lab	-91.690
ols diffgdp lagres dif3high dif3gdp dif2lab	-91.753
ols diffgdp lagres dif1lab dif2high dif3gdp	-87.486
ols diffgdp lagres dif1lab dif3high dif2gdp	-95.603
ols diffgdp lagres dif2lab dif1high dif3gdp	-83.736
ols diffgdp lagres dif2lab dif3high dif1gdp	-102.340
ols diffgdp lagres dif3lab dif1high dif2gdp	-82.057
ols diffgdp lagres dif3lab dif2high dif1gdp	-93.555
With lagged residual and three variables, each with two lags	
ols diffgdp lagres dif1lab dif2lab dif1high dif2high dif1gdp dif2gdp	-92.568
ols diffgdp lagres dif1lab dif2lab dif1high dif2high dif1gdp dif3gdp	-91.479

ols diffgdp lagres dif1lab dif2lab dif1high dif2high dif2gdp dif3gdp	-88.557
ols diffgdp lagres dif1lab dif2lab dif1high dif3high dif1gdp dif2gdp	-95.663
ols diffgdp lagres dif1lab dif2lab dif1high dif3high dif1gdp dif3gdp	-94.334
ols diffgdp lagres dif1lab dif2lab dif1high dif3high dif2gdp dif3gdp	-94.093
ols diffgdp lagres dif1lab dif2lab dif2high dif3high dif1gdp dif2gdp	-94.889
ols diffgdp lagres dif1lab dif2lab dif2high dif3high dif1gdp dif3gdp	-91.950
ols diffgdp lagres dif1lab dif2lab dif2high dif3high dif2gdp dif3gdp	-96.099
ols diffgdp lagres dif1lab dif3lab dif1high dif2high dif1gdp dif2gdp	-88.761
ols diffgdp lagres dif1lab dif3lab dif1high dif2high dif1gdp dif3gdp	-91.075
ols diffgdp lagres dif1lab dif3lab dif1high dif2high dif2gdp dif3gdp	-86.103
ols diffgdp lagres dif1lab dif3lab dif1high dif3high dif1gdp dif2gdp	-89.704
ols diffgdp lagres dif1lab dif3lab dif1high dif3high dif1gdp dif3gdp	-91.209
ols diffgdp lagres dif1lab dif3lab dif1high dif3high dif2gdp dif3gdp	-86.019
ols diffgdp lagres dif1lab dif3lab dif2high dif3high dif1gdp dif2gdp	-89.414
ols diffgdp lagres dif1lab dif3lab dif2high dif3high dif1gdp dif3gdp	-89.229
ols diffgdp lagres dif1lab dif3lab dif2high dif3high dif2gdp dif3gdp	-87.525
ols diffgdp lagres dif2lab dif3lab dif1high dif2high dif1gdp dif2gdp	-94.053
ols diffgdp lagres dif2lab dif3lab dif1high dif2high dif1gdp dif3gdp	-93.524
ols diffgdp lagres dif2lab dif3lab dif1high dif2high dif2gdp dif3gdp	-82.970
ols diffgdp lagres dif2lab dif3lab dif1high dif3high dif1gdp dif2gdp	-96.772
ols diffgdp lagres dif2lab dif3lab dif1high dif3high dif1gdp dif3gdp	-95.205
ols diffgdp lagres dif2lab dif3lab dif1high dif3high dif2gdp dif3gdp	-90.341
ols diffgdp lagres dif2lab dif3lab dif2high dif3high dif1gdp dif2gdp	-95.412
ols diffgdp lagres dif2lab dif3lab dif2high dif3high dif1gdp dif3gdp	-92.302
ols diffgdp lagres dif2lab dif3lab dif2high dif3high dif2gdp dif3gdp	-91.491
With lagged residual and all three variables with all lags	
ols diffgdp lagres dif1lab dif2lab dif3lab dif1high dif2high dif3high dif1gdp dif2gdp dif3gdp	-89.580
Test with the lowest BIC:	
ols diffgdp lagres dif2lab dif3high dif1gdp	**-102.340**

Returned Estimates:

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO 28 DF	P-VALUE
LAGRES	-1.3909	0.2556	-5.443	0.000
DIF2LAB	0.63794	0.2567	2.485	0.019
DIF3HIGH	1.4844	0.6350	2.338	0.027
DIF1GDP	0.69174	0.1712	4.041	0.000
CONSTANT	-0.68404E-01	0.3249E-01	-2.106	0.044

GDP = CONSTANT + LABOUR + HIGHWAY + CAPITALS	BIC
With lagged residual only	
ols diffgdp lagres	-90.471
With lagged residual and one variable with one lag	

ols diffgdp lagres dif1lab	-93.018
ols diffgdp lagres dif1high	-87.063
ols diffgdp lagres dif1gdp	-99.933
ols diffgdp lagres dif1bme	-92.134
ols diffgdp lagres dif2lab	-88.962
ols diffgdp lagres dif2high	-87.349
ols diffgdp lagres dif2gdp	-88.094
ols diffgdp lagres dif2bme	-87.852
ols diffgdp lagres dif3lab	-87.600
ols diffgdp lagres dif3high	-89.931
ols diffgdp lagres dif3gdp	-87.031
ols diffgdp lagres dif3bme	-87.171
With lagged residual and two variables, each lagged once, with the same lag	
ols diffgdp lagres dif1lab dif1high	-89.697
ols diffgdp lagres dif1lab dif1gdp	-98.227
ols diffgdp lagres dif1high dif1gdp	-99.038
ols diffgdp lagres dif1high dif1bme	-88.645
ols diffgdp lagres dif1gdp dif1bme	-101.034
ols diffgdp lagres dif1lab dif1bme	-90.690
With lagged residual and three variables, each lagged once, with the same lag	
ols diffgdp lagres dif1lab dif1high dif1bme	-87.256
ols diffgdp lagres dif1lab dif1high dif1gdp	-97.046
ols diffgdp lagres dif1lab dif1bme dif1gdp	-97.548
ols diffgdp lagres dif1high dif1bme dif1gdp	-99.432
With lagged residual and all four variables, each with one lag	
ols diffgdp lagres dif1lab dif1high dif1bme dif1gdp	-95.959
ols diffgdp lagres dif1lab dif1high dif2bme diflgdp	-95.147
ols diffgdp lagres dif1lab dif1high dif3bme dif1gdp	-93.955
ols diffgdp lagres dif1lab dif1high dif1bme dif2gdp	-89.453
ols diffgdp lagres dif1lab dif1high dif2bme dif2gdp	-87.524
ols diffgdp lagres dif1lab dif1high dif3bme dif2gdp	-87.612
ols diffgdp lagres dif1lab dif1high dif1bme dif3gdp	-85.227
ols diffgdp lagres dif1lab dif1high dif2bme dif3gdp	-83.220
ols diffgdp lagres dif1lab dif1high dif3bme dif3gdp	-83.181
ols diffgdp lagres dif1lab dif2high dif1bme dif1gdp	-94.671
ols diffgdp lagres dif1lab dif2high dif2bme dif1gdp	-92.649
ols diffgdp lagres dif1lab dif2high dif3bme dif1gdp	-91.743
ols diffgdp lagres dif1lab dif3high dif1bme dif1gdp	-98.435
ols diffgdp lagres dif1lab dif3high dif2bme dif1gdp	-96.920
ols diffgdp lagres dif1lab dif3high dif3bme dif1gdp	-95.426
ols diffgdp lagres dif2lab dif1high dif1bme dif1gdp	-97.014
ols diffgdp lagres dif2lab dif1high dif2bme dif1gdp	-96.744
ols diffgdp lagres dif2lab dif1high dif3bme dif1gdp	-96.558
ols diffgdp lagres dif3lab dif1high dif1bme dif1gdp	-96.861

ols diffgdp lagres dif3lab dif1high dif2bme dif1gdp	-96.153
ols diffgdp lagres dif3lab dif1high dif2bme dif1gdp	-96.153
ols diffgdp lagres dif3lab dif1high dif3bme dif1gdp	-93.159
ols diffgdp lagres dif2lab dif2high dif1bme dif1gdp	-94.914
ols diffgdp lagres dif2lab dif2high dif2bme dif1gdp	-93.464
ols diffgdp lagres dif2lab dif2high dif3bme dif1gdp	-93.232
ols diffgdp lagres dif2lab dif2high dif1bme dif2gdp	-89.192
ols diffgdp lagres dif2lab dif2high dif2bme dif2gdp	-85.451
ols diffgdp lagres dif2lab dif2high dif3bme dif2gdp	-86.720
ols diffgdp lagres dif2lab dif2high dif1bme dif3gdp	-85.252
ols diffgdp lagres dif2lab dif2high dif2bme dif3gdp	-80.776
ols diffgdp lagres dif2lab dif2high dif3bme dif3gdp	-80.653
ols diffgdp lagres dif2lab dif1high dif1bme dif2gdp	-86.037
ols diffgdp lagres dif2lab dif1high dif1bme dif2gdp	-86.037
ols diffgdp lagres dif2lab dif1high dif2bme dif2gdp	-83.259
ols diffgdp lagres dif2lab dif1high dif3bme dif2gdp	-84.196
ols diffgdp lagres dif2lab dif3high dif1bme dif2gdp	-91.995
ols diffgdp lagres dif2lab dif3high dif2bme dif2gdp	-89.916
ols diffgdp lagres dif2lab dif3high dif3bme dif2gdp	-91.333
ols diffgdp lagres dif1lab dif2high dif1bme dif2gdp	-93.433
ols diffgdp lagres dif1lab dif2high dif2bme dif2gdp	-90.520
ols diffgdp lagres dif1lab dif2high dif3bme dif2gdp	-90.529
ols diffgdp lagres dif3lab dif2high dif1bme dif2gdp	-90.568
ols diffgdp lagres dif3lab dif2high dif2bme dif2gdp	-80.783
ols diffgdp lagres dif3lab dif2high dif3bme dif2gdp	-79.483
ols diffgdp lagres dif3lab dif3high dif1bme dif1gdp	-98.881
ols diffgdp lagres dif3lab dif3high dif2bme dif1gdp	-96.826
ols diffgdp lagres dif3lab dif3high dif3bme dif1gdp	-93.709
ols diffgdp lagres dif3lab dif3high dif1bme dif2gdp	-90.365
ols diffgdp lagres dif3lab dif3high dif2bme dif2gdp	-83.368
ols diffgdp lagres dif3lab dif3high dif3bme dif2gdp	-82.249
ols diffgdp lagres dif3lab dif3high dif1bme dif3gdp	-89.378
ols diffgdp lagres dif3lab dif3high dif2bme dif3gdp	-84.117
ols diffgdp lagres dif3lab dif3high dif3bme dif3gdp	-83.267
ols diffgdp lagres dif3lab dif1high dif1bme dif3gdp	-83.752
ols diffgdp lagres dif3lab dif1high dif2bme dif3gdp	-78.433
ols diffgdp lagres dif3lab dif1high dif3bme dif3gdp	-77.986
ols diffgdp lagres dif3lab dif2high dif1bme dif3gdp	-85.484
ols diffgdp lagres dif3lab dif2high dif2bme dif3gdp	-78.913
ols diffgdp lagres dif3lab dif2high dif3bme dif3gdp	-78.399
ols diffgdp lagres dif1lab dif3high dif1bme dif3gdp	-91.642
ols diffgdp lagres dif1lab dif3high dif2bme dif3gdp	-88.868
ols diffgdp lagres dif1lab dif3high dif3bme dif3gdp	-88.293
ols diffgdp lagres dif2lab dif3high dif1bme dif3gdp	-91.542
ols diffgdp lagres dif2lab dif3high dif2bme dif3gdp	-88.584
ols diffgdp lagres dif2lab dif3high dif3bme dif3gdp	-88.257
ols diffgdp lagres dif1lab dif2high dif1bme dif3gdp	-86.885

ols diffgdp lagres dif1lab dif2high dif2bme dif3gdp	-84.053
ols diffgdp lagres dif1lab dif2high dif3bme dif3gdp	-83.989
ols diffgdp lagres dif1lab dif3high dif1bme dif2gdp	-94.628
ols diffgdp lagres dif1lab dif3high dif2bme dif2gdp	-92.525
ols diffgdp lagres dif1lab dif3high dif3bme dif2gdp	-92.167
ols diffgdp lagres dif2lab dif1high dif1bme dif3gdp	-83.642
ols diffgdp lagres dif2lab dif1high dif2bme dif3gdp	-80.303
ols diffgdp lagres dif2lab dif1high dif2bme dif2gdp	-83.259
ols diffgdp lagres dif2lab dif3high dif1bme dif1gdp	-99.868
ols diffgdp lagres dif2lab dif3high dif2bme dif1gdp	-99.131
ols diffgdp lagres dif2lab dif3high dif3bme dif1gdp	-98.918
ols diffgdp lagres dif3lab dif1high dif1bme dif2gdp	-87.137
ols diffgdp lagres dif3lab dif1high dif2bme dif2gdp	-79.552
ols diffgdp lagres dif3lab dif1high dif3bme dif2gdp	-78.587
ols diffgdp lagres dif3lab dif2high dif1bme dif1gdp	-96.062
ols diffgdp lagres dif3lab dif2high dif2bme dif1gdp	-93.044
ols diffgdp lagres dif3lab dif2high dif3bme dif1gdp	-90.385
With lagged residual and all four variables, each with the same two lags	
ols diffgdp lagres dif1lab dif2lab dif1high dif2high dif1bme dif2bme dif1gdp dif2gdp	-87.006
ols diffgdp lagres dif1lab dif3lab dif1high dif3high dif1bme dif3bme dif1gdp dif3gdp	-87.462
ols diffgdp lagres dif2lab dif3lab dif2high dif3high dif2bme dif3bme dif2gdp dif3gdp	-95.307
With lagged residual and all four variables, each with all three lags	
ols diffgdp lagres dif1lab dif2lab dif3lab dif1high dif2high dif3high dif1bme dif2bme dif3bme dif1gdp dif2gdp dif3gdp	-89.464
With lagged residual, with BME lagged three times and the others once	
ols diffgdp lagres dif1lab dif1high dif1bme dif2bme dif3bme dif1gdp	-89.368
With lagged residual, with BME lagged twice and the others lagged once	
ols diffgdp lagres dif1lab dif1high dif1bme dif2bme dif1gdp	-92.474

Test with the lowest BIC with all four variables:

ols diffgdp lagres dif2lab dif3high dif2bme dif1gdp **-99.131**

Returned Estimates:

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO 27 DF	P-VALUE			
LAGRES	-1.4158	0.2643	-5.357	0.000			
DIF2LAB	0.53611	0.3488	1.537	0.136			
DIF3HIGH	1.4818	0.6440	2.301	0.029			
DIF2BME	0.15963	0.3554	0.4492	0.657			
DIF1GDP	0.70231	0.1749	4.016	0.000	0.611	0.6996	0.6938
CONSTANT	-0.72583E-01	0.3411E-01	-2.128	0.043	-0.379	0.0000	-1.4082

APPENDIX 5

The Top 10 Error Correction Models with the Highest BIC

GDP = CONSTANT + LABOUR + HIGHWAY + SUM OF CAPITALS

(1)

|_ols diffgdp dif1gdp dif2lab dif1high dif2bme lag1res / resid=resid dwpvalue

```
DURBIN-WATSON STATISTIC  =   1.60770
DURBIN-WATSON P-VALUE =    0.057261

 R-SQUARE =   0.5261     R-SQUARE ADJUSTED =   0.4383
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.10454E-02
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.32333E-01
SUM OF SQUARED ERRORS-SSE=  0.28227E-01
MEAN OF DEPENDENT VARIABLE =  0.51542E-01
LOG OF THE LIKELIHOOD FUNCTION =  69.7308
```

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO 27 DF	P-VALUE	PARTIAL CORR.	STANDARDIZED COEFFICIENT	ELASTICITY AT MEANS
DIF1GDP	0.83684	0.1884	4.443	0.000	0.650	0.8337	0.8267
DIF2LAB	0.42610	0.3553	1.199	0.241	0.225	0.2282	0.2735
DIF1HIGH	-1.1139	0.6380	-1.746	0.092	-0.318	-0.2436	-0.9183
DIF2BME	0.14559	0.3687	0.3949	0.696	0.076	0.0757	0.1270
LAG1RES	-1.4884	0.2825	-5.269	0.000	-0.712	-1.0265	-0.0607
CONSTANT	0.38750E-01	0.2931E-01	1.322	0.197	0.247	0.0000	0.7518

BIC = -96.74

(2.5) (tie for second and third)

|_ols diffgdp dif1gdp dif1lab dif1high dif1bme lag1res / resid=resid dwpvalue

```
DURBIN-WATSON STATISTIC  =   1.80097
DURBIN-WATSON P-VALUE =    0.158406

R-SQUARE =   0.5146     R-SQUARE ADJUSTED =   0.4247
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.10708E-02
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.32724E-01
SUM OF SQUARED ERRORS-SSE=  0.28913E-01
MEAN OF DEPENDENT VARIABLE =  0.51542E-01
LOG OF THE LIKELIHOOD FUNCTION =  69.3347
```

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO 27 DF	P-VALUE	PARTIAL CORR.	STANDARDIZED COEFFICIENT	ELASTICITY AT MEANS
DIF1GDP	0.72995	0.2101	3.474	0.002	0.556	0.7272	0.7211
DIF1LAB	0.40401E-01	0.3865	0.1045	0.918	0.020	0.0216	0.0259
DIF1HIGH	-0.82449	0.6511	-1.266	0.216	-0.237	-0.1803	-0.6797
DIF1BME	0.52108	0.3650	1.428	0.165	0.265	0.2736	0.4612
LAG1RES	-1.4376	0.2792	-5.149	0.000	-0.704	-0.9915	-0.0587
CONSTANT	0.27325E-01	0.3117E-01	0.8768	0.388	0.166	0.0000	0.5302

BIC = -95.96

(2.5) |_ols diffgdp dif1gdp dif1lab dif1high dif1bme lag2res / resid=resid dwpvalue

```
 DURBIN-WATSON STATISTIC  =   1.80097
 DURBIN-WATSON P-VALUE =    0.158406

 R-SQUARE =   0.5146      R-SQUARE ADJUSTED =   0.4247
 VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.10708E-02
 STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.32724E-01
 SUM OF SQUARED ERRORS-SSE=  0.28913E-01
 MEAN OF DEPENDENT VARIABLE =  0.51542E-01
 LOG OF THE LIKELIHOOD FUNCTION =  69.3347
```

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO 27 DF	P-VALUE	PARTIAL CORR.	STANDARDIZED COEFFICIENT	ELASTICITY AT MEANS
DIF1GDP	-0.70763	0.2306	-3.069	0.005	-0.509	-0.7049	-0.6991
DIF1LAB	1.2931	0.4448	2.907	0.007	0.488	0.6929	0.8295
DIF1HIGH	-0.97761E-01	0.6366	-0.1536	0.879	-0.030	-0.0214	-0.0806
DIF1BME	0.52333	0.3651	1.433	0.163	0.266	0.2748	0.4632
LAG2RES	-1.4376	0.2792	-5.149	0.000	-0.704	-1.0008	-0.0432
CONSTANT	0.27325E-01	0.3117E-01	0.8768	0.388	0.166	0.0000	0.5302

BIC = -95.96

(4)

|_ols diffgdp dif3gdp dif1lab dif3high dif1bme lag1res lag2res lag3res / resid=resid dwpvalue

```
 DURBIN-WATSON STATISTIC  =   2.16945
 DURBIN-WATSON P-VALUE =    0.500147

  R-SQUARE =   0.6017      R-SQUARE ADJUSTED =   0.4902
 VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.94885E-03
 STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.30803E-01
 SUM OF SQUARED ERRORS-SSE=  0.23721E-01
 MEAN OF DEPENDENT VARIABLE =  0.51542E-01
 LOG OF THE LIKELIHOOD FUNCTION =  72.6003
```

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO 25 DF	P-VALUE	PARTIAL CORR.	STANDARDIZED COEFFICIENT	ELASTICITY AT MEANS
DIF3GDP	-0.14919	0.2207	-0.6758	0.505	-0.134	-0.1472	-0.1533
DIF1LAB	0.68004	0.3399	2.001	0.056	0.372	0.3644	0.4362
DIF3HIGH	1.4758	0.7009	2.106	0.045	0.388	0.3078	1.2837
DIF1BME	0.55225	0.3775	1.463	0.156	0.281	0.2900	0.4888
LAG1RES	-0.66463	0.2476	-2.684	0.013	-0.473	-0.4584	-0.0271
LAG2RES	-0.69858	0.2551	-2.738	0.011	-0.480	-0.4863	-0.0210
LAG3RES	0.41835	0.2627	1.593	0.124	0.303	0.2975	0.0042
CONSTANT	-0.52131E-01	0.3250E-01	-1.604	0.121	-0.305	0.0000	-1.0114

BIC = -95.5

(5)

|_ols diffgdp dif1gdp dif3lab dif3high dif3bme lag3res lag1res / resid=resid dwpvalue

```
DURBIN-WATSON STATISTIC  =   2.30171
DURBIN-WATSON P-VALUE =    0.643273

R-SQUARE =   0.5427     R-SQUARE ADJUSTED =   0.4371
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.10477E-02
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.32369E-01
SUM OF SQUARED ERRORS-SSE=  0.27241E-01
MEAN OF DEPENDENT VARIABLE =  0.51542E-01
LOG OF THE LIKELIHOOD FUNCTION =  70.3175
```

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO 26 DF	P-VALUE	PARTIAL CORR.	STANDARDIZED COEFFICIENT	ELASTICITY AT MEANS
DIF1GDP	0.88081	0.2111	4.173	0.000	0.633	0.8775	0.8701
DIF3LAB	-0.12659	0.3903	-0.3243	0.748	-0.063	-0.0680	-0.0810
DIF3HIGH	1.2815	0.6624	1.935	0.064	0.355	0.2673	1.1147
DIF3BME	0.43213E-01	0.3763	0.1148	0.909	0.023	0.0225	0.0377
LAG3RES	0.51010	0.2711	1.882	0.071	0.346	0.3628	0.0051
LAG1RES	-1.2730	0.2648	-4.807	0.000	-0.686	-0.8780	-0.0520
CONSTANT	-0.46115E-01	0.3380E-01	-1.365	0.184	-0.259	0.0000	-0.8947

BIC = -94.43

(6)

|_ols diffgdp lag1res / dwpvalue

```
DURBIN-WATSON STATISTIC  =   1.36271
DURBIN-WATSON P-VALUE =    0.026369

R-SQUARE =   0.1243     R-SQUARE ADJUSTED =   0.0960
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.16826E-02
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.41020E-01
SUM OF SQUARED ERRORS-SSE=  0.52162E-01
MEAN OF DEPENDENT VARIABLE =  0.51542E-01
LOG OF THE LIKELIHOOD FUNCTION =  59.5985
```

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO 31 DF	P-VALUE	PARTIAL CORR.	STANDARDIZED COEFFICIENT	ELASTICITY AT MEANS
LAG1RES	-0.51111	0.2437	-2.097	0.044	-0.353	-0.3525	-0.0209
CONSTANT	0.52617E-01	0.7159E-02	7.350	0.000	0.797	0.0000	1.0209

BIC = -90.47

(7)

|_ols diffgdp dif1gdp dif2lab dif1high dif2bme lag3res lag1res / resid=resid dwpvalue

```
 DURBIN-WATSON STATISTIC  =   1.73354
 DURBIN-WATSON P-VALUE =    0.103744

  R-SQUARE =   0.5366     R-SQUARE ADJUSTED =   0.4296
 VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.10617E-02
 STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.32583E-01
 SUM OF SQUARED ERRORS-SSE=  0.27603E-01
 MEAN OF DEPENDENT VARIABLE =  0.51542E-01
 LOG OF THE LIKELIHOOD FUNCTION =  70.0994
```

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO 26 DF	P-VALUE	PARTIAL CORR.	STANDARDIZED COEFFICIENT	ELASTICITY AT MEANS
DIF1GDP	0.89216	0.2031	4.393	0.000	0.653	0.8888	0.8813
DIF2LAB	0.35451	0.3700	0.9581	0.347	0.185	0.1899	0.2275
DIF1HIGH	-1.0172	0.6552	-1.553	0.133	-0.291	-0.2224	-0.8386
DIF2BME	0.91654E-01	0.3781	0.2424	0.810	0.047	0.0476	0.0800
LAG3RES	0.18771	0.2449	0.7664	0.450	0.149	0.1335	0.0019
LAG1RES	-1.4594	0.2872	-5.082	0.000	-0.706	-1.0065	-0.0596
CONSTANT	0.36462E-01	0.2969E-01	1.228	0.230	0.234	0.0000	0.7074

BIC = -93.99

(8.5) (tie with places eight and nine)

|_ols diffgdp dif1gdp dif1lab dif1high dif1bme lag2res lag3res / resid=resid dwpvalue

```
 DURBIN-WATSON STATISTIC  =   1.92236
 DURBIN-WATSON P-VALUE =    0.246386

  R-SQUARE =   0.5349     R-SQUARE ADJUSTED =   0.4276
 VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.10655E-02
 STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.32642E-01
 SUM OF SQUARED ERRORS-SSE=  0.27703E-01
 MEAN OF DEPENDENT VARIABLE =  0.51542E-01
 LOG OF THE LIKELIHOOD FUNCTION =  70.0401
```

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO 26 DF	P-VALUE	PARTIAL CORR.	STANDARDIZED COEFFICIENT	ELASTICITY AT MEANS
DIF1GDP	-0.58484	0.2572	-2.274	0.031	-0.407	-0.5826	-0.5777
DIF1LAB	1.2168	0.4494	2.707	0.012	0.469	0.6520	0.7805
DIF1HIGH	-0.43245E-01	0.6371	-0.6788E-01	0.946	-0.013	-0.0095	-0.0357
DIF1BME	0.44221	0.3721	1.189	0.245	0.227	0.2322	0.3914
LAG2RES	-1.4260	0.2787	-5.116	0.000	-0.708	-0.9927	-0.0428
LAG3RES	0.24623	0.2311	1.066	0.296	0.205	0.1751	0.0025
CONSTANT	0.24836E-01	0.3117E-01	0.7967	0.433	0.154	0.0000	0.4819

BIC = -93.87

(8.5)

|_ols diffgdp dif1gdp dif1lab dif1high dif1bme lag3res lag1res / resid=resid dwpvalue

```
DURBIN-WATSON STATISTIC  =   1.92236
DURBIN-WATSON P-VALUE =    0.246386

 R-SQUARE =   0.5349     R-SQUARE ADJUSTED =   0.4276
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.10655E-02
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.32642E-01
SUM OF SQUARED ERRORS-SSE=  0.27703E-01
MEAN OF DEPENDENT VARIABLE =  0.51542E-01
LOG OF THE LIKELIHOOD FUNCTION =  70.0401
```

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO 26 DF	P-VALUE	PARTIAL CORR.	STANDARDIZED COEFFICIENT	ELASTICITY AT MEANS
DIF1GDP	0.84114	0.2341	3.593	0.001	0.576	0.8379	0.8309
DIF1LAB	-0.25831E-01	0.3905	-0.6615E-01	0.948	-0.013	-0.0138	-0.0166
DIF1HIGH	-0.76411	0.6520	-1.172	0.252	-0.224	-0.1671	-0.6299
DIF1BME	0.43998	0.3720	1.183	0.248	0.226	0.2310	0.3894
LAG3RES	0.24623	0.2311	1.066	0.296	0.205	0.1751	0.0025
LAG1RES	-1.4260	0.2787	-5.116	0.000	-0.708	-0.9835	-0.0582
CONSTANT	0.24836E-01	0.3117E-01	0.7967	0.433	0.154	0.0000	0.4819

BIC = -93.87

(10)

|_ols diffgdp dif1gdp dif3lab dif3high dif3bme lag1res / resid=resid dwpvalue

```
DURBIN-WATSON STATISTIC  =   1.93268
DURBIN-WATSON P-VALUE =    0.258180

R-SQUARE =   0.4804     R-SQUARE ADJUSTED =   0.3842
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.11463E-02
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.33857E-01
SUM OF SQUARED ERRORS-SSE=  0.30950E-01
MEAN OF DEPENDENT VARIABLE =  0.51542E-01
LOG OF THE LIKELIHOOD FUNCTION =  68.2110
```

VARIABLE NAME	ESTIMATED COEFFICIENT	STANDARD ERROR	T-RATIO 27 DF	P-VALUE	PARTIAL CORR.	STANDARDIZED COEFFICIENT	ELASTICITY AT MEANS
DIF1GDP	0.68851	0.1932	3.564	0.001	0.566	0.6859	0.6802
DIF3LAB	0.14899	0.3785	0.3937	0.697	0.076	0.0801	0.0953
DIF3HIGH	1.1959	0.6912	1.730	0.095	0.316	0.2494	1.0402
DIF3BME	0.17122	0.3871	0.4423	0.662	0.085	0.0890	0.1494
LAG1RES	-1.2515	0.2768	-4.522	0.000	-0.656	-0.8631	-0.0511
CONSTANT	-0.47108E-01	0.3535E-01	-1.333	0.194	-0.248	0.0000	-0.9140

BIC = -93.71

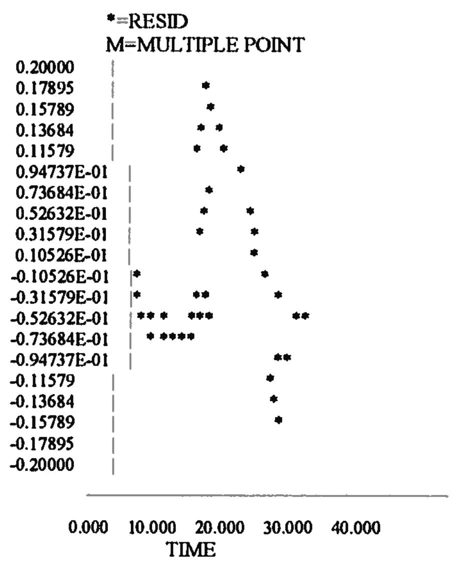
APPENDIX 6

Trending the Variables Over TIME

LOGLAB = 3.7426 + 0.035646 * TIME

(127.3) (26.42)

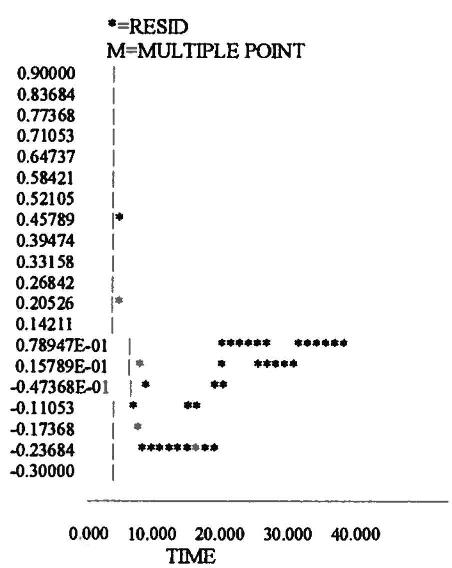
|_plot resid



LOGLAB = 3.2884 + 0.42148 * LOGTIME

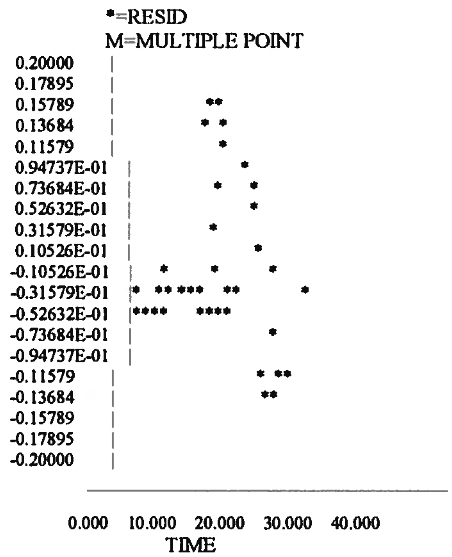
(39.79) (14.37)

|_plot resid



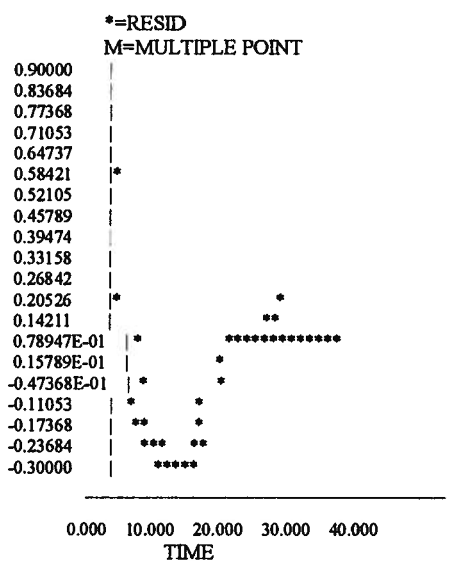
LOGBME = 8.5582 * 0.047631 * TIME
(315.4) (38.25)

|_plot resid



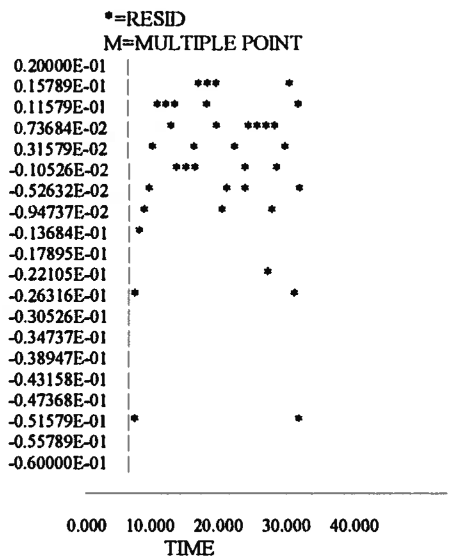
LOGBME = 7.9676 + 0.55709 * LOGTIME
(73.83) (14.55)

|_plot resid



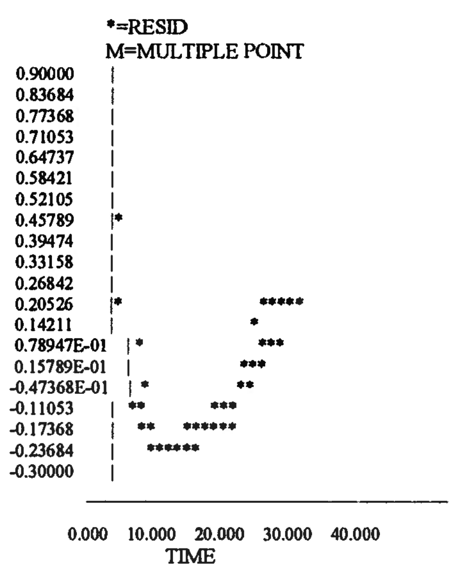
LOGHIGH = 6.9231 + 0.042893 * TIME
(169.2) (1253)

|_plot resid



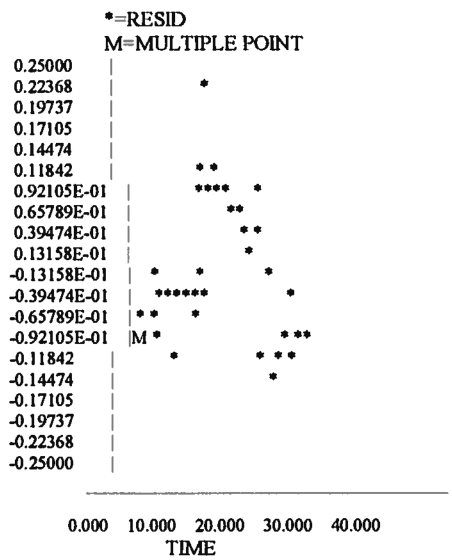
LOGHIGH = 6.4076 * 0.49559 * LOGTIME
(66.28) (14.45)

|_plot resid



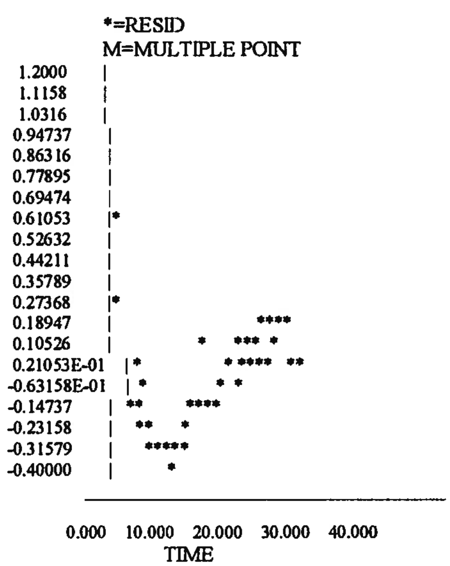
LOGGDP = 7.1592 + 0.052797 * TIME
(246.3) (39.58)

|_plot resid



LOGGDP = 6.4873 + 0.62395 * LOGTIME
(58.39) (15.83)

|_plot resid



Chapter 5
Calculating the Benefit Cost Ratio

5.1 Introduction

The ultimate goal of this study is to produce a benefit cost analysis of twinning highway 3. Recall from Chapter 1 that a benefit cost ratio (BCR) is defined as

(5.1) BCR = Dollar Value of All Benefits/Dollar Value of all Costs

In this study we have estimated the benefits as the increase in GDP in the southern Alberta region that would accrue due to twinning of highway 3. In the last chapter we estimated these increases in GDP through an econometric model of a production function. We saw that the future stream of benefits will depend upon the particular form of the model that is chosen. In all, we chose ten models that were statistically acceptable, and presented forecasting results from eight of these models in Chapter 4. In this chapter we estimate the benefit cost ratio for all ten models.

5.2 The Present Value of the Benefits

In order to calculate the numerator of the benefit cost ratio, any stream of future GDP benefits must be discounted to the present. Therefore, the present value of any stream of GDP gains will depend upon the discount rate chosen. Given this, we present a short digression on the nature of a discount rate

The Nature of Discounting

In order to understand discounting, consider the following example. Suppose that you have $100 today. If you put his in the bank, and the interest rate on your account is 10 percent, you will have $110 on year from now. You can look at this in another manner. It is equivalent to say that $110 tomorrow is worth 100 today. In this manner, $100 is said to be the present discounted value of $110 tomorrow, and the discount rate would be 10 percent. Essentially, you are saying that $110 tomorrow is equivalent to $100 today. The reason that money in the future is worth less than money today, is that you will not have the services of this money until some point in the future. [1]

In the above example, the amount of difference in value of money in the future relative to money today depends upon the size of the discount rate. Generally speaking, the larger the discount rate, the greater the difference in present and future value. In this study, the increases in GDP that are estimated to accrue from twining highway 3 will not be realized until some future date. Therefore, they must be discounted to today's present value. It can be seen then, the larger the discount rate, for a given future value, the smaller will be the present value.

There is no universally accepted manner in which to choose an appropriate discount rate. For this project, an appropriate discount rate would be the return on funds that could be obtained by the government if, instead of investing in highway 3, the money was put to an alternative use.

[1] For this example, we abstract from inflation, and therefore we are using a real discount rate. For all of the calculations in this study, all values are in real dollars. Therefore, we use real discount rates.

The Discounted Value of the Benefits

Given the above discussion, for each potential stream of increased GDP, we present the present discounted value using different interest rats. We discount using 3 percent, 4 percent, 5 percent, 6 percent, and 10 percent. The first four of these discount rates constitute what we consider to be reasonable discount rates. We offer calculations with a 10 percent discount rate to show that even with an abnormally high discount rate, the benefits are still substantial.

Table 5-1 shows the present value of the estimated increases in GDP for the ten models summarized in Chapter 4, each discounted using the discount rates outlined above.

Table 5-1
Cumulated Estimated Benefits
Various Discount Rates
($millions)

	Model									
Discount Rate	1	2	3	4	5	6	7	8	9	10
0	1072	1059	1078	1032	926	1113	1090	1087	1087	933
3	899	889	905	947	907	910	905	903	903	870
4	848	840	854	919	894	853	852	851	851	848
5	801	794	808	891	880	801	803	802	802	826
6	757	751	764	863	863	753	757	757	757	803
10	607	606	617	756	788	594	603	607	607	715

On Table 5-1 a discount rate of 0 simply means that these are sums the actual values of the forecasts of the gain in GDP in millions of dollars for each of the 10 models. Therefore, the cumulated value of increased GDP over 20 years varies from $926 million (model 5) to $1,087 million (models 8 and 9).

It can be seen from Table 5-1 that using a higher discount rate decreases the present value of the amounts. As an example, consider the figures in Column 1. This is the cumulated increase in GDP in southern Alberta, estimated from model 1. If we do not allow for discounting, we estimate that GDP will increase by $1,072 over 20 years. If we discount this amount by 3 percent, this decreases to $899 million.

Any discounted value of benefits from Table 5-1 forms the numerator of a benefit cost ratio. This then can be compared to a discounted cost to form a benefit cost ratio.

5.3 The Discounted Value of Costs

It is our understanding that twinning highway 3 will cost approximately $1,000,000 per kilometer, and there are approximately 220 kilometers to be twinned. In addition, structures will cost approximately $25,000,000, for a total direct twining cost of approximately $245,000,000. Future costs of maintenance are estimated to be approximately $1,000,000 per year.[2] Table 5-2 shows the present discounted value of these amounts, using the same discount rates that were used in Table 5-1.

Table 5-2
Discounted Value of Twinning Costs
($million)

Discount Rate	Discounted Cost
3	$238,500
4	$232,100
5	$226,100
6	$220,400
10	$200,300

Table 5-2 shows that the discounted value of the cost of twining highway 3 varies from $230,500 million to $200,300 million, depending on the discount rate used.

[2] These figures were supplied by Alberta Transportation.

5.4 *Calculating the Benefit Cost Ratio*

The final step in this exercise is to calculate the benefit cost ratio from the above information. This is accomplished by dividing each benefit from Table 5-1 by the cost on Table 5-2 that pertains to the same discount rate. The Final benefit cost ratios are given on Table 5-3.

Table 5-3
Calculated Benefit Cost Ratios

Discount Rate	Model 1	2	3	4	5	6	7	8	9	10
3	3.77	3.73	3.79	3.97	3.80	3.82	3.79	3.79	3.79	3.65
4	3.65	3.62	3.68	3.96	3.85	3.68	3.67	3.67	3.67	3.65
5	3.54	3.51	3.57	3.94	3.89	3.54	3.55	3.55	3.55	3.65
6	3.43	3.41	3.47	3.92	3.92	3.42	3.43	3.43	3.43	3.64
10	3.03	3.03	3.08	3.77	3.93	2.97	3.01	3.03	3.03	3.57

Table 3 shows that the benefit cost ratios are all in the neighborhood of 3, implying that $1.00 invested in highway expenditure will return up to $3.00 in increases in GDP in the southern Alberta region. Notice that all of these benefit cost ratios are greater than 1, no mater which model is chosen, or which discount rate is chose. This is very solid evidence that twining highway 3 is a sound economic decision.

5.5 Sensitivity Analysis

In this study care has been taken to ensure that a wide variety of econometric specifications have been considered. This was done to ensure that the results were not sensitive to any particular model that was chosen. In this section we undertake a further check of the sensitivity of the results in the following manner. One of the key parameters estimated in this model was the long run elasticity of output to a change in highway capital, β_1 from equation (4.1). This parameter was estimated to equal 0.50553. Intuitively, the higher this elasticity, the more output will respond to a change in highway capital, and the higher will be the benefit cost ratio. Given this, we test the sensitivity of the results to the size of this parameter estimate by recalculating all of the forecasts, assuming that this elasticity is one standard error *lower* that what we have estimated. One standard error of this estimated elasticity is equal to 0.08434. Therefore, in recalculating the forecasts, we assume that the long ling elasticity equals 0.42119, rather than 0.50553.

The new forecasted output gains are on Table 5-4.

Table 5-4
Forecasts of GDP Gains
Long Run Elasticity Reduced to 0.42119

Discount Rate	Model 1	2	3	4	5	6	7	8	9	10
0	533	460	461	506	438	445	525	471	481	396
3	442	385	388	457	423	365	431	391	397	375
4	416	364	367	442	415	342	404	369	373	367
5	391	344	347	427	407	321	380	348	351	359
6	369	325	329	413	399	302	357	328	331	350
10	294	262	267	359	362	239	281	263	263	316

Table 5-4 shows that with a one standard error reduction in the long run of highway expenditure, the output gains from every model are reduced by approximately one-half. However, even with this reduction, all of the output gains are still positive and reasonably large.

Given these new estimates of the output gains, Table 5-5 presents the results of recalculating the benefit cost ratios.

Table 5-5
Benefit Cost Ratios
Long Run Elasticity Reduced to 0.42119

3	1.85	1.61	1.63	1.92	1.77	1.53	1.81	1.64	1.66	1.57
4	1.79	1.57	1.58	1.90	1.79	1.47	1.74	1.59	1.61	1.58
5	1.73	1.52	1.53	1.89	1.80	1.42	1.68	1.54	1.55	1.59
6	1.67	1.47	1.49	1.87	1.81	1.37	1.62	1.49	1.50	1.59
10	1.47	1.31	1.33	1.79	1.81	1.19	1.40	1.31	1.31	1.58

Table 5-5 shows that, even though the output gains have been reduced by approximately one-half, the benefit cost ratios are still greater than one for every model and for every discount rate used.

5.6 Summary

In this chapter we have used the results of model estimation from Chapter 4 to calculate several benefit cost ratios for twining highway 3. The results in this chapter show that the benefit cost ratio is always greater than one for a wide variety of models and discount rates. Further, sensitivity analysis shows that results are sensitive to a change in the key parameter of the model. If the output elasticity of highway expenditure is reduced by one standard error, even this reduces the output gains by approximately one half, but leaves the benefit cost ratios greater than one.

Chapter 6
Summary and Conclusions

6.1 Summary of the Study

The purpose of this project was to undertake a benefit cost analysis of twinning of Highway 3 from the British Columbia border to Medicine Hat. A benefit cost analysis is a general methodology, which provides a decision rule for whether or not capital projects are viable. The basis of a benefit cost study is to attach dollar values to all benefits and all costs that result from undertaking a project. Once all dollar values are ascertained, a benefit cost ratio (BCR) is then calculated as

(6.1) BCR = Dollar Value of All Benefits/Dollar Value of all Costs

The decision criterion is that a project is economically viable if the benefits exceed the costs. Therefore the decision rule is: if BCR > 1, project is viable; if BCR < 1, project is not viable. Of course, in the case of projects competing for limited investment resources, the project with the highest BCR provides the best return.

The benefits to twinning Highway 3 accrue in (at least) two areas: safety improvements and increases in economic activity. Although the safety benefits that accrue from highway improvement are definitely positive, and possibly large, we have shown in this study that estimates of these benefits are not needed to show that twining of Highway 3 is economically viable. Therefore, calculation of these benefits would simply serve to increase any calculated benefit cost ratio.

The major benefits that accrue from twining Highway 3 are the benefits that come from increased economic activity related to the increase in infrastructure expenditure. These benefits are by far the largest benefit and must be estimated via an econometric model. An econometric model is simply an equation, or set of equations, that is estimated through statistical techniques. The goal of constructing an econometric model is to describe economic activity in some region. For the purposes of this project, it was our goal to build an econometric model of economic activity in Southern Alberta.

In this study we built an econometric model based on the production function, where the inputs to the production process are assumed to be highway capital, all other capital and labour. We chose to estimate a log linear production function of the following form:

$$y = \beta_0 + \beta_1 k^h + \beta_2 k^o + \beta_3 l + \mu \qquad (6.2)$$

In this study we faced two problems in estimating equation (6.2). First there is no existing data on the relevant variables for the southern Alberta region, and, second, we faced the statistical problem that all of the variables in equation (1.6) do not conform to normal stationarity requirements. We overcame the data problem by creating a data set specific to the southern Alberta region. This data was derived from various existing sources. We dealt with the statistical problems associated with the data by applying the advanced statistical methodology of unit roots, cointegration, and error correction modeling. We believe that this is the first study in this area to apply these techniques.

Once the final form of the model was ascertained, it was used to forecast GDP under two scenarios. First, the model was used to forecast base line values of GDP in Southern Alberta, based on the assumption that highway capital, all other capital, and labour would all grow in the future according to a log linear time trend, estimated from the past behaviour of these variables. Second, the model was used to forecast GDP in southern Alberta based on the assumption that labour and all capital other than highway capital would grow in the future according to a linear time trend, and highway capital would increase by the amount of the construction cost. The accumulated difference in GDP over the forecast horizon is an estimate of the economic benefit to the southern Alberta region from twinning Highway 3.

Once the forecasting exercise was completed, the benefit cost ratio could be calculated. The benefits to the Southern Alberta region are the accumulated increases in GDP as a result of twinning Highway 3. As the benefits to twinning Highway 3 accrue in the future, they must be discounted to the present. In addition, the costs of construction were spread over 5 years, and these, along with the future maintenance cost also had to be discounted to the present. Therefore, the BCR will vary depending on the discount rate chosen. In Table 6-1 below, reports a summary of the benefit cost ratios for a representative sample from the models that were estimated. The benefits and costs are discounted assuming different discount rates, and a BCR is calculated for each different discount rate.

Table 6-1
Benefit Cost Ratio Calculations
Different Real Discount Rates

Real Discount Rate	Present Value of Future GDP ($millions)	Cost ($millions)	BCR
3.00%	$899,000	$238,500	3.76
4.00%	848,000	232,100	3.65
5.00%	801,000	226,100	3.54
6.00%	757,000	220,400	3.43
10.00%	607,000	200,300	3.03

The most important feature of Table 1-1 is that the BCR is greater than 1 for all reasonable discount rates. Notice that the BCR is also greater than 1 for a real discount rate of 10 percent, which, by economic theory standards, should be considered to be quite high.

Recall that the estimated benefits for the calculations on Table 1-1 do not include any benefits that accrue to safety improvements from twinning Highway 3. Including these benefits would only serve to increase any of the BCR shown on Table 1.

6.2 Conclusions

The conclusion from of this study is that twinning Highway 3 will bring about economic benefits to the region of Southern Alberta which exceed the costs of building the highway. Thus, according to the results in this study, twinning Highway 3 is an economically viable infrastructure project.

However, as with all studies, we should be aware of any possible caveats regarding the conclusion. First, although we have provided a sensitivity analysis in Chapter 5, which tests the sensitivity of the results to changes in some assumptions, there are other areas where the results could be tested. Primarily, the results depend upon the data gathering methods, and upon the choice of modeling technique. There is always more than one method of accomplishing either of these tasks. We believe that we have chosen the best methods, but knowledge proceeds by questioning existing results, and we would welcome questioning of our methodology. Due to the sheer volume of time that was spent gathering data and testing the specification, this testing could not be done within this study.

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