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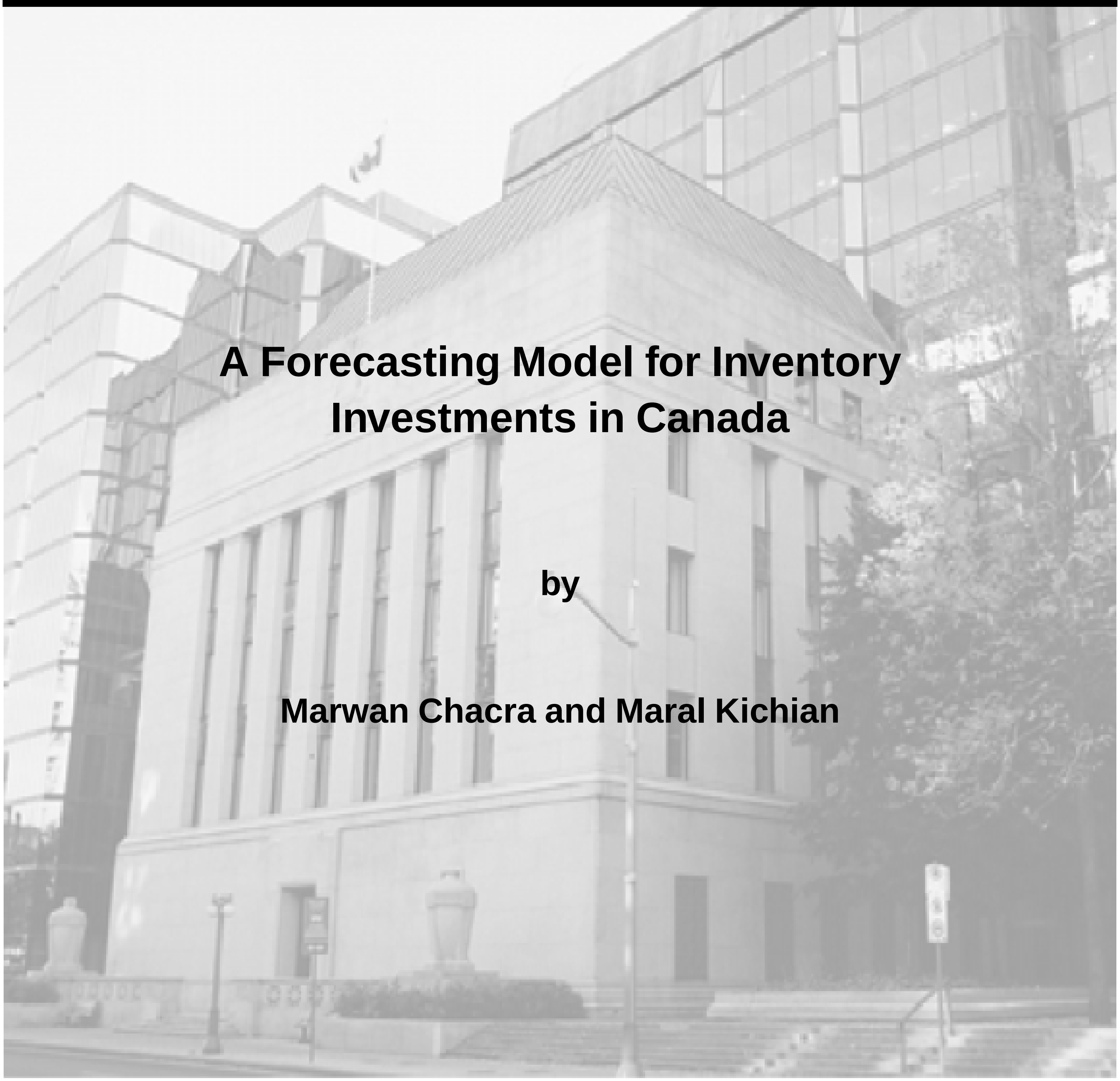

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Abstract

The authors present an empirical model to forecast short-run inventory investment behaviour for Canada. As with other recent studies that examine this series, they adopt an error-correction framework. Estimations using non-linear least squares and quarterly data yield both a good model fit and good out-of-sample forecasts. Given the debate in the United States on whether the adoption by firms of new information-technology-based methods of inventory management led to a decline in the volatility of U.S. output growth, the authors examine this issue for Canada. Results of the heteroscedasticity-robust Quandt likelihood ratio test advocated by Stock and Watson (2002) reveal very different dates for structural breaks in the volatilities of the growth contribution of inventory investment and of Canadian output growth: 1984Q1 and 1991Q2, respectively. Thus, the authors conclude that the "inventory hypothesis" is likely not an important explanation for the decline in the volatility of Canadian GDP growth.

JEL classification: E22, E62, C53
Bank classification: Domestic demand and components; Econometric and statistical methods

Résumé

Les auteurs présentent un modèle empirique qui permet de prévoir le comportement à court terme des investissements en stocks au Canada. À l'instar d'autres chercheurs s'étant penchés récemment sur cette série de données, ils adoptent un modèle à correction d'erreurs. L'emploi de la méthode des moindres carrés non linéaires et de données trimestrielles conduit à la fois à une bonne adéquation statistique du modèle et à de bonnes prévisions hors échantillon. Dans la foulée du débat en cours aux États-Unis sur la question de savoir si l'adoption par les entreprises de nouvelles méthodes de gestion des stocks basées sur les technologies de l'information a fait diminuer la volatilité de la croissance de la production américaine, les auteurs examinent le cas du Canada. D'après les résultats du test du rapport des vraisemblances de Quandt robuste en présence d'hétéroscédasticité, dont Stock et Watson (2002) préconisent l'utilisation, les ruptures structurelles dans la volatilité de la contribution des investissements en stocks à la croissance et dans la volatilité de la croissance de la production canadienne sont loin de coïncider : la première est survenue au premier trimestre de 1984 et la seconde au deuxième trimestre de 1991. Les auteurs en concluent que l'« hypothèse des stocks » ne constitue vraisemblablement pas une explication valable de la baisse de la volatilité de la croissance du PIB canadien.

Classification JEL : E22, E62, C53
Classification de la Banque : Demande intérieure et composantes; Méthodes économétriques et statistiques

1. Introduction

In an early model of inventory adjustment, Lovell (1961) assumes that firms balance the costs of having inventories deviate from their desired level against the costs of adjusting production. The optimal trade-off is based on current values and expected future paths of inventories, sales, and output. In addition, lagged inventory investment and lagged sales growth both affect current inventory investments.

One implication of this early model is that empirical models of inventory investment should incorporate both long-term and short-term dynamics. A flexible econometric framework that integrates such dynamics is the error-correction set-up. A number of authors, including McCarthy and Zakrajsek (2003), Ramey and West (1999), Claus (1997), and Bechter and Stanley (1992), examine the empirical behaviour of inventory investment in the United States and adopt such a framework. The main difference between these models is their specification of the desired "target" inventory-to-sales ratio, since it is an unobserved variable. Nevertheless, Ramey and West (1999) indicate that relative price changes and holding or stockout costs likely influence this ratio.

In this paper, we propose an error-correction (EC) equation to forecast short-run inventory investment dynamics for Canada. Our EC model is similar to that of McCarthy and Zakrajsek (2003) in some respects, but it differs in others, partly because of data considerations, and partly because of econometric concerns. More precisely, theirs is a system of EC equations that represent various stages of production and include time-varying unobserved target inventory-to-sales ratios. Operationally, these expected ratios are proxied by symmetric centred moving-average processes, thus creating a correlation between the disturbances of the system and the explanatory variables. The ensuing seemingly unrelated regression (SUR) system is then estimated using generalized method of moments (GMM).

In contrast, our model is a single-equation EC set-up, with a target inventory-to-sales ratio that is proxied by variables likely to influence this target; the target ratio is based on variables suggested by Ramey and West. Two factors motivate our modelling choice: (i) the limitations imposed on us by the availability of data,[1] and (ii) the desire to avoid estimation and testing based on GMM, because outcomes depend crucially on the validity of the chosen instruments.[2] Despite the parsimonious nature of our specification, however,

[1]McCarthy and Zakrajsek use monthly data for the U.S. manufacturing sector extending from January 1967 to December 2000, whereas we use quarterly data for the period 1981Q1 to 2003Q1.

[2]A large econometric literature documents the failure of GMM-based outcomes when some of the instruments used are uninformative (or so-called "weak"). For details, see Dufour (1997), Staiger and Stock (1997), and Stock, Wright, and Yogo (2002). McCarthy and Zakrajsek (2003) use lags 7 to 12 of

we will show that it has a good forecasting performance out-of-sample.

In addition to modelling inventory behaviour for Canada, we examine whether inventories can explain the drop in the volatility of Canadian output growth observed since the early 1990s. Several studies have examined this issue for the United States. Some have adopted an EC framework to examine whether there has been a change over time in the speed-of-adjustment parameter. The conjecture is that information technologies (IT) that evolved over the early 1980s have importantly changed the business environment, particularly inventory management, thus leading to a faster speed of adjustment of inventories to their desired levels. In turn, the adoption by firms of such new IT-based methods of inventory management may have led to the observed decline in the volatility of U.S. output growth. The latter hypothesis is supported by the finding, on the one hand, of almost coincidental structural break dates in the volatilities of output growth and of changes in inventory investment weighted by its share of total durable goods output, and, on the other hand, of no break in the change in the final sales component of durable goods output.[3]

This "inventory explanation" for the moderation in U.S. output is not unanimous. For example, McCarthy and Zakrajsek (2003) contend that it is the change in the way aggregate macroeconomic variables respond to shocks that seems to have resulted in a change in inventory investment behaviour—the latter characterized by a faster speed of adjustment of inventories to their target levels—rather than the reverse. Similarly, highlighting the fact that different structural break tests can yield different results, Ahmed, Levin, and Wilson (2002) report a break in the volatility of U.S. final sales in 1983Q3 using a Bai and Perron (1998) test, while Stock and Watson (2002) and Kim, Nelson, and Piger (2001)—the former using heteroscedasticity-consistent Quandt likelihood ratio (QLR) tests and the latter using Bayesian techniques—report breaks in the sales of U.S. durable goods in the early 1990s.

Although our main aim is to suggest a good forecasting model for Canadian business inventory investment, we also apply structural break tests to various components of GDP in order to compare the timing of any breaks, and to comment on the possible role of changes in inventory management methods in explaining the drop in the volatility of

their ratios as their instruments, and there is a high likelihood that the longer lags, in particular, may not be very informative.

[3]See McConnell and Perez-Quiros (2000). Further support for this finding is provided by Kahn, McConnell, and Perez-Quiros (2002). Using a general-equilibrium model, they show that, for a given demand shock, firms that adopt IT-based inventory control practices better anticipate and sooner change their productions to that effect, generating smaller inventory imbalances and a smoother output series.

Canadian output growth.[4] For the latter, and unlike Debs (2001), who uses Andrews (1993) and Andrews and Ploberger (1994) structural break tests to examine this issue (as in McConnell and Perez-Quiros 2000), we use the QLR tests for structural breaks with an unknown change point, as advocated by Stock and Watson (2002).

This paper is organized as follows. Section 2 discusses the data and the specification of our EC model. Section 3 describes the QLR structural break tests used in the paper, reports outcomes, and discusses the implications of our findings for the volatility of output growth. Section 4 concludes.

2. An Empirical Model for Inventory Investment

Error-correction-type equations lend themselves well to econometric models of inventory investment that are based on the flexible accelerator model suggested by Lovell (1961). Using such a model, Ramey and West (1999) derive a cointegrating relationship between inventories, sales, and observable cost variables for the United States. Indeed, many models have been suggested for inventory investment behaviour in that country, but less so for the case of Canada. An exception is Thurlow (1995); he adopts a theoretical approach to examine the relationship between inventory investment and capital market conditions.[5] In this section, we address the gap in the literature by proposing an empirical model for inventory investment for Canada. The ensuing estimation results are also reported herein.

2.1 Data and unit-root tests

Throughout our analysis, we use quarterly data for the period 1981Q1 to 2003Q1.[6] All variables are seasonally adjusted and measured in logarithms, with the exception of the inflation rate and the short-term real interest rate, which are in levels. Inventories represent the book value of total economy inventories held by the business sector, measured in chain-weighted 1997 dollars. The sales variable is defined as final sales of goods by the business sector, also measured in chain-weighted 1997 dollars. Technological innovation is proxied by the price of investment in computers, office equipment, and software,

[4] We resort to only time-series analysis, because our short sample size prevents us from conducting meaningful structural stability examinations of the EC model's parameters.

[5] Other studies, such as by Bilkes, Harris, and Jenkins (1978) and Lau (1996), provide overviews and surveys.

[6] The exception is the sample size used in the stability tests, which extends from 1962Q1 to 2002Q4.

deflated by the industrial product price index (IPPI).[7] Raw material costs, measured by the commodity price index, are in Canadian dollars and are also deflated by the IPPI. All Canadian data are provided by Statistics Canada, except the commodity price index and the real interest rates, whose source is the Bank of Canada.

The time-series properties of the variables are examined using the augmented Dickey-Fuller (ADF) and the Phillips-Perron tests. These tests are applied to both the level and first differences of each series to determine the order of integration. We test at the 5 per cent level the null hypothesis of a unit root against the alternative of stationarity. Table 1 shows the results of these tests. All the tested variables are found to be integrated of order one.

Table 1: Unit-Root Test Results

	Level[a]				First Difference[b]			
Series	ADF Lags[c]	P.P. Lags	t_{ADF}	$Z(t_\rho)$	ADF Lags	P.P. Lags	t_{ADF}	$Z(t_\rho)$
I_t	4	4	-1.3	-2.7	3	3	-4.3	-3.5
$Sales_t$	6	6	-2.6	-2.5	2	2	-3.6	-8.1
$Tech_t$	4	4	-1.5	-1.9	3	3	-5.8	-8.8
P_t^m	8	8	-1.1	-1.1	7	7	-4.0	-6.3
Inf_t	5	5	-3.5	-2.3	4	4	-3.2	-5.9
R_t	3	3	-2.5	-2.1	2	2	-4.3	-9.3

a. $t_{critical}$ = - 3.45 at the 5 per cent level for an ADF test including a time trend.
b. $t_{critical}$ = - 2.89 at the 5 per cent level for an ADF test excluding a time trend.
c. The number of lags in the ADF regression is chosen based on the last lag that is significantly different from zero.

2.2 The long-run equation

Lovell (1961) explains that the ratio of firms' inventory-to-sales in the long run is determined by their expectations of the future path of these same variables, as well as that of output. Ultimately, the decision of how much inventories to hold at each time period is assumed to be based on the relative cost of straying from this desired ratio to the cost of

[7]This variable is an implicit price, defined as the ratio of nominal to real investment in computers, office equipment, and software.

adjusting production. From an empirical modelling perspective, this means: (i) finding appropriate proxies to represent the expected future evolution of the pertinent variables, and (ii) estimating the relative weights on deviations of inventories-to-sales from this target and on adjusting production in the short term.

That businesses are mindful of a long-run target implies that inventories, sales, and the desired-ratio proxy variables all move together in the long run. In econometric terms, this means that they are cointegrated. Therefore, at the first stage, it is important to find relevant proxies and to establish the existence of a cointegration relation. Our search for relevant proxies starts with the suggestion of Ramey and West that holdout costs, stockout costs, and relative price changes (possibly stemming from expected future demand conditions and various input costs) are all likely to influence the desired inventory-to-sales ratio. We therefore consider the following candidate variables.

The first variable is technological innovation, measured by the relative price of computers, office equipment, and software. The sustained decline in the relative price of information technology reflects the technological progress embodied in new equipment and provides an incentive for firms to adopt new production and inventory management techniques. For example, innovations in the manufacturing sector such as just-in-time (JIT) and material resource planning (MRP) systems have enabled a more efficient management of inventories and have helped reduce inventories relative to sales in that sector.[8] Indeed, Little (1992) finds a statistically significant negative relationship between investment in information technologies and the inventory-to-sales ratio for the majority of the U.S. manufacturing industries. Lau (1996) reaches a similar conclusion for Canada, suggesting that advances in inventory-control techniques have allowed firms in the manufacturing and wholesale sectors to substantially trim their inventory requirements relative to sales. In our analysis, we expect a positive relationship between the cost of technology and inventories. A decline in equipment costs associated with technological progress allows for a more efficient management of inventories, and hence leads to a lower level of inventories in the long run.

The second variable is input costs, measured by the real commodity price index. A rise in material costs increases the marginal cost of production and may lead firms to hold less inventories in the long run.

The third variable is expected demand measured by final sales of goods. Firms anticipating an increase in future demand would likely hold more inventories, to maintain a stable inventory-to-sales ratio. Inventories and sales would be expected to be positively

[8] Using JIT and MRP systems, firms are better able to manage their inventory levels by allowing for more frequent deliveries of raw materials and by more closely matching production with sales.

correlated in the long run, with a coefficient close to one.

Given this choice of variables, we expect to find the following long-run cointegration relationship:

$$I_t = c + \alpha_1 Sales_t + \alpha_2 Tech_t + \alpha_3 P_t^m + \epsilon_t, \tag{1}$$

where I_t is the level of aggregate inventories, $Sales_t$ is business sales of goods, $Tech_t$ is the relative price of computers and software, P_t^m is the real price of commodities, and ϵ_t is a residual term. We test for cointegration among these variables using the Johansen and Juselius methodology. Both the λ_{max} and the λ_{trace} statistics show evidence consistent with the presence of a single cointegration vector (Table 2).[9]

Table 2: Cointegration Test Results[a]

Max-eigenvalue statistic			
	r^b	λ-max	Critical value (5%)
	0^c	37.29	28.14
	1^d	20.72	22.00
	2	6.82	15.67
	3	4.82	9.24
Trace statistic			
	r^b	λ-trace	Critical value (5%)
	0^c	69.64	53.12
	1^d	32.35	34.91
	2	11.63	19.96
	3	4.82	9.24

a. Tests are conducted on regressions with four lags of the dependent variable and with a constant restricted to the cointegrating relationship.

b. r denotes the number of cointegrating vectors under the null hypothesis.

c. Rejection of the null hypothesis of no cointegration at both the 5% and 1% levels.

d. No rejection of the null hypothesis of one (or at most one) cointegrating vector. The maximum-likelihood parameter estimates of the cointegration vector are 1.1 for $Sales_t$, 0.4 for $Tech_t$, and -0.3 for P_t^m.

Furthermore, a likelihood ratio test does not reject the hypothesis that the adjustment coefficients on the $Sales_t$, $Tech_t$, and P_t^m are jointly zero, which indicates that these three

[9] The Stock and Watson methodology with four leads and lags of the various variables added to equation (1) yields similar coefficient estimates and signs. More importantly, the fitted residual from the generalized least-squares regression is found to be stationary.

variables are weakly exogenous to the long-run parameters of the model.[10]

2.3 The error-correction model

Judging from the cointegration test results, the variables that proxy the desired inventory-to-sales ratio appear satisfactory. We therefore proceed to estimate a dynamic EC model (ECM) for aggregate inventory investment—a model that incorporates both the long-run and the short-run behaviour of inventory investment. Using non-linear least squares, we estimate the following general form of the model:

$$\Delta I_t = \lambda(I_{t-1} - c - \alpha_1 Sales_{t-1} - \alpha_2 Tech_{t-1} - \alpha_3 P^m_{t-1}) + \sum_{i=1}^{4} \delta_i X_{t-i} + v_t, \qquad (2)$$

where X_t is a vector of variables representing the short-run dynamics of inventory investment and v_t are regression residuals.

If inventories are above their equilibrium level, firms are expected to correct this imbalance by adjusting inventories back towards their target. The coefficient on the long-run imbalance, λ, is therefore expected to be negative.

Apart from the gap between the actual and desired level of inventories, represented by the error term in the ECM, many factors are likely to influence inventory investment in the short run. A relevant variable is the lagged growth in the final sales of goods, representing recent demand conditions. A rise in lagged sales is expected to be positively correlated with current inventory investment, as firms respond with a lag to previous demand conditions by increasing production and restocking inventories.[11]

Demand uncertainty, measured by the volatility of sales (Vol_Sales), is also likely to play a role in explaining inventory investment behaviour.[12] High demand uncertainty may lead firms to accumulate inventories in order to avoid possible stockouts if demand proves to be higher than expected.

Another variable included in the short-term dynamics is the change in the short-term real interest rate (ΔR), a proxy for short-run financing costs. This variable is expected to be negatively correlated with inventory investment, since a rise in interest rates raises the opportunity cost of investing in inventories.

[10] The p-value for the cointegration test is 0.14. See Johansen (1994) for details.

[11] Contemporaneously, inventory investment and growth in final sales are negatively correlated, because firms liquidate inventories in response to unexpected increases in sales.

[12] The volatility measure is constructed by calculating the standard deviation of lags 1 to 4 of the sales growth variable.

Inventory behaviour could also be related to the lagged change in inflation (ΔInf) and the lagged change in raw material costs, as a rise in either of these variables could possibly lead to higher inventory accumulation in the short run, for speculative and precautionary reasons. Four lags of all the variables that represent the short-term dynamics are included in the model, with the exception of the volatility measure, which was represented by a single lag.[13]

The version of the model that we retain is the following:

$$\begin{aligned}\Delta I_t \;=\; & \lambda(I_{t-1} - c - \alpha_1 Sales_{t-1} - \alpha_2 Tech_{t-1} - \alpha_3 P^m_{t-1}) + \delta_1 \Delta I_{t-1} \\ & + \delta_2 \Delta I_{t-2} + \delta_3 \Delta I_{t-3} + \delta_4 \Delta I_{t-4} + \mu_1 \Delta Sales_{t-1} \\ & + \mu_2 \Delta Sales_{t-2} + \mu_3 \Delta Sales_{t-3} + \xi_1 Vol\_Sales_{t-1} \\ & + \gamma_1 \Delta R_{t-1} + \beta_1 \Delta Inf_{t-1} + \omega_1 \Delta P^m_{t-1} + v_t. \end{aligned} \tag{3}$$

Table 3 shows estimation results for the period 1981Q1 to 2003Q1. The λ coefficient on the EC term is negative and significant, indicating partial adjustment of inventories to their target level. Notable as well is the value of the parameter, α_1, which is close to one, indicating that sales and inventories move together and by roughly equal magnitudes in the long run. The coefficients α_2 and α_3 also have the expected signs. Regarding the volatility-of-sales measure, our evidence shows that this variable has a significant positive impact on inventory investment in the short run, indicating that firms facing considerable demand uncertainty build up inventories to avoid stockout.[14] The parameter estimates of the lagged dependent variable are consistent with the lagged adjustment of inventories to demand shocks. The positive and significant coefficients on the lagged change in inflation and the lagged change in material costs are suggestive of speculative and precautionary inventory accumulation. Lagged sales growth and lagged changes in interest rates are insignificant, but nevertheless should be included according to the R-bar squared criterion.

To guard against any misspecification error, we test the residuals from the estimated model for the presence of serial correlation and heteroscedasticity. The LM test for serial correlation and the autoregressive conditional heteroscedasticity (ARCH)-type tests reveal that the residuals are well-behaved (Table 4).

[13] Lagged changes in the price of computer equipment and software were also included, to account for any short-run effects of technological innovation on inventory investment. These lags were insignificant and are not included in the equation.

[14] Another volatility measure, calculated using a 2-year moving standard deviation of growth in sales, was insignificant in estimations.

Table 3: Inventory Investment Model Estimates

Parameter	Estimate	Standard error	t-stat.
λ	-0.13	0.02	-5.2
c	-2.57	1.07	-2.4
α_1	1.18	0.09	12.9
α_2	0.19	0.03	6.9
α_3	-0.14	0.05	-2.6
δ_1	0.68	0.10	7.0
δ_2	-0.21	0.17	-1.3
δ_3	0.37	0.15	2.5
δ_4	-0.30	0.10	-3.0
μ_1	0.07	0.08	0.9
μ_2	-0.05	0.05	-1.1
μ_3	0.06	0.06	1.0
ξ	0.31	0.11	2.7
γ_1	0.04	0.09	0.4
β_1	0.003	0.00	3.1
ω_1	0.04	0.02	2.3
$\bar{R}^2$		80.0%	

Table 4: Tests for Serial Correlation and Heteroscedasticity

Test	ρ-value
LM(1)	0.55
LM(2)	0.43
LM(3)	0.30
LM(4)	0.39
ARCH(1)	0.98
ARCH(2)	0.98
ARCH(3)	0.91
ARCH(4)	0.95

2.4 Forecast performance

As stated earlier, our objective is to forecast short-run inventory investment for Canada. To evaluate the performance of the ECM, we first plot one-quarter-ahead out-of-sample forecasts over the period 1998Q1–2003Q1 (Figure 1). The model does reasonably well in tracking actual movements in inventory investment, both in terms of magnitude and direction. In addition, we compute one-step-ahead forecasts over the periods 2000Q1–2003Q1 and 2002Q1–2003Q1. To better assess the predictive power of the ECM over these periods, we compare the forecasts from that model with those from autoregressive (AR) models of different lags. Table 5 shows that the ratio of the root-mean-squared error (RMSE) of the ECM forecasts to that of the AR model forecasts is less than one over all subperiods, indicating that the ECM forecasts outperform those of the AR model, according to the RMSE criterion.

Table 5: Forecast Performance, ECM versus AR Models

Competing model	2002Q1–2003Q1	2000Q1–2003Q1	1998Q1–2003Q1
	One-step-ahead forecast RMSE (ECM) / RMSE (AR model)		
AR(1)	0.470	0.779	0.864
AR(2)	0.479	0.795	0.870
AR(3)	0.469	0.781	0.864
AR(4)	0.454	0.811	0.861

Static forecasts are a good tool with which to evaluate the very short-term performance of the model. In addition, researchers are sometimes also interested in forecasting one year out or longer. For this reason, we compute a number of dynamic forecasts, over five years, three years, and one year.[15] The corresponding graphs are plotted in Figures 2, 3, and 4.

A couple of interesting facts can be gleaned from these figures and numbers. First, notice that whether forecasts are made starting in 1998, 2000, or 2002, the model does a very good job of forecasting dynamically over the initial one-year interval. This indicates not only the good forecast performance of the model over such an interval, but also that the parameters of the model are fairly stable over time. Second, it is reassuring to see,

[15]More specifically, we estimate the model over each of the samples 1981Q1–1997Q4, 1981Q1–1999Q4, and 1981Q1–2001Q4, and calculate the dynamic forecasts starting in 1998Q1, 2000Q1, and 2002Q1, respectively.

from the five-year-ahead forecasts, that the model is able to capture the general trends in the data over business cycle durations. Where the model is less accurate, however, is beyond the initial forecast year.

3. Implications for Output Volatility

Many authors, including Morgan (1991), Bechter and Stanely (1992), Little (1992), Filardo (1995), and Allen (1995), agree that advances in information technology over the past two decades have led firms to economize on their inventory holdings, thus contributing to the observed decline in the U.S. inventory-to-sales ratio over that period. Conclusions regarding the effect of these innovations on cyclical fluctuations, however, are mixed. As stated earlier, work by McConnell and Perez-Quiros (2000) and Kahn, McConnell, and Perez-Quiros (2002) concludes that improved inventory management by U.S. manufacturers has resulted in a more stable inventory cycle since the mid-1980s, and is the primary cause of the decline in U.S. output volatility since that time. McCarthy and Zakrajsek (2003) examine this issue using disaggregated data for the U.S. manufacturing sector. They find some evidence that is consistent with technological progress, particularly a faster speed of adjustment of inventories to their equilibrium level, but they conclude that this change has reinforced other factors in stabilizing production since the mid-1980s.

In this section, we examine this issue for Canada. We proceed by applying structural break tests, recently used by Stock and Watson (2002), to Canadian output growth and to selected components of GDP. The testing methodology used by Stock and Watson (2002) is general, in that it allows each of the conditional means and the conditional variances of a series to break at unknown points, and at potentially different dates. The test used is the heteroscedasticity-robust QLR test. In the first stage, the AR parameters of the mean process are tested for a structural break at an unknown time. If a break is found, it is then imposed and residuals are obtained. In stage two, the mean of the absolute value of these residuals is tested for a break at an unknown point.

Stock and Watson (2002) also show how to calculate confidence intervals for the conditional variance break date, using the second-stage estimator. They modify Bai's (1997) limiting distribution for this estimator, scaling it by the appropriate estimated variance on each side of a structural break. Inverting the test of the break date, and using this new distribution, they can thus obtain confidence intervals for the break date. Stock and Watson explain that these confidence intervals are asymmetric, because they express a higher uncertainty about the break date in the higher volatility period than in the lower volatility period.

We follow the above testing strategy, applying the QLR test to the quarter-over-quarter growth rate in Canadian GDP over the sample extending from 1962Q1 to 2002Q4. The test yields a structural break in the conditional mean of the series in 1972Q4, and a structural break in its conditional variance in 1991Q2. The break date in volatility corresponds to that found by Debs (2001), who uses Andrews (1993) and Andrews and Ploberger (1994) tests with an unknown change point. Following Stock and Watson (2002), we also report 67 per cent confidence intervals for these break dates.[16] The estimated break dates are highly significant, and, in the case of the structural break in volatility, the associated confidence intervals indicate a range varying from 1990Q4 to 1993Q1.

We disaggregate the output growth series into growth contributions of sales and growth contributions of inventory investment, and test these components for structural breaks. In addition, we test the volatility of growth contributions of manufacturing inventories.

Table 6: QLR Break Test Results, Quarter-over-Quarter Growth Rates

	Conditional mean			Conditional variance		
Series	p-value	Break date	67% C.I.	p-value	Break date	67% C.I.
GDP	0.02	1972Q4	1972Q2–1973Q2	0.00	1991Q2	1990Q4–1993Q1
Final sales	0.03	1973Q4	1973Q2–1974Q2	0.03	1991Q2	1990Q2–1994Q3
Inv. invest.	0.00	1981Q4	1981Q2–1982Q2	0.01	1984Q1	1983Q3–1987Q3
Manuf. ii.	0.54			0.00	1985Q4	1985Q2–1986Q4

Note: The sample size is 1962Q1–2002Q4 for all the variables, except Manuf. ii., which extends from 1982Q2–2002Q4. The variables Final sales, Inv. invest, and Manuf. ii. measure the contributions to aggregate GDP growth. The GDP series represents quarterly GDP growth.

Table 6 shows that the volatility of growth contributions of final sales manifests a structural break at precisely the same time as the break in output growth volatility. Conversely, the volatility of growth contributions of total inventories and the volatility of growth contributions of manufacturing inventories break much earlier: the former in 1984Q1 and the latter in 1985Q4. In addition, for both cases, the confidence intervals do not include 1991Q2. Thus, results from the structural break tests suggest that the decline in GDP growth volatility in 1991Q2 coincides with a decline in the volatility of sales, but not with the volatility of inventory investments (Figures 5, 6, and 7).

[16] Stock and Watson (2002) point out that, since the break estimator has a heavy-tailed non-normal distribution, 95 per cent intervals calculated using Bai's method are uninformative.

The structural break tests, as used here, are more likely to identify abrupt changes in a moment of a series. Of course, the case can be made that information technologies were slow to get integrated into the business environment on a widespread basis, the process having started in the 1970s and continued well into the 1980s. Such slow changes in inventory investment dynamics could arguably still have contributed to the decline in the volatility of output. Unfortunately, given our very short sample sizes, it would be uninformative to estimate a cointegration relationship on subsamples, and to conduct tests on the equality of parameters in them. We leave this issue open for future research.

4. Conclusion

Error-correction models have been used quite frequently to model the behaviour of inventory investment in the United States, but, to our knowledge, never in Canada. We have thus proposed and estimated such a model to examine that behaviour and to forecast inventory investment in the short-run in Canada.

We found that the non-linear least squares estimates were generally significant and had the expected signs. In particular, the coefficient on imbalances of the inventory-to-sales ratio from its desired target was significant and negative. Similarly, the model fit was quite high, with an R-bar squared value of 80 per cent, and the residuals did not show evidence for autocorrelation and heteroscedasticity over a 4-quarter period. In addition, the model yielded fairly good out-of-sample forecasts, particularly for periods of up to 4 quarters ahead (both statically and dynamically).

We completed our analysis by applying a number of structural break tests with unknown change points to examine the timing of any breaks in the contributions to growth of inventory investment and sales, as well as in output growth. The hypothesis tested is that the inventory investment series may have changed over time because of the adoption of technology-intensive management methods, and that this may have contributed to a decline in the volatility of output growth.

We applied a heteroscedasticity-consistent QLR test to the Canadian output growth series and found a break in its volatility in 1991Q2. Applications of the same test to the volatilities of two components of output—the growth contribution of final sales and the growth contribution of inventories—reveal a structural break in the volatility of sales series at precisely the same date as the break in the output volatility, whereas a break in the inventory series occurs well before 1991Q2. These results suggest that changes in inventory investment dynamics probably did not play a major role in the decline of Canadian GDP volatility.

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Figure 1: Inventory Investment: Actual vs Forecasts*

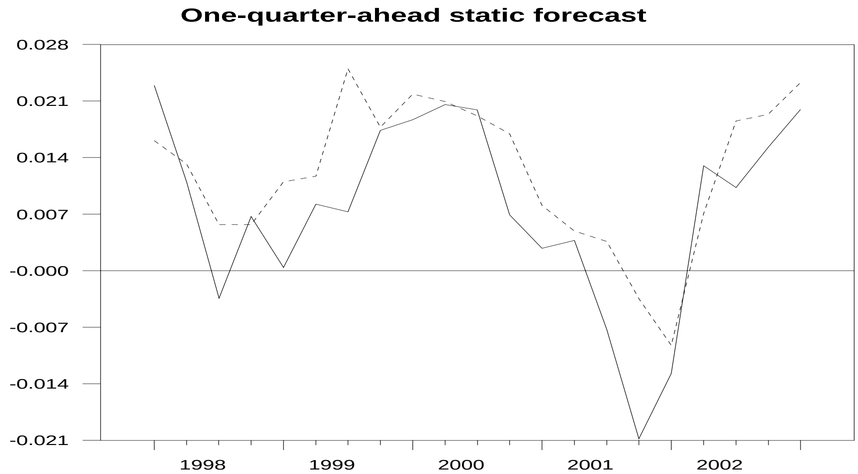
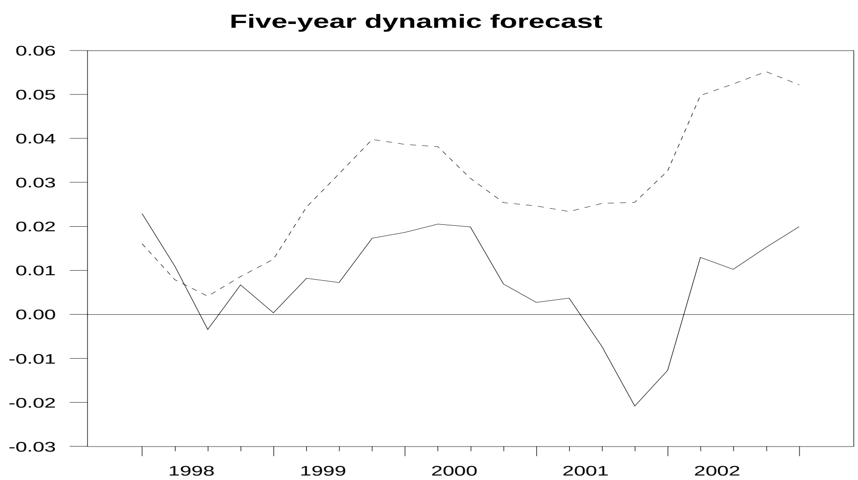


Figure 2: Inventory Investment: Actual vs Forecasts



*In Figures 1 to 4, the solid line equals actual values and the dashed line indicates forecast values.

Figure 3: Inventory Investment: Actual vs Forecasts

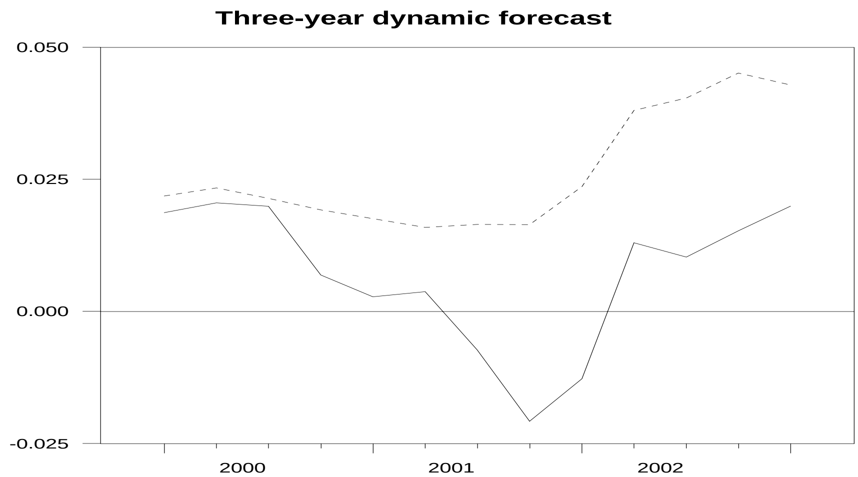


Figure 4: Inventory Investment: Actual vs Forecasts

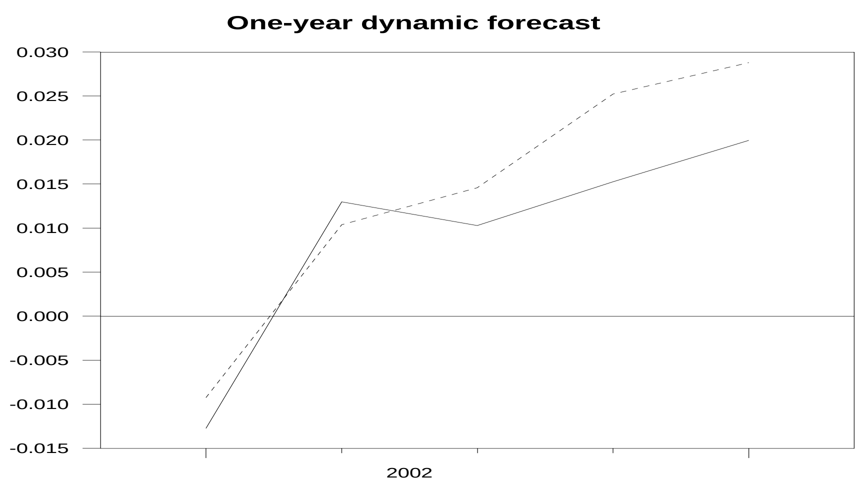


Figure 5: Output Growth: Quarterly at Annual Rates

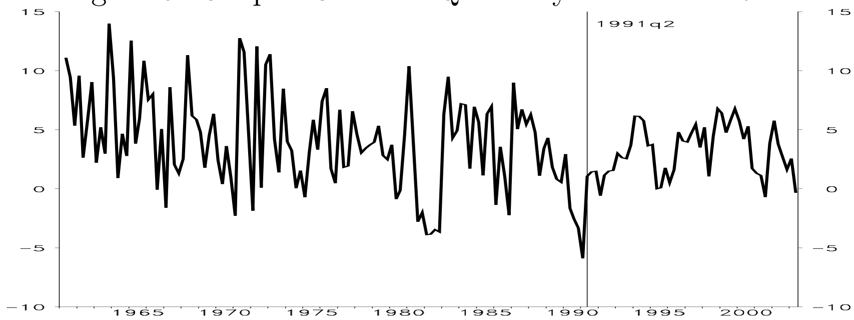


Figure 6: Contributions to Growth: Final Sales

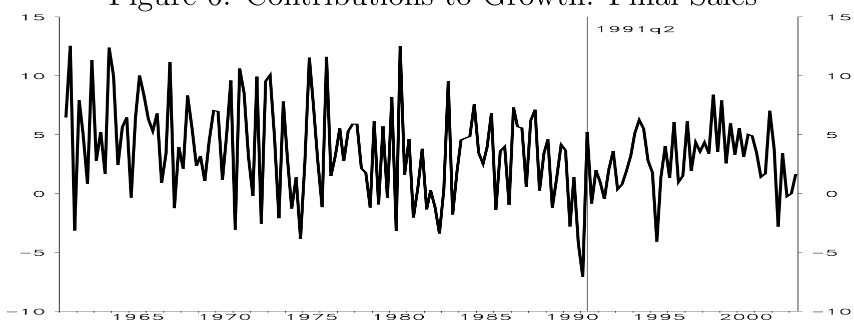
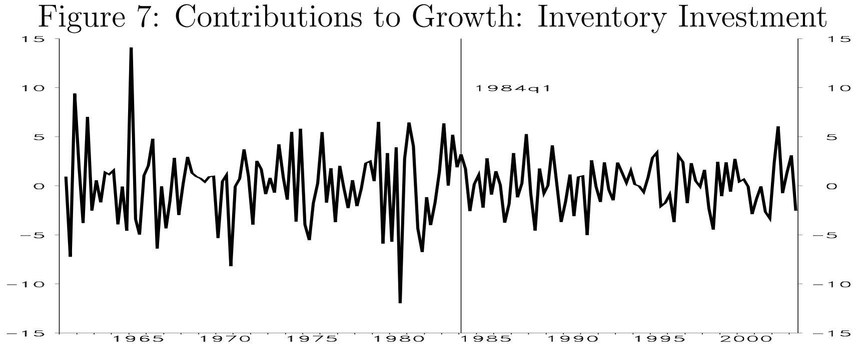


Figure 7: Contributions to Growth: Inventory Investment



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