Short-run Dynamics of the Canadian Wood Pulp Industry: A Vector Autoregression Analysis

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Abstract

The short-run dynamic impacts of macroeconomic variables on the Canadian pulp industry and the interactions among pulp sector variables are investigated using the vector autoregression (VAR) approach. In contrast to the findings of earlier studies, our results show that an increase in the value of the Canadian dollar will result in an increase in pulp production. We also find that Canadian pulp exporters decrease their prices in response to a rise in the value of the Canadian dollar, suggesting that maintaining market share is important to Canadian pulp producers. Impulse response functions suggest that pulp price is more volatile than production in response to shocks in macroeconomic and pulp sector variables. This result is thought to be due to the inventory levels being maintained to follow a "production smoothing" strategy. We also find that pulp exports and domestic use of pulp are not very responsive to an increase in Canadian pulp price. This suggests that paper manufacturers' demand for pulp may be inelastic because of their capacity constraints.

Introduction

Canada is the world's second largest producer of pulp, after the United States, and is the world's largest pulp exporter. In 1991, the Canadian pulp industry produced a total of 23.3 million tones of pulp and exported 8.6 million tones valued at $4.8 billion (Canadian Pulp and Paper Association 1992)[1]. Despite the importance of the pulp sector to the nation's economy, very few studies have been conducted to evaluate the dynamic interactions between macroeconomic and pulp sector variables. Schembri and Robicheau (1986) analyzed the effect of the Canada-U.S. exchange rate on profits and output in the Canadian pulp and paper industry. Roberts (1988) studied the short-term exchange rate effects on the Canadian forest product producers' profitability and competitiveness. Gilles and Buongiorno (1988) investigated the effects of a U.S. tariff and increasing Canadian manufacturing costs on long-term pulp imports from Canada.

The above review reveals that studies to date have concentrated on how a specific macroeconomic variable, or government policy, affects the Canadian pulp industry. However, by concentrating on specific macro policy issues, these studies have neglected several types of dynamic interactions. First, interrelationships between macroeconomic variables such as interest rates, gross national product (GNP), and the world pulp price and pulp sector variables have not been investigated. Second, previous studies have not taken account of indirect effects that each macroeconomic variable may have on the pulp industry by influencing other macroeconomic variables. For example, an increase in the value of the Canadian dollar would be expected to cause a decrease in exports as Canadian pulp becomes relatively expensive to importers. If the money

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[1]Canada accounts for 15% of the world's pulp production and 27% of the world's market pulp.

supply is fixed and capital is mobile, an appreciation of the dollar will have a depressing effect on domestic interest rates (Mundell 1963). Lower interest rates are thought to stimulate the economy and thereby cause an increase in the domestic use of pulp. This chain of events may, therefore, offset the depressing effect of exchange rates on pulp exports. Accordingly, analyses that do not account for indirect effects of macroeconomic variables may result in biased estimates. A third shortcoming of studies to date is that they have not investigated the interactions among various components of the wood pulp industry. In short, the models used in earlier studies were not designed to capture the dynamic interactions within and between macroeconomic and pulp sector variables.

In this paper, we investigate short-term dynamic interactions within the framework of vector autoregression (VAR)[2]. Although criticism over the alleged atheoretical nature of VAR continues, VAR models are frequently used for policy analysis (Hafer and Sheehan 1991)[3]. They are convenient tools to investigate the structure of economic relations between macroeconomic impacts and any sector by placing minimal restrictions on the parameters of the equation system (Orden and Fackler 1989).

This paper is organized as follows. A graphical model describing possible relationships among macroeconomic and pulp sector variables is presented in the next section. A brief review

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[2]Jennings et al. (1990) were the first to apply a VAR approach to the forestry sector. They used this technique to investigate the causal relationships between the Canadian lumber industry and the macroeconomy.

[3]Cooley and Leroy (1985) argued that VAR models cannot be used for policy analysis since the equations are not structural. In the more recent past, other studies have addressed various charges levelled against the use of VAR models to investigate the dynamics of industries. See Bessler and Kling (1986); Bernanke (1986); Sims (1986); Fackler (1988); Sims et al. (1990); and Adamowicz et al. (1991); for extensions on VAR models.

of the VAR approach is presented in the third section. The fourth section deals with model specification and data. Results of the VAR analysis are discussed in the fifth section, and summarized in the final section.

A theoretical framework

Figure 1 presents a model which may be used to study macroeconomic effects on the pulp industry and interactions among pulp sector variables. Canada is shown as the exporting nation while the rest of the world is the importing region. The supply curve, S, for pulp is shown to be vertical beyond a certain point because the industry has a capacity constraint in the short-run. The shaded area represents pulp inventories which augment the supply curve. It is shown that beyond a certain price level, P_{max}, and at P=0 the inventories are completely drawn down. This implies that firms maximize their profits by drawing down all the inventory stock if the price level is at P_{max}, and minimize their costs by disposing all inventories if the price level is at P=0.[4] The domestic demand, D, is shown to be relatively large. Although Canada is said to be the largest market pulp producer in the world and relies heavily on international market (Jegr 1985), approximately two thirds of total production is used by domestic paper or paper board

[4]Pulp inventory is an important component in the Canadian pulp industry, equalling, approximately half the quantity of total production. Maintaining inventories helps the industry follow a "production smoothing" strategy and reduces the costs of production which would be associated with fluctuations. Expectations about future market conditions influence pulp production decisions and planned inventory behaviour (See Hirsch and Lovell (1969) for more discussion on inventory behaviour). Changes in planned inventory levels which are caused by shocks in the economy will be corrected by either increasing or decreasing pulp production. The speed of correction, however, depends upon the additional costs and capacity limitations of the pulp industry. If the industry operates closer to its capacity levels, it will have less scope to close the inventory gap at a faster rate suggesting that the industry may likely follow a partial adjustment pattern in correcting the inventory gaps.

manufacturers (Canadian Pulp and Paper Association 1992).[5] In the rest of the world market, the absence of an infinitely elastic excess demand, ED, implies that importers also face capacity constraints in their use of imported pulp. The excess supply, ES, is shown to be relatively small, because of large domestic demand.

Initially the equilibrium between Canada and the rest of the world occurs at price P, where Q_{tot} quantity of pulp is supplied out of which Q_{prod} is production and Q_{tot}- Q_{prod} is inventory stock. Effects of changes in macroeconomic variables may be modelled using the figure. For example, by causing the value of the Canadian dollar to increase, we would expect a fall in the demand for Canadian pulp in the international market. This causes the excess demand curve to shift from ED to ED´ and exports to fall from E to E´. This results in a decrease in the domestic price of pulp from P to P´. Pulp inventories are shown to accumulate more accompanied by a reduction in pulp production and an increase in domestic use of pulp. The model can also be used to describe the relationships among pulp sector variables. For example, an increase in the domestic use of pulp will cause the domestic demand, D, to shift upwards and to the right. Consequently, production increases, pulp inventory levels decrease[6], excess supply decreases and pulp price increases. Alternatively, a fall in the demand for paper, and decrease use of domestic pulp, may result in a surge of pulp into the international market. This increase in market pulp may cause a decrease in the price of the pulp. The magnitudes of these changes, however, may be quite sensitive to the

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[5]Reasons for vertical integration within the pulp industry are discussed by Schwindt R.W. (1985) and Woodbridge et al. (1988).

[6]Pulp inventories may either decrease or increase depending upon the initial position of the domestic demand curve.

supply and demand elasticities both in domestic and international markets.[7]

The VAR approach: theory and estimation

The VAR approach is essentially a dynamic simultaneous equation system. The dependent variables are endogenous to the equation system, and all independent variables are lagged observations of dependent variables in the system. The system of lags allows for all variables to affect one another. Unlike traditional structural models, a VAR model uses a set of lags of all dependent variables in each equation as the reduced form. Therefore, meaningful interpretation can not be made on the parameters of each individual equation in a VAR model. Instead, use of the VAR approach necessitates interpreting the system of equations as a whole. Shocks to the individual variables within the system of equations may then be introduced in order to assess the industry's dynamic response (Orden and Fackler 1989).

Following Jennings et al. (1990), the VAR approach starts with a set of dynamic regression equations of the form:

$$\sum_{k=0}^{\infty} X_{t-k}\beta(k) = \sum_{k=0}^{\infty} v_{t-k} \qquad (1)$$

where X_t is 1 x n vector of endogenous variables; $\beta(k)$ is a n x n matrix of coefficients for each time period (k) previous to current time (t); and v_{t-k} is a 1x n vector of error terms. It is assumed that v_{t-k} equals zero for all k greater than zero. The vector v_t is assumed to have a mean of zero

[7] In figure 1, both domestic and export demand elasticities are shown to be relatively inelastic thereby causing substantial price fluctuations. However, if demands are elastic, price fluctuations are minimal, while fluctuations in the quantity are large. The results reported later suggest that demands are inelastic in both markets. Further, it should be noted that the model in figure 1 is static. Therefore, the dynamic paths of adjustment of variables are not shown, but will be explored with the VAR model.

and a diagonal covariance matrix, Ω. As a consequence, the individual shocks in v_t apply to only one behavioral equation at a time, and the effects of a shock to each behavioral equation on each variable in the system can be determined. The shocks in v_t are assumed to "represent behaviorally distinct sources of variation that drive the economy over time" (Orden and Fackler, 1989). Equation (1) can be written in autoregressive form as:

$$\beta(0)X_t = -\sum_{k=1}^{\infty} \beta(k)X_{t-k} + v_t \tag{2}$$

where matrix $\beta(0)$ is a set of contemporaneous parameters on X_t. Multiplying equation (2) by $\beta(0)^{-1}$ yields:

$$X_t = \sum_{k=1}^{\infty} D(k)X_{t-k} + u_t \tag{3}$$

where $D(k) = -\beta(0)^{-1}\beta(k)$ and $u_t = \beta(0)^{-1}v_t$. The vector u_t is the "one step ahead" prediction error in X_t and the covariance matrix of u_t is Σ. Equation (3) is the autoregressive equation that can be estimated given a specification of the length of lags. As the right hand side regressors are the same for all equations, the ordinary least squares (OLS) method will produce efficient estimates.

By inverting the autoregressive system in equation (3), the following moving-average representation can be obtained:

$$X_t = \sum_{k=1}^{\infty} G(k)u_t \tag{4}$$

where G(k) is a matrix of moving-average coefficients derived from equation (3). Equation (4) expresses the level of a particular variable as a function of the error process. The innovation process, u_t, shows both current and future impacts of a single shock on all variables, assuming that no future shocks occur and all variables evolve naturally. Given the estimate of the covariance of u_t, the parameters of $\beta(0)^{-1}$ can be derived using the Choleski decomposition approach.[8] The parameters of $\beta(0)^{-1}$ give the impacts of v_t on X_t. Given the identification for $\beta(0)^{-1}$, equation (4) can be written as

$$X_t = \sum_{k=1}^{\infty} G(k)\,\beta(0)^{-1} v_t \qquad \textbf{(5)}$$

Equation (5) is the impulse response function (IRF), which provides the response of all variables in the system to a unit shock in one element of the vector v_t. Equation (5) can also be used to decompose the forecast error variance (FEV) of the variables in the system into portions attributable to each element in X_t. The decomposition of FEV indicates the relative strength of interactions between variables (See Judge et al. 1988 for details).

Model specification and data

The variables used and their sources are presented in Table 1. Macroeconomic variables which were thought to have a major influence on the Canadian pulp sector were chosen for the study. First, several authors have identified the exchange rate as having an important influence on Canadian wood product industries (Roberts 1988; Buongiorno et al. 1988; Jennings et al. 1990; Sarker 1993a). Canadian pulp exports to the U.S., Western Europe and Japan account for more than 90% of total exports. Therefore, we expected that any change in the exchange rate with respect to those nations could have a significant impact on the pulp sector and, have chosen to

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[8]Note that $u_t = \beta(0)^{-1} v_t$. The Choleski decomposition approach assumes that the v_t have unit variance and are orthogonal. Therefore, the matrix $\beta(0)^{-1}$ is derived by solving the equation $\beta(0)^{-1}\beta(0)^{-1\prime}$. The Choleski decomposition removes any portion of a shock to each variable that is explained by contemporaneous shocks to variables previously estimated. This implies that a recursive causality must be imposed on variables included in the model.

use the g10-exchange rate in the analysis. Second, the U.S. is the largest wood pulp producer in the world and is also the biggest competitor for Canada in the international pulp market. In addition to accounting for more than 50% of total Canadian pulp exports, the U.S. is the largest importer of Canadian wood pulp. These considerations led us to believe that U.S. pulp price may have significant effects on the Canadian pulp industry. We also reasoned that this price could serve as a proxy for world price. Third, Jennings et al. (1990) argued that the lumber industry is adversely affected by policies that encourage high interest rates. We believe that the wood pulp industry will also be affected by higher interest rates. In particular, higher interest rates are thought to cause lower investment in pulp and paper industries. This may result in a decrease in production of pulp and domestic use of pulp and thus a decrease in pulp price. Finally, it is reported in the literature that factors which influence economic growth also affect the consumption of paper (Jegr 1985). This suggests that an economic boom/recession will cause a rise/fall in the demand for, and price of, pulp. Therefore, the Canadian GNP was chosen as the fourth macroeconomic variable.

Variables within the pulp sector were chosen to provide an indication of how the industry would respond to macroeconomic shocks. Chosen variables include pulp exports, pulp production, Canadian pulp price, domestic use of pulp, and pulp inventories. Besides the variables listed in Table 1, two weather dummies for the months of April and September[9], a constant, and a time trend were also included to capture unknown deterministic trends.

One of the specification issues to be addressed, in recursive VAR models, is determining

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[9]Most pulp mills undertake boiler maintenance during these months which decreases production (personal communication with the Canadian Pulp and Paper Association).

the order of the variables which affects contemporaneous correlations among residuals (Sarker 1993b). The variables in our model are ordered, as shown in Table 1, based on economic reasoning. In general those variables which are more dependent on other variables should receive a lower place in the list. The macroeconomic variables (g10-exchange rate, U.S. pulp price, interest rates and GNP) are placed at the top of the list because we expect these variables to have a greater influence on the pulp industry than the pulp industry has on the overall economy.[10]

Within the macroeconomic block of variables, the g10-exchange rate and U.S. pulp price were thought to be most exogenous, causing impacts to flow from these variables to the domestic interest rates and the GNP. Within the pulp sector variables, exports are listed at the top of the ordering based on the belief that in the short-term, exports are fixed because of contractual agreements between firms. Accordingly, exports are not expected to be affected by production variables. Pulp production is placed above price by reasoning that, in the short-run, increasing costs (with capacity constraints) may not allow firms to respond to price. Canadian pulp price is placed above the domestic use of pulp by assuming that the price of pulp influences the production of paper products and thereby the use of pulp. Pulp inventory is placed at the bottom of the list because it is considered to be a residual realized after accounting for exports and the domestic use of pulp.[11]

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[10]The results presented later in this study also provide evidence for this reasoning.

[11]The economic reasoning for the ordering of the variables provided in the foregoing discussion is not unique. Alternative explanations can be provided to place either price above production or domestic use of pulp above price and production. We also cannot rule out the possibility of simultaneity among these variables. Therefore, the model was reestimated with several orderings of the variables to see if the results change significantly. The results were fairly robust.

The second specification issue is the determination of lag length for the model. Hafer and Sheehan (1991) have recently shown that policy recommendations are quite sensitive to changes in lag structure. The lag length for the model was determined by using Sims (1980) likelihood ratio test. This method compares the models of different lag lengths sequentially to see if there is a significant difference in results. The likelihood ratio has an asymptotic χ^2 distribution. The sequential pairwise equivalence of models with one through six lags were rejected at 5% critical level. However, the hypothesis that there was no significant difference between a six and a seven-lag model could not be rejected (χ^2=96.37, df=81). Therefore, a lag length of 6 was used for further analysis.

The data set contains 198 monthly observations for the period 1976:1 to 1992:6. The data used in this study were not differenced. This is consistent with recent trends in VAR analysis which suggest that differencing removes information that exists in the raw data series, and produces no gains in the asymptotic efficiency of estimates (Doan 1992). Furthermore, Sims et al. (1990) indicate that transforming models to stationary form, by differencing, is in many cases unnecessary if the distributions of statistics of interest are unaffected by the non-stationarity. In this study, variables are log transformed, except the g10-exchange rate and the interest rate whose values are already expressed in rates. Further, exchange rate, interest rate, GNP, and Canadian pulp price variables are expressed in real terms by deflating with the consumer price index.

Results and discussion of the VAR analysis

The summary statistics of the 9-variable, 6-lag autoregressive model are presented in Table 2. Adjusted R square values, in all of the equations, show that the variations in dependent variables are reasonably well explained by the model. The residuals from each equation were used to calculate DF test statistics (Dickey and Fuller 1979). The values indicate that the residuals from all equations are stationary. This implies that the use of the VAR approach with undifferenced data is justified even if some or all the variables have unit roots (See Sims et al. 1990). The figures in the fifth column of Table 2 are the Q values from Ljung-Box Q-test (Ljung and Box 1978). The results suggest that the hypothesis of serially uncorrelated errors can not be rejected at the 1% critical level.

We tested the null hypothesis that the set of pulp sector variables does not have a significant effect on macroeconomic variables using a likelihood ratio test. We could not reject the null hypothesis at a 5% critical level (χ^2=143.29 df=120)[12]. This suggests that pulp sector activity alone is not big enough to have a significant influence on macroeconomic variables. However, the hypothesis that the set of macroeconomic variables does not have a significant effect on the pulp sector was rejected at 5% critical level (χ^2= 211.90 df=120).

Forecast error variance decompositions were calculated using the Choleski decomposition. These were calculated from the parameters of the moving-average representation of the VAR model. Table 3 presents the variance decompositions for forecast horizons of 6, 12, 18, and 24 months. The decomposition divides the forecast variance into parts explained by each variable in the system. The diagonal values represent FEVs of each variable explained by own innovations. Higher diagonal values of any variable implies that the variable is more exogenous to the system. Among macroeconomic variables, the g10-exchange rate and interest rates are relatively more exogenous as is evident with over 60% of their FEV explained by own innovations after two years. Pulp exports and pulp production appear to be more exogenous among pulp sector

[12] The null hypothesis could be rejected at a critical level of 8%.

variables, while U.S. pulp price, Canadian GNP, Canadian pulp price, domestic use of pulp, and pulp inventories appear to be more endogenous.

The results in Table 3 also show the evidence of interactions between macroeconomic and pulp sector variables, with macroeconomic variables explaining greater percentages of the error variance in the pulp sector variables than vice versa. Interest rates explain much of the error variance in all pulp sector variables after a period of one year. This suggests that a change in interest rates stimulates the pulp economy slowly. The U.S. pulp price appears to be the second key variable in explaining the error variance in all pulp sector variables except for the domestic use of pulp. This may be because domestic users of pulp are limited by capacity constraints. The exchange rate effects on the Canadian pulp price are shown to be greatest in the initial periods of the forecast indicating an immediate pulp sector response. Pulp production and exports explain approximately one half of the FEV in U.S. world pulp price after one year.

The results also indicate evidence of interaction among the pulp sector variables. Approximately 30% of the error variance of exports is explained by pulp production and the domestic use of pulp. Also, domestic use of pulp and exports explain about 30% of variation in pulp production after one year. Pulp production explains approximately one fourth of the error variance in the Canadian pulp price after 6 months. Pulp production also explains one third of error variance in the domestic use of pulp after one year. Approximately 50% of the error variance in pulp inventories is explained by production, domestic use of pulp and exports.[13]

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[13]Jennings et al. (1990) note that VAR models with over parameterization may reflect random fluctuations in the data, but not the systematic variation. This concern led us to re-estimate the model by including Bayesian prior restrictions (see Bessler and Kling 1986). In this approach it is assumed that each variable follows a random walk process. We used a mean of zero for the prior on all coefficients except the first own lag in each equation. The lags of the dependent

Although decomposition of FEV measures the relative strength of relationships among the variables, it does not indicate the time path of a variable's response to a shock in one variable. In order to asses the effects of shocks, impulse response functions (IRFs) were calculated. Specifically, mean responses and variances of IRFs were calculated for twenty four future months using a Monte Carlo integration procedure outlined by Kloek and Van Dijk (1978). IRF confidence intervals were calculated by making 500 draws from autoregressive parameters of the VAR model (See Doan 1992). Figures 2 through 8 show the effect of a one-time, 1-SD (standard deviation) shock of each variable on pulp sector variables over a 24 months future period. Any impulse response for which both mean and confidence interval values lie above or below zero is considered significantly different from zero at the 5% critical level.

Figure 2 shows responses of pulp exports to shocks in the macroeconomy. Responses to shocks in the g10-exchange rate, interest rates and U.S. pulp price are shown to be significant. An increase in the g10-exchange rate (which implies that the Canadian dollar becomes stronger) causes a significant decrease in pulp exports in the third month (Figure 2a). A significant decrease in pulp exports in response to an increase in U.S. pulp price (Figure 2b) may be explained by a lower quantities demanded for pulp and thus a fall in pulp exports. A significant increase in exports is shown for one period in response to an increase in interest rates (Figure 2c). One could assume that with an increase in interest rates, pulp inventories become costly to hold thereby increasing exports. However, the effect is short lived, disappearing after inventory adjustments are

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variable in each equation were given a weight of one and the lags of all other variables a weight of one half (See Doan 1992). Although all variables explained more of their own error variance than in the unrestricted model, the patterns, however, were similar to those of unrestricted VAR model. Therefore, we use the results of unrestricted VAR model for further analysis.

made.

Figure 3 indicates that the response of pulp production to shocks in each macroeconomic variable is significant but short-lived. With an increase in the g10-exchange rate, a brief significant increase in pulp production is noticed after ten months (Figure 3a). This result runs counter to one obtained by Schembri and Robicheau (1986) which showed a stronger Canadian dollar to cause a decrease in pulp paper production. Our results may be explained by considering the indirect effects of exchange rate on domestic interest rates. From other IRFs of this model (not presented here) it is evident that an increase in exchange rate has a strong negative effect on interest rates. The lower interest rate stimulates the domestic economy and may result in an increase in the demand for pulp in domestic markets and thus an increase in production. The increase appears to be big enough to offset the depressing effect of the exchange rate on the production of pulp. This argument is supported by noting the prolonged depressing effect of an increase in interest rates on pulp production (Figure 3c). A significant decrease in production is noticed in response to an increase in U.S. pulp price (Figure 3b). This result is likely reflecting the change in the quantity demanded which would be expected with a rise in U.S. pulp price. A shock in GNP results in a overall increase in production by the tenth month (Figure 3d). However, there is also a significant drop in the first month, which may be attributed to drawing down of inventories in anticipation of an increase in interest rates.

The response of the Canadian pulp price to a shock in each macroeconomic variable, except GNP, is significant and prolonged (Figure 4). Unlike the shocks in interest rate and GNP, the shocks in the exchange rate and the world pulp price are shown to have immediate effects on the Canadian pulp price. The increase in the g10-exchange rate has a prolonged significant decreasing effect on pulp price (Figure 4a). This effect may be due to a small decrease in excess demand for pulp because of a rise in the value of the Canadian dollar (as noted in Figure 2a). An alternative explanation is that if Canadian pulp producers expect that the rise in the value of the Canadian dollar is temporary, they may lower the export price to maintain or even increase their share in the international pulp market (See Froot and Klemperer 1989 for more details). This suggests Canadian pulp producers do not have market power to absorb exchange rate changes in their profit margins. When U.S. pulp price increases, Canadian pulp price is shown to follow (Figure 4b). While an increase in interest rates causes a significant depressing effect (Figure 4c), a shock in GNP results in a significant increase in pulp price (Figure 4d). The inverse relationship between interest rate and GNP explains why quantity demanded and price for paper, and accordingly price of pulp would be expected to increase with increased GNP and decreased interest rates.

Figure 5 shows the response of domestic use of pulp to shocks in each macroeconomic variable. A significant increase in domestic use of pulp in response to a shock in the exchange rate is shown in Figure 5a. Two possible factors causing this increase are: 1) an increase in the value of the Canadian dollar causes exports to fall, and may, therefore, lower domestic price and lead to an increase in the domestic use of pulp; 2) an increase in the value of the Canadian dollar has a depressing effect on interest rates thereby increasing the demand for pulp in domestic markets. The significant decrease in domestic consumption of pulp in response to a shock in interest rates, after approximately one year, (Figure 5c) supports the second argument. There is also a significant increase in the domestic consumption of pulp, for a short period, in response to a shock in interest rates. This may be explained by noting the effect of an increase in interest rates on pulp inventories. Increased interest rates cause the industry to bear higher costs if they maintain large inventories. As a result, inventories are drawn down, either to increase exports[14] and/or to use domestically. The effect of an increase in U.S. pulp price does not have a significant effect on the domestic use of pulp (Figure 5b). An increase in GNP is shown to have a significant positive effect on the domestic use of pulp (Figure 5d) as more income leads to increased demand.

Figure 6 shows the response of pulp inventories to shocks in each macroeconomic variable. The shock in the exchange rate is shown to not have a highly significant effect (Figure 6a). The increase in U.S. pulp price is shown to have an insignificant depressing effect in the initial period (Figure 6b), however after 8 months, pulp inventories start accumulating significantly. As U.S. pulp price increases initially, Canadian pulp producers respond by drawing down inventories. However, over time, the increase in U.S. pulp price also causes the Canadian pulp price to increase, and thereby causes a decrease in the quantity demanded for pulp. As a result pulp inventories start increasing. The effect of an increase in interest rates is shown to have no significant effect initially (Figure 6c). However, as higher interest rates cause a fall in the demand for pulp in the domestic market, inventories start to accumulate again. Finally, a shock to GNP increases pulp demand, and thereby, cause pulp inventories to be run down (Figure 6d).

The responses of pulp sector variables to shocks in other pulp variables are also examined. Figure 7 indicates that Canadian pulp price is highly sensitive to the shocks in pulp production and inventories. Pulp price decreases significantly for over a year in response to an increase in pulp production (Figure 7b). However, the significant decrease in pulp price in response to a shock in

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[14]Recall that a shock in interest rates caused a significant initial increase in exports (Figure 2c).

pulp inventories lasts only for one quarter (Figure 7d). Increases in either pulp exports or the domestic use of pulp is also shown to have a small, insignificant, upward effect on pulp price for a long period (Figure 7a and 7c).

In further simulations we observed that an exogenous increase in Canadian pulp price does not result in significant effects on the level of exports, production, or domestic use of pulp. This may be because both importers and domestic users of pulp, use constant quantities of pulp, perhaps to keep their paper manufacturing companies running or to maintain planned level of input. In other words, pulp producers face a relatively inelastic demand in the short-run. The limited responsiveness of production to an increase in pulp price can be explained by noting that pulp inventory levels are drawn down significantly in response to an increase in pulp price (Figure 8c). This suggests that inventory levels act as a buffer in mitigating the fluctuations in the production of pulp. We also noticed that either an increase in pulp exports or domestic use of pulp will have a spontaneous significant negative effect on inventories (Figure 8a and 8d). Taken together, these results support the argument made earlier that inventories help the industry follow a "production smoothing" strategy and reduce the costs of production which would be associated with fluctuations.

Summary and conclusions

This paper explores the short-run dynamic interactions between several macroeconomic variables and the Canadian wood pulp sector, and analyzes the interrelationships among price and other variables within the wood pulp industry. A simple theoretical trade model is presented to explain both the impact of macroeconomic variables on the pulp sector and interactions among pulp sector variables. The VAR approach is used to estimate an empirical model. Results indicate that macroeconomic variables affect the wood pulp sector, but there is less evidence to suggest that the pulp sector has a significant influence on the macroeconomy. Accordingly, this analysis does not provide strong support for the arguments of Constantino and Percy (1988) who advocate the use of a general equilibrium approach to forest sector modelling because of large sectoral effects.

The decomposition of FEV shows that interest rates explain large amount of error variance in all pulp sector variables. On the contrary the exchange rate shows significant interactions only with pulp price. Pulp production is identified as a key variable in explaining variations in U.S. pulp price.

IRF results indicate that pulp production increases in response to a rise in the value of the Canadian dollar. This result may be explained by considering the depressing effect that a strong Canadian dollar has on interest rates, which in turn increase the use of domestic pulp and thus causes an increase in pulp production. By ignoring this chain of events, previous studies have over estimated the negative effects of an appreciation of the Canadian dollar on production. Results also show that the response of pulp exports to shocks in both the macroeconomy and other pulp sector variables are short-lived. It is hypothesized that importers demand is relatively inelastic thereby limiting fluctuations in pulp exports. Canadian pulp price is found to be sensitive to shocks in the macroeconomy and in other pulp sector variables. The immediate significant decrease in the Canadian pulp price with a rise in the value of the Canadian dollar indicates that pulp exporters appear to place more importance on maintaining their share in international pulp markets. This is not unreasonable when one considers that new contenders such as Brazil, Chile, Portugal, and Spain, are competing with Canada for increased market share. In contrast to price effects, results also show that production is not highly responsive either to the shocks in macroeconomic variables or in pulp price. This limited responsiveness is hypothesized to be largely due to: (1) inventory levels which act as a buffer against the shocks in the economy (2) capacity constraints faced by paper manufacturers. One could also attribute this result to the oligopolistic nature of the industry where price adjustments rather than production adjustments are common.

IRF results also indicate that changes in pulp exports and domestic use accompany fluctuations in the Canadian pulp price, but a shock in Canadian pulp price causes no significant effects on pulp production, exports, or inventories. This limited responsiveness of pulp exports and domestic use of pulp to a shock in Canadian pulp price suggests, once again, an inelastic demand for importers or domestic users of pulp, likely because of capacity constraints in the production of paper.

Finally, some of the limitations of results should be noted. First, the assumption of recursive identification restricts the contemporaneous interactions among the variables. Although the use of recursive VAR models is common, structural models may produce different results (Adamowicz et al. 1991). Secondly, the model incorporated only a few macroeconomic variables. The results obtained may not be consistent if any theoretically relevant variables have been omitted. Furthermore, the use of VAR models are justified by using asymptotic distribution theory. The coefficients are asymptotically normal only if they are not of a variable which is non-stationary and which does not appear in any of the system's stationary linear combinations (Sims et al. 1990). An alternative approach for addressing the problem of non-stationarity would be the use of vector error correction models.[15]

[15]See Engle and Granger (1987) for more discussion on error-correction models.

References

Adamowicz, W., Armstrong, G., and Lee, G. 1991. Structural Versus Non-structural VAR Models of Agricultural Prices and Exports. Department of Rural Economy, University of Alberta, Staff Paper 91-03.

Bernanke, Ben S. 1986. Alternative explanations of the money-income correlation. Carnegie-Rochester Conference Series on Public Policy **25**: 49-100.

Bessler, D.A. and Kling, J.L. 1986. Forecasting vector autoregressions with Bayesian priors. Ame. Agri. Eco. Asso.: 144-151.

Canadian Pulp and Paper Association 1992. The role of Canadian wood pulp in world markets. Sunlife building, 1155 Metcalfe, Montreal, Quebec, Canada.

Constantino, L., and M. Percy 1988. A Policy simulator for forest sector of British Columbia. Forest Economics and Policy Analysis Research Unit, University of British Columbia, Vancouver. Work.Pap. No. 109.

Cooley, T. F. and LeRoy, S. F. 1985. A theoretical macroeconomics: A critique. J. of Monetary Eco. **16**: 283-308.

Dickey, D., and Fuller, W. 1979. Distribution of the estimators for autoregressive time series with a unit root. J. Ame. Stat. Asso. **74**: 427-431.

Doan, Thomas A. 1992. User's Manual RATS Version 4. VAR Econometrics, Inc. Evanston, IL 60201.

Fackler, P.L. 1988. Vector autoregression techniques for structural analysis. Department of Economics and Business, North Carolina State University, Raleigh.

Froot, K.A. and Klemperer, P.D. 1989. Exchange rate pass-through when market share matters. Ame. Eco. Rev. **79**: 637-54.

Gilles, J.K., and Buongiorno, J. 1988. Long-term forecasting of trade in wood pulp between Canada and the United States. In Canada/U.S. forest products: Analysis of north American and world trade opportunities, edited by Stairs, G.R., Salinger, M.C., and Durham, N.C.: Duke University, Centre for International Studies, pp. 51-68.

Hafer, R.W., and Sheehan, Richard G. 1991. Policy inference using VAR models. Economic Inquiry **29**: 44-52.

Hirsch, Albert A. and Lovell, Michael C. 1969. Sales anticipations and inventory behaviour. John

Wiley & sons, Inc. New York.

Jegr, Karel M. 1985. Overview of the North American pulp and paper industry. Forest Economics and Policy Analysis Research Unit, University of British Columbia, Vancouver. Information Report 85-6.

Jennings, S., Adamowicz, W.L., and Constantino, L. 1991. The Canadian lumber industry and the macroeconomy: a vector autoregression analysis. Can. J. For. Res. **21**: 288-299.

Judge, G.H.R., Griffith, W., Lutkepohl, H., and Lee, T. 1988. Introduction to the theory and practice of econometrics. 2nd edition. John Wiley & Sons, New York.

Kloek, T., and Van Dijk, H.K. 1978. Bayesian estimates of equation system parameters: an integration of Monte Carlo. Econometrica **46**: 1-20.

Ljung, G.M., and Box, G.E.P. 1978. On a measure of lack of fit in time series models. Biometrica **65**: 297-303.

Mundell, R.A. 1963. Capital mobility and stabilization policy under fixed and flexible exchange rates. Can. J. Eco. and Pol. Sci. **29**: 475-485.

Orden, D., and Fackler, P.L. 1989. Identifying monetary impacts on agricultural prices in VAR models. Ame. J. Agric. Econ. **71**: 495-502.

Roberts, D.G. 1988. The impact of exchange rate changes on the Canadian forest products sector. Economics Branch Working Paper. Forestry Canada, Ottawa.

Sarker, R.C. 1993a. A maximum likelihood cointegration analysis of Canadian lumber exports. Can. J. Agric. Econ. **41**: 97-110.

__________ 1993b. Selection of the dependent variable in Canadian meat demand analysis: A vector autoregression approach. A paper presented in the WAEA/CAEFMS joint annual meetings, Edmonton, Alberta, Canada, July 11-14, 1993.

Schembri, L. and Robicheau, R. 1986. Estimating the Effect of Exchange Rate Changes on the Canadian Pulp and Paper Industry: A Dual Approach. Economic Branch, Canadian Forestry Service, Ottawa.

Schwindt, Richard W. 1985. An analysis of vertical integration and diversification strategies in the Canadian forest sector. Forest Economics and Policy Analysis Research Unit, University of British Columbia, Vancouver. Information Report 85-5.

Sims, C.A. 1980. Macroeconomics and reality. Econometrica, **48**:1-48.

Sims, C.A. 1986. Are forecasting models useful for policy analysis? Federal Reserve Bank Minn. Q. Rev. Winter: 2-16.

Sims, C.A., Stock, J.H., and Watson, M.W. 1990. Inference in linear time series models with some unit roots. Econometrica **58**: 171-86.

Woodbridge, Reed & Associates 1988. Canada's forest industry: pulp and paper the next twenty years prospects and priorities. Prepared for Government of Canada, Canadian Forest Service Industry, Trade and Technology Directorate Economics Branch, Ottawa.

Table 1. Variables and their sources

Variable	Variable definitions and source
G10XR	G-10 exchange rate (1981=100) (CANSIM B 3418)
USPR1	Index of the U.S. dollar selling price per tonne of wood pulp in the U.S.. Values are expressed in Canadian dollars by multiplying the index of the Canada-U.S. exchange rate (Producer Price Index, U.S. department of Labor, Commodity code 0911, 1967=100)
IRATE	Average of interest rates on Canadian bond yield (CANSIM D 14006)
CNGNP	Canadian gross national product in millions of dollars (CANSIM D 10056)
TOTXP	Total Canadian wood pulp exports in thousands of tonnes (Canadian pulp and paper Association Statistics Bulletin)
PRODN	Total Canadian wood pulp production in thousands of tonnes (Canadian pulp and paper Association Statistics Bulletin)
CNPRI	Index of the Canadian dollar selling price per tonne of wood pulp sold in Canada (Statistics Canada catalogue 62-001 1971=100)
DOUSE	Total Canadian integrated and affiliated use of wood pulp in thousands of tonnes (Derived by subtracting total exports and domestic shipments from total production)
NVEN	Total Canadian wood pulp inventories in thousands of tonnes (Canadian Pulp and Paper Association Statistics Bulletin)

NOTE: As GNP data were only available quarterly, an interpolation was used to create monthly data. The months in the middle of a quarter (February, May, August, November) were assigned the quarterly GNP value. The rate of increase between quarters, d_q, was calculated as $d_q = (GNP_{q+1} - GNP_q)/GNP_q$. The monthly rate of increase, d_m, between quarters was calculated as $d_m = (1+d_q)^{1/3}-1$. Monthly GNP values for months not in the middle of a quarter were calculated using d_m. The first values in the monthly series (January 1976) was assigned the value of the first quarter in the actual series , and the last value in the monthly series was given the value of the last quarter in the series (June 1992).

Table 2. Regression results for 9-variable 6-lag VAR

Dep. Variable	N	R^2_{adj}	DF test	Q value (39)	Sig. level of Q(39)
G10XR	192	0.99	-196.89	53.99	0.3
USPRI	192	0.99	-190.45	29.96	0.75
IRATE	192	0.97	-187.93	50.59	0.05
CNGNP	192	0.99	-195.22	36.75	0.43
TOTXP	192	0.78	-202.40	28.81	0.79
PRODN	192	0.81	-183.27	49.12	0.07
CNPRI	192	0.98	-187.15	26.45	0.87
DOUSE	192	0.76	-185.15	37.42	0.40
INVEN	192	0.91	-203.25	36.45	0.44

NOTE: The abbreviated variables are as defined in Table 1. N= Total number of observations used in estimation. The critical values of the DF (Dickey-Fuller) test at 95% level of significance is -2.89.

Table 3. Forecast error Variance (FEV) decomposition (%) of M-months ahead

		Shock to								
FEV in	M	G10XR	USPRI	IRATE	CNGNP	TOTXP	PRODN	CNPRI	DOUSE	INVEN
G10XR	6	90.57	0.37	2.48	1.04	0.32	1.32	0.77	2.64	0.45
	12	78.07	0.27	2.72	1.91	0.55	7.59	3.10	5.16	0.58
	18	68.52	0.25	3.21	2.94	0.57	9.63	8.06	6.31	0.47
	24	62.58	0.96	4.21	3.19	0.47	9.47	10.83	7.86	0.40
USPRI	6	20.50	49.17	0.61	1.52	3.90	14.03	9.70	0.18	0.34
	12	10.57	40.35	0.35	2.58	9.74	26.92	8.21	0.54	0.70
	18	8.37	32.31	2.44	5.38	12.55	30.40	6.49	0.98	1.03
	24	7.09	29.07	10.85	6.67	11.17	26.94	5.74	1.48	0.92
IRATE	6	5.58	0.42	86.87	1.05	3.93	0.04	1.08	0.22	0.77
	12	5.20	0.49	73.14	1.41	8.77	0.24	4.42	2.04	4.27
	18	4.99	0.48	66.16	1.52	10.64	1.24	4.28	4.87	5.33
	24	4.71	0.50	62.62	1.67	10.34	1.92	6.00	6.95	5.25
CNGNP	6	7.59	1.01	3.09	78.97	0.41	3.21	1.04	3.19	1.45
	12	8.48	0.56	26.00	48.05	1.85	6.71	1.14	6.15	1.01
	18	7.54	0.36	42.05	28.74	1.15	6.99	5.80	5.71	1.60
	24	7.52	1.30	47.47	20.62	2.51	5.04	8.33	4.32	2.85
TOTXP	6	3.44	9.60	5.07	1.28	54.57	13.20	0.96	8.69	3.14
	12	3.77	8.46	6.68	1.50	45.40	15.38	2.19	12.59	3.97
	18	3.78	9.15	7.00	1.41	43.50	15.91	3.24	11.91	4.04
	24	3.86	9.01	7.74	1.45	42.62	16.27	3.49	11.25	4.27
PRODN	6	1.35	4.37	0.33	3.83	15.13	61.02	1.63	11.31	0.97
	12	4.94	3.85	4.27	5.79	12.37	48.13	2.12	17.31	1.37
	18	5.54	4.92	9.29	5.86	12.01	42.58	2.63	15.28	1.84
	24	5.42	4.39	16.72	5.52	12.24	36.02	3.91	13.05	2.69

CNPRI	6	12.02	24.15	0.56	2.16	2.09	14.88	39.62	2.21	2.26
	12	6.89	22.57	0.40	4.07	4.96	25.67	29.62	4.64	1.15
	18	8.32	17.74	4.61	8.21	5.59	26.35	22.43	5.83	0.88
	24	7.98	16.35	17.18	9.06	4.36	20.21	17.87	5.90	1.05
DOUSE	6	4.12	1.42	4.12	2.95	5.23	46.97	0.78	31.99	2.38
	12	7.85	1.38	7.13	7.29	5.29	37.34	1.12	30.57	1.98
	18	7.71	1.51	16.98	7.40	5.61	30.99	1.89	25.24	2.63
	24	7.08	1.24	26.01	6.62	6.20	25.02	3.79	20.42	3.58
INVEN	6	0.47	2.04	2.33	3.59	11.60	37.74	4.05	30.65	7.46
	12	1.80	14.66	3.27	4.86	10.80	29.53	3.34	25.58	6.11
	18	1.44	22.32	9.46	5.80	9.29	23.53	2.93	20.68	4.51
	24	1.14	19.60	14.77	4.84	12.57	21.87	4.71	15.71	4.74

NOTE: M= number of months

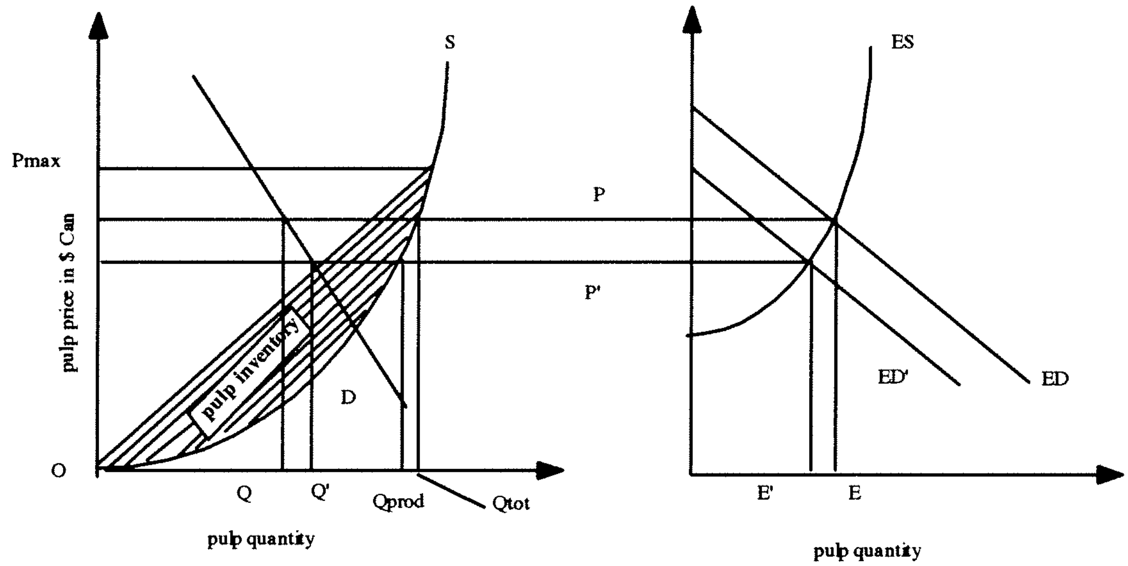

FIG. 1. Canada-rest of the world pulp trade model.

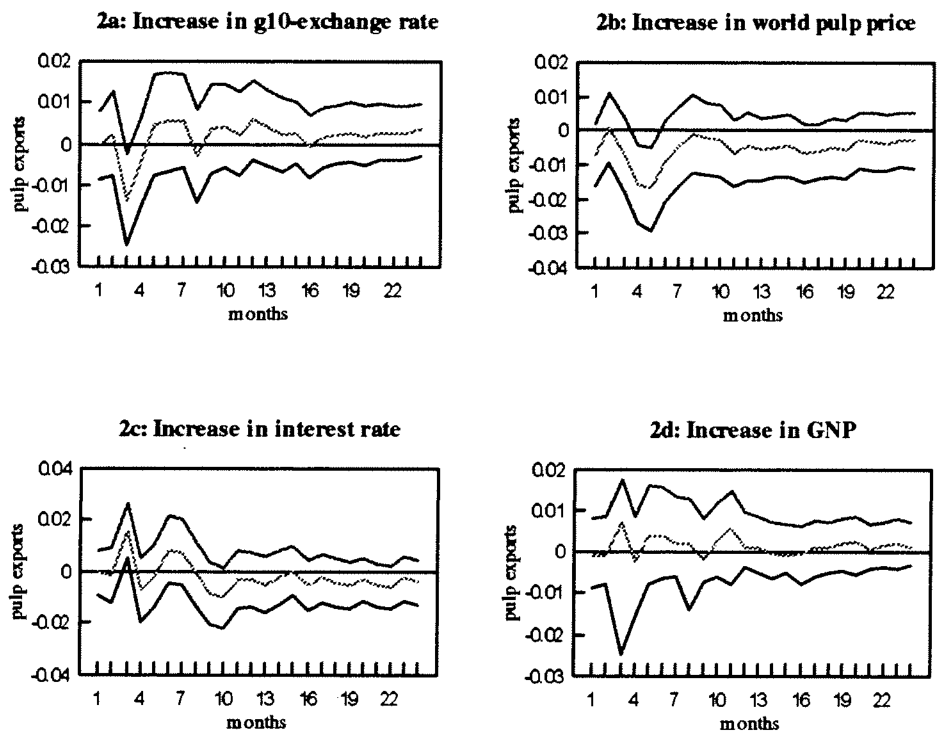

FIG. 2. Response of pulp exports to a shock in macroeconomic variables. Y-axis values are in thousands of tonnes expressed in log form.

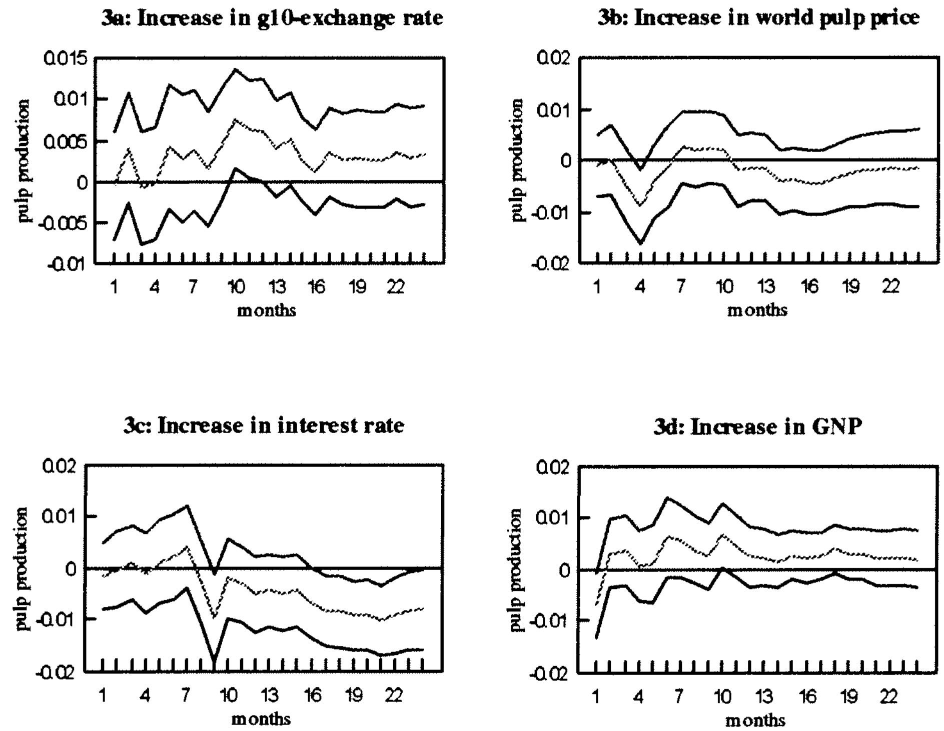

FIG. 3. Response of pulp production to a shock in macroeconomic variables. Y-axis values are in thousands of tonnes expressed in log form.

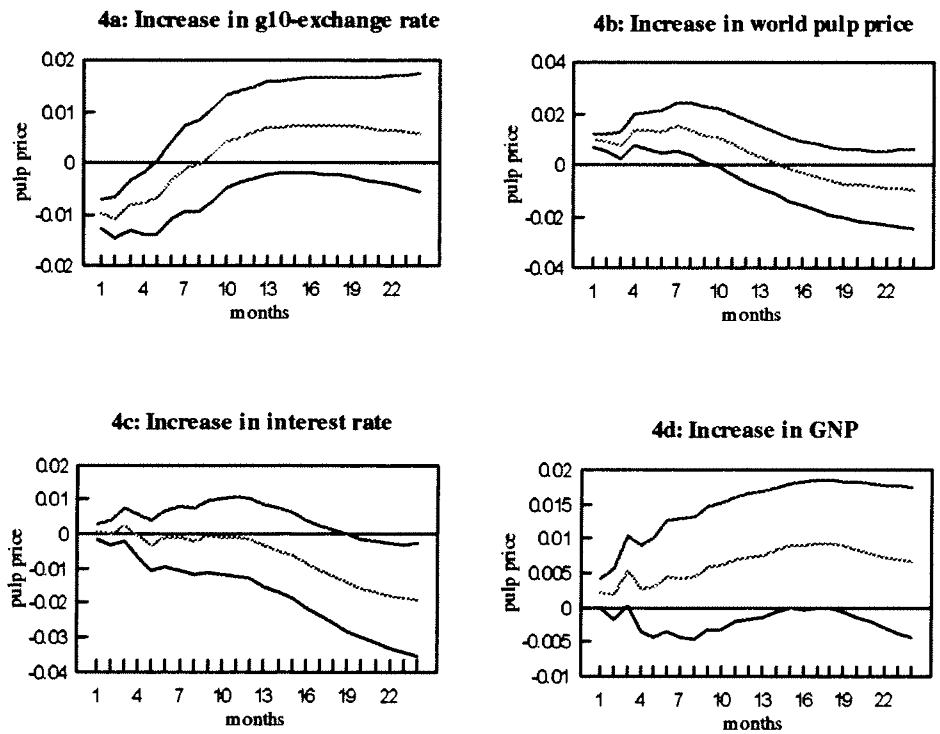

FIG. 4. Response of Canadian pulp price to a shock in macroeconomic variables. Y-axis values are in units expressed in log form.

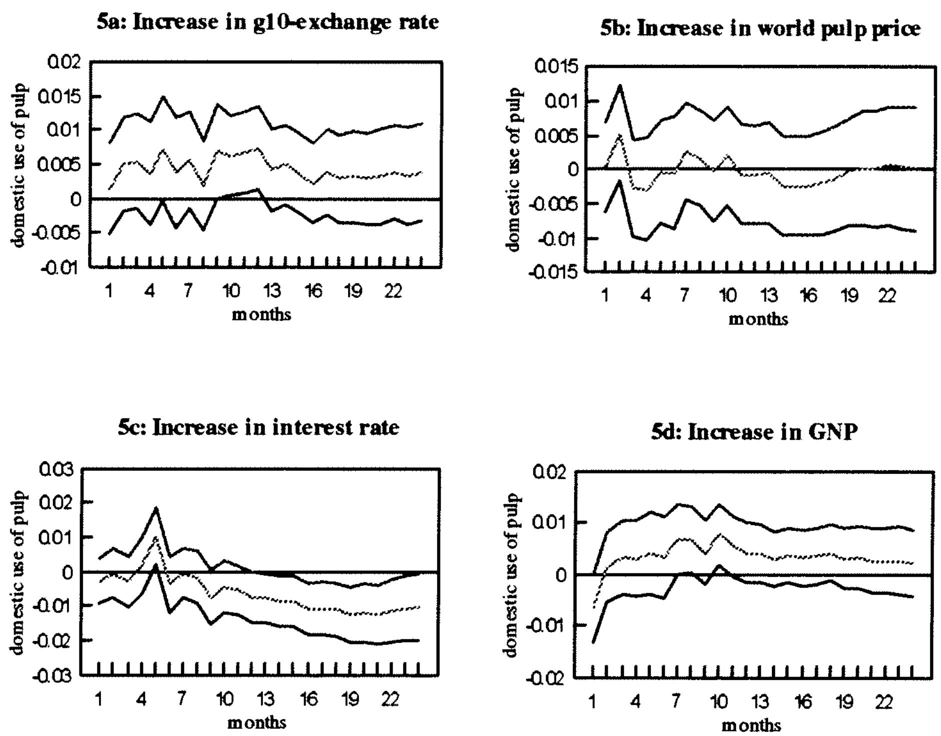

FIG. 5. Response of the domestic use of pulp to a shock in macroeconomic variables. Y-axis values are in thousands of tonnes expressed in log form.

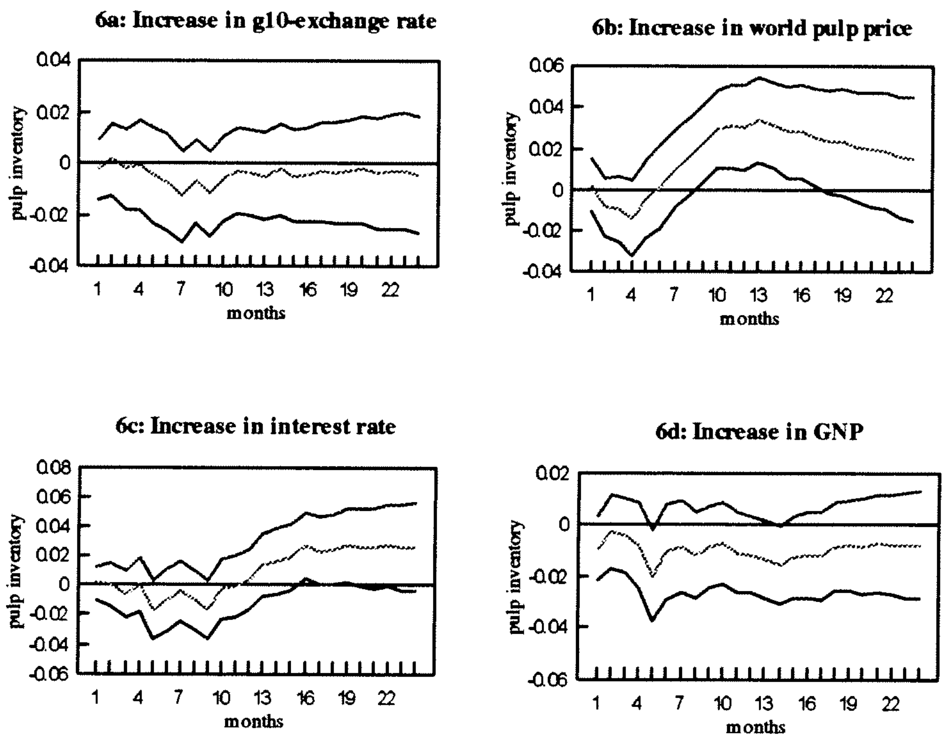

FIG. 6. Response of pulp inventory to a shock in macroeconomic variables. Y-axis values are in thousands of tonnes expressed in log form.

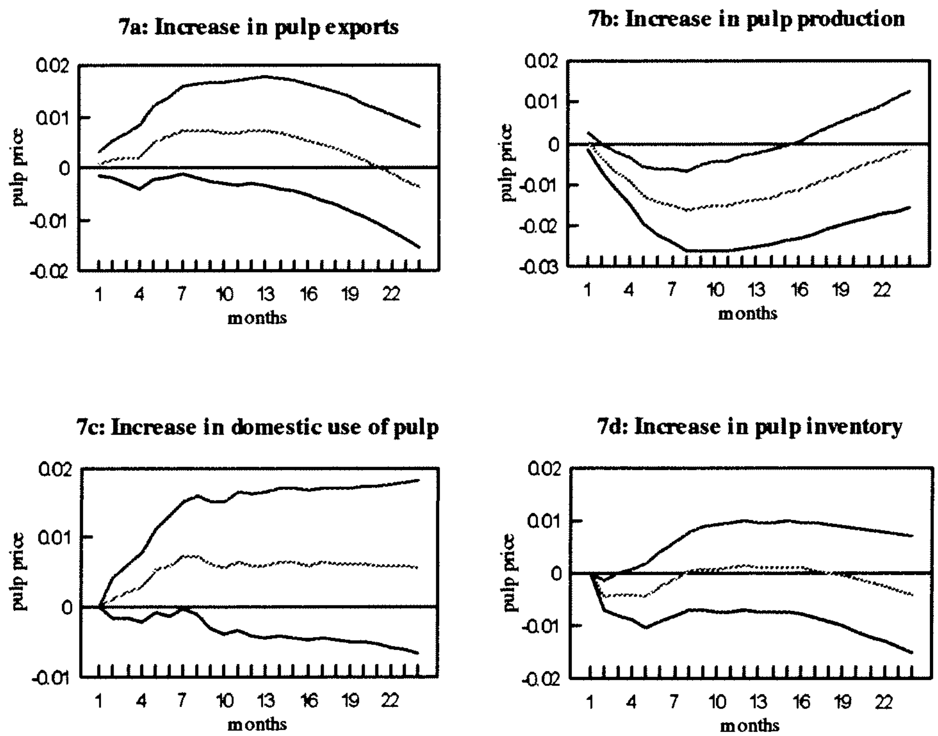

FIG. 7. Response of Canadian pulp price to a shock in pulp sector variables. Y-axis values are in units expressed in log form.

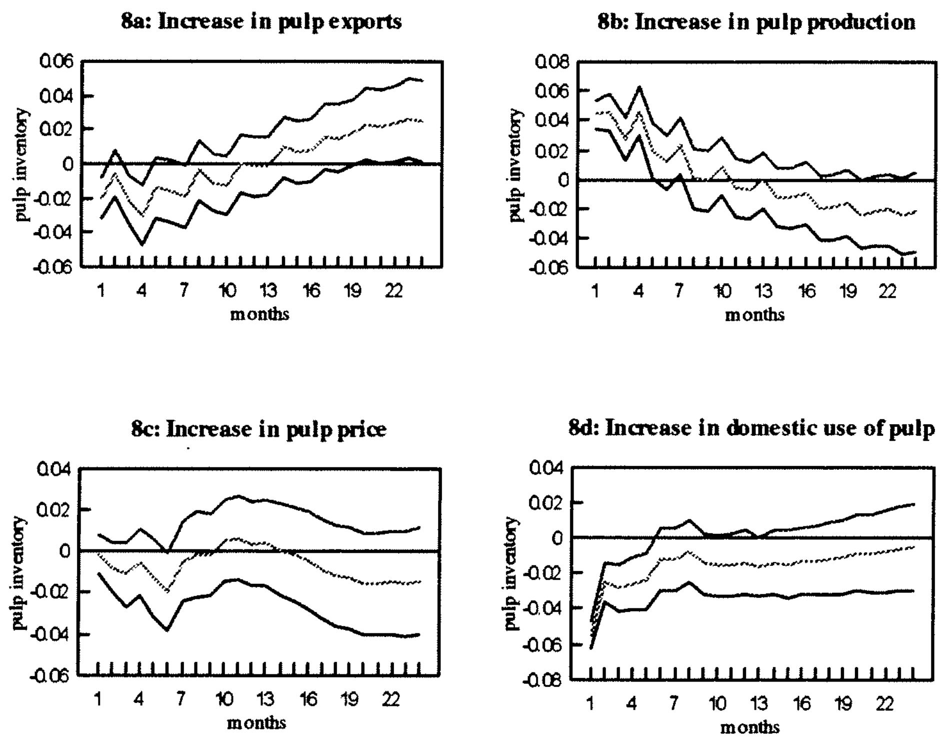

FIG. 8. Response of pulp inventory to a shock in pulp sector variables. Y-axis values are in thousands of tonnes expressed in log form.