The Impact of Monetary Policy Shocks on Stock Prices: Evidence from Canada and the United States

by

Yun Daisy Li
University of Western Ontario

Talan B. İşcan
Dalhousie University

Kuan Xu
Dalhousie University

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DALHOUSIE UNIVERSITY
HALIFAX, NOVA SCOTIA, CANADA
B3H 3J5

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Yun Daisy Li
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Dalhousie University

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Abstract

Using structural VAR models with short-run restrictions appropriate for Canada and the United States, we empirically examine whether openness and macroeconomic interdependence matter for the *impact* on and *transmission* to stock prices of monetary policy shocks. We find that, in Canada, the immediate response of stock prices to a domestic contractionary monetary policy shock is small and the dynamic response is brief, whereas in the U.S., the immediate response of stock prices to a similar shock is relatively large and the dynamic response is relatively prolonged. We argue that these results are largely driven by differences in dynamic responses of domestic short-term interest rates to monetary policy shocks, and are ultimately due to structural differences between the two countries that we model in this paper.

Keywords: monetary policy shocks, stock prices, open economy, structural vector autoregressive model

JEL Classification: E440, E520, G100, C300

Corresponding author:
Kuan Xu
Department of Economics
Dalhousie University
Halifax, Nova Scotia, Canada B3H 3J5
Tel.: 902-494-6996
Fax: 902-494-6917
E-mail: Kuan.Xu@Dal.Ca

1 Introduction

Stock markets are notoriously sensitive to changes in monetary policy. But this sensitivity may vary across different economies. In this paper we investigate whether the response of stock markets to changes in monetary policy differ significantly between a small open economy (Canada) and a large and relatively-closed economy (the United States, henceforth U.S.). This is motivated by the possibility that the impact of monetary policy on asset prices varies significantly in economies with different degrees of trade and financial market openness, and macroeconomic interdependence. There are at least four theoretical reasons underlying this possibility.

First, small open economies tend to have less diversified economic structures than large and relatively-closed economies do. In this regard, the transmission of monetary policy shocks to asset prices in small open economies works through a smaller set of sectors and industries, possibly leading to different dynamic responses in asset prices. Second, international trade is typically a larger share of GDP in small economies than in large and relatively-closed economies. Thus, the degree of trade openness may influence the impact and transmission of monetary policy shocks on domestic asset prices. Third, stock prices in small open economies are susceptible to international capital flows. Thus, the degree of financial market openness may affect asset price adjustments after monetary policy shocks. Fourth, different degrees of international macroeconomic interdependence may also affect the transmission of monetary policy shocks to asset prices. The exchange rate in small open economies opens the possibility of an additional propagation mechanism that is absent in large economies, which have a major influence on the rest of the world.[1]

Given these theoretical considerations, in this paper we specifically address two important and related empirical issues: whether trade openness, financial market openness, or macroeconomic interdependence matter for (i) the *impact* on and (ii) the *transmission* to stock prices of monetary policy shocks.

Our empirical results suggest that indeed openness and macroeconomic interdepen-

[1]A separate issue is whether monetary policy should target asset price volatility. See, Bernanke and Gertler (2001), Geithner (2006), and Roubini (2006), for a recent debate relevant to the U.S. There appears to be fewer compelling reasons to target asset price volatility in small open economies. See Hördahl and Packer (2007) for a succinct review.

dence matter significantly in terms of the overall response of stock prices to unanticipated changes in monetary policy. Using structural VAR models with short-run restrictions, we find that in Canada the immediate response of stock prices to a domestic contractionary monetary policy shock is small and that the dynamic response is brief. By contrast, in the U.S. the immediate response of stock prices to a domestic contractionary monetary policy shock is relatively large and the dynamic response is relatively prolonged. We also provide an economic explanation of these differences, which are largely driven by differences in dynamic responses of domestic short-term interest rates to monetary policy shocks in Canada and the U.S., and are ultimately due to structural differences between the two countries that we model in this paper.

Our findings underscore for Canada the relative importance of financial openness for the transmission of monetary policy shocks to stock prices. And, as an indication of strong macroeconomic interdependence, we find that changes in the U.S. federal funds rate significantly affect the forecast error variance of the Canadian stock prices. While we find that the overall impact of external demand shocks on Canadian stock prices is relatively small, our interpretation of this finding is that the floating exchange rate regime provides a cushion for the real sector in Canada.

Even though monetary policy primarily regulates the aggregate demand, we think of asset and stock prices as an important channel of the monetary transmission mechanism. Stock prices influence financial wealth, and hence affect consumption, investment and labor supply decisions (e.g., Poterba (2000) and Lettau and Ludvigson (2004)). Moreover, the share of financial assets in household wealth has been growing rapidly in both Canada and the U.S.[2] Thus, it is increasingly important to understand whether, and how, monetary policy affects stock prices over time in the context of trade and financial market openness, and macroeconomic interdependence.

Despite the growing prominence of the link between asset prices and aggregate demand, most empirical open economy models continue to rely on the conventional Mundell-Fleming framework. In this framework, given that households divide a fixed amount of wealth between a (riskless) bond portfolio and domestic money holdings, one can write

[2] In the United States, either directly or indirectly, more than two thirds of the households own financial securities (Wolff, 2006: Table 5). In Canada, about one-third of the households own financial securities as part of their overall wealth (Pichette, 2004).

down equilibrium conditions in terms of either the bond market or the money market, which typically is the one specified in the empirical models. The bond portfolio, on the other hand, consists of domestic and foreign bonds, which are perfect substitutes. Consequently, empirical models appeal to the uncovered interest parity condition to link interest rates for domestic and foreign bonds to the exchange rate.

In our analysis, for the Canadian economy, we adopt the basic features of the Mundell-Fleming-type small open economy model. However, we extend this framework by including stocks in the menu of assets in the domestic portfolio. We allow stock prices to depend on real and nominal variables, and allow stock prices to change in response to portfolio shocks. We model the U.S. economy following the lead of Christiano, Eichenbaum and Evans (1996, 1999), but also augment their model by including stocks as a component of wealth.

From a methodological standpoint, the core of our empirical analysis is the *identification* of the impact of monetary policy shocks on stock prices. We follow the extensive empirical literature using vector autoregressive models (VARs) to examine this interaction. There are three commonly used methods of identification in these VAR models:

(1) *Recursive VARs*, which assume a causal chain among variables, whereby the first variable in the VAR system is assumed to be contemporaneously exogenous to all the remaining variables, and the second variable is contemporaneously exogenous to all except the first variable, and so on (Sims 1980).[3]

(2) *Structural VARs with long-run restrictions*, which impose the restriction that changes in the money supply have no long-run effects on the real variables (Blanchard and Quah 1989).[4]

(3) *Structural VARs with short-run restrictions*, which impose restrictions on the contemporaneous ("short-run") effects of shocks upon certain variables included in the model (Bernanke 1986, and Sims 1986). This is the approach we take in this paper.

[3]For example, Thorbecke (1997), Patelis (1997), and Park and Ratti (2000) use this approach to identify the impact of monetary policy shocks on stock prices.

[4]For example, Lastrapes (1998) uses this approach to identify the impact of monetary policy shocks on stock prices.

We take the third approach because there are several important advantages to estimating the interaction between monetary policy and stock prices using short-run restrictions: it allows us—within a unified empirical framework—to impose (arguably) weak restrictions based on economic and structural considerations, to use statistical model selection techniques in conjunction with macroeconomic theory, and to identify *structural* shocks, including unanticipated changes in monetary policy. Earlier studies also provide a useful guidance on this choice. Kim and Roubini (2000) argue that recursive VAR models for open economies lead to a number of anomalies, which they resolve using structural VARs. Christiano, Eichenbaum, and Vigfusson (2006) argue that structural VARs with short-run restrictions yield remarkably sharp inference in the context response analysis with structural shocks. According to Faust and Leeper (1997), VAR models with long-run restrictions, by contrast, do not necessarily lead to unique short-run dynamics.

There are complementary approaches to structural VARs. Rigobon and Sack (2004) and Corallo (2006) use a heteroskedasticity-based approach. Their identification methodology involves examining the changes in the covariance between interest rates and asset prices within a window when the variance of the monetary policy shock is *a priori* known to have shifted. Bernanke and Kuttner (2005) employ an event-study approach to examine the unexpected and expected components of the change in monetary policy on stock prices. Dufour and Tessier (2006) study the relationship between stock prices, interest rates, inflation, output, and money aggregates in an unrestricted VAR, but their main focus is on multi-horizon Granger-causality tests.

While these studies use different methods to identify the impact of monetary policy on stock prices, their findings suggest that monetary policy shocks affect stock prices in important ways. There is considerable research using the U.S. data. For instance, Thorbecke (1997), Patelis (1997), and Park and Ratti (2000) use orthogonalized innovations in the federal funds rate to measure monetary policy shocks, and find that a contractionary monetary policy shock leads to a fall in stock prices. Thorbecke (1997) finds that an unanticipated one percent increase in the federal funds rate leads upon impact to about 0.8% decrease in stock prices. Rigobon and Sack (2004) find that a 25 basis points increase in the three-month interest rate results in a 1.7% decline in the S&P 500 index and a 2.4% decline in the Nasdaq index.

There are also several studies that provide comparative international evidence on the link between monetary policy and stock prices. Lastrapes (1998) presents cross-country evidence, and finds that in Canada an unanticipated 1% decrease in the nominal money stock (M1) leads to a 1.6% fall in stock prices (at the trough of the impulse response), whereas in the U.S. a similar shock reduces stock prices by about 2.4%. However, Siklos and Anusiewicz (1998) find that an unanticipated decrease in Canadian M1 weekly growth leads to an *increase* in the Canadian stock index. Corallo (2006) studies the effect of monetary policy on asset prices in Germany and the U.K. using the heteroskedasticity-based approach, and finds that an unexpected increase in the interest rate depresses equity prices, but this relationship is not statistically significant. Our findings suggest that an unanticipated 25 basis points increase in the federal funds rate leads, upon impact, U.S. stock prices to decline by 0.55 percent, whereas a similar increase in the overnight interest rate in Canada leads to stock prices to decline by only 0.0025 percent.

The relative difference in openness between Canada and the U.S., and the macroeconomic interdependence mostly running from the large U.S. economy to the small Canadian economy are the distinguishing features of our analysis. It is perhaps surprising that these differences have not been fully explored in the existing literature on the link between stock prices and monetary policy shocks. In a framework that is closest to ours, Lastrapes (1998) uses the *same* structural model with long-run restrictions for eight countries (G7 plus the Netherlands), but does not control for their potential differences in economic structure, and does not allow for macroeconomic interdependence.[5] Consequently, our analysis builds on a framework that explicitly models the structural differences between Canada and the U.S., and that accounts for the differences in their responses of stock prices to monetary policy shocks in an internally consistent way.

We organize the paper as follows. In section 2, we provide a background discussion of monetary policy instruments and our structural VARs. In section 3, we present our baseline VAR models, and discuss the identification strategy. In section 4, we present and discuss our key empirical findings. In section 5, we evaluate the robustness of our results to alternative identification restrictions. We conclude in section 6.

[5]Dufour and Tessier (2006) recognize these differences between Canada and the U.S., but they do not incorporate variables related to financial market openness into their model.

2 Background

Before we formally present our structural VAR models, it is useful to discuss several background issues concerning our choice of the sample period, and monetary policy instruments. We start our sample period from January 1988 because of two important considerations: (i) the continuity and similarity of monetary policy operating procedures in the Canadian and U.S. economies, and (ii) the growing integration of the two economies since 1988.

Since 1988 both economies have been marked by continuity and similarity in terms of their monetary policy *instruments*, *objectives*, and low inflation. This continuity in the U.S. has been primarily characterized by the "Greenspan regime," whereby the federal funds rate is the key instrument of monetary policy.[6] Similarly, this continuity in Canada has been characterized by the "inflation-targeting regime," whereby the overnight interest rate is the key policy instrument.[7] Consequently, we use the federal funds rate in the U.S. and the overnight interest rate in Canada as the monetary policy instrument.

Since 1988, there has also been an increasing integration of the Canadian and U.S. economies. The 1988 free trade agreement has accelerated and bolstered the already extensive economic integration of these two economies. Of course, given the significant difference in the sizes of these economies, the U.S. economy has a considerably larger influence on the Canadian economy. Currently, the Canadian exports to the U.S. amount to about 35 percent of the Canadian GDP, and the weight of the Canadian trade with the U.S. represents above 75 percent of the total Canadian foreign trade. The financial sectors in both the U.S. and Canada are also highly integrated. These considerations

[6]See also http://www.frbsf.org/publications/federalreserve/monetary/tools.html, and Bernanke and Blinder (1992). Bernanke and Mihov (1998) consider alternative monetary policy instruments such as the federal funds rate, non-borrowed reserves, borrowed reserves, and total reserves, and examine innovations to these instruments. They find that innovations to the federal funds rate perform as the best indicator of unanticipated changes in monetary policy for the post-1988 period in the U.S.

[7]Although in January 1988, John Crow, the Governor of Bank of Canada, stated the monetary policy objective as "price stability," the Bank of Canada ("Bank") later defined this objective as inflation targeting, with explicit targets since February 1991. The Bank has also been explicit about the overnight interest rate as the monetary policy instruments, at least since 1994, when it started making the target band for the overnight rate public (but not the target rate within this band). Since early 1999, the Bank has been announcing the target rate. Thiessen (1995) also emphasizes the overnight interest rate as the key instrument of monetary policy in Canada.

lead us to model the Canadian economy with appropriate channels for macroeconomic interdependence. Clearly, some of these channels are not essential for modeling the U.S. economy.

Aside from the differences in the degree of macroeconomic interdependence, in our analysis, oil prices also play different roles in the two countries: the U.S. is a net oil importer whereas Canada is a net oil exporter. Thus, in our U.S. model below, we explicitly control for the adverse effects of oil price hikes.[8]

3 Modeling strategy

While our primary interest is in the relationship between monetary policy and stock prices, we model this relationship within a general equilibrium framework in which major macroeconomic variables interact contemporaneously and over time. We thus examine the qualitative and quantitative information about the relationship between monetary policy shocks and stock prices using multivariate structural VAR models for the U.S. and Canadian economies.

3.1 The structural VAR models

The baseline U.S. VAR model consists of, as in Christiano et al. (1996), real output (Y), the price level (P), the money supply ($M2$), the federal funds rate (R), and the price of oil (OP), which are standard in the empirical monetary business-cycle models of the U.S., plus stock prices (SP), which are included to control for (stock market driven) wealth effects. The baseline Canadian VAR model, on the other hand, consists of real output, the price level, the money supply, the overnight interest rate, the US-Canada bilateral nominal exchange rate (E), and the U.S. federal funds rate, which are also standard in the Mundell-Fleming-type models for open economies,[9] plus stock prices, which are included to control for wealth effects. Our empirical model for Canada accommodates a range of

[8]Incidentally, Canada switched from being a net oil importer to a net oil exporter in 1988, which is the beginning of our sample period. Jiménez-Rodriguez and Sánchez (2004) discuss the differential influence of oil price shocks on the Canadian and U.S. economies. See, also, Hamilton and Herrera (2004) for an assessment of the impact of oil price shocks on the US economy.

[9]See, e.g., Cushman and Zha (1997) and Kim and Roubini (2000).

open economy models with incomplete markets.[10]

Specifically, for each country, we consider the following reduced-form VAR model:

$$y_t = \sum_{l=1}^{p} \beta_l y_{t-l} + u_t, \tag{1}$$

where y_t is a vector of endogenous variables, β_l is a matrix of parameters, y_{t-l} for $l = 1, \ldots, p$ is a vector of lagged y variables, and the disturbance term, u_t, is a vector of white noises with $E(u_t) = 0$, and $E(u_t u_t^{'}) = \Sigma$. The reduced-form disturbances, u_t, are linear combinations of structural shocks ν_t in the form of $A_0 u_t = \nu_t$ (including the monetary policy shocks). After pre-multiplying equation (1) by A_0, we obtain the structural VAR model

$$A_0 y_t = \sum_{l=1}^{p} A_l y_{t-l} + \nu_t, \tag{2}$$

where $A_l = A_0 \beta_l$, $A_0 u_t = \nu_t$, and $E(\nu_t \nu_t^{'}) = \Omega$. Thus, $\Sigma = A_0^{-1} \Omega (A_0^{-1})^{'}$. There are six structural shocks in the U.S. model, and seven structural shocks in the Canadian model. In the next section, we discuss our strategy to identify the structural shocks.

3.2 Identification

In order to identify the structural shocks, we impose a set of restrictions on the contemporaneous correlations in our structural VAR model (2) to reflect the operating procedures of the two central banks (as discussed above in section 2) and basic economic principles. We start the discussion with the identification of monetary policy shocks (ν_{MP}), because this identification is central to our analysis and the methodology is similar in both the Canadian and U.S. models.

As in Christiano et al. (1996) and Kim and Roubini (2000), we characterize monetary policy by a feedback rule, which is a linear function relating the monetary policy

[10] We use a combination of economic theory and statistical criteria (the Schwartz and Akaike information criteria, and log-likelihood function values) for model selection. Our baseline specifications for Canada and the U.S. are an outcome of this model-search approach. At the same time, one fundamental limitation is that the short-run restrictions and the models on which these restrictions are imposed can only be jointly tested. In section 5, we thus discuss the sensitivity of our results to alternative model specifications and identification restrictions.

instrument to the information set available to the central bank. We identify *monetary policy shocks* as innovations to the monetary policy instrument given a set of conditioning variables. The monetary policy instrument is the federal funds rate for the U.S. and the overnight interest rate for Canada. The conditioning variables for the Fed's feedback rule include the contemporaneous values of money supply and lagged values of all the variables included in the model. The conditioning variables for the Bank of Canada's feedback rule include the contemporaneous values of money supply and exchange rate, as well as the lagged values of all the variables included in the model.[11] We thus have for the U.S. and Canadian models, respectively,

$$USR_t = a_{40} - a_{43}USM2_t + f_4(USy_{t-l}) + \nu_{USMP,t}, \tag{3}$$

$$CAR_t = a^*_{40} - a^*_{43}CAM2_t + a^*_{46}E_t + f^*_4(CAy_{t-l}) + \nu_{CAMP,t}, \tag{4}$$

where $\nu_{MP,t}$ is the monetary policy shock; f_i and f^*_i are the linear functions of lagged variables in the ith equation in the U.S. and Canadian structural VAR models, respectively; and a_{ij} and a^*_{ij} are the jth parameters in the ith equation in the U.S. and Canadian VAR models, respectively. (All variables, except the interest rate, are expressed in natural logarithms.) According to the Bank of Canada's view of the inflation process in Canada, a depreciation of the Canadian dollar (an increase in E) corresponds to an increase in domestic prices. Our formulation captures that expectation and suggests that the Bank may respond by raising the instrument interest rate.

We attribute monetary policy shocks to three possible sources (see also Christiano et al., 1996). The first source is the exogenous shocks to the preferences of central bankers, such as shifts in the relative weights given to unemployment, inflation, financial market stability, and foreign exchange rate stability. The second source is exogenous variations in policy to validate private agents' expectations about the central bank policy. Central banks may wish to avoid the costs of disappointing private agents' expectations and shocks to these expectations would in turn lead to monetary policy shocks. The third source is various technical factors, such as measurement error in the real time data available to

[11] The operating procedures of the central banks focus more on M2 than on M1 as the primary monetary aggregate. Our statistical model selection criteria also decisively favored the models with M2 rather than M1. We also estimated our models using M1. These results are available upon request.

the central bank. In addition, we will provide an extensive discussion of the influence of alternative conditioning variables in the feedback rule on our results in section 5.

The rest of our identification methodology reflects the interactions among three main markets (the goods, money, and stock markets), as well as, in the case of the Canadian model, the external sector. For each market we specify equilibrium conditions. We now discuss the remaining identifying restrictions of the U.S. and Canadian models separately.

3.2.1 Identification in the baseline U.S. model

In addition to the monetary policy shocks, in the baseline U.S. model, there are five other structural shocks. These are aggregate supply, aggregate demand, money market equilibrium, portfolio, and oil price shocks. Now we discuss them in turn.

An *aggregate supply* shock (ν_{AS}) reflects exogenous changes in productivity, mark-ups, and other supply side factors. We identify aggregate supply shocks by specifying real output as a function of the contemporaneous value of the oil price and the lagged values of all the variables included in the model. Thus, we have

$$Y_t = a_{10} - a_{16} OP_t + f_1(y_{t-l}) + \nu_{USAS,t}. \tag{5}$$

An *aggregate demand* shock (ν_{AD}) reflects an exogenous impact of fiscal policy (both spending and revenue shocks), wage-push inflation, and other demand side factors. We identify aggregate demand shocks by specifying aggregate demand as a function of the contemporaneous values of the price level and the oil price (to control for the impact of relative price changes on aggregate demand), as well as the lagged values of all the variables in the model. Of course, in equilibrium the aggregate quantity demanded equals that supplied, so we write:

$$P_t = a_{20} - a_{21} Y_t + a_{26} OP_t + f_2(y_{t-l}) + \nu_{USAD,t}. \tag{6}$$

A shock to the *money market equilibrium* (ν_{MME}) originates from an exogenous change in the velocity of money. We represent the money market equilibrium with a standard quantity-theory-of-money specification, whereby the demand for real money balance depends on income and the opportunity cost of holding money, the nominal interest rate:

$$M2_t - P_t = a_{30} + a_{31} Y_t - a_{34} R_t + f_3(y_{t-l}) + \nu_{MME,t}. \tag{7}$$

A *portfolio* shock (ν_{PORT}) represents an exogenous change in the demand for equities, which we interpret as an innovation in the time-varying equity risk premium. Stock markets aggregate all the publicly and privately available information, so stock prices to depend contemporaneously on all the variables in the model plus the portfolio shock (see equation (8), row 5).

Finally, to identify the *oil price* shock (ν_{OP}) we specify oil price as a contemporaneously exogenous variable, and allow it to be influenced only by the lagged values of all other endogenous variables (see equation (8), row 6).

We name the reduced-form shocks after the corresponding endogenous variables. For instance, the reduced-form output shock corresponds to u_Y in the output equation. For the U.S. model, we add "US" to the subscript of each of the reduced-form and structural shocks. Equation (8) summarizes the identification restrictions in the baseline US model:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & a_{16} \\ a_{21} & 1 & 0 & 0 & 0 & -a_{26} \\ -a_{31} & -1 & 1 & a_{34} & 0 & 0 \\ 0 & 0 & a_{43} & 1 & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & a_{56} \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} u_{USY} \\ u_{USP} \\ u_{USM2} \\ u_{USR} \\ u_{USSP} \\ u_{OP} \end{bmatrix} = \begin{bmatrix} \nu_{USAS} \\ \nu_{USAD} \\ \nu_{USMME} \\ \nu_{USMP} \\ \nu_{USPORT} \\ \nu_{OP} \end{bmatrix}. \tag{8}$$

3.2.2 Identification in the baseline Canadian model

In addition to the monetary policy shocks, in the baseline Canadian model, there are six other structural shocks. These are aggregate supply, aggregate demand, money market equilibrium, portfolio, external demand, and U.S. monetary policy shocks. (Our labeling convention for the reduced-form and structural shocks is identical to the one we used for the U.S. model.) Now we discuss them in turn.

The identification of the structural *aggregate supply*, *money market equilibrium*, and *portfolio* shocks in the baseline Canadian VAR model and their interpretations are identical to those for the U.S. model. The only difference is that to account for global shocks to the marginal product of capital, we augment the supply equation for Canada with the contemporaneous value of the U.S. federal funds rate, which is a proxy for global marginal product of capital (see below equation (9), row 1).[12] To identify portfolio shocks, we continue to let stock prices to depend contemporaneously on all the variables in the model plus the portfolio shock (see equation (8), row 5). The rest of the identifying restrictions in the baseline Canadian model are as follows.

In the context of Canada, we divide aggregate demand into domestic demand and external demand, and model them separately. In particular, we specify a domestic demand for goods equation, which is determined by the price level in Canada, the exchange rate and the foreign interest rate, as well as the lagged values of all the variables included in the model (see equation (8), row 2).[13] Thus, with some abuse of language, an *aggregate demand* shock in the Canadian system refers to an unexpected change in fiscal policy (both spending and revenue shocks), wage-push inflation, and other factors that determine domestic demand for goods.

The external demand for Canadian goods, on the other hand, depends in part on the exchange rate. We model the unexpected changes in the external demand as transmitted through the unexpected movements in the exchange rate and refer to them as *trade* shocks, ν_{CATR} (see equation (8), row 6).[14] An unexpected decline in the U.S. demand for Canadian goods, for instance, would lead to an unexpected depreciation of the Canadian dollar. In the baseline model, exchange markets aggregate all the publicly and privately available information, and that shocks to the exchange rate originate from contemporaneous values of all the variables in the system, except the stock prices.[15]

Finally, we include the U.S. federal funds rate in the Canadian models as a contemporaneously exogenous variable, and label the unexpected changes in this variable as the *U.S. monetary policy* shocks, ν_{USMP} (see equation (8), row 7). We should note that our specification allows both anticipated and unanticipated monetary policy changes in the

[12]The money market equilibrium condition is identical to that in the U.S. model, and is standard in open economy models, which assume no foreign currency holdings.

[13]We use the exchange rate and foreign interest rate, rather than the domestic interest rate, by appealing to the uncovered interest parity condition. We use the federal funds rate as the foreign interest rate in the Canadian model.

[14]In the new open economy models, the exchange rate is also the main channel of transmission of external shocks; see, e.g., Murchison and Rennison (2006, pp. 90–91).

[15]We have also estimated the specification in which the exchange rate responds to all the contemporaneous values of the model variables including the stock price. This is one place where statistical model selection criteria favored the model that excludes the contemporaneous values of stock prices, suggesting that they contain no information above and beyond those already included in the VAR system.

U.S. to influence Canadian real and nominal variables through both trade and financial market openness.[16]

Equation (9) summarizes the identification restrictions in the baseline Canadian VAR model:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & a^*_{17} \\ a^*_{21} & 1 & 0 & 0 & 0 & -a^*_{26} & a^*_{27} \\ -a^*_{31} & -1 & 1 & a^*_{34} & 0 & 0 & 0 \\ 0 & 0 & a^*_{43} & 1 & 0 & -a^*_{46} & 0 \\ a^*_{51} & a^*_{52} & a^*_{53} & a^*_{54} & 1 & a^*_{56} & a^*_{57} \\ a^*_{61} & a^*_{62} & a^*_{63} & a^*_{64} & 0 & 1 & a^*_{67} \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} u_{CAY} \\ u_{CAP} \\ u_{CAM2} \\ u_{CAR} \\ u_{CASP} \\ u_E \\ u_{USR} \end{bmatrix} = \begin{bmatrix} \nu_{CAAS} \\ \nu_{CAAD} \\ \nu_{CAMME} \\ \nu_{CAMP} \\ \nu_{CAPORT} \\ \nu_{CATR} \\ \nu_{USMP} \end{bmatrix}. \tag{9}$$

4 Empirical analysis

4.1 Data

Our data are monthly and cover the period from January 1988 to December 2003.[17] We measure real output by industrial production index, the price level by the consumer price index (CPI), and stock prices by a broad market index: S&P 500 for the U.S., and TSE 300 for Canada.[18] We normalize stock indexes by CPIs, so our interpretation of changes in stock prices is in real terms. We measure the exchange rate as the Canadian dollar price of one U.S. dollar, so an increase in E corresponds to a depreciation of the Canadian dollar. We express all variables in natural logarithms, except the interest rates. Appendix A provides more details on our variables and data sources.

[16] Our short-run identification restrictions for the money market, monetary policy, and external demand blocks of the baseline Canadian VAR model, and aggregate demand, aggregate supply, money market and oil price blocks of the U.S. VAR model are identical to those imposed by Kim and Roubini (2000) on *all* the non-U.S. G7 economies. Kim and Roubini (2000) also report that excluding oil prices from their Canadian VAR model had no qualitative impact on their results.

[17] We reserved the monthly observations from 1987 for lags. We have also used a longer sample from January 1982 to December 2003 and verified by a Chow test that, for the monetary policy reaction function and the stock price equations, there was indeed a structural change in January 1988 in both the Canadian and the U.S. data. We end the sample in 2004 to mitigate the influence of data revisions on the results.

[18] The TSE 300 Composite Index was renamed the S&P/TSX Composite Index on May 1, 2002.

4.2 Unit root tests and model selection

Both the baseline U.S. and Canadian VAR models (8) and (9) are over-identified. Therefore, we first estimate the lag coefficients in these models (in levels) by the ordinary least squares (OLS) method, and then estimate the free contemporaneous coefficients by the full-information maximum likelihood (FIML) method. Finally, we identify the structural shocks. The time-series data in our models are non-stationary and cointegrated. In this case, the OLS method delivers consistent estimates of the parameters. Indeed, the augmented Dickey-Fuller and Phillips-Perron tests indicate that a unit root cannot be rejected in all series except Canadian overnight interest rate and the federal funds rate. The cointegration tests also show that these variables are cointegrated.[19]

The Chow tests show that we cannot reject the hypothesis of structural change in the stock price equations starting from January 1996, which is the beginning of the run-up in the North American stock markets. We find that a dummy variable for the period from January 1996 to December 2002 is suitable for capturing the unusual behavior of the stock prices. The likelihood ratio tests show that this dummy variable matters for our VAR models. Thus, each equation in the VAR models contains a constant and a period-specific dummy variable. Accordingly, our interpretation of the response of stock prices to structural shocks is net of such structural breaks.

To select the lag length, we use the small-sample modified likelihood ratio test (Sims 1980). Based on these likelihood ratio tests, we include nine lags for the US model ($l = 9$), and six lags for the Canadian model ($l = 6$).[20]

[19]See, e.g., Hamilton (1994, pp. 454–460) on the superconsistency of OLS estimates, and on appropriateness of a VAR in levels relative to a VAR in first differences when there are cointegrating relationships (p. 652). For instance, most macroeconomic models imply a cointegrating relation between income and wealth (as proxied by stock prices here). In a cointegrated VAR model, first differencing leads to misspecification since it omits error correction mechanisms.

[20]We started with 12-month lags and shortened them progressively to 9-month, 6-month, 3-month and 1-month. The likelihood ratio tests support 9 lags for the U.S. model and 6 lags for the Canadian model at the 10% significance level. The values of the BIC for these specifications also confirm our choice of lags.

4.3 Impulse responses

4.3.1 The baseline U.S. model

Figure 1 displays the dynamic responses to structural shocks in the baseline U.S. model specified in equation (8). The intervals between the dashed lines are the 95% confidence intervals.[21] Column legends in the figure list types of structural shocks (*USAS, USAD, USMME, USMP, USPORT,* and *OP*), and row legends show macroeconomic variables (*USY, USP*, *USM*2, *USR, USSP*, and *OP*) that respond to these structural shocks. Individual graphs show the time path of a macroeconomic variable in reaction to a specific structural shock.

In the monetary business cycle literature the responses of output, prices, and monetary aggregates to monetary policy shocks have been extensively studied. Our estimation results show that the dynamic responses to a contractionary monetary policy shock (*USMP*) in our baseline U.S. model are consistent with those familiar estimates.[22] In particular, an unexpected increase in the federal funds rate leads to a sharp and persistent drop in M2, a gradual, but highly significant and persistent drop in real output, and a relatively sluggish decline in the price level. At the same time, the nominal interest rate remains above its pre-shock level for about a year. The combination of falling real output and rising interest rates lead to a drop in stock prices, which remain below their pre-shock levels for about two years. We will discuss the magnitude and economic significance of the estimated impact of monetary policy shocks on stock prices in more detail below. Here it suffices to note that qualitatively our estimates are remarkably similar to those estimated in the earlier literature, some of which use complementary methodologies (e.g., Rigobon and Sack 2004).

In addition to monetary policy shocks, both portfolio and oil price shocks have significant impact on the stock prices in the U.S. A portfolio shock (*USPORT*), which we interpret as an unanticipated decrease in the equity risk premium, has a large and persistent positive impact on the U.S. stock prices. An oil price shock (*OP*), on the other

[21] These confidence intervals are computed by the importance sampling Bayesian Monte Carlo method suggested by Sims and Zha (1999). The estimation is done by the RATS routine "`montezha.prg`."

[22] We implement a contractionary monetary policy shock by a positive one standard deviation innovation in the monetary policy reaction function in equation (3).

hand, has an immediate negative impact on stock prices in the U.S.

The econometric estimates of our VAR model are economically plausible in several other dimensions. Consider, for instance, the estimated dynamic responses to structural aggregate supply ($USAS$) and demand shocks ($USAD$). A positive supply shock tends to have no significant short- or medium-term effect on the price level. However, a positive supply shock has a significant impact on the interest rate in the short run, and on M2 in the medium to long run. Stock prices respond positively to rising real output, with stock prices peaking two years after the shock. On the other hand, a shock to aggregate demand leads to a significant and persistent increase in the price level. Upon impact, the short-term interest rate also rises, perhaps in part due to the endogenous response of the monetary authority to rising prices. This leads to a short-lived decline in real output. Stock prices respond negatively in the short-run to rising prices, rising interest rates and falling real output. Overall, then our results are consistent with the view that stock prices in the U.S. rise in response to a positive productivity shock, are negatively correlated with inflation, and fall in response to an unanticipated increase the federal funds rate and oil prices.[23]

4.3.2 The baseline Canadian model

Figure 2 shows the estimated impulse responses to structural shocks of the baseline Canadian model specified in equation (9). Again, since it has received considerable attention in the existing literature, we start our discussion with the responses of model variables to a contractionary monetary policy shock ($CAMP$), which increases the overnight interest rate (CAR). In response to a contractionary monetary policy shock in Canada, the monetary aggregate ($CAM2$) falls immediately, and real output falls in the short and medium run. Consistent with the uncovered interest parity condition, an unexpected increase in the Canadian short-term interest rate corresponds to an expected depreciation

[23]Several other aspects of the model are broadly consistent with a range of monetary business cycle models, and worth mentioning—although they are not the primary focus of this paper. For instance, real output (USY) responds positively to a portfolio shock ($USPORT$), or an unanticipated decrease in the equity risk premium. Also, shocks to money market equilibrium ($USMME$) have a statistically insignificant and economically small immediate impact on real output (USY), but they exert a statistically significant and immediate impact on the short-term interest rate (USR). The responses of the model variables to oil price shocks (OP) are also economically plausible.

of the exchange rate (+ is a depreciation).[24] In addition, in response to a contractionary monetary policy shock ($CAMP$) Canadian stock prices ($CASP$) fall immediately, but the impact is economically small, and the dynamic impact is not highly persistent. Our results also show that shocks to the Canadian overnight interest rate have no statistically significant impact on the U.S. federal funds rate. By contrast, and consistent with our conceptualization of macroeconomic interdependence, a contractionary monetary policy change in the U.S. ($USMP$) leads to a higher nominal interest rate in Canada, has a significant impact on Canadian real output in all horizons, except the short run, and leads to an *expected* appreciation of the Canadian dollar—which is again consistent with the uncovered interest parity condition.

Our findings further identify several major structural shocks that have significant influences on the Canadian stock prices. An unexpected positive shock to Canadian aggregate supply ($CAAS$) raises stock prices in the short run, whereas an aggregate demand ($CAAD$) shock has the opposite immediate effect. Positive portfolio shocks ($CAPORT$), which we interpret as unanticipated reductions in the equity risk premium, raise stock prices substantially, contractionary U.S. monetary policy shocks ($USMP$) dip Canadian stock prices briefly, but raise them in the medium term. An external trade shock ($CATR$) leads to an unexpected depreciation of the Canadian dollar, which in turn may reflect a decline in rest-of-the-world demand for Canadian goods. The impact of this shock on Canadian stock prices is relatively muted. Overall, these findings suggest that financial market openness plays a substantial role for Canadian stock prices, whereas the external demand shocks appear to be somewhat less significant, partly reflecting the fact that the adjustments in the nominal exchange rate cushion part of the adverse consequences of shifts in the demand for Canadian goods.

As further evidence on the economically plausible estimates that emerge from the baseline Canadian VAR model, we refer the reader to the estimated dynamic responses to structural aggregate supply ($CAAS$) and demand shocks ($CAAD$). Qualitatively, the responses of Canadian price level, M2, and the short-term interest rate to Canadian

[24] Our results do not show a statistically significant impact of a contractionary monetary policy on the CPI. This finding is common in the literature, and it should be viewed in relation to the overall empirical performance of our VAR model.

aggregate supply and demand shocks are remarkably similar to their U.S. counterparts.[25]

4.4 Comparative analysis of stock prices

Our estimates of dynamic responses to structural shocks for the U.S. and Canada suggest that individual impacts of aggregate supply, aggregate demand, monetary policy and portfolio shocks on stock prices is relatively short lived in Canada. Here we provide a comparative analysis of the responses of Canadian and U.S. stock prices to contractionary monetary policy shocks.

Our results, summarized in Figure 3, show that a contractionary monetary policy shock leads, upon impact, to a fall in stock prices in both the U.S. and Canada. Note, however, that stock prices in the U.S. (solid line) fall substantially more than the Canadian stock prices (dotted line) do in the medium and long term. Figure 3 also shows the time horizon within which the estimated dynamic responses are statistically different from zero. After a contractionary policy shock in Canada, the trough of the fall in Canadian stock prices occurs within four months and the dynamic impact lasts for about the first 12 months after the shock. Whereas in the U.S., the decline in stock prices prevails for at least 37 months, and the through of the decline does not occur until 17 months after the shock.

Also, the impact of Canadian monetary shocks on stock prices is milder than that of the U.S. ones: an unanticipated 25 basis points increase in the U.S. federal funds rate leads to an immediate (within the first month) decline in the real U.S. stock prices by 0.55 percent, whereas an unanticipated 25 basis points increase in the Canadian overnight interest rate leads to a negligible 0.003 percent immediate decrease in Canadian stock prices. The peak responses of stock prices to monetary policy shocks are also remarkably different. In response to a contractionary domestic monetary policy shock, stock prices in the U.S. decline by about 4 percent within seventeen months after the shock, while Canadian stock prices only decline by about 0.8 percent within four months after the shock. Note also

[25] One noticeable difference between the U.S. and Canadian results is that in Canada an increase in the velocity of money (a positive shock to the money equilibrium) leads to a decline in the price level, whereas in the U.S. a similar shock leads to an increase in the price level. However, an important similarity is the positive dynamic response of real output to one-time permanent portfolio shocks, even after controlling for the changes in the money market equilibrium. This suggests the usefulness of augmenting the conventional models with stock prices, which control for wealth effects. Another difference is the responses of real output to aggregate demand shocks.

that by the time U.S. prices reach their trough, the Canadian stock prices would have recovered most of their initial losses, and stand at merely 0.42 percent less than their pre-shock level.

What accounts for the finding that the response of stock prices to monetary policy shocks has a shorter duration in Canada relative to that of the U.S.? Although these differences appear in estimated dynamic responses of domestic short-term interest rates to monetary policy shocks both in Canada and the U.S, they ultimately can be traced to structural differences between the two economies. In particular, macroeconomic interdependence and financial market openness has several noticeable implications. First, in Canada, the interest rate response is rapid but not very persistent, whereas in the U.S. the response is prolonged. The latter imparts considerable persistence to decline in asset prices in the U.S., which is absent in the Canadian data.

Furthermore, upon a contractionary domestic monetary policy shock, the Canadian dollar appreciates (although slightly) as shown figure 2. Yet, this unanticipated increase in the short-term Canadian interest rate leads to an *expected* depreciation of the Canadian dollar in the medium-to-long horizon. This would in turn lead to an expected increase in the foreign demand for Canadian goods. In other words, a monetary tightening in Canada reduces demand for Canadian goods upon impact, but over time the responses of the exchange rate and foreign demand jointly mitigate the initial response, which simultaneously increase valuations in the stock market. This *dynamic* adjustment mechanism in the Canadian economy under a floating exchange rate regime is quite prominent. Moreover, a contractionary monetary policy in the U.S. leads to a rise in the Canadian short-term interest rate (in the short and medium term), a decline in real output (medium term), and an immediate decline in Canadian stock prices (figure 2).

Overall, the results suggest that trade and financial market openness are important for the transmission and duration of domestic monetary policy shocks in Canada, and in a dynamic sense, they help mitigate the initial impact of these shocks on stock prices. In the next section, we discuss the main sources of volatility in the Canadian and U.S. stock prices, and whether these also differ across these two economies.

4.5 Variance decompositions

Table 1 reports the forecast error variance decomposition of stock prices in the baseline U.S. model, together with two alternative models (alternative U.S. models 1 and 2, which we will discuss in the next section). The column legends specify the forecast horizon (months ahead), standard errors, and percentage of variance attributable various structural shocks. The row legends specify the forecast horizon. The standard errors are listed with corresponding forecast horizons. Each row shows the percentage distribution of the forecast error variance attributable to a structural shock given a forecast horizon.

In the baseline U.S. model (table 1, panel (a)), the contribution of monetary policy shocks ($USMP$) to the variance of stock prices is about 6% for the first month, but it declines to about 2% after the 24-month horizon. The major driving force of the variance of stock prices for both short and long horizons is the portfolio shock ($USPORT$), which accounts for about 86% of the variance within the first month and declines monotonically with the time horizon to about 40% by the 48-month. At the 3- to 6-month forecast horizons money market shocks ($USMME$) and oil price shocks (OP) each account for about 10% of the forecast error variance. Beyond a two year horizon the combined influences of aggregate supply ($USAS$) and demand shocks ($USAD$), and money market equilibrium shocks become gradually more important than the portfolio shocks.

Table 2, panel (a) reports the forecast error variance decomposition of stock prices in the baseline Canadian model. Overall, the contribution of monetary policy shocks ($CAMP$) to the variance of stock prices is small and never above 6% for all the horizons. The portfolio shocks in Canada contribute a (large) 85% share of variance of stock prices in the one-month ahead forecasts, but this share declines gradually to about 33 percent by the end of the 4-year horizon. Aggregate supply shocks ($CAAS$) and aggregate demand shocks ($CAAD$) contribute to the variance of stock prices in the medium and long run. These contributions are very comparable to those in the U.S. model. Trade shocks ($CATR$) have an immediate but limited impact (not beyond 4%) on the variance of stock prices. Their impact on long-horizon forecasts is economically negligible. Also, U.S. monetary policy shocks ($USMP$) have a delayed but substantial impact (as high as 16%) on the variance of the Canadian stock prices.

Figure 4 shows the proportion of the forecast error variance attributable to monetary policy shocks both in Canada and the U.S. over different time horizons. In the short run, a relatively larger proportion of the variance of stock prices is attributable to monetary policy shocks in the U.S., and the proportion falls rapidly over time and then gradually rises. In the baseline Canadian model, the proportion of forecast error variance of stock prices is much lower initially but rises (non-monotonically) over time. In both economies, however, the contribution of monetary policy shocks to forecast error variance of stock prices is typically relatively small (under 6%) at all horizons.

5 Sensitivity analysis

In structural VAR analysis, there are often alternative economically plausible short-run restrictions. The structural VAR model we specified is no exception. We thus examined the sensitivity of our results to a battery of alternative identification restrictions and specifications. In the interest of space, here we discuss two alternative specifications for the monetary policy reaction function.[26]

5.1 The U.S. model

In the baseline U.S. model ("US-B"), the Fed's reaction function depends on the current values of M2, and the lagged values of all the remaining variables included in the system. Since both real output and monetary aggregates have first order effects on the direction of monetary policy, an alternative to the baseline model is to augment this reaction function by including the contemporaneous values of real output. We label this first alternative as "US-AR1." Given the significance of the oil price for the price level in the U.S. (figure 1), another alternative is to augment the reaction function in the baseline model with the

[26]We also extended the baseline models by incorporating the producer price index for intermediate goods into the U.S. model, and an index of commodity prices into the Canadian model, while excluding the federal funds rate (*USR*). Statistical model selection criteria—AIC/BIC and likelihood ratio tests—suggest that the baseline Canadian model with the U.S. federal fund rate is better than the alternative Canadian model with the commodity price index. The same criteria suggest the alternative U.S. model with the producer price index has lower AIC/BIC values but a higher log-likelihood function value than the baseline U.S. model without the producer price index. Moreover, the baseline U.S. model has impulse-response results that are broadly consistent with the predictions of conventional macroeconomic theories.

contemporaneous value of the oil price. We label this second alternative as "US-AR2." These short-run restrictions are summarized in table 3.

Figure 5 (upper panel) presents the results of the dynamic responses of stock prices in the structural VAR models for the U.S. with three specifications for the Fed's reaction function (US-B, US-AR1, and US-AR2). The figure also shows the time horizons in which the estimated impulse responses are statistically significant (boxes for US-B SG, US-AR1 SG, and US-AR2 SG). As can be seen from figure 5, stock prices respond similarly to a contractionary monetary policy shock in all three U.S. models—although ranges of significant responses vary slightly: with US-B SG being the largest range, and US-AR1 SG being the smallest. The forecast error decompositions are also broadly consistent across the U.S. models (see table 1, panels a–c).

Overall, while including current output in Fed's reaction function renders the response of stock prices to a monetary policy shock noisier, and including current oil price increases the sharpness of our inference, these models provide a consistent picture of (i) the dynamic negative and significant response of stock prices to a contractionary monetary policy shock in the U.S., and (ii) forecast error variance decompositions in which the contribution of monetary policy shocks are relatively small for short-horizon forecasts, and declines (non-monotonically) as the forecast horizon increases.

5.2 The Canadian model

In the baseline Canadian model ("CA-B"), the Bank of Canada's reaction function depends on the contemporaneous values of M2 and the exchange rate, and the lagged values of all the variables included in the system. As an alternative, we augment this reaction function by including the current values of real output, and label this alternative as "CA-AR1". Given the volatility in the exchange rate market, it is possible that Bank of Canada may exercise caution in responding to changes in the bilateral exchange rate and may respond with a lag. Thus, the second alternative to the baseline specification ("CA-AR2") only incorporates the contemporaneous values of M2 and real output, as well as the lagged values of the variables in the VAR system. These short-run restrictions are summarized in table 4.

Figure 5 (lower panel) shows the results of the dynamic responses of stock prices in the structural VAR models for the Canadian VAR with three specifications for the Bank's reaction function (CA-B, CA-AR1, and CA-AR2), as well as the time horizons in which the estimated impulse responses are statistically significant (boxes for CA-B SG, CA-AR1 SG, and CA-AR2 SG). The results suggest that the response of stock prices to a contractionary monetary policy shock is quantitatively similar across the three Canadian models—although the ranges of statistically significant responses vary slightly.

The forecast error decompositions of stock prices are also broadly consistent across the three models (table 2).[27] The contribution of the U.S. monetary policy shocks (*USMP* in table 2) to the forecast error decomposition of Canadian stock prices is also robust to the short-run restrictions imposed on the Bank's reaction function. In all three specifications, this contribution is relatively small in horizons under 6 months, but increases to about 15 percent for 12-month horizons and beyond. This sensitivity of domestic asset prices, in particular, and wealth, in general, in Canada to U.S. monetary policy shocks underscores the appropriateness of our emphasis on macroeconomic interdependence for modeling small open economies.

In summary, our estimates of the dynamic responses of stock prices to monetary policy shocks from the baseline Canadian and U.S. models are robust to alternative (and economically plausible) specifications of the central banks' reaction functions. And, we find that there are indeed economically meaningful, and significant differences between the Canadian and U.S. dynamic responses. The peak response in Canada occurs relatively fast (within a quarter), and the statistically significant impact of a domestic contractionary monetary policy shock on stock prices disappears after about a year. By contrast, in the U.S. the peak response occurs much later (after about 6 quarters) and the statistically significant response is much more prolonged (about 2.5 to 3 years). Quantitatively, the peak response of stock prices to domestic monetary policy shocks are significantly

[27]There are, however, two significant differences worth mentioning. When contemporaneous values of real output are included in the Bank's reaction function, the contribution of monetary policy shocks to stock price uncertainty in long horizons *increases*, and this largely comes at the expense of the contribution of aggregate demand shocks. Excluding the contemporaneous values of bilateral exchange rate from the Bank's reaction function, while maintaining the current values of real output, on the other hand, *reduces* the contribution of monetary policy shocks to stock price forecast variance, and increases that of money market equilibrium shocks.

stronger in the U.S. In both economies portfolio shocks have significant dynamic impacts on real output suggesting that the inclusion of stock prices in a VAR model has economically important implications for aggregate demand. Furthermore, in both stock markets, portfolio shocks are the dominant sources of forecast error decomposition of stock prices, especially in the short horizons. The preponderance of such shocks, we think, present significant practical challenges for those proposals that recommend using monetary policy to influence asset price "misalignments."

6 Conclusion

In this study, we evaluated the economic significance of the stock prices in the transmission of domestic monetary policy shocks in Canada and the U.S. by incorporating stock prices into empirical monetary business-cycle models featuring open and closed economies, respectively. We relied on macroeconomic theories to impose short-run restrictions on the structural VAR models and to identify impulse responses, which provide valuable economic insights. We found that in response to an unanticipated 25 basis points increase in the instrument interest rate, stock prices in the U.S. decline by about 4 percent within seventeen months after the shock, and in Canada they only decline by about 0.8 percent within merely four months after the shock. These differences are largely attributable to the different dynamic responses of domestic short-term interest rates to monetary policy shocks. In Canada, the interest rate response is rapid, but not very persistent, whereas in the U.S. the response is prolonged.

We also paid particular attention to the differences in macroeconomic interdependence between these two economies, especially through external demand and monetary policy shocks. We found that monetary policy shocks in the U.S. have significant impact on the Canadian stock prices and contribute substantially to their variance. We also found that the contribution of external demand shocks to Canadian stock price variance is very small, suggesting that the flexible exchange rate acts as an important automatic stabilizer for the Canadian stock prices.

Our results, therefore, suggest that incorporating wealth effects into empirical open economy monetary-business cycle models is important in understanding the transmission of monetary policy shocks. We did not, however, distinguish between foreign and domestic currency denominated asset holdings of domestic residents. We also did not include shocks to real estate. Incorporating these refinements, and examining whether they have substantive influence on our findings from VAR models with short-run restrictions are left for future research.

A Data description and sources

All Canadian data are from CANSIMII.

- Industrial production (CAY): table 379-0019 series v2036138, GDP at basic prices, seasonally adjusted, 1997 constant dollars, all industries.
- Consumer price index (CAP): table 326-0001 series v735319, seasonally adjusted, 1996 basket, all items.
- Overnight interest rate (CAR): table 176-0043 series v122514.
- M2: ($CAM2$) table 176-0025 series v37128, seasonally adjusted, in millions.
- Stock prices ($CASP$): table 176-0047 series v122620, S&P TSE (300) composite index, close price.
- Exchange rate (E): table 176-0064 series v37426, U.S. dollar in Canadian units.

All U.S. data are also from CANSIMII, unless otherwise stated.

- Industrial production index (USY): table 451-0019 series v19650248, seasonally adjusted, 1997=100.
- Consumer price index (USP): table 451-0009 series v11123, seasonally adjusted, 1996 basket, all items.
- Federal funds rate (USR): table 176-0044 series v122150.
- M2: ($USM2$) table 451-0007 series v122446, seasonally adjusted, in millions.
- Stock prices ($USSP$): Standard & Poor's composite index. From Robert Shiller's webpage accessed at `http://www.econ.yale.edu/~shiller/`.
- Oil price (OP): crude oil price index, 1995=100, the average of three spot prices-Dated Brent, West Texas Intermediate, and Dubai Fateh. From International Financial Statistics.

We normalize stock indexes by consumer price indexes, so our interpretation of stock prices is in real terms. We measure the exchange rate as the Canadian dollar price of one U.S. dollar, so an increase in E corresponds to a depreciation of the Canadian dollar. In our empirical analysis, we express all variables in natural logarithms, except the interest rates (CAR and USR). Table A.1 reports summary statistics of the data used in the analysis.

References

Armour, J., Fung, B., and Maclean, D. (2002). Taylor rules in the quarterly projection model. Working Paper 2002-1, Bank of Canada.

Bank of Canada (1996). *The Transmission of Monetary Policy in Canada.* Bank of Canada.

Bank of Canada (2006). *Renewal of the Inflation-Control Target: Background Information.* Bank of Canada.

Bernanke, B.S. (1986). Alternative exploration of the money-income correlation. *Carnegie–Rochester Conference Series on Public Policy* 25: 49–99.

Bernanke, B.S., and Blinder, A. (1992). The federal funds rate and the channels of monetary transmission. *American Economic Review* 82: 901–921.

Bernanke, B.S., and Mihov, I. (1998). Measuring monetary policy. *Quarterly Journal of Economics* 113: 869–902.

Bernanke, B.S., and Gertler, M. (2001). Should central banks respond to movements in asset prices? *American Economic Review Papers and Proceedings* 91: 253–257.

Bernanke, B.S., and Kuttner, K.N. (2005). What explains the stock market's reaction to Federal Reserve policy? *Journal of Finance* 60: 1221–1257.

Blanchard, O.J., and Quah, D. (1989). The dynamic effects of aggregate demand and supply disturbances. *American Economic Review* 79: 655–673.

Christiano, L.J., Eichenbaum, M. and Evans, C.L. (1996). The effects of monetary policy shocks: evidence from the flow of funds. *Review of Economics and Statistics* 78: 16–34.

Christiano, L.J., Eichenbaum, M. and Evans, C.L. (1999). Monetary policy shocks: what have we learned and to what end? In Taylor, J.B., and Woodford, M. *Handbook of Macroeconomics*, vol. 1A: 65–148. New York, and Oxford: Elsevier.

Christiano, L.J., Eichenbaum, M. and Vigfusson, R. (2006). Assessing structural VARs, NBER Working Papers 12353.

Corallo, E. (2006). The effect of monetary policy on asset prices: evidence from Germany and U.K. Cattaneo University (LIUC) Papers in Economics No. 185.

Cushman, D.O. and Zha, T. (1997). Identifying monetary policy in a small open economy under flexible exchange rates. *Journal of Monetary Economics* 39: 433–448.

Dufour, J-M. and Tessier, D. (2006). Short-run and long-run causality between monetary policy variables and stock prices. Bank of Canada Working Paper No. 2006-39.

Faust, J. and Leeper, E. (1997). When do long-run identifying restrictions give reliable results? *Journal of Business and Economic Statistics* 15: 345–353.

Geithner, T.F. (2006). Remarks at the New York Association for Business Economics in New York City, 11 January 2006, accessed at http://www.newyorkfed.org/newsevents/speeches/2006/gei060111.html.

Hamilton, J.D. (1994). *Time Series Analysis.* Princeton University Press, Princeton, New Jersey.

Hamilton, J.D., and Herrera, A.M. (2004). Oil shocks and aggregate macroeconomic behavior: the role of monetary policy. *Journal of Money, Credit, and Banking* 36: 265–286.

Hördahl, P., and Packer, F. (2007). Understanding asset prices: an overview. Bank for International Settlements Papers No. 34.

Jiménez-Rodriguez, R., and Sánchez, M. (2004). Oil price shocks and real GDP growth: empirical evidence from some OECD countries. Working Paper Series No. 326, European Central Bank.

Judd, J.P., and Rudebusch, G. D. (1998). Taylor's rule and the Fed, 1970-1997. *Economic Review (Federal Reserve Bank of San Francisco)* No. 3, 1998: 3–16.

Kearney, A.A. (1996). The effect of changing monetary policy regimes on stock prices. *Journal of Macroeconomics* 18: 429–447.

Kim, S. and Roubini, N. (2000). Exchange rate anomalies in industrial countries: a solution with a structural VAR approach. *Journal of Monetary Economics* 45: 561–586.

Murchison, S. , and Rennison, A. (2006). ToTEM: the Bank of Canada's new quarterly projection model. Bank of Canada Technical Report No. 97.

Lastrapes, W.D. (1998). International evidence on equity prices, interest rates and money. *Journal of International Money and Finance* 17: 372–406.

Lettau, M., and Ludvigson, S. (2004) Understanding trend and cycle in asset values: reevaluating the wealth effect on consumption. *American Economic Review* 94: 276–299.

Ong, J. (2006). A new effective exchange rate index for the Canadian dollar. *Bank of Canada Review* Autumn 2006: 1–6.

Park, K., and Ratti, R.A. (2000). Real activity, inflation, stock returns, and monetary policy. *The Financial Review* 35 (2): 59–78.

Patelis, A.D. (1997). Stock return predictability and the role of monetary policy. *Journal of Finance* 52: 1951–1972.

Pichette, L. (2004). Are wealth effects important in Canada? *Bank of Canada Review* Spring: 29–35.

Poterba, J.M. (2000). Stock market wealth and consumption. *Journal of Economic Perspectives* 14: 99–118.

Rigobon, R., and Sack, B. (2004). The impact of monetary policy on asset prices. *Journal of Monetary Economics* 51: 1553–1575.

Roubini N. (2006). Why central banks should burst bubbles. Mimeo, Stern School of Business, NYU.

Shiller, R.J. (2000). *Irrational Exuberance.* Princeton University Press, Princeton, New Jersey.

Siklos, P.L., and Anusiewicz, J. (1998). The effect of Canadian and U.S. M1 announcements on Canadian financial markets: the Crow years. *Journal of Business and Economics* 50: 49–66.

Sims, C.A. (1980). Macroeconomics and reality. *Econometrica* 48: 1–48.
Sims, C.A. (1986). Are forecasting models usable for policy analysis? *Quarterly Review of the Federal Reserve Bank of Minneapolis* 10: 2–16.
Sims, C.A. (1992). Interpreting the macroeconomic time series facts: the effects of monetary policy. *European Economic Review* 36: 975–1000.
Sims, C.A., and Zha, T. (1998). Does monetary policy generate recessions? Working Paper 98-12, Federal Reserve Bank of Atlanta.
Sims, C.A., and Zha, T. (1999). Error bands for impulse responses. *Econometrica* 67: 1113–1156.
Thiessen, G.G. (1995). Uncertainty and the transmission of monetary policy in Canada. The HERMES-Glendon Lecture, York University, Toronto 30 March 1995.
Thorbecke, W. (1997). On stock market returns and monetary policy. *Journal of Finance* 52: 635–654.
Wolff, E. (2006). Changes of household wealth in the 1980s and 1990s in the US. In Wolff, E. (ed.). *International Perspectives on Household Wealth.* Elgar.

Table 1: Real stock price forecast error decompositions, the U.S. models

Months ahead	Standard error	Percentage of variance attributable to the shock					
		USAS	USAD	USMME	USMP	USPORT	OP
		a) Baseline US Model					
1	0.027	1.058	1.887	3.362	6.220	85.560	1.913
3	0.052	2.268	2.810	8.391	4.754	71.221	10.556
6	0.068	1.520	7.089	9.549	3.478	68.039	10.325
12	0.097	2.441	13.811	16.247	1.749	60.066	5.685
24	0.132	13.890	14.814	15.562	1.853	49.631	4.251
36	0.146	24.665	13.400	14.055	2.884	41.473	3.523
48	0.150	26.541	12.916	13.885	3.139	40.008	3.511
		b) Alternative US Model 1					
1	0.027	0.959	1.915	3.418	6.185	85.618	1.905
3	0.052	2.146	2.851	8.466	4.708	71.273	10.556
6	0.068	1.435	7.148	9.610	3.436	68.049	10.322
12	0.097	2.399	13.894	16.272	1.724	60.029	5.682
24	0.132	13.745	14.908	15.567	1.858	49.664	4.259
36	0.146	24.424	13.503	14.067	2.904	41.566	3.536
48	0.150	26.285	13.018	13.898	3.163	40.112	3.524
		c) Alternative US Model 2					
1	0.027	1.086	2.183	4.022	5.695	85.848	1.165
3	0.052	2.305	3.269	9.271	4.154	71.724	9.277
6	0.068	1.536	7.733	10.257	2.970	68.214	9.290
12	0.098	2.446	14.706	16.504	1.470	59.677	5.197
24	0.132	13.845	15.541	15.303	1.875	49.137	4.299
36	0.147	24.583	14.020	13.653	2.988	41.081	3.675
48	0.151	26.482	13.510	13.454	3.270	39.671	3.613

NOTES: Numbers may not add to 100 due to rounding. See Sections 3.2 and 5, and Tables 3 and 4 for model specifications and identifying restrictions.

Table 2: Real stock price forecast error decompositions, the Canadian models

Months ahead	Standard error	Percentage of variance attributable to the shock						
		CAAS	CAAD	CAMME	CAMP	CAPORT	CATR	USMP
		a) Baseline Canadian Model						
1	0.037	4.376	0.628	0.490	2.621	85.395	4.490	1.999
3	0.061	8.320	0.408	4.636	4.518	77.676	3.623	0.820
6	0.079	14.781	0.427	9.507	3.096	65.324	2.825	4.041
12	0.097	15.004	4.504	12.864	2.186	48.323	2.916	14.203
24	0.112	13.268	11.517	15.123	4.018	37.260	2.753	16.062
36	0.117	15.090	12.723	14.197	5.227	34.425	2.662	15.675
48	0.119	15.667	13.041	14.411	5.278	33.261	2.691	15.651
		b) Alternative Canadian Model 1						
1	0.037	4.654	7.452	0.550	0.008	84.882	0.115	2.339
3	0.061	8.884	9.145	0.804	1.282	77.222	1.700	0.963
6	0.079	15.304	7.902	1.507	4.918	65.087	1.385	3.897
12	0.096	15.819	7.165	2.943	8.483	49.247	3.738	12.606
24	0.110	14.172	5.891	7.901	13.408	38.613	6.106	13.909
36	0.115	16.074	6.243	9.603	12.804	35.529	5.979	13.767
48	0.117	16.639	6.577	10.167	12.683	34.241	5.856	13.838
		c) Alternative Canadian Model 2						
1	0.037	4.667	6.408	0.135	0.100	84.775	1.476	2.439
3	0.061	8.794	5.003	3.071	1.972	77.219	2.961	0.979
6	0.079	15.235	4.794	6.588	2.268	65.091	2.119	3.905
12	0.097	15.500	3.581	13.572	1.787	48.737	3.219	13.604
24	0.111	13.771	5.249	22.062	1.850	37.984	3.654	15.430
36	0.116	15.735	7.394	21.082	2.296	35.036	3.413	15.044
48	0.118	16.338	8.489	20.494	2.450	33.815	3.430	14.984

NOTES: Numbers may not add to 100 due to rounding. See Sections 3.2 and 5, and Tables 3 and 4 for model specifications and identifying restrictions.

Table 3: Summary of alternative identifying restrictions and models, U.S.

a) Restrictions on Fed's reaction function

Baseline	$R_t = a_{40} - a_{43}M2_t + f_4(y_{t-l}) + \nu_{USMP,t}$
Alternative 1	$R_t = a_{40} + a_{41}Y_t - a_{43}M2_t + f_4(y_{t-l}) + \nu_{USMP,t}$
Alternative 2	$R_t = a_{40} - a_{43}M2_t + a_{46}OP_t + f_4(y_{t-l}) + \nu_{USMP,t}$

b) Models

Baseline see equation (8)

Alternative 1

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & a_{16} \\ a_{21} & 1 & 0 & 0 & 0 & -a_{26} \\ -a_{31} & -1 & 1 & a_{34} & 0 & 0 \\ -a_{41} & 0 & a_{43} & 1 & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & a_{56} \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} u_{USY} \\ u_{USP} \\ u_{USM2} \\ u_{USR} \\ u_{USSP} \\ u_{OP} \end{bmatrix} = \begin{bmatrix} \nu_{USAS} \\ \nu_{USAD} \\ \nu_{USMME} \\ \nu_{USMP} \\ \nu_{USPORT} \\ \nu_{OP} \end{bmatrix}$$

Alternative 2

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & a_{16} \\ a_{21} & 1 & 0 & 0 & 0 & -a_{26} \\ -a_{31} & -1 & 1 & a_{34} & 0 & 0 \\ 0 & 0 & a_{43} & 1 & 0 & -a_{46} \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & a_{56} \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} u_{USY} \\ u_{USP} \\ u_{USM2} \\ u_{USR} \\ u_{USSP} \\ u_{OP} \end{bmatrix} = \begin{bmatrix} \nu_{USAS} \\ \nu_{USAD} \\ \nu_{USMME} \\ \nu_{USMP} \\ \nu_{USPORT} \\ \nu_{OP} \end{bmatrix}$$

Table 4: Summary of alternative identifying restrictions and models, Canada

a) Restrictions on the Bank's reaction function

Baseline	$R_t = a^*_{40} - a^*_{43}M2_t + a^*_{46}E_t + f^*_4(y_{t-l}) + \nu_{CAMP,t}$
Alternative 1	$R_t = a^*_{40} + a^*_{41}Y_t - a^*_{43}M2_t + a^*_{46}E_t + f^*_4(y_{t-l}) + \nu_{CAMP,t}$
Alternative 2	$R_t = a^*_{40} + a^*_{41}Y_t - a^*_{43}M2_t + f^*_4(y_{t-l}) + \nu_{CAMP,t}$

b) Models

Baseline see equation (9)

Alternative 1

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & a^*_{17} \\ a^*_{21} & 1 & 0 & 0 & 0 & -a^*_{26} & a^*_{27} \\ -a^*_{31} & -1 & 1 & a^*_{34} & 0 & 0 & 0 \\ -a^*_{41} & 0 & a^*_{43} & 1 & 0 & -a^*_{46} & 0 \\ a^*_{51} & a^*_{52} & a^*_{53} & a^*_{54} & 1 & a^*_{56} & a^*_{57} \\ a^*_{61} & a^*_{62} & a^*_{63} & a^*_{64} & 0 & 1 & a^*_{67} \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} u_{CAY} \\ u_{CAP} \\ u_{CAM2} \\ u_{CAR} \\ u_{CASP} \\ u_E \\ u_{USR} \end{bmatrix} = \begin{bmatrix} \nu_{CAAS} \\ \nu_{CAAD} \\ \nu_{CAMME} \\ \nu_{CAMP} \\ \nu_{CAPORT} \\ \nu_{CATR} \\ \nu_{USMP} \end{bmatrix}$$

Alternative 2

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & a^*_{17} \\ a^*_{21} & 1 & 0 & 0 & 0 & -a^*_{26} & a^*_{27} \\ -a^*_{31} & -1 & 1 & a^*_{34} & 0 & 0 & 0 \\ -a^*_{41} & 0 & a^*_{43} & 1 & 0 & 0 & 0 \\ a^*_{51} & a^*_{52} & a^*_{53} & a^*_{54} & 1 & a^*_{56} & a^*_{57} \\ a^*_{61} & a^*_{62} & a^*_{63} & a^*_{64} & 0 & 1 & a^*_{67} \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} u_{CAY} \\ u_{CAP} \\ u_{CAM2} \\ u_{CAR} \\ u_{CASP} \\ u_E \\ u_{USR} \end{bmatrix} = \begin{bmatrix} \nu_{CAAS} \\ \nu_{CAAD} \\ \nu_{CAMME} \\ \nu_{CAMP} \\ \nu_{CAPORT} \\ \nu_{CATR} \\ \nu_{USMP} \end{bmatrix}$$

Table A.1: Summary statistics, 1988:1–2003:12

	Variables	Mean	St. Dev.	Min.	Max.
Canada	CAY	13.5992	0.1345	13.4218	13.8428
	CAP	4.6476	0.0990	4.4188	4.8106
	CAM2	12.9663	0.1822	12.4992	13.2945
	CAR	0.0615	0.0309	0.0199	0.1380
	CASP	3.8927	0.2731	3.4833	4.5926
	E	0.2989	0.1024	0.1203	0.4702
U.S.	USY	4.5265	0.1604	4.3135	4.7570
	USP	4.6035	0.1306	4.3294	4.7999
	USM2	8.2786	0.2145	7.9559	8.7189
	USR	0.0507	0.0217	0.0098	0.0985
	USSP	1.8479	0.4279	1.1940	2.5725
	OP	3.0441	0.2434	2.4230	3.5813

NOTES: The number of observations is 192. Stock indexes are normalized by consumer price indexes. The exchange rate is the Canadian dollar price of one U.S. dollar. All variables are in natural logarithms, except the interest rates (CAR and USR). See also appendix A for detailed data descriptions and sources.

Figure 1. Dynamic responses to structural shocks in the baseline U.S. model with short-run restrictions as in equation (9) (intervals between the dashed lines correspond to two standard errors)

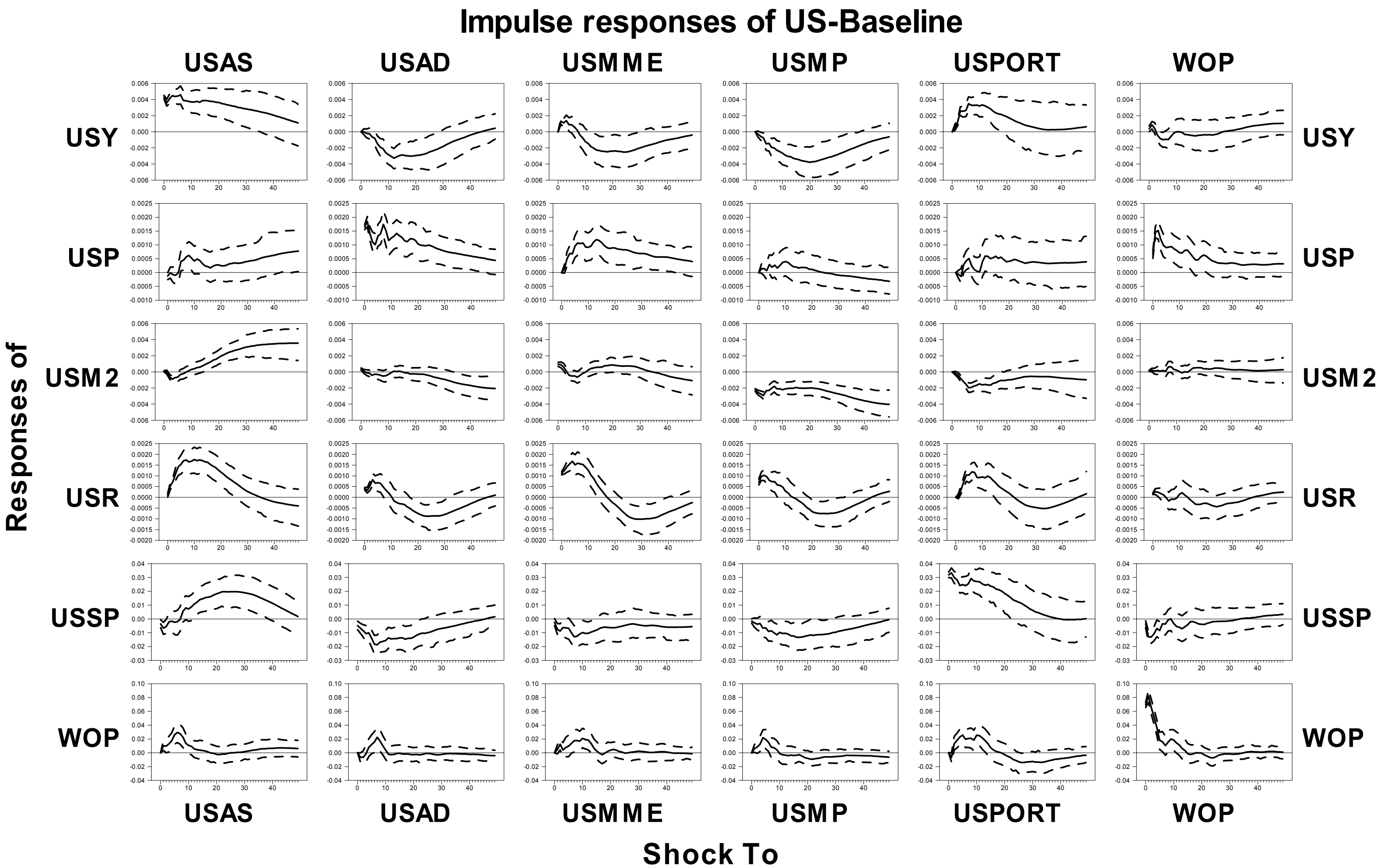


Figure 2. Dynamic responses to structural shocks in the baseline Canadian model with short-run restrictions as in equation (10) (intervals between the dashed lines correspond to two standard errors)

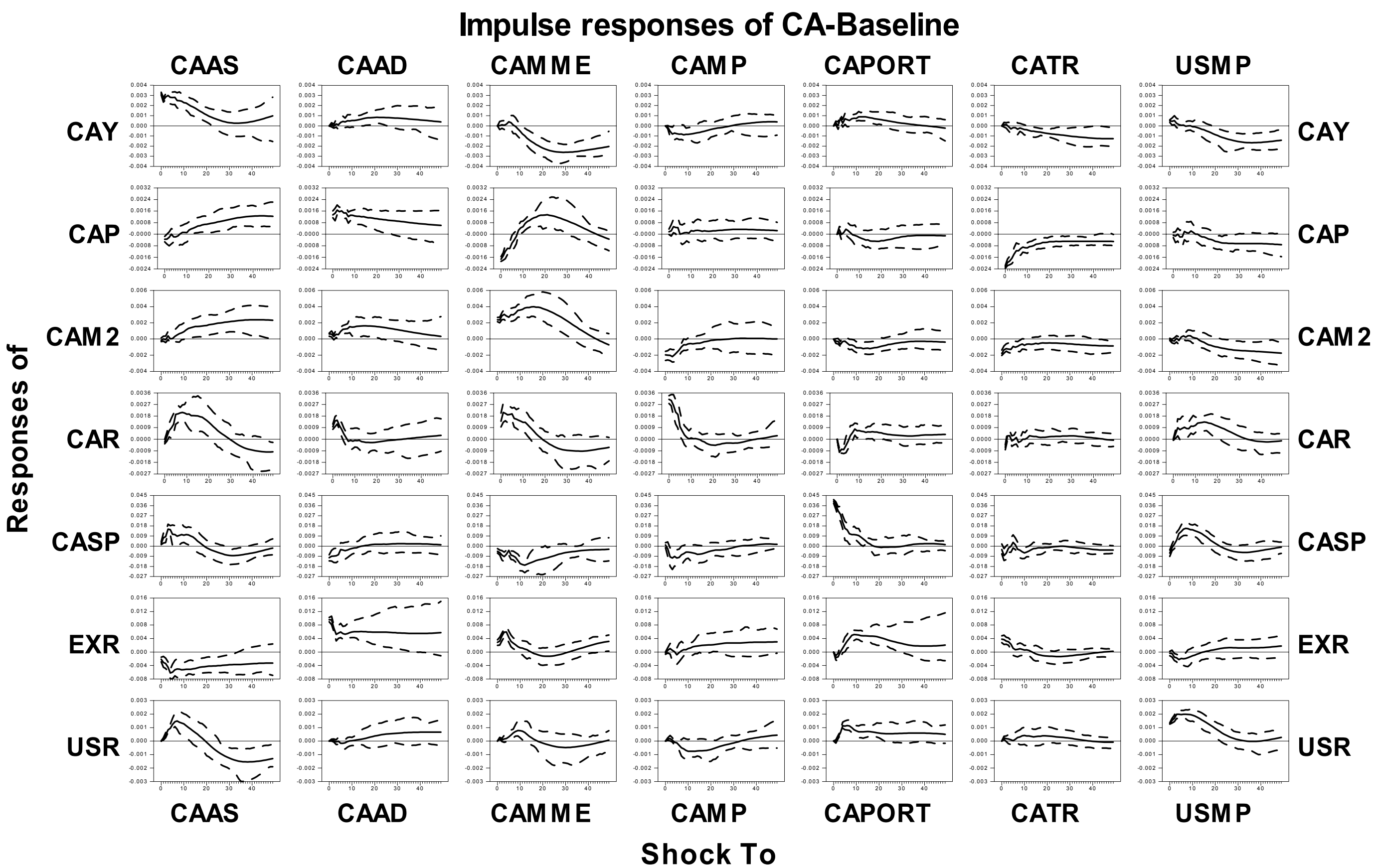
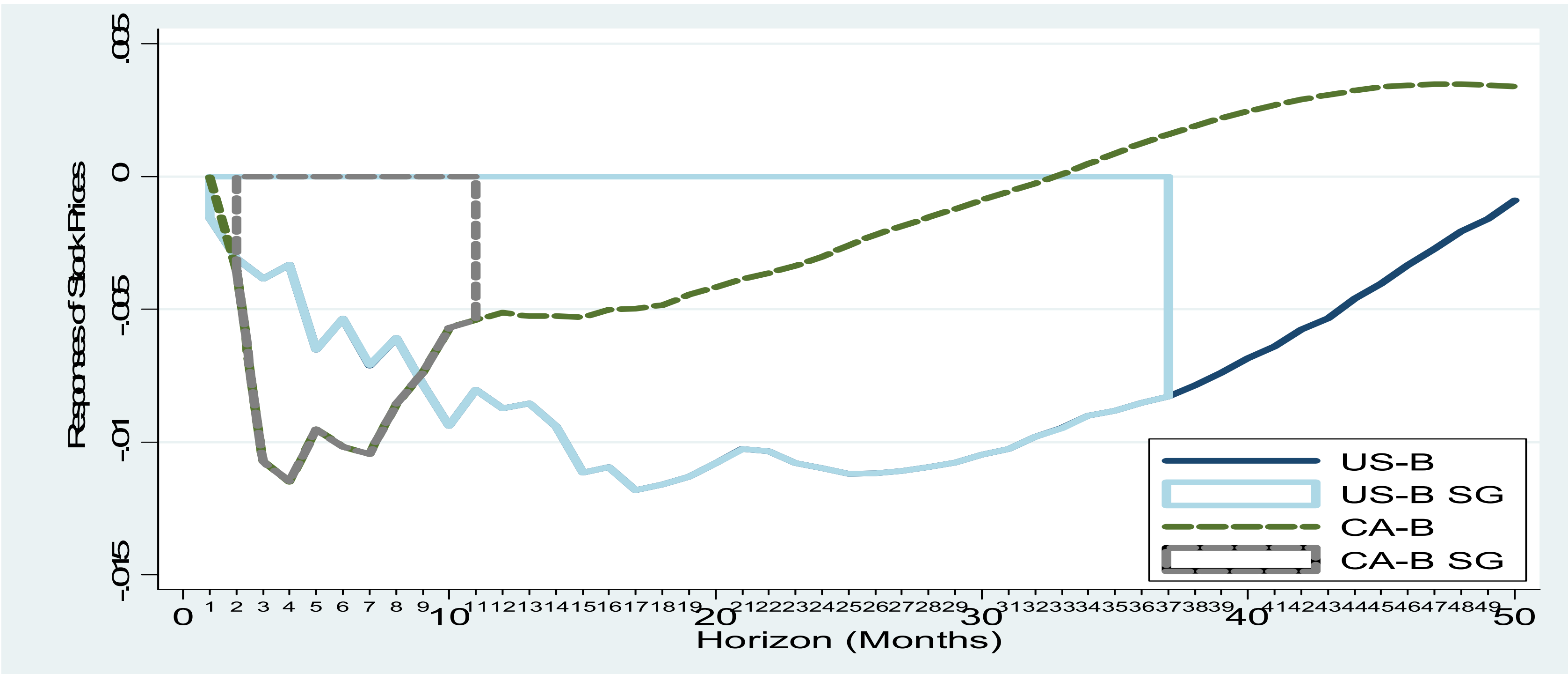


Figure 3. Dynamic responses of stock prices to a domestic monetary policy shock in the baseline U.S. and Canadian models



Note: US-B refers to US-baseline model; US-B SG refers to the horizons in which the response of stock prices is statistically significant from zero.

Figure 4: Forecast error variance decomposition of stock prices attributable to domestic monetary policy shocks in the baseline U.S. and Canadian models

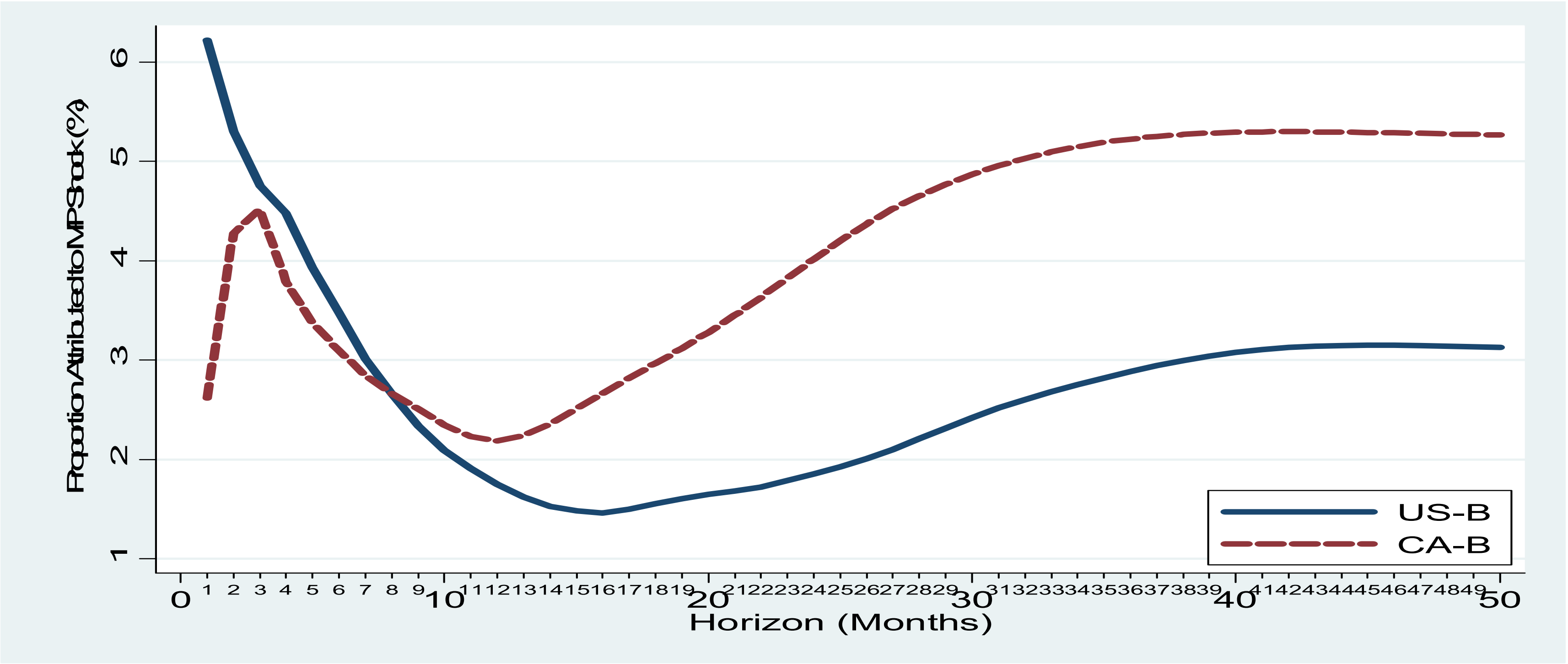


Figure 5: Comparison between dynamic responses of stock prices to a domestic monetary policy shock: comparison of U.S. and Canadian models