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

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Abstract

Using structural VAR models with short-run restrictions appropriate for Canada and the United States, we empirically examine whether trade and financial market openness 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 United States, the immediate response of stock prices to a similar shock is relatively large and the dynamic response is relatively prolonged. We find that these differences are largely driven by differences in financial market openness and hence different dynamic responses of monetary policy shocks 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

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1 Introduction

Stock markets are notoriously sensitive to unexpected 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 the U.S.).

There are several (related) reasons to hypothesize that in small open economies a contractionary domestic monetary policy shock would have a smaller negative influence on stock prices and that domestic monetary policy shocks have a relatively smaller contribution to overall stock price volatility. First, in small open economies domestic monetary policy takes the world interest rate as given, and as such has a relatively limited influence on the discount rate that matters for domestic stock prices. At the same time, shocks originating from the rest of the world have a larger impact on stock prices in small open economies. This is in part due to the fact that small open economies operate in international financial markets and unexpected (gross) capital inflows and outflows tend to be a larger share of their GDPs, and in part because small open economies tend to have less diversified economic structures than large and relatively-closed economies do.[1]

Second, in small open economies the exchange rate is an important component of propagation mechanisms, especially compared to in large economies. 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 influences the impact and transmission of *domestic* monetary policy shocks on domestic asset prices to the extent that monetary policy affects the exchange rate.[2]

Given the above considerations and the fact that Canada is a quintessential small open

[1]For instance, Johnson and Schembri (1990) and Souki (2008) find that shocks originating from the United States are more important in explaining fluctuations in Canadian macroeconomic variables than domestic shocks.

[2]A separate issue is whether monetary policy should target asset price volatility. In this regard, economists are still debating the pros and cons of interventions in 2008 by the U.S. Federal Reserve in order to stave off a financial crisis largely prompted by the collapse in housing prices. See, Bernanke and Gertler (2001), Geithner (2006), and Roubini (2006), for the 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.

economy, and the United States is a large and relatively-closed economy, in this paper we address two important and related empirical issues in the context of Canada and the United States: whether trade openness and financial market openness matter for the monetary policy shocks' *impact* on and *transmission* to stock prices.

Our empirical results based on the comparison between Canada and the United States suggest that indeed openness matters 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 United States, 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 financial market openness and hence different dynamic responses of monetary policy shocks between the two countries that we model in this paper.

Our findings underscore for Canada the relative importance of financial market openness for stock prices. We find that unanticipated changes in the U.S. federal funds rate significantly affect the forecast error variance of the Canadian stock prices. On the other hand, we find that the overall impact of external demand shocks on Canadian stock prices is relatively small. One interpretation of this finding is that the floating exchange rate regime provides a cushion for the real sector in Canada.

While monetary policy primarily influences aggregate demand, stock market wealth also serves as an important channel of the monetary transmission mechanism. Stock prices influence financial wealth, and hence affect consumption, investment and labor supply decisions (Poterba, 2000; Lettau and Ludvigson, 2004). Moreover, in both Canada and the United States, the share of financial assets in household wealth grew rapidly during the time period we examine in this paper.[3] 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.

[3] 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).

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 bond portfolio and domestic money holdings, one can write 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, 2000), 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 after taking into account the important interactions among main macroeconomic variables. To examine this interaction, we use structural vector autoregressive models (VARs), which impose restrictions on the contemporaneous ("short-run") effects of shocks upon certain variables included in the model (Bernanke 1986, and Sims 1986). 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) more plausible 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 structural VARs resolve a number of anomalies detected in the empirical small open economy recursive VAR models. Christiano, Eichenbaum, and Vigfusson (2006) argue that structural VARs with short-run restrictions yield remarkably sharp inference in the context of response analysis with structural shocks.[4]

The structural differences between Canada and the United States, and the macroeconomic dependence of the small open Canadian economy on the large and relatively-closed U.S. economy are the distinguishing features of our analysis. It is perhaps surprising that the existing literature has not fully explored how these differences affect 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 brief review of the literature on stock prices and monetary policy shocks, and discuss the relevant monetary policy instruments in Canada and the U.S. 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.

2 Background

2.1 Previous literature

VAR models are frequently used to investigate the relationship between the monetary policy and stock prices. Thorbecke (1997), Patelis (1997), and Park and Ratti (2000) use recursive VARs (Sims 1980) to identify the impact of monetary policy shocks on stock prices. Lastrapes (1998) uses structural VARs with long-run restrictions to identify the impact of monetary policy shocks on stock prices.

[4]By contrast, according to Faust and Leeper (1997), VAR models 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), do not necessarily lead to unique short-run dynamics.

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

There are also 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. By comparison, we find 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.

2.2 Monetary policy

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.

2.3 Trade and financial market openness

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 in-

[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.

fluence on the Canadian economy. Currently, the Canadian exports to the United States 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. There is also significant capital mobility between Canada and the United States. These considerations lead us to model the Canadian economy with appropriate channels for trade and financial openness.[8] Clearly, some of these channels are not essential for modeling the U.S. economy.

Aside from the difference in the degree of openness, in our analysis, the oil price also play different roles in the two countries: the United States 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.[9]

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 Canadian and U.S. economies.

[8] In quantitative real-business-cycle models, Canada is often modeled as a quintessential small open economy with strong links to the United States; e.g., Cardia (1991) and Smith-Grohé (1999). We think of capital mobility (i.e., no or limited capital controls, and domestic and foreign equity substitutability) as a determinant of financial market openness. Cushman and Zha (1997) report evidence in favor of the uncovered interest parity condition between Canada and the United States, which captures the main features of our conceptualization of capital mobility.

[9] Incidentally, Canada switched from being a net oil importer to a net oil exporter in 1988, which is the beginning of our sample period. As we discuss below, the oil price is not directly included in our baseline Canadian model. However, since the resource sector has a relatively larger share in the Canadian GDP, we indirectly control for the possible effects of commodity prices through the aggregate supply. Jiménez-Rodriguez and Sánchez (2004) discuss the differential influence of oil price shocks on the Canadian and U.S. economies. See Hamilton and Herrera (2004) for an assessment of the impact of oil price shocks on the U.S. economy.

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 control for (stock market driven) wealth effects.[10] The baseline Canadian VAR model, on the other hand, consists of real output, the price level, the money supply, the overnight interest rate, the U.S.-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,[11] plus stock prices, which are included to control for wealth effects. Our empirical model for Canada accommodates a range of open economy models with incomplete markets.[12]

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 expectation $\mathcal{E}(u_t) = 0$, and variance-covariance matrix $\mathcal{E}(u_t u_t^{'}) = \Sigma$. 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

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

[10]We model the United States as closed economy: the US-Canada bilateral nominal exchange is more relevant for the Canadian economy than for the U.S. economy.

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

[12]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 United States are an outcome of this model-search process. In particular, these statistical criteria selected the baseline open-economy Canadian model over alternative closed-economy models (results not reported). 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 (and we conduct these tests below). In section 5, we thus discuss the sensitivity of our results to alternative model specifications and identification restrictions.

where $A_l = A_0\beta_l$, $A_0 u_t = \nu_t$, and $\mathcal{E}(\nu_t \nu_t') = \Omega$. 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 macroeconomic 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 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.[13]

Specifically, for the United States, we have

$$R_t = a_{40} - a_{43}M2_t + f_4(y_{t-l}) + \nu_{USMP,t}, \tag{3}$$

and for Canada, we have

$$R_t = a^*_{40} - a^*_{43}M2_t + a^*_{46}E_t + f^*_4(y_{t-l}) + \nu_{CAMP,t}, \tag{4}$$

where $\nu_{USMP,t}$ is the U.S. monetary policy shock, and $\nu_{CAMP,t}$ is the monetary policy shock in Canada; f_i and f^*_i are the linear functions of lagged variables in the ith equation

[13] 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.

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 induced by changes in private agents' inflationary expectations, which are not necessarily directly linked to economic fundamentals. The third source is various technical factors, such as measurement error in the real time data available to 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[14]

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

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 balances depends on income and the opportunity cost of holding money, the nominal interest rate:

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

A *portfolio* shock (ν_{PORT}) represents an exogenous change in the demand for equities, which lead to portfolio imbalances. Stock markets aggregate all the publicly and privately available information, so stock prices 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 world 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. Equa-

[14] We add "US" to the subscript of each of the reduced-form and structural U.S. shocks.

tion (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. interest rate shocks.[15]

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 we augment the supply equation for Canada with the contemporaneous value of the U.S. federal funds rate. We use this variable as a control for the rate of return to international capital (see below equation (9), row 1).[16] 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 (9), row 5).

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 (9), row 2). 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.

[15] We add "CA" to the subscript of each of the reduced-form and structural Canadian shocks.

[16] For the distinction between global and country-specific shocks in open economy models, see Glick and Rogoff (1995). 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.

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_{TR} (see equation (9), row 6).[17] 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.[18]

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. interest rate* shocks, ν_{USR} (see equation (9), row 7). We should note that our specification allows both anticipated and unanticipated monetary policy changes in the U.S. to influence Canadian variables through both trade and financial market openness.[19]

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

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

[17] 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).

[18] 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.

[19] 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. We exclude oil prices from the baseline Canadian model because we have found that (i) inclusion of oil prices has a negligible impact on our variance decompositions, and (ii) our model selection criteria favor the baseline model over a model with oil (or commodity) prices (results available from the authors upon request). Kim and Roubini (2000) also report that excluding oil prices from their Canadian VAR model has no qualitative impact on their results.

4 Empirical analysis

4.1 Data

The data are monthly and cover the period from January 1988 to December 2003.[20] We measure real output by the 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 United States, and TSE 300 for Canada.[21] 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.

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.[22]

The Chow tests show that we cannot reject the hypothesis of structural change in

[20] We reserve 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 is 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.

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

[22] 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 measured by stock prices here). In a cointegrated VAR model, first differencing leads to misspecification since it omits error correction mechanisms.

the stock price equations starting from January 1996, which is the beginning of the "dot-com" bubble in the U.S. stock market. We find that a dummy variable for the period from January 1996 to December 2002 is suitable for capturing the run-up in stock prices. The likelihood ratio tests show that this dummy variable is a valid addition to 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 U.S. model ($l = 9$), and six lags for the Canadian model ($l = 6$).[23]

Finally, the test for over-identification restrictions indicate that the baseline Canadian and U.S. models cannot be rejected at the 5 percent significance level. Given both the economic and statistical support for our baseline models, we now turn to the estimated impulse response functions.

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.[24] 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 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*)

[23] We started with 12-month lags and shortened them progressively to 9-month, 6-month, 3-month and 1-month. The likelihood ratio tests indicate 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 confirm our choice of lags.

[24] 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`."

in our baseline U.S. model are consistent with those familiar estimates.[25] 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 United States. A portfolio shock ($USPORT$), which we interpret as an unanticipated increase in the demand for equity, has a large and persistent positive impact on the U.S. stock prices. An oil price shock (OP), on the other hand, has an immediate negative impact on stock prices in the United States.

There are several interesting observations that emerge from 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, but 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 aggregate supply, with stock prices peaking two years after the aggregate supply shock. On the other hand, a shock to aggregate demand leads to a significant and persistent increase in the price level while, upon impact, output does not change. This initial aggregate demand shock also causes, over time, a rise in the price level, a rise in the interest rate, and a fall in stock prices, which in turn lead to lower output in the medium run. Our results indicate that stock prices in the United States rise in response to a positive aggregate supply shock, and fall in response to an unanticipated increase the federal funds rate and oil prices.[26]

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

[26] 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,

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 upon impact 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 (CAY) falls in the short and medium run. Consistent with the uncovered interest parity condition, an unexpected increase in the Canadian short-term interest rate ($CAMP$) corresponds to an expected depreciation of the exchange rate (EXR, + is a depreciation).[27] 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. Moreover, shocks to the Canadian overnight interest rate have no statistically significant impact on the U.S. federal funds rate. This is consistent our hypothesis that the U.S. economy is relatively closed. By contrast, an unexpected increase in the U.S. interest rates (USR) 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 causes an *expected* appreciation of the Canadian dollar—which is consistent with the uncovered interest parity condition. These findings support our hypothesis that the response of the Canadian economy to internal and external disturbances depends critically on financial market openness.

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 effect. Positive portfolio shocks ($CAPORT$), which cor-

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. See Figure 1.

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

respond to a higher demand for equity, raise stock prices substantially. An unexpected increase in the U.S. federal funds rate initially increases Canadian stock prices, but these effects subside in the medium and long run. An external trade shock (TR) 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. Hence, we do not find a strong influence directly through trade channels on stock prices. Overall, these findings suggest that financial market openness directly affects for Canadian stock prices, whereas trade openness does not have a strong, direct influence on stock prices—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 aggregate supply and demand shocks are remarkably similar to their U.S. counterparts.[28]

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 are 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 United States and Canada. Note, however, that stock prices in the United States (left panel) fall more than the

[28]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.

Canadian stock prices (right panel) do in the medium and long run. Figure 3 also shows for both the United States and Canada the time horizon within which the estimated dynamic responses are statistically different from zero. After a contractionary monetary policy shock in Canada, the trough of the fall in Canadian stock prices occurs within four months and the dynamic impact lasts for about 12 months after the shock—whereas in the United States, the trough of the decline in stock prices does not occur until 17 months after the shock and the decline persists for about 37 months.

Also, the impact of Canadian monetary policy 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 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 United States? Although these differences appear in estimated dynamic responses of domestic short-term interest rates to monetary policy shocks both in Canada and the United States, it is likely that structural differences between the two economies partly account for these differences. As illustrated in Figure 2, trade shocks (TR) have significant and direct impact on the Canadian price level (CAP) and the exchange rate (EXR) while the U.S. monetary policy shocks (USR) have significant and direct impact on the Canadian interest rate (CAR) and stock prices ($CASP$). These indicate that trade and financial market openness have noticeable implications for the Canadian economy, and through different channels.

In addition, Figure 2 shows that upon a contractionary domestic monetary policy shock, the Canadian dollar appreciates (although slightly). 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 the demand for Canadian goods upon impact, but over time the responses of the exchange rate and foreign demand jointly mitigate this initial impact, which are eventually reflected in stock market valuations. This *dynamic* adjustment mechanism in the Canadian economy under a floating exchange rate regime is quite prominent. Moreover, a rise in the U.S. federal funds rate 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 a short-lived increase in Canadian stock prices.

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 shocks to money market equilibrium ($USMME$) 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 (TR) have an immediate but limited impact (not beyond 4%) on the variance of stock prices. Their impact on long-horizon forecasts is economically negligible. However, U.S. interest rate shocks (USR) have a substantial (as high as 16%) but delayed impact on the variance of the Canadian stock prices. This is further evidence on the strong influence of financial market openness for 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 models we specified in Section 3 are no exceptions. We have examined the sensitivity of our results to a battery of alternative identification restrictions and specifications. In the interest of space, we discuss only two alternative specifications for the monetary policy reaction function.[29]

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 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 having the largest range, and US-AR1 SG having 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 the U.S. monetary policy reaction function renders the response of stock prices to a monetary policy shock noisier, and including cur-

[29] We have also extended the baseline U.S. model by incorporating the producer price index for intermediate goods and by excluding the exchange rate and U.S. federal funds rate, and the baseline Canadian model by adding an index of commodity prices while excluding excluding the federal funds rate. 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.

rent 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).[30] The contribution of the U.S. interest rate shocks (*USR* in

[30]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

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 Canadian stock prices to U.S. interest rate shocks underscores the appropriateness of our emphasis on modeling Canada as a small open economy.

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 and quantitatively 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 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 United States 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

market equilibrium shocks.

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 United States the response is prolonged.

In the model, we paid attention to the differences in trade and financial market openness between these two economies, especially through external demand and monetary policy shocks. We found that monetary policy shocks in the United States have significant impact on the Canadian stock prices and contribute substantially to their variance. We note that the contribution of external demand shocks to Canadian stock price variance is very small.

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. This analysis did not include real estate and other forms of wealth. 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, monthly average of close prices.
- 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 (monthly average). 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).

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.

Cardia, E. (1991). The dynamics of a small open economy in response to monetary, fiscal and productivity shocks. *Journal of Monetary Economics* 28: 411–434.

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. (2000). 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.

Glick, R., and Rogoff, K. (1995). Global versus country-specific productivity shocks and the current account." *Journal of Monetary Economics* 35: 159–92.

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.

Johnson, D. R., and Schembri, L. (1990). Atheoretical and structural approaches to modelling Canadian-American macroeconomic interaction. *Empirical Economics* 15: 367-382.

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.

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.

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

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. (1999). Error bands for impulse responses. *Econometrica* 67: 1113–1156.

Schmitt-Grohé, S. (1998). *The international transmission of economic fluctuations: Effects of U.S. business cycles on the Canadian economy. Journal of International Economics*, 44: 257-287.

Souki, K. (2008). Assessing the effects of U.S. shocks on the Canadian economy using alternative identification methods. *North American Journal of Economics and Finance* 19: 193-213.

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	TR	USR
		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

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

Alternative 2

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

Figure 1. Dynamic responses to structural shocks in the baseline U.S. model (intervals between the dashed lines correspond to two standard errors)

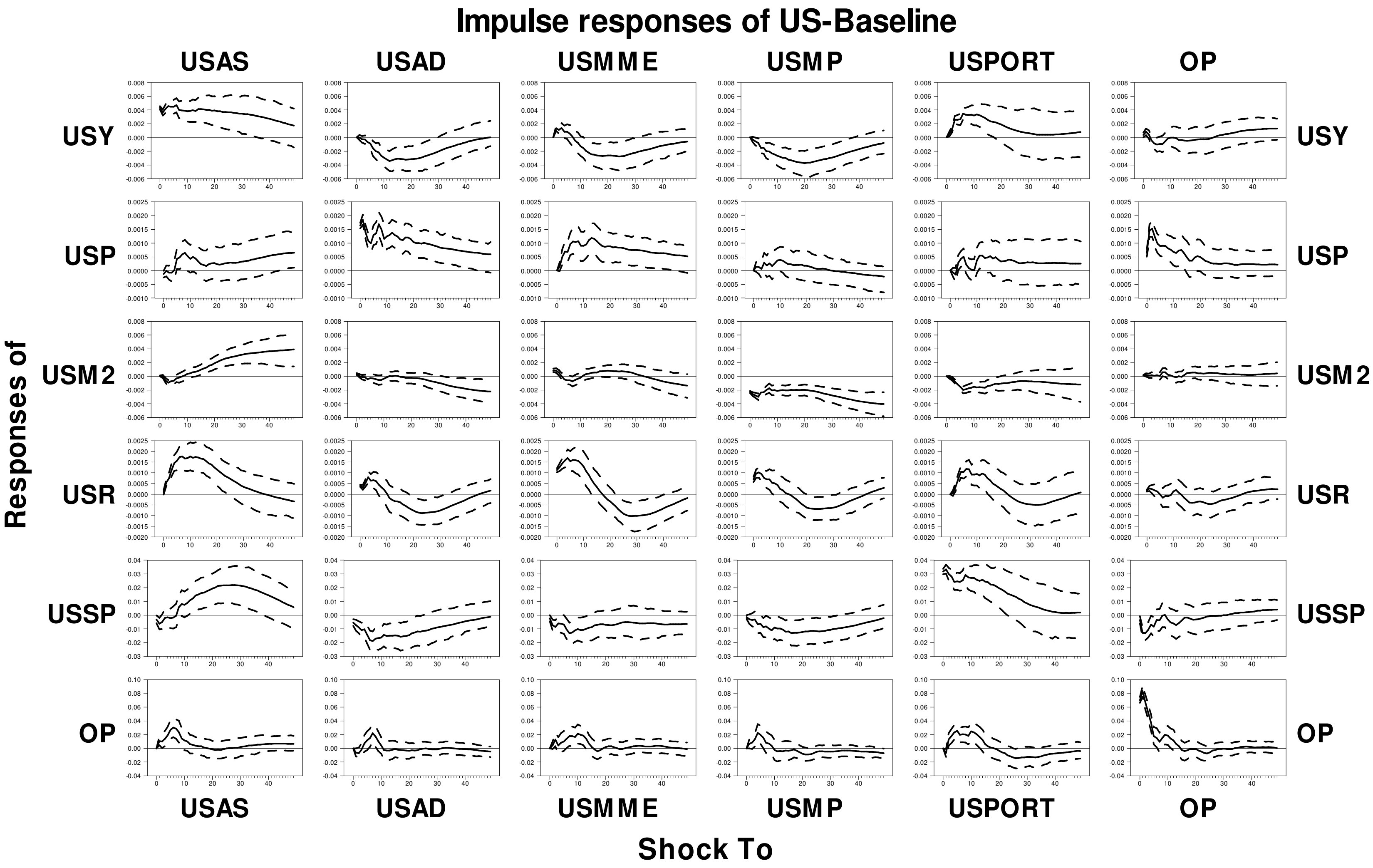

Figure 2. Dynamic responses to structural shocks in the baseline Canadian model (intervals between the dashed lines correspond to two standard errors)

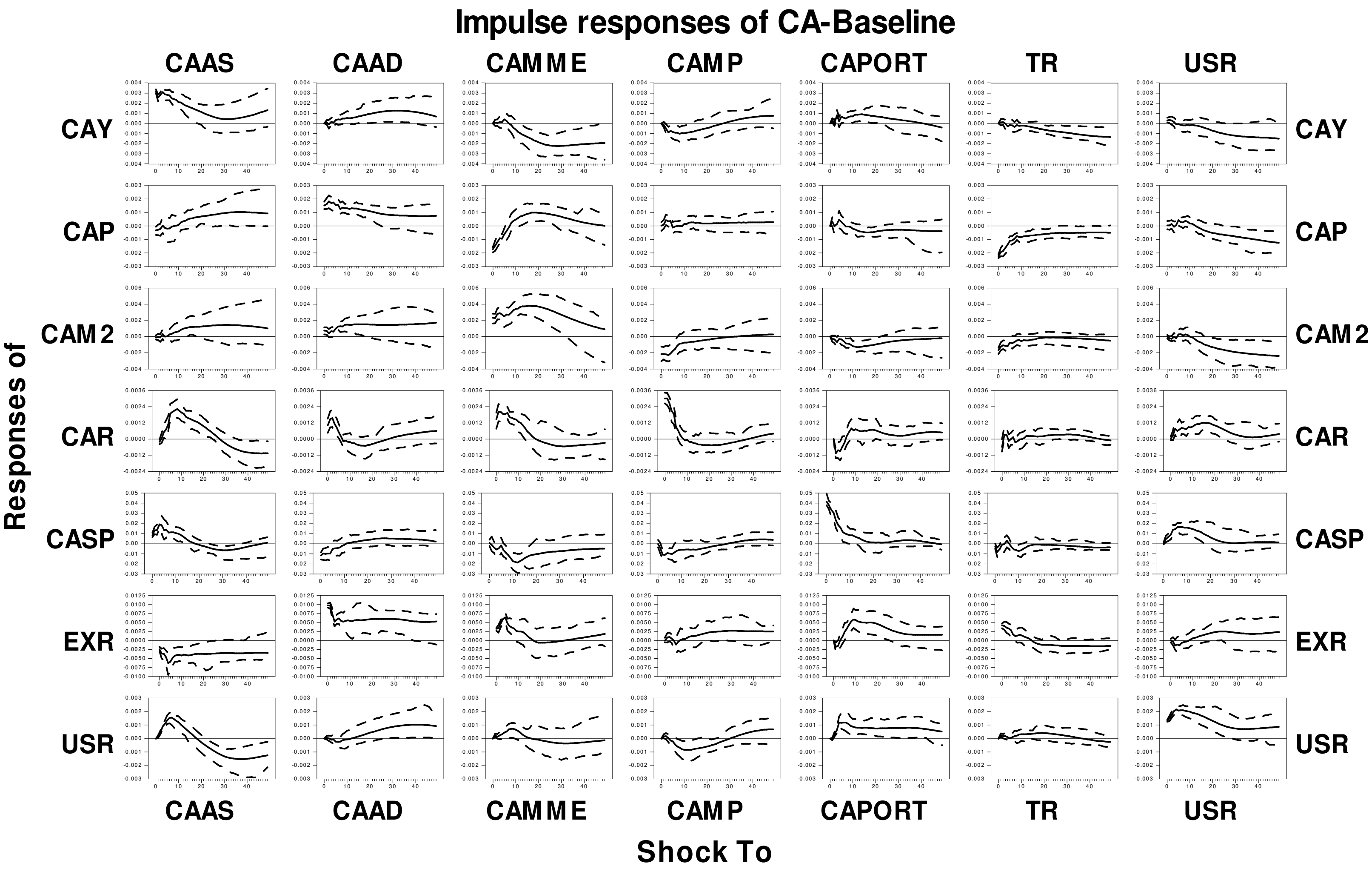

Figure 3. Dynamic responses of stock prices to a contractionary domestic monetary policy shock in the baseline U.S. and Canadian models (intervals between the dashed lines correspond to two standard errors).

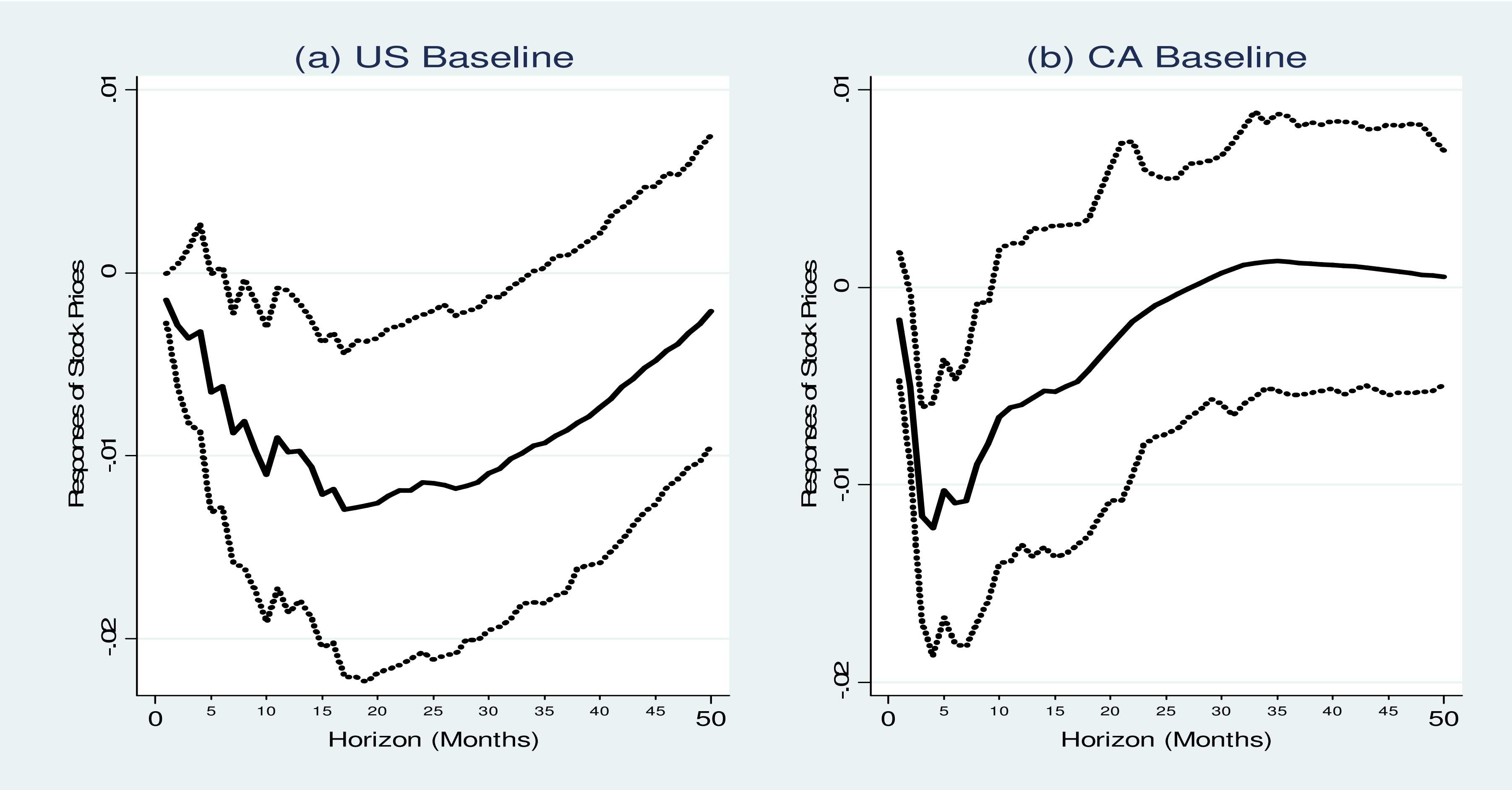

Figure 4: Forecast error variance decomposition of stock prices attributable to domestic monetary policy shocks in the baseline U.S. and Canadian models

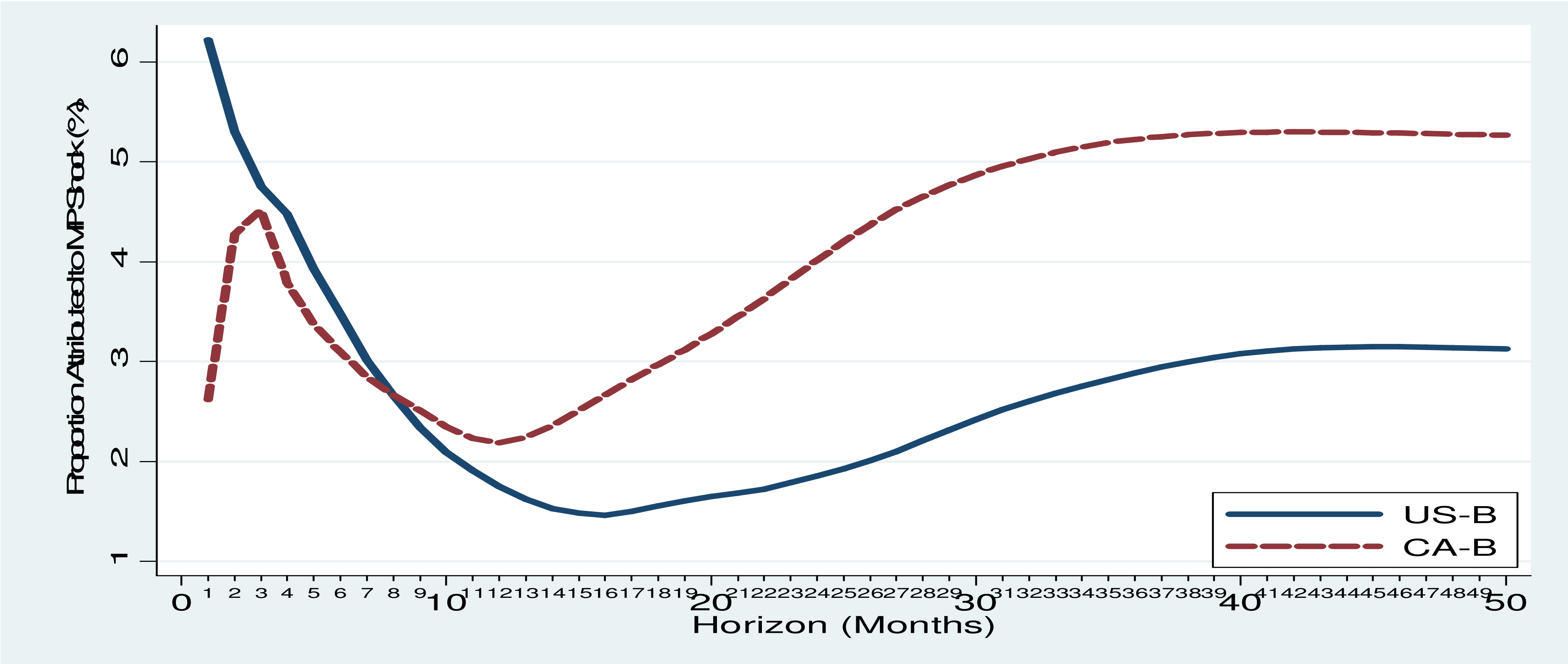

Figure 5: Comparison between dynamic responses of stock prices to a domestic monetary policy shock: comparison of U.S. and Canadian models (vertical lines show the intervals within which the estimate responses are statistically different from zero)