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# The Performance and Robustness of Simple Monetary Policy Rules in Models of the Canadian Economy

by

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## Abstract

In this paper, we evaluate a common set of simple monetary policy rules in a wide range of private and public sector models of the Canadian economy (12 models). Our results indicate that none of the seven simple policy rules is robust to model uncertainty, in the sense that no single rule performs well in all models. In fact our results show that the performance of some of the simple rules, particularly interest rate smoothing rules and rules which have a high coefficient on the inflation gap, can substantially deviate from the optimal rule and can even be unstable in some models. Our results are thus very different from Levin, Wieland and Williams (1999) who argue that simple policy rules are not only robust but also generate essentially the same policy frontier as more complicated rules or rules that respond to a large number of variables. Furthermore, we find that “open economy” rules do not perform well in many models. In fact, we find that adding an exchange rate term to a simple policy rule often increases the loss function value. This result is thus very different from Ball (1999) who argues in favour of an MCI-based type rule. Adding the exchange rate to a simple rule often increases the loss function value in the models we consider because smoothing fluctuations in the exchange rate impedes on economic adjustment.

Although not robust, we find however that a simple Taylor type rule which has a coefficient of 2 on the inflation gap and 0.5 on the output gap outperforms the other simple rules in a certain class of models. However, even in these models, this rule often leads to an important deterioration of the loss function value when compared with the optimal or ‘base-case’ rule.

## 1. Introduction

When formulating monetary policy, the monetary authorities have to face several sources of uncertainty. In particular, there is uncertainty surrounding the channels through which monetary policy affects the economy and the types of shocks hitting the economy. One way to address this problem is to use many different models in the decision-making process. However, the attractiveness of this approach is reduced by the fact that it is expensive to build and maintain several models. Moreover, forecasts generated by different models may lead to contradictory recommendations, in which case decision-makers must then decide how much weight to assign to each model. Unfortunately, determining these weights is not an easy task. Another strategy which has been recommended and pursued by several researchers is to search for a simple monetary policy rule that performs well across a wide range of models and hence is robust to model uncertainty.[2]

We define a simple rule as a rule which is linear and which contains a small number of state variables. A particular advantage of simple rules is that they are relatively easy to build and communicate. Moreover, simple rules are less model dependent as they use available information and hence do not depend on the forecasts of specific models. An example of a simple rule is the now famous Taylor rule proposed by John Taylor (1993) to describe the behaviour of the U.S. Federal Reserve between 1987 and 1992.

Numerous studies have shown that simple rules do not only perform well but are also more robust to model uncertainty compared to complicated rules. This result is obtained by several researchers who participated at the 1998 NBER conference on “Monetary Policy Rules”, in particular Levin, Wieland and Williams (1999). Levin et al. (1999) find that simple policy rules, in particular rules with a high degree of interest rate smoothing and which respond to the contemporaneous output gap and to the deviation of inflation from its target, perform nearly as well as more complicated rules in four models of the U.S. economy. Moreover, they find that although optimal in some models, complicated rules are not particularly robust as they lead to substantial deterioration in the loss function value when they are tested out in different models.[3]

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[2] See Levin, Wieland and Williams (1999) and McCallum (1999) for example.

[3] This result is rather intuitive as complex rules are usually fine-tuned to account for the specific dynamics of a given model. When tested out, they often perform poorly.

Most studies on simple monetary policy rules have involved models of the U.S. economy and there have been few studies to evaluate this type of rules in models of the Canadian economy.[4] This paper fills this gap partially by investigating the performance and robustness of several simple monetary policy rules in twelve models of the Canadian economy. Our work is different from the previous literature on simple rules in several ways. First, we use a very large number of models to evaluate simple policy rules (these models are presented in Appendix 1). Moreover, the models involved in this paper are very diverse and are all used either for forecasting key variables of the Canadian economy and/or for policy analysis. As a result, careful attention has been paid to how they fit the data.[5] By considering a large variety of models, we are able to address some of the criticisms, notably by Hetzel (2000) and Svensson (2001), that the models used in the past to evaluate simple monetary policy rules were too similar in structure and did not really constitute a test of robustness for the rules. Second, we pay close attention not only to model uncertainty but also to shock uncertainty. Research on policy rules to date has mostly emphasized the robustness of simple rules with respect to model uncertainty. Finally, in this paper, we conduct an analysis on the fit of each model. The models are compared to a benchmark VAR model of the Canadian economy. This exercise is used to help us assign weights on each model in our robustness exercise (see Table 4).

To understand and compare the characteristics of the different models, participants were first required to supply information on their model’s structure and were then asked to simulate their model subject to a series of deterministic shocks. A VAR model of the Canadian economy was subsequently estimated and the historical response of CPI inflation, Canadian real GDP and the exchange rate to two types of shocks (a shock to real U.S. GDP and a shock to commodity prices) was obtained. These shocks are selected because their identification is relatively uncontroversial since these variables are generally assumed to be exogenous with respect to the Canadian economy. We then compare the impulse response functions of the different models following these two shocks with the benchmark VAR model of the Canadian economy. The model

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[4] Exceptions are Amano (1998), Armour et al. (2000), Côté and Lam (2001), and Srour (2001, 2002). These authors studied the performance of simple rules using a given model. Consequently, they cannot say much about the robustness of simple policy rules in various models. Note, however, that Amano and Srour study the performance of simple rules in different versions of a same model.

[5] Sims (2001) argues that existing studies have not paid enough attention to how models used to evaluate policy rules fit the data.

whose impulse response functions come closest to the VAR is assumed to have the best fit.

The common set of simple rules which were evaluated by all participants were chosen according to very specific criteria. We proceeded in two steps:

i.) Participants who could either perform stochastic simulations or solve their model analytically were first asked to identify the "best" simple rule in their models. Those simple rules are evaluated according to a simple loss function comprising of the unconditional variance of the deviations of inflation from its target and of the variance of the output gap.[6] The "best" simple rule is assumed to be the one that minimizes the loss function. Since only five participants were able to run stochastic simulations, five "best" simple rules were identified.[7]

ii.) These five "best" simple rules in addition to the original Taylor rule and an open-economy rule (rule including an exchange rate term) were then submitted to the participants who were only able to perform deterministic simulations.[8] To evaluate the "seven simple" rules, these participants were asked to simulate five deterministic shocks. Since the unconditional variance for inflation and the output gap cannot be generated in this case to compute the loss function value of each rule, we take a different but complimentary approach. We use instead a simple statistic which calculates the mean squared deviation of the "shock minus control" response of inflation and output from equilibrium. These two statistics are assumed to be the equivalent of the unconditional variances of inflation and the output gap and are thus used to compute the loss function value for each rule. The rules are then ranked according to their ability to minimize the loss function.

Our results indicate that none of the "seven simple" rules is robust to model uncertainty. In fact we find that only four rules are stable in all models.[9] Moreover, unlike Levin et al. (1999), we find that simple rules can lead to substantial deterioration in the loss function value when compared to the base case or optimal rule of each model. We also find that rules with interest rate

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[6] These are QPM, MULTIMOD, NAOMI, M1-VECM and LPM.

[7] Apart from testing virtually thousands of rules, we made sure that these participants evaluated each other's "best" simple rule. Note that Multimod is the only model which did not evaluate open-economy rules.

[8] These rules are shown in Table 1.

[9] The simple rule from NAOMI, QPM, the original Taylor rule and the open-economy rule are the only rules that are stable in all models. It is interesting to note that all of these four rules have the same coefficient on the output gap with the simple rule from QPM, NAOMI and the open-economy rule having higher coefficient on the inflation gap compared to that of the original Taylor rule.

smoothing perform poorly or are often unstable, particularly in models which fall under the "conventional" paradigm.[10] However, rules with interest rate smoothing perform relatively well in the M1-VECM and the LPM - models which fall under the "money matters" paradigm.[11] In the LPM, a rule with interest rate smoothing works well because agents are completely forward-looking and also because such types of rules decrease the likelihood of inflationary expectations from becoming self-fulfilling. On the other hand, a rule with interest rate smoothing outperforms the other simple rules in the M1-VECM since it is optimal in this model for policymakers to keep interest rates high for a long period of time once inflation increase because the money gap (which causes inflation) is very persistent.

Our results are thus different from Levin et al (1999) who find that rules with a high degree of smoothing work well in four models of the U.S. economy. They argue that these rules perform well since they offer policymakers greater control on long-term rates. As argued by Goodfriend (1991) and discussed in Levin et al. (1999), a rule with interest rate smoothing, by moving short rates in a smooth but persistent manner will induce persistent movements in long-term rates and hence allow policymakers to have greater control on output and inflation. This argument relies on the assumption that long-term interest rates have an important role in the transmission mechanism and that smooth and persistent changes in short-term rates can influence the long rate via the term structure. Since the long-term rate on its own probably does not play such a vital role in the transmission mechanism in Canada as compared to the U.S., there may be fewer reasons to adopt an interest rate smoothing rule in models of the Canadian economy.[12]

We also find that rules which contain an exchange rate term often lead to a deterioration in the loss function. Our findings are thus similar to Taylor (1999c) but different from Ball (1999). Working with a backward-looking small open economy model, Ball (1999) concludes that incorporating the exchange rate in a policy rule leads to a significant improvement in output and inflation volatilities.[13] On the other hand, Taylor (1999c), after simulating his multi-country

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[10] The models who fall under such a category are mostly backward-looking models. Our results are thus similar to Ball (1999) and Rudebusch and Svensson (1999).

[11] These two paradigms are described in Section 2.

[12] This may be because the monetary authority has less influence on long-term rates in Canada as they are mostly determined by global markets.

[13] Ball (1999) argues that his "open-economy" rule when compared to Taylor-type rules reduces output variability by around 17% without inducing an increase in inflation volatility.

model, finds that the rule proposed by Ball often creates more instability than the basic Taylor rule.

There are several reasons that can explain why rules which contain an exchange rate term do not perform well even in open economy models. Since the exchange rate is a highly endogenous variable, movements in the exchange rate may already be reflected in inflation and the output gap. Hence in that case, including an exchange rate term in a policy rule which already contains inflation and the output gap may be superfluous. Uncertainty associated with the determination of the equilibrium exchange rate may also partly explain why such types of rules do not perform particularly well. In addition to the above, if movements in the exchange rate are mostly due to fundamentals and not to portfolio shocks, this reduces the likelihood of having an exchange rate term in a Taylor-type specification. In that case, if the monetary authorities try to smooth fluctuations in the exchange rate, this will undermine the ability of the exchange rate to act as a shock absorber, hence causing output and inflation to be more volatile.[14]

This paper is organized as follows. In Section 2 we present an overview of the models involved in this paper. Section 3 analyses the performance of simple monetary policy rules in models which performed stochastic simulations and in models performing deterministic simulations. Section 4 concludes.

## 2. Comparison and Evaluation of the Models

In this section, we offer a basic overview of the different models involved in our paper. The models considered in this study differ in several ways (these models are presented in Appendix 1).[15] We start our analysis by examining and comparing the basic features of the different models with respect to their paradigm, structure and dynamic properties. We then present two examples of how the models respond following a short-term interest rate shock and an exchange rate shock.

The twelve models involved in this paper can be classified under two economic

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[14] This is consistent with the conclusions reached by Djoudad, Murray, and Daw (2001) and Djoudad, Gauthier, and St-Amant (2001) who use different methodologies.

[15] The frequency of all models is quarterly, except MULTIMOD, which is an annual model, and INTERLINK, which is semi-annual.

paradigms. The first one is the “conventional” paradigm and the second one is the “money matters” paradigm. Under the conventional paradigm, monetary policy actions affect inflation mainly through their effects on aggregate demand and the output gap. While most models fall under the “conventional paradigm”, there are nevertheless important differences within this paradigm. There are differences in estimation techniques, size, structure and parametrization. For example, NAOMI is a small estimated model while QPM is a large-scale calibrated model. MTFM, on the other hand is a fairly disaggregated model compared to most of the other models. Under the “money matters” paradigm, monetary policy actions affect inflation mostly through movements in monetary aggregates. Only two models fall under this category: the M1-VECM in which the money gap - the disequilibrium between money supply and estimated long-term money demand - influences inflation while still allowing a role for the output gap, and the Limited Participation Model (henceforth LPM), in which rigidities in adjusting money balances are the main source of the short-run non-neutrality of monetary policy.

The models can be also differentiated based on the channels through which monetary policy actions affect the economy. In most participating models, monetary policy actions affect the economy through the level of short-term interest rates. This is the case of the following models: CEFM, DRI, FOCUS, FOCUS-CE, INTERLINK, MTFM, WEFA, LPM and MULTIMOD. In other models, such in the M1-VECM, NAOMI and QPM, the monetary policy transmission mechanism works through the slope of the yield curve.

Inflation is determined by a linear Phillips curve in most participating models: CEFM, DRI, FOCUS, INTERLINK, WEFA and NAOMI. While the M1-VECM falls under the “money matters” paradigm, the disequilibrium in the product market plays also a role in the adjustment of prices. Asymmetries in the inflation process are introduced in the models of FOCUS-CE, MULTIMOD and QPM. On the other hand, the MTFM model of the Conference Board uses a very disaggregate approach to determining the adjustment of prices.

Eight out of twelve models assume purely backward-looking inflation expectations: CEFM, DRI, FOCUS, INTERLINK, MTFM, WEFA, M1-VECM, and NAOMI while the following three models include both backward-looking and model-consistent inflation expectations: FOCUS-CE, MULTIMOD, and QPM. In QPM and MULTIMOD, in particular, the hybrid phillips curve assigns more weight to backward-looking inflation expectations as compared to model-consistent inflation expectations.[16] The LPM is the only model which incorporates purely model-consistent behaviour and is optimally derived from microfoundations.

To further understand the structure and properties of the different models i.e., the way the various models respond to different macroeconomic shocks, we perform several deterministic simulations. Because output and inflation dynamics depend in part on the specification of monetary policy, to compare and evaluate the different models, we specify a common policy reaction function. The original Taylor rule is thus imposed as the baseline reaction function in each model. Eight deterministic shocks (seven temporary and one permanent) are then simulated in 11 of the twelve models.[17] The seven temporary shocks which are simulated in most models are as follows: a demand shock, an external shock, a shock to commodity prices, a price shock, a wage growth shock, a shock to short-term interest rates, and a shock to the exchange rate. Finally, the deterministic permanent shock is a shock to long-term interest rates.[18]

Tables 2 and 3 respectively present a summary of the first four quarter response of real GDP, CPI inflation and exchange rate following a transitory increase in short-term interest rates and a depreciation in the exchange rate.[19] For comparison purposes, the models are divided into three categories: “Least Sensitive”, “Moderately Sensitive”, and “Most Sensitive”, depending on the sensitivity of real GDP, CPI inflation and the exchange rate with respect to the interest rate shock. Most models do not appear to be very sensitive to changes in interest rates. In fact, the peak response of real GDP and CPI inflation is muted in most models. However, when the sensitivity of the exchange rate is considered, it is seen that several models appear to be very responsive to changes in interest rates. When the exchange rate shock is considered, it is seen that it does not have a big impact on real GDP and CPI inflation in most models (except for QPM and the M1-VECM to a lesser extent - these two models are highly responsive to this shock). There

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[16] In QPM, the weight on lagged inflation is 0.7 whereas it is 0.75 in MULTIMOD.

[17] Except for LPM which was not able to simulate any of the shocks described in Appendix 2.

[18] These deterministic shocks are described in Appendix 2. Several of them require some explanation. The price shock, for example, is interpreted as a temporary change to firms’ profit margins. The temporary shock to short-term interest rates is interpreted as a modification of the inflation target, while the permanent shock to long-term interest rates represents a permanent change in the term premium. Finally, the transitory shock to the exchange rate is interpreted as a temporary loss of confidence by investors in the Canadian economy.

[19] The detailed results of the eight deterministic shocks are not presented here. They are, however, available on our website at http://www.bankofcanada.ca/workshop2001/. See “Simple Monetary Policy Rules in Canadian Macroeconomic Models: A Comparison and Evaluation of the Participating Models”.

are two reasons why this might be the case. Some models do not have a well developed external sector, hence the linkages between the exchange rate, output and inflation may be weak. Moreover, if most models are interpreting this shock not as a portfolio shock but rather as a fundamental one, the response of output and inflation will be muted.

## 3. Comparison of rules

The common set of rules which we evaluate in this paper are presented in Table 1. The simple rules from the M1-VECM and LPM have a high coefficient on the lagged interest rate, with the simple rule from the LPM having a zero weight on the output gap and the simple rule from the M1-VECM having a small weight on both the inflation and output gaps. The simple rules from MULTIMOD, NAOMI and QPM, on the other hand, are all variants of the rule proposed by Taylor (1993). All three simple rules have a higher coefficient on the inflation gap compared to Taylor's original specification with the simple rule from MULTIMOD having also a higher coefficient on the output gap.

It is interesting to note that all of the models which performed stochastic simulations found that rules which contain an exchange rate term were dominated by "closed-economy" rules. We have already offered an intuition for this finding. Despite this finding, we have nevertheless included an open economy rule in our exercise as Canada is a small open economy and because it has been shown that open economy rules can perform well in small open economy models.

### 3.1 Results From Stochastic Simulations

The performance of the "seven simple" rules is first analysed in models which were able to derive efficiency frontiers either analytically or by performing stochastic simulations. These models are: LPM, M1-VECM, MULTIMOD, NAOMI and QPM. Except for NAOMI which was solved analytically, stochastic simulations were implemented by drawing from a random process that reflect the historical distribution of shocks. In MULTIMOD, for example, the shock processes are obtained from the estimated residuals of the model and 100 random draws each lasting 100 years are generated. The simulation results are then summarized by calculating the unconditional variances of inflation, the output gap and nominal interest rates. A similar type of exercise is performed in QPM, the M1-VECM and LPM. On the other hand, in NAOMI, since this model is solved analytically, the variances of inflation, the output gap and nominal interest rates are calculated simply as a function of the model's residuals variance and covariance and coefficient matrix.

In each model, all simple rules are evaluated according to an explicit loss function comprising of the unconditional variance of the deviation of inflation from its target and of the variance of the output gap. This loss function is given by:

$$\text{Loss} = \text{Var}(\tilde{\pi}) + 0.25\text{Var}(\tilde{y}) \tag{1}$$

Our specification of the loss function is similar to those commonly found in the literature (see for example Jensen (2001), Levin, Wieland and Williams (1999), Rotemberg and Woodford (1999), Svensson (1999, 2000) and Walsh (2000,2001)).[20] The smaller weight on the variability of the output gap indicates that the policymakers have a stronger preferences for minimizing the variability of inflation as compared to the latter. Since the Bank of Canada is an inflation targeter and is primarily concerned with stabilizing inflation around its target, we feel that it is reasonable to assume that the monetary authority would assign a bigger weight on the latter and a smaller weight on stabilizing the output gap.[21]

We do not include interest rate volatility in our base case loss function but do provide some sensitivity tests by including a non zero weight on interest rates volatility. It is true that by doing so, we might favour rules which stabilize inflation and output at the expense of generating large swings in interest rates and hence running the risk of choosing a rule which can violate the lower zero bound of nominal interest rates and which may not be feasibly implemented in practice.[22] Moreover, as discussed in Levin, Wieland and Williams (1999, 2001), the model parameters are unlikely to remain invariant to policy rules that have dramatically different interest rate volatility. This is why it may be important to consider rules that do not generate a high level of interest rate volatility and/or reflect historical variations in interest rates.[23] However, in our analysis, we do not include interest rate volatility in our base case loss function mostly for practical and computational reasons. If the zero bound on nominal interest rates were taken into

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[20] Woodford (1999) has shown that such a loss function can be derived as a second order approximation of a representative agent's utility function.

[21] Since the output gap is included in the loss function, the central bank is not an "inflation nutter" but can be viewed as targeting inflation in a flexible manner.

[22] In this group of models, 4 out of 5 models do not impose such an explicit constraint. In QPM, although the lower zero bound is not strictly imposed, rules that violate this condition were nevertheless discarded.

account in all models, this would greatly increase the computational costs of these models and would not necessarily lead to very different results. Moreover, because of the large number of models involved in this workshop and to keep our analysis as general and simple as possible, we have decided to use the loss function given by equation (1).We first evaluate the common set of rules in these five models by comparing their performance with the optimal rule. As defined previously, a robust rule is one which performs well and when tested in different models, will have a loss function value which does not substantially deviate from the optimal or base case rule in each model. We find that none of the seven rules tested is very robust to model uncertainty. In fact, our findings indicate that the performance of some of the simple rules, more particularly rules with interest rate smoothing, can substantially deviate from the optimal or base case rule in some models.

For example, when the seven rules are tested in QPM, it can be seen in Table 5 that except for the simple rule from MULTIMOD, QPM and NAOMI, the other rules perform very poorly compared to the base case rule of the model, indicating that replacing the optimal or base case rule by a simple rule can lead to substantial deterioration in the loss function. Table 5 shows that if the Inflation Forecast Based (IFB) rule, which is the base case reaction function in QPM, is replaced by the original Taylor rule, the loss function value in this model increases by 128%. On the other hand, if the simple rule from the M1-VECM replaces the IFB rule, the loss function value increases by 750%. The choice of the “best” simple rule in QPM deserves some explanation. The simple rule from MULTIMOD is not selected in this model despite having a lower loss function value than the simple rule from QPM. This is because the former generates too much volatility in interest rates and also frequently violates the lower zero bound of nominal interest rates.

Simple rules, particularly rules which are not very aggressive, do not work well in QPM because they do not bring inflation back to target quickly enough. On the other hand, rules that are fairly aggressive and which bring inflation back to equilibrium quickly work well in this model

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23. There are also several other reasons to explain why a central bank may care about interest rate volatility. For example, large swings in interest rates can destabilize financial markets and can also undermine the credibility of central banks, especially if large positive swings are followed by large negative swings. Moreover, as argued by Rudebusch (2001), the lagged interest rate term may reflect factors not accounted for by the simple policy rule. Srour (2001) has shown that the historical reaction of central banks to economic shocks in Canada has been significantly more gradual and persistent than what an optimal rule would call for.

mainly for two reasons. In QPM, current inflation depends partly on expected future inflation and on lagged inflation but also indirectly on the credibility of the central bank. A rule that is fairly aggressive and which returns inflation to target within the desired horizon will send the right signal to agents and will influence their expectations of future inflation in a positive manner. Since current inflation depends, at least partially, on expected future inflation, if the latter is influenced in a positive manner, so will current inflation. Moreover, a policy rule that returns inflation to its target within the desired horizon will enhance the credibility of the central bank and thus in turn will help reduce current inflation. The same type of argument can be applied to MULTIMOD which shares these similar features with QPM.

We also find that our common set of simple rules are not particularly robust in the other models. For example, in the LPM, it is seen in Table 6 that except for the simple rule from LPM, the other simple rules perform very poorly when compared to the optimal rule. For instance, the simple rules from QPM and NAOMI have loss function values which are respectively 181% and 220% higher compared to the optimal rule in LPM.[24] A similar result is obtained in this model when the other simple rules (except the simple rule from LPM, for which it was designed to work well) are used.

Rules that have a high coefficient on inflation and interest rates and a zero (or negative) coefficient on the output gap work well in this model for mainly two reasons. Rules that do respond aggressively to inflation and which respond with a negative or zero weight on the output gap, decrease the likelihood of inflation expectations from becoming self-fulfilling in this model. The argument is best illustrated with this example. Higher anticipated inflation in LPM will make agents reallocate their portfolio, thereby decreasing the amount of funds flowing to the financial sector, hence putting pressure on nominal interest rates to increase. If the weight on inflation in the policymakers’ rule is small, to prevent a large increase in nominal interest rates, a large amount of liquidity has to be injected in the economy. This increase in liquidity will produce the increase in inflation agents anticipated. As a result, agents inflation expectations become self-fulfilling and the economy can remain trapped in such an equilibria.[25] This chain of causation from expected inflation to actual inflation can be eliminated if the policy rule places a high weight

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[24] The optimal rule in this model responds to all the state variables of the model and is thus not in the class of simple rules.

on inflation and a zero or negative weight on the output gap.

There is another reason why such type of rules work well in this model. Most of the shocks built in the LPM can be interpreted as supply shocks (the contemporaneous correlation between output and inflation is negative for most shocks). As a result, a rule that responds strongly to inflation and/or weakly or even negatively to the output gap is recommended in this case.

In NAOMI, the results are even more dramatic. Out of the seven rules, only four are stable: the simple rule from NAOMI, QPM, the original Taylor rule and the open economy rule. However, as shown in Table 7, the simple rule from QPM lead to a very large deterioration in the loss function value when compared to the simple rule from NAOMI (832%). One of the reasons why fairly aggressive rules and rules with interest rate smoothing do not work well or are unstable in this model is because of a timing issue. Since monetary policy operates with a lag in this model, it pays the central bank from "avoiding doing too little too late". However, if the central bank is too aggressive, this can lead to large secondary cyclings which can only be reversed at the cost of large swings in output and inflation. Hence, a "good" rule in this model is one which is relatively pre-emptive but not too aggressive.

In the M1-VECM, a rule with a high degree of interest rate smoothing works well because it helps to mitigate the negative impact the money gap - the disequilibrium between money supply and long-run money demand - has on inflation. Since the money gap is persistent and influences inflation in the model, it pays the central bank to keep interest rates high for a long period of time. It is to be noted that the simple rules from NAOMI, QPM and the original Taylor rule also perform relatively well in this model.

Overall, our results indicate that the "seven simple" rules are not particularly robust in these five models, especially the simple rules from the M1-VECM, LPM and MULTIMOD. These three rules are unstable in at least one of the five models and their performance often deviates

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25. A high weight on the output gap is bad in this model for similar reasons. If higher anticipated inflation causes interest rates to rise for the reasons explained above, this in turn will produce a fall in output. This fall in output will put downward pressure on interest rates. The bigger the coefficient on the output gap in the policymakers' reaction function, the bigger will be the decrease in interest rates. As a result of this downward pressure on interest rates, inflation will increase. Hence in this case also, expectations can become self fulfilling. A similar argument can be used to explain why a rule with a high degree of smoothing works well in this model.

substantially from the base case or optimal policy rule. On the other hand, the simple rules from NAOMI, QPM, the original Taylor rule and the open economy rule are stable in all five models. It is interesting to note that all of these four rules have the same coefficient on the output gap but different coefficients on the inflation gap. However, even if these four rules are stable, their performance, particularly the original Taylor rule, can substantially deviate from the optimal or base case rule.

The results presented in Table 8 shows the ordinal ranking of each rule in each model. Note that we have used an ordinal ranking to avoid the scaling problem introduced by the lack of uniformity in the design of the shocks. In case a rule is unstable in a model, it is penalized by a score of 10.[26] It is seen that, on average, the simple rules from QPM and NAOMI outperform the other simple rules, particularly rules with interest rate smoothing and the open economy rule. Although the average ranking of the simple rule from QPM is lower, as shown in Table 8, nevertheless, the simple rule from NAOMI seems to be more robust, in the sense that on average it deviates less from the optimal or base case rule as compared to the former. This result is shown in Table 9. It is seen in this table that the simple rule from QPM does very poorly in the model of NAOMI. It generates a loss function which is 832% higher than the simple rule from NAOMI in that model. This difference is particularly important if policymakers have strong beliefs that NAOMI is the correct representation of the economy. In that case, the simple rule from NAOMI clearly dominates the simple rule from QPM.

Our findings are thus very different to many other studies (mostly for U.S. models) which have shown that rules with interest rate smoothing not only perform well but are also fairly robust. In particular, our results are different from those of Levin et al. (1999) who conclude that "... for a given model, complicated rules perform only slightly better than simple one... and... simple rules are robust to model uncertainty." This indicates that policy rules can not only be model specific but also country specific. In general, we find that simple rules can lead to a substantial deterioration in the loss function value when compared to more complex rules in some models and that they are not particularly robust to model uncertainty. However, if we restrict ourselves to

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[26] We have experimented with a rank of 6 but this made no difference to our results. A weight of 10 penalizes rules that are unstable in one or more models. We have also experimented with different weights on the output and inflation gap in the loss function. These sensitivity tests did not affect our baseline results.

a certain class of models, the simple rule from NAOMI seems to perform reasonably well compared to the other rules, although in this case also, there can be substantial deviation from the optimal rule.

### 3.2 Results from Deterministic Simulations

This section discusses the simulation results obtained from the remaining seven models.[27] As mentioned in the introduction, the seven participants which were unable to conduct stochastic simulations were asked to perform deterministic simulations. The performance of the seven "workshop" rules are analysed in these seven models by simulating five deterministic shocks which we believe are important for the Canadian economy: domestic demand, external demand, commodity prices, consumer prices and exchange rate. We evaluate the "seven simple" rules according to a simple statistic which computes the mean squared deviation of output and inflation from equilibrium. The statistics for output and inflation are assumed to be comparable to the unconditional variance of the output and inflation gap and hence are used to compute the loss function. Moreover, in these seven models, each rule is compared to the simple rule which ranks first in that model and not to the optimal rule.[28] To assess for robustness, the rules are compared to each other using an ordinal approach.

In the context of deterministic simulations, we use three general criteria to evaluate the policy rules and assume that a "good" policy rule should satisfy these three criteria. A "good" policy rule should avoid unstable response, avoid excessive secondary cycling (which occurs when a secondary cycle is greater than the primary cycle) and minimize the variability of key variables such as inflation, output and interest rates. A response is assumed to be unstable if at the end of the simulation horizon (responses are simulated for 24 quarters), the impulse response function (IRF) significantly diverges from the X-axis, i.e., the control solution or equilibrium.[29]

To apply the first two criteria, we simply look at the impulse response functions of all models once the shocks are simulated. However, we cannot apply the third criterion by merely inspecting these IRFs. To circumvent this problem, we construct an index which we use as a

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[27] The seven models are CEFM, DRI, FOCUS, FOCUS-CE, INTERLINK, MTFM and WEFA.

[28] Many of these models cannot identify an optimal rule. Moreover, in many models, the simple rules outperformed their base case reaction function.

[29] This is not an unreasonable assumption since only temporary shocks are simulated.

proxy to calculate the variance of output and inflation. We use the mean squared deviation of the "shock minus control" from equilibrium for output and inflation.[30] This statistic is given by:

$$S = \frac{\sum_{n=1}^{24} x^2}{24} \tag{2}$$

To evaluate the performance of each simple rule in each model, we again use a simple loss function which is given by equation (5) below.

$$\text{Loss} = S_{INF} + 0.25S_{GDP} \tag{3}$$

where $S_{INF}$ is the mean squared deviation of the shock minus control for inflation and $S_{GDP}$ is the same statistic but for output. Equation (3) is assumed to be similar to the loss function which we used earlier.[31]

In the previous section, the rules were evaluated by relying more on an ordinal approach, thus on the rankings of the rules mainly because of the lack of uniformity in the design and distribution of shocks. In this case also, we use a similar approach. Although each model is simulating the same shocks, the distribution between the different shocks can be quite different. For example, the price shock that we impose may be at the extreme end of the distribution of price shocks, while the demand shock may be closer to the middle of the distribution of demand shocks. Comparing the values of the loss function from these events may not be representative of the expected value of the loss function for all the realization of the shock in a particular model. We thus focus on the ranking of the rules to correct the scaling problem introduced by the difficulty to design representative shocks.[32] We further assume that each shock can occur with equal probability and thus assign equal weights to each of the five shocks.

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30. We ignore the responses which are truncated before the 24th quarter. These responses mainly occur in the FOCUS model with the simple rule from the M1-VECM and the LPM.

31. As in the previous section, we perform several sensitivity tests on equation (3) by varying the weight on the output and inflation gap. We also include the volatility of interest rates. As in Section 3.1, our results remain unchanged.

32. We also use a cardinal ranking as a robustness check.

As mentioned in the introduction, the deterministic simulations not only enable us to measure the robustness of a given rule with respect to model uncertainty but also to shock uncertainty. The latter to our knowledge has not received much attention in the literature. This information would be useful if we have some knowledge on the nature of the shock hitting the economy. We start our analysis by comparing the average performance of the rules in these seven models when the five shocks are simulated. We take an average of the loss function value of each rule in each model for all the five shocks and on the basis of this information rank the rules using an ordinal approach. For example in Table 10, the simple rule from MULTIMOD has the lowest average loss function value across the five shocks in CEFM and is thus ranked first in that model.

Overall, our results are very similar to those obtained in the context of stochastic simulations. There is no robust rule, in the sense that no single rule performs well in all models. Our results also indicate that some of the rules, particularly the simple rule from MULTIMOD, LPM and the M1-VECM, are highly model dependent and are even unstable in some models. For example, the simple rule from MULTIMOD ranks first in four out of the seven models, but is unstable in two. On the other hand, the two rules with smoothing (LPM and M1-VECM) perform generally poorly in all seven models. This result is thus similar to Ball (1999) and Rudebusch and Svensson (1999) who also find that rules with interest rate smoothing perform poorly or can be unstable in backward-looking models.[33]

Our results also show that only four simple rules are stable in all models: the original Taylor rule, the open-economy rule and the simple rules from NAOMI and QPM. This result is thus similar to the one obtained from the stochastic simulations. However, there is one important difference between the results from the two sets of models. The Taylor rule does reasonably well compared to the simple rules from NAOMI and QPM in this set of models. In many cases, the Taylor rule is ranked first or second and does not perform well in only two out of the seven models. The simple rule from NAOMI also does reasonably well compared to the other rules, indicating that this rule may be the most robust one among our set of simple policy rules across all 12 models.

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[33] This argument can also be illustrated by looking at the performance of the two rules with smoothing in the two versions of the FOCUS model. The two rules with smoothing are unstable in FOCUS, a completely backward-looking model but not unstable in its more forward-looking version, although their performance remains poor.

Taking a closer look at the results, we find that less aggressive rules tend to work relatively well in models where output and inflation are relatively sensitive to changes in interest rates. For example, in MTFM, the Taylor rule and the simple rule from NAOMI, which are not very aggressive, outperform the other simple rules whereas the simple rule from MULTIMOD, which is a fairly aggressive rule, is unstable in this model. On the other hand, models with low interest rate sensitivity tend to favour more aggressive rules (see Table 2). This is clearly the case for the models of WEFA and FOCUS-CE. These two models have a low interest rate sensitivity but prefer aggressive rules, in our case, the simple rule from MULTIMOD or QPM. This result is fairly intuitive. If output and inflation respond aggressively to changes in interest rates, the monetary authority is thus not required to move interest rates a lot to get a significant effect on these two variables.

However, interest rate sensitivity alone cannot explain why some models prefer less or more aggressive rules. For example, both the Taylor rule (the least aggressive) and the simple rule from MULTIMOD (the most aggressive) work well in the models of CEFM, DRI and FOCUS, which have various degrees of interest rate sensitivities. An important similarity between the two rules, however, is that their ratios between the coefficients on the inflation gap and the output gap are relatively low compared to the other rules[34]. Therefore, it may be the case that it is the relative and not the absolute weight on the inflation and output gap terms that plays a role in these three models.

Table 11 presents the percentage deviation of the loss function value of each rule with respect to the best simple rule in a particular model. In this case also, we can see that the performance of a given rule can deviate substantially from the “best” simple rule in a given model, indicating that these simple rules are not particularly robust. For example, the Taylor rule and the simple rule from NAOMI can lead to substantial deviation when compared to the “best” simple rule in many of these models (for example in DRI, FOCUS, FOCUS-CE, CEFM and INTERLINK). This result thus reinforces our findings of the previous section.

Table 12 presents the average ranking of the simple rules for a given shock. This

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[34] This ratio is two for the simple rule from Multimod, three for the original Taylor rule, four for the simple rule from NAOMI and the open-economy rule and six for the simple rule from QPM.

information would be useful to policy makers if they are confident about the nature of the shocks affecting the economy but are uncertain about which model is the true representation of the economy (paradigm and parameter uncertainties). We do not find a robust rule across shocks, in the sense that none of the rules perform well under all shocks. However, the standard deviations of these rankings show that the performance of the rules vary more across models than across shocks, implying that the performance of rules is more model dependent than shock dependent. While the Taylor rule performs well in the face of demand and commodity prices shocks, the simple rule from NAOMI outperforms the other rules in the face of the external and price shocks. The simple rule from MULTIMOD is probably the least robust rule across shocks. This rule yields unstable responses in MTFM when all shocks are simulated and for the external and commodity price shocks in INTERLINK. However, the simple rule from MULTIMOD dominates the other simple rules in the CEFM model in all five shocks.

Table 13 presents the results when the rankings from the stochastic and deterministic simulations are combined. The original Taylor rule, the open-economy rule and the simple rules from NAOMI and QPM are the only stable rules in all twelve models. As argued in the previous section, overall the simple rule from NAOMI outperforms the other simple rules, although the performance of this rule can deviate substantially from the optimal or base case rule in some models. Table 13 also shows that the rules with interest rate smoothing (simple rule from LPM and the M1-VECM) are the least robust rules since they are either unstable or perform poorly in many models.

As mentioned in the previous section, we perform several sensitivity tests on the loss function and find that our results did not change. For example, including the volatility of the interest rate in the loss function or altering the relative weights on the variance of the inflation gap and output gap did not change our results. We also perform a different sensitivity test by assigning weights to the various models according to their ability to match certain features of a benchmark VARX (see Table 4). In this case also, we find that our results are robust.

## 4. Conclusions

One of the primary objectives of this paper is to identify a simple monetary policy rule that is robust in a very large number of models of the Canadian economy. Our analysis includes both models which use the “conventional” or the “money matters” paradigm. Because of the diverse array of models used in this paper, our robustness test is more rigorous than many other studies which have used many similar models to evaluate rules. Unlike Levin et al. (1999), we find that simple policy rules are not particularly robust to model uncertainty. Out of the seven simple rules we tested, only four are stable in all models. These are: the original Taylor rule, the simple rule from NAOMI and QPM and the open economy rule. However, these rules are not particularly robust to model uncertainty, since they do not perform well compared to the base case or optimal rule in several models.

Moreover, we also find that these rules are not robust to shock uncertainty, in the sense that a rule would perform differently in many models for a given shock. Nonetheless, some rules perform better than others in certain models. For example, the simple rule from NAOMI performs quite well in a certain class of models, particularly NAOMI, QPM, and some similar types of models. However, it is to be noted that, compared with the base case or optimal rule, even this rule can lead to a significant deterioration of the loss function in these models.

We also find that rules with interest rate smoothing perform poorly in most models, particularly in backward-looking models. In these models, rules with smoothing are either unstable or are ranked last. On the other hand, rules with smoothing perform better in models which fall under the “money matters” paradigm (LPM and the M1-VECM). This result is, however, explained by the fact that one of these models (LPM) is completely forward-looking, while the other (the M1-VECM) includes an important variable, the money gap, that is very persistent.

We also find that adding the exchange rate to a simple Taylor type rule often leads to a deterioration in the loss function value in most models. This is mostly because the exchange rate is a built-in stabilizer in these models and helps the economy return to equilibrium after a shock. As a result, any attempt by the monetary authority to smooth fluctuations in the exchange rate, interferes with that adjustment process.

Despite not finding a robust simple rule for Canada, our results do not necessarily imply that simple rules do not have a role to play in the conduct of monetary policy. Our results indicate that a certain class of rules, particularly the simple rule from NAOMI can be potentially useful for the conduct of monetary policy, especially if policymakers prefer and believe in a certain class of models. Moreover, although we did not test for this result, this simple rule is likely to be more robust than complex rules in different models. In addition to the above, simple rules like NAOMI remain relatively easy to build, communicate, and do not depend on specific models, since they use only the available information. However, our results do not enable us to quantify the value of this contribution nor the weight that the monetary authorities should assign to these rules. This remains to be determined by future research.

# References

Armour, J, B. Fung and D. Maclean, "Taylor Rules in the Quarterly Projection Model," Working Paper 2002-1, Bank of Canada.

Ball, Laurence, "Policy Rule For Open Economies," in John B. Taylor, ed., *Monetary Policy Rules,* Chicago: University of Chicago Press, 1999, 127-154.

Christiano Lawrence J., and Christopher J. Gust, "Taylor Rules in a Limited Participation Model, "1999, Federal Reserve Bank of Cleveland Working Paper.

Côté, Denise and Jean-Paul Lam, "Simple Rules in the M1-VECM," presented at the 2001 meeting of the Canadian Economic Association at McGill University (Montréal).

Clarida, Richard., Jordi Gali, and Mark Gertler, "Monetary Rules in Practice: Some international Evidence," *European Economic Review,* 1998, 42, 1003-1067.

Clarida, Richard., Jordi Gali, and Mark Gertler, "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory." *Quarterly Journal of Economics*, 1999, 115, 147-180.

Clarida, Richard., Jordi Gali, and Mark Gertler, "Optimal Monetary Policy in Open Versus Closed Economies: An Integrated Approach," *The American Economic Review,* 2001, 91, 248-252.

Goodfriend, Marvin, "Interest Rates and the Conduct of Monetary Policy," *Carnegie-Rochester Conference Series on Public Policy,* 1991, 34, 7-30.

Huang A, D.Margaritas and D. Mayes, "Monetary Policy Rules in New Zealand 1988-1998," 2000, Working Paper, University of Waikako.

Hendry, Scott, Wai-Ming Ho and Kevin Moran, "Open Economy in a Liquidity Effect Model," 2001, mimeo.

Kozicki, Sharon, "How Useful are Taylor Rules for Monetary Policy," Federal Reserve Bank of Kansas City *Economic Review,* 1999.

Laxton Douglas, Peter Isard, Hamid Faruqee, Eswar Prasad and Bart Turtelboom, "MULTIMOD Mark III The Core Dynamic and Steady-State Models," 1998, IMF Working Paper.

Leitemo Kai and Ulf Söderström, "Simple Monetary Policy Rules and Exchange Rate Uncertainty," Working Paper No 122, Sveriges Riksbank, 2001.

Levin, Andrew, Volker Wieland and John C. Williams, "Robustness of Simple Monetary Policy Rules under Model Uncertainty," in John B. Taylor, ed., *Monetary Policy Rules,* Chicago: University of Chicago Press, 1999, 263-299.

Levin, Andrew, Volker Wieland and John C. Williams, "The Performance of Forecast-Based Monetary Policy Rules under Model Uncertainty," 2001, ECB Working Paper.

Murchison, Stephen, "A New Quarterly Forecasting Model Part II: A Guide to Canadian NAOMI," Dept of Finance Working Paper 2001-25.

Nelson, Edward, “UK Monetary Policy 1972-97: A Guide Using Taylor Rules,” Bank of England Working Paper, 2000, No 120.

Rotemberg, Julio J. and Michael Woodford, “An Optimization-Based Econometric Framework for the Evaluation of Monetary Policy,” in NBER *Macroeconomics Annual 1997,* ed. Ben S. Bernanke and Julio J. Rotemberg: Cambridge, Mass: MIT Press, 1997, 297-346.

Rotemberg, Julio J. and Michael Woodford, “Interest Rate Rules in an Estimated Sticky Price Model,” in John B. Taylor, ed., *Monetary Policy Rules*, Chicago: University of Chicago Press, 1999, 57-118.

Rudebusch, Glenn D. and Lars E.O Svensson, “Policy Rules for Inflation Targeting,” in John B. Taylor, ed., *Monetary Policy Rules*, Chicago: University of Chicago Press, 1999, 203-252.

Sims Chris, “A Review of Monetary Policy Rules, John B. Taylor, ed.,” Journal of Economic Literature, 2001, 39(2).

Svensson, Lars E.O, “What Is Wrong with Taylor Rules? Using Judgment in Monetary Policy Through Targeting Rules,” 2001, Working Paper.

Taylor, John B., “Discretion Versus Policy Rules in Practice,” *Canergie-Rochester Conference Series on Public Policy*, 1993, 39, 195-214.

Taylor, John B, “The Robustness and Efficiency of Monetary Policy Rules as Guidelines for the ECB,” *European Economic, Review,* 1999,

Taylor, John B, “The Role of the Exchange Rate in Monetary Policy Rules,” *The American Economic Review*, 2001, 91.

Williams John C. “Simple Rules for Monetary Policy,” 1999, FEDS Working Paper.

Woodford, Michael, “The Taylor Rule and Optimal Monetary Policy,” 2001, Working Paper.

# Appendix 1: Participating Models

This study considers twelve private and public sector models of the Canadian economy. Five of them are maintained by private sector organizations. The models are:

i.) CEFM: Canadian Economic and Fiscal Model, Department of Finance Canada;

ii.) DRI: Data Resources of Canada;[35]

iii.) FOCUS: Policy and Economic Analysis Program (PEAP), Institute for Policy Analysis, University of Toronto;

iv.) FOCUS-CE: the version incorporating forward-looking expectations;

v.) INTERLINK: Organization for Economic Co-operation and Development;

vi.) MTFM: The Conference Board of Canada's Medium-Term Forecasting Model;

vii.) WEFA: Wharton Economic Forecasting Associates;

viii.) LPM: Limited Participation Model, Monetary and Financial Analysis Department, Bank of Canada;

ix.) M1-VECM: Vector-error-correction model, based on the M1 aggregate, Monetary and Financial Analysis Department, Bank of Canada;

x.) MULTIMOD: International Monetary Fund;

xi.) NAOMI: North American Open-Economy Macroeconometric Integrated Model, Department of Finance Canada;

xii.) QPM: Quarterly Projection Model, Research Department, Bank of Canada;

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35. Data Resources of Canada and Wharton Economic Forecasting Associates have recently merged.

# Appendix 2: Model Shocks

| Shock | Description | Details |
|---|---|---|
| 1. Domestic Demand | A 4-quarter transitory increase to the levels of consumption and investment at the same time. | Shock on consumption and investment:<br>Q1: 1.00%<br>Q2: 0.75%<br>Q3: 0.50%<br>Q4: 0.25%<br>i.e. the levels of consumption and investment increase by one percent at the 1-quarter horizon and then progressively come back to control (there is no permanent increase in the level of output). |
| 2. External Demand | A 4-quarter transitory increase in the level of real U.S. output with endogenous responses of U.S. inflation and interest rate, and world commodity prices. | Shock on U.S. GDP:<br>Q1: 1.00%<br>Q2: 0.75%<br>Q3: 0.50%<br>Q4: 0.25%<br>Endogenous response of U.S. inflation<br>Endogenous response of U.S. short-term interest rate<br>Endogenous response of world commodity prices<br>(The above endogenous responses can be found in the following text file: endo_resp_usy.txt) |
| 3. Commodity prices | A 8-quarter transitory increase in the level of real commodity prices with endogenous responses of U.S. output, inflation and interest rate. | Shock on commodity prices:<br>Q1: 4.00%<br>Q2: 3.50%<br>Q3: 3.00%<br>Q4: 2.50%<br>Q5: 2.00%<br>Q6: 1.50%<br>Q7: 1.00%<br>Q8: 0.50%<br>Endogenous response of U.S. output<br>Endogenous response of U.S. inflation<br>Endogenous response of U.S. short-term interest rate<br>(The above endogenous responses can be found in the following text file: endo_resp_comm.txt) |

| Shock | Description | Details |
|---|---|---|
| 4. Consumer Price | A 4-quarter transitory increase to the level of CPI excluding food, energy and indirect taxes. | Shock on CPI:<br>Q1: 1.00%<br>Q2: 0.75%<br>Q3: 0.50%<br>Q4: 0.25% |
| 5. Wage growth | A 4-quarter transitory increase to nominal wage growth. | Shock on wage growth:<br>Q1: 1.00 percentage point<br>Q2: 0.75 of a percentage point<br>Q3: 0.50 of a percentage point<br>Q4: 0.25 of a percentage point |
| 6. Short-term interest rate | A 4-quarter transitory increase in short-term interest rate. | Shock on short-term interest rate:<br>Q1: 100 basis points<br>Q2: 75 basis points<br>Q3: 50 basis points<br>Q4: 25 basis points |
| 7. Long-term interest rate | A permanent change in the term premium. | Shock on long-term interest rate:<br>Permanent increase of 100 basis points |
| 8. Nominal exchange rate shock | A 4-quarter temporary increase to the risk premium on the exchange rate (a depreciation). | Shock on exchange rate:<br>Q1: 1.00%<br>Q2: 0.75%<br>Q3: 0.50%<br>Q4: 0.25% |

## Table 1: “Seven Simple” Rules

The simple rules have the following form:

$$i_t = \rho i_{t-1} + (1-\rho)[i_t^e + \alpha_\pi(\pi_t - \bar{\pi}_t) + \alpha_y \tilde{y}_t + \alpha_\varepsilon(e_t - e_{t-1})]$$

where $i_t$ is the nominal interest rate, $(\pi_t - \bar{\pi}_t)$ is the inflation gap , $\tilde{y}_t$ is the output gap and $e_t$ is the nominal bilateral Canada/U.S. exchange rate.

| | $\rho$ | $\alpha_\pi$ | $\alpha_y$ | $\alpha_\varepsilon$ |
|---|---|---|---|---|
| Original Taylor Rule | 0 | 1.5 | 0.5 | 0 |
| Simple Rule from LPM | 0.9 | 1.0058 | 0 | 0 |
| Simple Rule from M1-VECM | 0.9 | 1.5 | 0.5 | 0 |
| Simple Rule from MULTIMOD | 0 | 4 | 2 | 0 |
| Simple Rule from NAOMI | 0 | 2 | 0.5 | 0 |
| Simple Rule from QPM | 0 | 3 | 0.5 | 0 |
| Open Economy rule | 0 | 2 | 0.5 | 0.2 |

## Table 2: Peak Response to a Transitory Change in Short-Term Interest Rates

| | Least Sensitive<br>peak response in the first four quarters is less than 0.25% | Moderately Sensitive<br>peak response in the first four quarters is between 0.25% and 0.5% | Most Sensitive<br>peak response in the first four quarters is more than 0.5% |
|---|---|---|---|
| Real GDP | CEFM<br>FOCUS-CE<br>WEFA | DRI<br>INTERLINK<br>MULTIMOD<br>NAOMI<br>QPM<br>M1-VECM | FOCUS<br>MTFM |
| CPI Inflation | CEFM<br>DRI<br>INTERLINK<br>MTFM<br>MULTIMOD<br>QPM<br>WEFA | FOCUS<br>FOCUS-CE<br>NAOMI | M1-VECM |
| Exchange rate | CEFM<br>DRI | QPM<br>WEFA | FOCUS<br>FOCUS-CE<br>INTERLINK<br>MTFM<br>MULTIMOD<br>NAOMI<br>M1-VECM |

* Short-term interest rates are increased by 100 basis points, 75 basis points, 50 basis points, and 25 basis points, respectively, during the first four quarters. Results for the LPM model were not available.

## Table 3: Peak Response to a Transitory Change in the Exchange Rate

| | Least Sensitive peak response in the first four quarters is less than 0.25% | Moderately Sensitive peak response in the first four quarters is between 0.25% and 0.5% | Most Sensitive peak response in the first four quarters is more than 0.5%. |
|---|---|---|---|
| Real GDP | CEFM<br>DRI<br>FOCUS<br>FOCUS-CE<br>INTERLINK<br>MULTIMOD<br>NAOMI<br>WEFA | MTFM | QPM<br>M1-VECM |
| CPI Inflation | DRI<br>FOCUS<br>INTERLINK<br>MTFM<br>MULTIMOD<br>NAOMI<br>M1-VECM | CEFM<br>FOCUS-CE<br>WEFA | QPM |

* The Canadian currency relative to that of the United States depreciates by 1 per cent in the first quarter, by 0.75 per cent in the second, 0.50 per cent in the third and 0.25 during the fourth. Results for the LPM model were not available.

## Table 4: Distance of the Models from the VAR

| Models | Shock to real U.S. GDP | | | Shock to commodity prices | | | |
|---|---|---|---|---|---|---|---|
| | Real GDP | CPI Inflation | Exchange Rate | Real GDP | CPI Inflation | Exchange Rate | Aggregate Measure |
| DRI | 5 | 8 | 8 | 4 | 7 | 10 | 9 |
| FOCUS | 6 | 1 | 4 | 9 | 9 | 2 | 5 |
| FOCUS-CE | 3 | 4 | 3 | 6 | 11 | 8 | 6 |
| INTERLINK | 11 | 10 | 10 | 11 | 6 | 9 | 11 |
| CEFM | 9 | 3 | 2 | 1 | 5 | 7 | 3 |
| MTFM | 1 | 2 | 5 | 10 | 2 | 3 | 1 |
| MULTIMOD | 7 | 6 | 6 | 5 | 1 | 5 | 4 |
| M1-VECM | 8 | 7 | 9 | 8 | 4 | 6 | 8 |
| NAOMI | 2 | 9 | 7 | 3 | 3 | 1 | 2 |
| QPM | 4 | 11 | 11 | 2 | 8 | 11 | 10 |
| WEFA | 10 | 5 | 1 | 7 | 10 | 4 | 7 |

## Table 5: Performance of the Simple Rules in QPM

| Rules | Value of loss function | % deviation from “optimal” rule |
|---|---|---|
| Optimal rule - IFB rule | 2.32 | 0.00 |
| Simple rule from LPM | 7.16 | 209 |
| Simple rule from M1-VECM | 19.71 | 750 |
| Simple rule from MULTIMOD | 2.74 | 18 |
| Simple rule from NAOMI | 3.84 | 66 |
| Simple rule from QPM | 2.96 | 28 |
| Original Taylor rule | 5.28 | 128 |
| Open Economy rule | 6.99 | 201 |

## Table 6: Performance of the Simple Rules in LPM

| Rules | Value of loss function | % deviation from “optimal” rule |
|---|---|---|
| Optimal rule | 0.92 | 0.00 |
| Simple rule from LPM | 1.43 | 50 |
| Simple rule from M1-VECM | 2.42 | 162 |
| Simple rule from MULTIMOD | unstable | unstable |
| Simple rule from NAOMI | 2.96 | 220 |
| Simple rule from QPM | 2.60 | 181 |
| Original Taylor rule | 4.54 | 390 |
| Open Economy rule | 4.05 | 340 |

## Table 7: Performance of the Simple Rules in NAOMI

| Rules | Value of loss function | % deviation from “best” simple rule |
|---|---|---|
| Simple rule from LPM | unstable | unstable |
| Simple rule from M1-VECM | unstable | unstable |
| Simple rule from MULTIMOD | unstable | unstable |
| Simple rule from NAOMI | 1.22 | 0 |
| Simple rule from QPM | 11.39 | 832 |
| Original Taylor rule | 1.51 | 24 |
| Open Economy rule | 1.48 | 21 |

## Table 8: Summary of the Performance of the seven simple rules in LPM, M1-VECM, MULTIMOD, NAOMI and QPM

| Rules | LPM | M1-VECM | MultiMod | NAOMI | QPM | AVG | STD |
|---|---|---|---|---|---|---|---|
| Original Taylor rule | 6 | 2 | 4 | 3 | 4 | 3.4 | 1.2 |
| NAOMI rule | 4 | 4 | 3 | 1 | 3 | 3 | 1.09 |
| QPM rule | 3 | 2 | 2 | 4 | 2 | 2.4 | 0.49 |
| MULTIMOD rule | 10 | 6 | 1 | 10 | 1 | 5.6 | 4.02 |
| M1-VECM rule | 2 | 1 | 10 | 10 | 7 | 5.8 | 3.81 |
| LPM rule | 1 | 5 | 5 | 10 | 6 | 5.2 | 2.86 |
| Open economy rule | 5 | 7 | N/A | 2 | 5 | 4.75 | 1.79 |

## Table 9: Average of Loss Function Value in LPM, M1-VECM, MULTIMOD, NAOMI and QPM

| Rules | LPM | M1-VECM | MultiMod | NAOMI | QPM | AVG[a] |
|---|---|---|---|---|---|---|
| Original Taylor rule | 4.54 | 2.00 | 4.84 | 1.51 | 5.28 | 3.63 |
| NAOMI rule | 2.96 | 2.05 | 3.42 | 1.22 | 3.84 | 2.70 |
| QPM rule | 2.60 | 2.01 | 2.64 | 11.39 | 2.96 | 4.32 |
| MULTIMOD rule | unstable | 2.64 | 2.11 | unstable | 2.74 | n/a |
| M1-VECM rule | 2.42 | 1.98 | unstable | unstable | 19.71 | n/a |
| LPM rule | 1.43 | 2.08 | 6.20 | unstable | 7.16 | n/a |
| Open economy rule | 4.05 | 3.05 | N/A | 1.48 | 6.45 | 3.76 |

[a] The average is calculated for rules that are stable in all models.

## Table 10: Summary of the Performance of the "Workshop" rules in CEFM, DRI, FOCUS, FOCUS-CE, INTERLINK, MTFM and WEFA - Base Case Loss function

| Rules | CEFM | DRI | FOCUS | FOCUS\|CE | INTERLINK | MTFM | WEFA | AVG | STD |
|---|---|---|---|---|---|---|---|---|---|
| Original Taylor rule | 3 | 1 | 2 | 6 | 1 | 1 | 6 | 2.9 | 2.1 |
| NAOMI rule | 4 | 3 | 3 | 3 | 2 | 2 | 3 | 2.9 | 0.6 |
| QPM rule | 5 | 6 | 5 | 2 | 3 | 4 | 2 | 3.7 | 1.7 |
| MULTIMOD rule | 1 | 2 | 1 | 1 | 10 | 10 | 1 | 3.9 | 3.9 |
| M1-VECM rule | 6 | 4 | 10 | 7 | 4 | 5 | 7 | 6.1 | 2.0 |
| LPM rule | 10 | 10 | 10 | 5 | 10 | 6 | 5 | 8.0 | 2.3 |
| Open economy rule | 2 | 5 | 4 | 4 | 5 | 3 | 4 | 3.9 | 1.0 |

## Table 11: Average Percentage Deviation from the Best Simple Rule for all Shocks

| Rules | CEFM | DRI | FOCUS | FOCUS\|CE | INTERLINK | MTFM | WEFA | AVG | STD |
|---|---|---|---|---|---|---|---|---|---|
| Original Taylor rule | 38.5 | 49.4 | 50.9 | 86.1 | 53.5 | 4.6 | 19.7 | 43.2 | 24.2 |
| NAOMI rule | 41.1 | 297.8 | 65.1 | 67.8 | 60.9 | 4.9 | 14.6 | 78.9 | 92.3 |
| QPM rule | 45.6 | 395.1 | 102.0 | 37.9 | 100.6 | 6.8 | 6.7 | 99.2 | 126.1 |
| MULTIMOD rule | 0.0 | 240.8 | 13.3 | 4.9 | n/a | n/a | 0.4 | n/a | n/a |
| M1-VECM rule | 94.5 | 236.5 | n/a | 187.8 | 192.3 | 33.7 | 33.2 | n/a | n/a |
| LPM rule | n/a | n/a | n/a | 95.8 | n/a | 62.1 | 25.7 | n/a | n/a |
| Open economy rule | 37.7 | 314.0 | 54.8 | 64.4 | 243.0 | 2.7 | 14.6 | 104.4 | 113.4 |

## Table 12: Ranking Across all Models for a Given Shock

| Rules | Demand shock | External shock | Commodity price shock | Price shock | Exchange rate shock | AVG | STD |
|---|---|---|---|---|---|---|---|
| Original Taylor rule | 1 | 2 | 1 | 3 | 3 | 2.0 | 0.9 |
| NAOMI rule | 2 | 1 | 2 | 1 | 4 | 2.0 | 1.0 |
| QPM rule | 3 | 3 | 3 | 2 | 2 | 2.6 | 0.5 |
| MULTIMOD rule | 10 | 10 | 10 | 10 | 10 | 10 | 0 |
| M1-VECM rule | 10 | 10 | 10 | 10 | 10 | 10 | 0 |
| LPM rule | 10 | 10 | 10 | 10 | 10 | 10 | 0 |
| Open economy rule | 4 | 3 | 3 | 4 | 1 | 3.0 | 1.1 |

## Table 13: Overall Rankings

| Rules | CEFM | DRI | FOCUS | FOCUS\|CE | INTERLINK | MTFM | WEFA | LPM | M1VECM | MULTIMOD | NAOMI | QPM | AVG | STD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Original Taylor rule | 3 | 1 | 2 | 6 | 1 | 1 | 6 | 6 | 2 | 4 | 3 | 4 | 3.3 | 1.9 |
| NAOMI rule | 4 | 3 | 3 | 3 | 2 | 2 | 3 | 4 | 4 | 3 | 1 | 3 | 2.9 | 0.9 |
| QPM rule | 5 | 6 | 5 | 2 | 3 | 4 | 2 | 3 | 2 | 2 | 4 | 2 | 3.3 | 1.4 |
| MULTIMOD rule | 1 | 2 | 1 | 1 | 10 | 10 | 1 | 10 | 6 | 1 | 10 | 1 | 4.5 | 4.1 |
| M1-VECM rule | 6 | 4 | 10 | 7 | 4 | 5 | 7 | 2 | 1 | 10 | 10 | 7 | 6.1 | 2.9 |
| LPM rule | 10 | 10 | 10 | 5 | 10 | 6 | 5 | 1 | 5 | 5 | 10 | 6 | 6.9 | 2.9 |
| Open economy rule | 2 | 5 | 4 | 4 | 5 | 3 | 4 | 5 | 7 | n/a | 2 | 5 | 4.2 | 1.4 |