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Measuring Core Inflation in Canada

by

Geoffrey L. Hansen

A thesis submitted to
the faculty of Graduate Studies and Research
in partial fulfilment of
the requirements for the degree of

Master of Arts

Department of Economics

Carleton University

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The undersigned hereby recommend to
the Faculty of Graduate Studies and Research
acceptance of the thesis.

"MEASURING CORE INFLATION IN CANADA"

submitted by

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in partial fulfilment of the requirements
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Abstract

Quah and Vahey (1995) argue in "Measuring Core Inflation" that the (U.K.) Retail Price Index (RPI) measure of inflation is mismatched with core inflation. They propose a technique for deriving a core measure which places restrictions on a Vector Auto Regression (VAR) to minimize the effect of a core shock on output. This paper applies their technique to Canadian data, and reports similar results. As well, it examines models using different frequencies, different aggregate price indices, and different assumptions about the order of integration of the price measure. It is shown that the Quah Vahey technique does not generally yield a measure of core inflation with no long-run impact on output, and is not consistent with the hypothesis of a positively-sloped short-run Phillips curve. However, the closely-related Blanchard-Quah method does yield a measure of core inflation with no long-run impact on output.

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1 Introduction

Due to concern over the costs of inflation, monetary policy in Canada has been directed towards reducing inflation over time until 'price stability' has been reached. As an intermediate step in achieving this longer-term goal, the Bank of Canada and the Federal Government in 1991 jointly announced gradually decreasing targets for inflation, as measured by the Consumer Price Index (CPI). In 1993, the 1 to 3 percent target range for CPI inflation was extended until 1998. Targeting inflation has become a common monetary policy objective in other countries, including Australia, Finland, Italy, New Zealand, Spain, Sweden, and the UK.¹

In trying to achieve inflation targets, the monetary authority does not want to react to transitory inflation shocks. If a policy tool existed that worked quickly enough, the monetary authority might want to counteract transitory shocks, but this is not the case. Monetary policy is assumed to work with a long lag. If the monetary authority reacted to a transitory inflation shock, the shock would be over before the policy took effect.²

Any official inflation measure will include the effects of transitory shocks, thus measured inflation may not be what the monetary authority is interested in. It would be useful for the monetary authority to have a 'core' measure of inflation that excluded transitory shocks. One possible solution is to use a technical or theoretical model to derive a core series that is better matched with underlying inflation (the slope of the price index vs. time, excluding price level shifts). One popular method of deriving a core inflation measure is to zero-weight certain volatile components of the price index, as is done in Canada.

The Canadian CPI is particularly sensitive to certain volatile components, such as food and energy prices and changes in indirect taxes. These components cause large swings in measured inflation which may not be indicative of changes in the underlying inflation process. In order to reduce the influence of these swings on monetary policy, the Bank of Canada considers an index which excludes food and energy prices and the effects of

1. Wolf (1996).

2. Although the monetary authority does not want to react to transitory inflation shocks, it does want to react to resulting changes in inflation expectations which could have a lasting impact on inflation.

indirect tax changes.³ However, an index which zero-weights certain components may not yield the most appropriate inflation measure to target. Zero-weighting is somewhat arbitrary, and throws out some potentially important information.

Quah and Vahey propose a different method of deriving core inflation in their paper "Measuring Core Inflation". They assert that the commonly used inflation measure for the UK (calculated from the Retail Price Index) is mismatched with inflation. They identify several popular techniques for deriving core measures of inflation and argue that each is subject to shortcomings. These shortcomings are summarized in Table 1.

Table 1

TECHNIQUE	PROBLEM
Taking a moving average, smoothing, or filtering.	How many leads/lags; what stiffness parameter?
Using a Kalman Filter.	What is the correct underlying functional form?
Zero-weighting components of the price index.	Throws out some information.
Zero-weighting some components in the tails of the cross-sectional distribution.	Throws out some information.

Quah and Vahey seek to derive an estimate of 'core inflation' that is free from these shortcomings. They define what core inflation should be in terms of its properties, then derive it accordingly. They propose a measure of core inflation that has no long-run impact on output, consistent with the theory of a vertical long-run Phillips curve.

To derive this measure of core inflation, the authors identify a transformation of a VAR which minimizes the effect of a core shock on output in the long run. They then use the transformed VAR to obtain core and non-core shocks and create a 'core inflation' series using these shocks.

In doing so, Quah and Vahey derive a measure of core inflation for the UK that has no

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3. *Bank of Canada Review*: March 1991 "Targets for reducing inflation: Announcements and background material", Sept. 1991 "Targets for reducing inflation: Further operational and measurement considerations", Winter 93-94 "Statement of the Government of Canada and the Bank of Canada on monetary policy objectives".

long-run effect on real output, and only a small short run effect. In general, their measure of core inflation matches the peaks and troughs of the official inflation measure (at least on a year-over-year basis), though it is higher in some periods and lower in others. They conclude that their core measure responds more quickly to recent inflationary tendencies than other commonly used measures.

This study applies the Quah-Vahey (QV) technique to Canadian data and examines the associated measure of core inflation. The resulting measure of core inflation would be difficult to explain to the public, thus would be an unlikely candidate for targeting inflation. However, if the derived core measure is deemed to identify the underlying inflation process better than conventional measures it could be a useful internal guide for short-run policy.

In judging whether this method provides a good measure of core inflation, one could compare the derived core measure with official inflation measures. If the core measure that deviates from the official measures over long periods of time, this would raise serious doubts about the validity of the core measure. As well, if the a core measure includes the effects of temporary inflation shocks, it would not be of interest to the monetary authority.

In order to be of interest to the monetary authority, the QV method should identify underlying inflation as core inflation, excluding transitory inflation shocks. It is reasonable to assume that underlying inflation will not affect output in the long run, thus would be identified by the vertical long-run Phillips curve. However, the QV method could also include some transitory inflation shocks (i.e. price level shifts) as core inflation. If any of these transitory shocks have a zero long-run effect on output, they will be identified as core shocks. To test if the QV technique excludes transitory inflation shocks, the resulting core measures of inflation are examined to see if they exclude the effects of the GST and cigarette tax shocks, which (arguably) should not have a long-run effect on output.

This method is only useful in the context of a particular price index and gives no insight as to whether consumer inflation (using the CPI) or some broader measure of inflation (using the implicit GDP deflator) should be targeted. In this study the method is applied to both indices.

The implementation of the QV method does require the researcher to make some relatively arbitrary decision regarding the data to use, the appropriate frequency, and the

specification of the estimated VAR. Accordingly, the sensitivity of the results is explored in some detail.

In addition, the QV method is itself not without some shortcomings. In particular there are two theoretical concerns regarding the interpretation of results from the QV technique. First, when estimating a VAR using the second difference of prices only interpretations based on changes in core inflation are meaningful, not those based on the level. Second, the QV technique identifies the measure of core inflation that has a minimal effect on output. This allows for the possibility of the measure of core inflation having a negative long-run effect on output, which would be consistent with the desire for price stability.⁴ If the QV technique does not yield a result consistent with the hypothesis of a vertical long-run Phillips curve one must reconsider what these identified 'core' shocks are and whether they have any economic meaning. Both of these concerns are addressed in the current study.

The remainder of the paper is organized as follows: section two discusses the implementation of the Quah-Vahey technique. Section three addresses issues of concern regarding model specification and the interpretation of results, and suggests several criteria by which to evaluate alternative specifications. Section four presents detailed results from a base model using Canadian data, and contrasts them with the results presented by Quah and Vahey. As well, it presents extensions of the model that address the issues brought up in section three. Section five critiques the QV method, by examining how well the theoretical definition of core inflation matches the identifying restrictions. Section six presents alternative results derived from the closely-related Blanchard-Quah technique. Section seven discusses the conclusions of this paper.

4. See Selody (1990) and Howitt (1990).

2 Implementation of the Technique

Quah and Vahey seek a transformation of a VAR which yields a measure of core inflation that has no long-run impact on output.⁵ They identify a transformation of the VAR that minimizes the sum of the squared effects of a core shock on the change in output at each lag in the moving-average representation. They argue that their technique yields two sets of disturbances. The first set has no long-run effects on output. The measure of inflation derived from this set is said to be core inflation. The second set (non-core) can have long-run effects on both inflation and output.

The first step in implementing this technique is to estimate a VAR. Following Quah and Vahey, a VAR consisting of the first difference in the log of output (ΔY) and the first difference of inflation ($\Delta\pi$) is estimated:

$$X = \begin{bmatrix} \Delta Y \\ \Delta\pi \end{bmatrix}, \quad X = B(L)X + e.$$

The moving average representation of the VAR is as follows:

$$(1) \quad X_t = C(0)e_t + C(1)e_{t-1} + \dots + C(\infty)e_{t-\infty}$$

$$X_t = \left(\sum_{j=0}^{\infty} C(j)e_{t-j} \right) \quad \text{Var}(e) = \Omega.$$

In this case, one wants to identify two shocks: core shocks (η_1) and non-core shocks (η_2).⁶ This is accomplished by finding a transformation of the VAR from which one can recover these shocks. The moving average representation of the transformed VAR would be:

$$(2) \quad X_t = D(0)\eta_t + D(1)\eta_{t-1} + \dots + D(\infty)\eta_{t-\infty}$$

$$X_t = \left(\sum_{j=0}^{\infty} D(j)\eta_{t-j} \right) \quad \text{Var}(\eta) = I.$$

5. For a more detailed technical examination of this section, refer to Appendix 3.

6. Core shocks are those that have minimal long-run effects on output. This is slightly different than the better known Blanchard-Quah technique which identifies core shocks as those that have a zero effect on output in the long run.

From (1) and (2) one can see that

$$X_t = \left(\sum_{j=0}^{\infty} [C(j)D(0)] D(0)^{-1} e_{t-j} \right)$$

$$D(0)^{-1} e = \eta \text{ or } e = D(0)\eta, \quad \text{and}$$

$$C(j)D(0) = D(j).$$

Once core and non-core shocks are identified, inflation can be separated into two components: core inflation due to core shocks (η_1), and non-core inflation due to non-core shocks (η_2).

$$\text{Thus } \Delta\pi(t) = \underbrace{\sum_j d_{21}(j) \eta_1(t-j)}_{\text{core}} + \underbrace{\sum_j d_{22}(j) \eta_2(t-j)}_{\text{non-core}}.$$

In order to perform this task, one must identify some transformation matrix S such that $D(0) = S^{-1}$ and $D(0)D(0)^T = \Omega$. Because Ω is a symmetric matrix only $n(n-1)/2$ additional restrictions are needed to fully identify $D(0)$. In order to derive the appropriate transformation matrix S , Quah and Vahey (1995) construct a matrix which minimizes the long-run effect on output of core inflation shocks by minimizing the sum of the squared changes in output. Core shocks are therefore defined as those that have a minimal long-run effect on output.⁷ In this two variable case,

$$\begin{array}{ll} D(0)D(0)^T = \Omega & \text{yields three restrictions, and} \\ \min. \sum d_{11}(j)^2 & \text{yields the fourth restriction} \end{array}$$

$$\text{where } \sum D(j) = \begin{bmatrix} \sum d_{11}(j) & \sum d_{12}(j) \\ \sum d_{21}(j) & \sum d_{22}(j) \end{bmatrix} = \sum C(j)D(0).$$

7. When typically using a VAR, one uses a Choleski decomposition which sets $n(n-1)/2$ elements in the $D(0)$ matrix equal to 0 and in effect imposes contemporaneous restrictions on the shocks.

To impose this fourth restriction, one does the following.⁸

$$\begin{aligned} \min_{D(0)} \sum_{j \geq 0} d_{11}(j)^2 &\iff \min_{D(0)} \sum_{j \geq 0} \left(\begin{bmatrix} c_{11}(j) & c_{12}(j) \end{bmatrix} \begin{bmatrix} d_{11}(0) \\ d_{21}(0) \end{bmatrix} \right)^2 \\ &\iff \min_{D(0)} \begin{bmatrix} d_{11}(0) & d_{21}(0) \end{bmatrix} \sum_{j \geq 0} \begin{bmatrix} c_{11}(j)^2 & c_{11}c_{12}(j) \\ c_{11}c_{12}(j) & c_{12}(j)^2 \end{bmatrix} \begin{bmatrix} d_{11}(0) \\ d_{21}(0) \end{bmatrix}. \end{aligned}$$

A standard property of symmetric matrices proves that $\begin{bmatrix} d_{11}(0) \\ d_{21}(0) \end{bmatrix}$ is an eigenvector

associated with an eigenvalue of $\sum_{j \geq 0} \begin{bmatrix} c_{11}(j)^2 & c_{11}c_{12}(j) \\ c_{11}c_{12}(j) & c_{12}(j)^2 \end{bmatrix}$.

To minimize one uses the eigenvector associated with the smallest eigenvalue. The resulting eigenvector yields the desired relationship between $d_{11}(0)$ and $d_{21}(0)$ in the $D(0)$ matrix and imposes the fourth restriction. Coupled with the three restrictions implied by $D(0)D(0)^T = \Omega$, one can uniquely determine $D(0)$ which is the inverse of the transformation matrix S .

Alternately, a decomposition that imposes neutrality can be identified by using the methodology described in Blanchard and Quah (1989). For this model

$D(0)D(0)^T = \Omega$ yields three restrictions, and

$\sum_{j=0}^N d_{11}(j) = 0$ yields the fourth restriction.

This fourth restriction is that core inflationary shocks (η_1) have no long-run impact on output, i.e. inflation is output-neutral in the long run. This is imposed by setting the sum of the changes in log output equal to zero.

8. Quah and Vahey use the general notation $j > N$ in their paper. More specifically $j \geq 0$ is used. If any coefficients in the infinite moving average specification are skipped at the beginning (i.e. $j > 0$), the effects on the level of output will not be captured in the minimization process.

$$\sum d_{11}(j) = \sum [c_{11}(j) \ c_{12}(j)] \begin{bmatrix} d_{11}(0) \\ d_{21}(0) \end{bmatrix} = \sum c_{11}(j) d_{11}(0) + \sum c_{12}(j) d_{21}(0) = 0$$

Thus the fourth restriction again involves the relationship between $d_{11}(0)$ and $d_{21}(0)$ and is easily derived from the infinite moving-average representation of the untransformed VAR.

3 Criteria for Judging the Results

There are three issues that must be considered when interpreting the results of this methodology. The first is whether the resulting impulse responses from the model are reasonable. The second is whether to use the level of inflation or its first difference in the VAR. The final is whether there is a conceptual mismatch between the identifying assumption and the identifying technique. A discussion of each point follows.

3.1 Reasonable effects of core/non-core shocks

In order for the core measure to be meaningful, one should see two things in the impulse responses. Core shocks should not have a significant long-run effect on output, and non-core shocks should not have a significant long-run effect on inflation.

The identifying assumption of a vertical long-run Phillips curve implies a measure of core inflation that has no long-run impact on output. If core shocks have a significant long-run effect on output this contradicts the identifying assumption. Therefore the first criteria for judging reasonable results is that core shocks should not have a significant long-run effect on output.

The monetary authority desires a measure of core inflation which excludes all transitory inflation movements and includes all permanent inflation movements. If the non-core shocks resulting from this technique have a significant long-run effect on inflation, core inflation will not include all permanent inflation movements. This would imply that a measure of core inflation of interest to the monetary authority has not been identified. Thus the second criteria for judging reasonable results is that non-core shocks should not have a significant long-run effect on inflation.

3.2 Models with the second vs first difference of the price measure

When using a VAR with the second difference of prices one can only derive inferences about movements in core inflation, not the level. In order to get a core inflation measure, one must sum all the changes in the measure obtained by the technique and add some initial level of core inflation.

$$\pi_{t+n}^{\text{core}} = \underbrace{\Delta\pi_{t+n}^{\text{core}} + \Delta\pi_{t+n-1}^{\text{core}} \dots + \Delta\pi_{t+1}^{\text{core}} + \Delta\pi_t^{\text{core}}}_{\text{derived from technique}} + \underbrace{\pi_{t-1}^{\text{core}}}_{\text{unknown}}$$

One can derive the changes in core inflation at each period using the QV technique, but core inflation in time period (t-1) will still be unknown. In order to identify core inflation in time period (t+n) an assumption about what core inflation was in time (t-1) must be made. This assumption could be either too high or too low. The assumption of what core inflation was in time (t-1) is extremely important if one wants to get a core price index back. A small change in the assumption will dramatically affect the path of the core price index.

When using a VAR with the first difference of prices one can get back a measure of core inflation and a measure of the core price level. The core price level is just an index, so

$$\log p_{t+n}^{\text{core}} = \underbrace{\Delta \log p_{t+n}^{\text{core}} + \Delta \log p_{t+n-1}^{\text{core}} \dots + \Delta \log p_t^{\text{core}}}_{\text{derived from technique}} + \underbrace{\log p_{t-1}^{\text{core}}}_{\text{unknown}}$$

although the level of the index is not known in time (t-1) this is not extremely important. The assumption about whether this core index is equal to the official index in time (t-1) does not have any detrimental effects on interpretation of the core price measure.

If the price measure is I(1) and one uses $\Delta\pi$ in their VAR, some important information is lost. The result in Fuller (1976, Theorem 8.5.1) shows that differencing produces no gain in asymptotic efficiency in an autoregression, even if is appropriate.⁹ Even if the price measure is I(2) one gains nothing by using $\Delta\pi$ instead of π .

9. Doan (1992).

3.3 Conceptual Mismatch

This methodology is based on the identifying assumption of a vertical long-run Phillips curve. The issue of whether there is a conceptual mismatch between this identifying assumption and the QV technique is discussed in section five.

4 Base Results

Quah and Vahey (1995) estimate a VAR with $\Delta \log$ of industrial production and $\Delta \Delta \log$ of the Retail Price Index using monthly UK data with a trend, seasonal dummies, a constant and twelve lags.¹⁰ Imposing the restriction specified by their technique yields impulse responses which imply the following: core shocks have no long-run impact on output and have a positive long-run impact on measured inflation, and non-core shocks have a positive long-run impact on output and a small (within one standard deviation of 0) positive long-run effect on measured inflation.¹¹

As a basis for comparison, a VAR with $\Delta \log$ of GDP at factor cost and $\Delta \Delta \log$ CPI was estimated using monthly seasonally adjusted Canadian data, with a trend, seasonal dummies, a constant and twelve lags. Imposing the restriction specified by the Quah-Vahey technique yields impulse responses with properties very similar to the UK model. A core shock has a positive long-run effect on measured inflation and a zero effect on output. A non-core shock has a (smaller) positive effect on measured inflation and a positive effect on output.¹²

For a more rigorous examination of this technique quarterly Canadian data was used. Although this results in the loss of some information present in the monthly CPI series, it allows on to use National Accounts GDP, which has longer history than GDP at factor

10. Quah and Vahey do not specify whether they used seasonally adjusted data or not. I contacted Mr. Quah to clarify this, but he was unable to recall which data was used for the final draft of the paper. I then attempted to replicate their work using UK data. The results I obtained in replicating their work led me to believe that they used seasonally adjusted data. Based on this assumption, I used seasonally adjusted series in replicating the QV model using Canadian data, even though the specification includes seasonal dummies.

11. In replicating their work I determined that the imposed restriction was over lags 0 to n (using values for n of 60 or 120 had negligible differences).

12. Refer to Figure 1.

cost. Additionally, one can look at models using the implicit GDP deflator as well those using the CPI.

4.1 Base Model

The base model is as follows:
$$X = \begin{bmatrix} \Delta Y \\ \Delta \pi \end{bmatrix}, X = \alpha + \sum_{i=1}^n B_i X_{(t-i)}.$$

A quarterly version of this model with seasonally adjusted $\Delta \log$ of GDP, $\Delta \Delta \log$ CPI, a constant and four lags yields results similar to the monthly model discussed above.¹³ A core shock has a positive long-run effect on measured inflation and a zero effect on output. A non-core shock has a (smaller) positive effect on measured inflation, and a positive effect on output. The initial choice of four lags was arbitrary, meant to span the same amount of history as the monthly twelve lag model. Lag length tests suggested that six lags should be used instead of four (Table 7b). The results of this model are summarized in Table 2 and Figures 2 and 3.

This model yields two main differences from the results presented by Quah and Vahey. Core shocks have a slightly negative long-run effect on output (Figure 2a) and non-core shocks have a positive long-run effect on the measured inflation, even greater than the effect of core shocks. This yields a measure of core inflation that has movements broadly consistent with official inflation, except for the decline over 1991-1994 (Figure 2d). This would suggest that much of the recent decline in official inflation is associated with non-core shocks.

A specification of this model using the implicit GDP deflator instead of the CPI was estimated as well, although lag length tests suggested using eight lags (Table 8b). The resulting impulse response functions were quite similar with two exceptions. Core shocks had a slightly positive long-run effect on output, and non-core shocks had a much smaller positive effect on inflation (Figure 3a). As with the model using the CPI, this specification yields a measure of core inflation that has movements which are broadly consistent with

13. Seasonal dummies were not used, as the data was seasonally adjusted. A time trend was not used in the VAR, as it would pick up a quadratic time trend, and the economic meaning behind a quadratic time trend in the change in output and inflation is unclear.

official inflation, except for the decline over 1991-1994 (Figure 3d). This would suggest that much of the recent decline in official inflation is associated with non-core shocks (Figure 3c).

Section 3.1 outlined two criteria that should be used when judging what are reasonable results. A core shock should not have a significant long-run effect on output, and a non-core shock should not have a significant long-run effect on inflation. To test the significance of these results, 90% confidence intervals around the impulse responses were created using the Monte-Carlo technique and 1000 draws.¹⁴ Table 2 summarizes the long-run effects of the two shocks on the different variables for specifications with CPI and PGDP inflation. The sections of the table that address the two criteria are highlighted and be insignificant to infer that the model yields reasonable results.

Table 2: Long-run Effects, Quah-Vahey Decomposition

CPI inflation				
shock	effect on output	significant	effect on inflation	significant
core	negative	no	positive	yes
non-core	positive	yes	positive	yes
PGDP inflation				
shock	effect on output	significant	effect on inflation	significant
core	positive	no	positive	yes
non-core	positive	yes	positive	no

The results of the base model using the CPI inflation violate the second criteria. Non-core shocks have a significant long-run effect on inflation (Figure 2b, Table 2), an effect of greater magnitude than from core shocks. This implies core inflation has not been identified properly.

The base model using the implicit GDP deflator (PGDP) for inflation yields much more reasonable results, satisfying both of the criteria (Figure 3b, Table 2). However, there remains the issue of using the first difference in the VAR as addressed in section 3.2:

14. Confidence intervals were created using 1000 Bootstrap simulations. Refer to Appendix 4 for details regarding this technique.

one cannot make inferences regarding the level of core inflation and may lose some information present in the level series. For these reasons the former specification may not yield a reliable estimate of core inflation. Therefore it is necessary to investigate models that use the level of inflation instead of the first difference.

4.2 Alternate Model

The alternate model is $X = \begin{bmatrix} \Delta Y \\ \pi \end{bmatrix}$, $X = \alpha + \sum_{i=1}^n B_i X_{(t-i)}$, the results of which

are summarized in Table 3, and in Figures 4 and 5.

Table 3: Long-run Effects, Quah-Vahey Decomposition

CPI inflation				
shock	effect on output	significant	effect on inflation	significant
core	negative	yes	positive	yes
non-core	positive	no	positive	yes
PGDP inflation				
shock	effect on output	significant	effect on inflation	significant
core	negative	no	positive	yes
non-core	positive	yes	positive	no

A specification of this model using CPI inflation has six lags (Table 5b) and yields impulse response functions that are unreasonable according to both criteria (Figures 4a-b, Table 3). Core shocks have a significant long-run impact on output and non-core shocks have a significant long-run effect on inflation. This specification is not given any further consideration.

The specification using PGDP inflation has eight lags (Table 6b) and yields impulse response functions that meet both of the criteria. Core shocks do not have a significant effect on output and non-core shocks do not have a significant effect on inflation (Figure 5a-b, Table 3). This yields a measure of core inflation that is closely matched with the official measure over most of history, with the exception of the 1991 to 1994 period where

core inflation is higher than official inflation (Figure 5d).

Assuming core inflation has been identified correctly this result implies that some of the recent disinflation is due to negative non-core shocks, thus is only transitory. Given the consistently low rate of inflation encountered over the past few years, it seems unlikely that the 1990 to 1994 disinflation was transitory. This suggests that core inflation has not been well identified.

Additionally, it is interesting to note that the effect of a core shock on output in the long run is negative (Figure 5a). The negative effect is consistent with the prior that core inflation has long-run costs, therefore implying a backward-bending long-run Phillips curve. This is not consistent with the identifying assumption of a vertical long-run Phillips curve and raises serious concerns about the identification technique.

5 Critique of the Quah-Vahey Method

The Quah-Vahey (QV) technique does not generally yield core shocks that are output-neutral in the long run. Although in many cases the effects are not significant at the 90% level, the construction of core inflation implies non-zero long-run effects on output. This is in conflict with the identifying assumption, and suggests some re-examination of what is really being identified. In order to do this, the QV technique is compared to the BQ technique.

Blanchard and Quah identify a shock that has a zero long-run effect on a variable (Y). In order to do this, they include ΔY in the VAR, and identify a transformation of the VAR

that restricts the effects of a shock on ΔY of a to sum to zero ($\sum_{j=0}^L d_{11}(j) = 0$). It is clear

that if the changes sum to zero, the effect on the level of Y will be zero as well. The restriction must be over lags 0 to L (where L is the definition of the long run). If the first

few lags were skipped (i.e. $\sum_{j=4}^L d_{11}(j) = 0$) this would be ignoring the short-run effects

and the long-run effect on Y of a shock would not be 0. The long-run effect but would be

the sum of the effects over lags 0 to 3 ($\sum_{j=0}^3 d_{11}(j)$). This is clearly not what is desired.

Quah and Vahey seek to minimize the long-run effect of a shock on Y instead of imposing it to be zero. In order to do this they include ΔY in the VAR, but instead of

imposing a long-run restriction ($\sum_{j=0}^L d_{11}(j) = 0$) they come up with a method of

minimization. They look at the sum of the squared coefficients in the transformed model

($\sum_{j>N} d_{11}(j)^2$) and pick a transformation to minimize this term. Although their notation is

not precise, to minimize the effect on Y it is clear that they must sum from lag zero

($\sum_{j \geq 0} d_{11}(j)^2$). If any lags in the beginning of moving average representation were

skipped (i.e. in the former notation $N=3$) the short run effects would be ignored and only the effects taking place after the short-run would be minimized. As illustrated in the BQ discussion, this is clearly not desired.

The QV method minimizes the sum of squares which highly penalizes any large responses at any lag. The resulting impulse function has small coefficients for the effect of core shocks on ΔY at every lag. If one assumes that a significant short-run Phillips curve exists, one would expect relatively large coefficients over the short run, (i.e. $d_{11}(0)$ to $d_{11}(3)$). As is illustrated above, this technique does take into account the coefficients in the infinite moving average representation which correspond with the short run and will include them in the minimization process. As a result, the coefficients over the short run will be minimized and this is inconsistent with the hypothesis of a positively sloped short-run Phillips curve.

In addition to not guaranteeing a measure of core inflation consistent with a vertical long-run Phillips curve, the QV method yields a measure of core inflation that is inconsistent with the hypothesis of a positively sloped short-run Phillips curve. Clearly this method is not useful for deriving core inflation.

6 Alternate Method: Blanchard - Quah Technique

The previous section shows that the Quah-Vahey method does not generally derive a measure of core inflation with no long-run impact on output and imposes a restriction with undesirable properties. However, an alternate method exists which could be used to derive such a measure. Blanchard and Quah (1989) propose a method which identifies a shock that has a zero long run effect on output. It was originally proposed to identify supply and demand shocks, but in the context of inflation and change in output can ensure a measure of core inflation that has a zero long-run impact on output.

6.1 Reasonable effects of core/non-core shocks

With this technique core shocks have a zero long-run effect on output by definition. This attribute can therefore no longer be used as a criteria by which to judge the results of models. One still expects to see non-core shocks with an insignificant effect on inflation, so the second criteria stated in section 3.1 is unchanged.

With this methodology the definition of the long-run is now an exogenous specification in the model. In order to have confidence in the resulting measure of core inflation one would hope to use a model that is not particularly sensitive to changes in this specification. This provides a new criteria for judging results: the model should not be particularly sensitive to different reasonable definitions of the long run.

6.2 Model

The reasons for using inflation instead of the change in inflation stated in section 3.2

still hold, so the model under examination becomes: $X = \begin{bmatrix} \Delta Y \\ \pi \end{bmatrix}$,

$X = \alpha + \sum_{i=1}^n B_i X_{(t-i)}$, and the results of this model are summarized in Table 4, and in

Figures 6, 7, and 8.

The specification with CPI inflation includes six lags (Table 5b). Two variations are considered; one assumes neutrality in five years (20 quarters) and the other assumes neutrality in ten years (40 quarters). The resulting impulse responses (Figure 6a) and

inflation decompositions (Figure 6b) are somewhat different. Thus one must conclude that this specification is questionable according to the first criteria. In order to examine how well this specification meets the second criteria the model with a long-run definition of 40 quarters is examined further. This specification meets the second criteria, as non-core shocks do not have a significant long-run effect on inflation (Figures 6c). As this specification does not meet the first criteria, its results are judged with some suspicion. This suggests that the BQ method using CPI inflation does not identify a measure of core inflation that the monetary authority would be interested in.

Table 4: Long-run Effects, Blanchard-Quah decomposition

CPI inflation				
shock	effect on output	significant	effect on inflation	significant
core	0	imposed	positive	no
non-core	positive	no	negative	no
Sensitive to long-run specification	yes			
PGDP inflation				
shock	effect on output	significant	effect on inflation	significant
core	0	imposed	positive	yes
non-core	positive	yes	negative	no
Sensitive to long-run specification	no			

The specification with PGDP inflation includes eight lags (Table 6b). Two variations are considered; one assumes neutrality in five years (20 quarters) and the other assumes neutrality in 10 years (40 quarters). The resulting impulse responses (Figure 7a) and inflation decompositions (Figure 7b) are quite similar, therefore this specification meets the first criteria. The specification with neutrality imposed in 40 quarters meets the second

criteria as well, as non-core shocks do not have a significant long-run effect on inflation (Figure 7c).

Although both of the criteria for judging what are reasonable results are met, the core measure based on the implicit GDP deflator does not take out the effects of tax rate changes. This can be seen in Figure 8a, where the effects of the GST (1991Q1) and the cigarette tax reduction (1994Q1) clearly show up in the implicit GDP deflator and the core measure (the CPI is included as a reference).

The Blanchard-Quah method does not result in a well-behaved measure of core inflation using the CPI, as the core measure is sensitive to the time horizon defining the long run. The model using the implicit GDP inflation yields a measure of core inflation that is well behaved and is very well matched with the official price measure (Figure 8a). However, this core measure does not exclude the effects of tax shocks. Given that the monetary authority would like a core measure to exclude shocks that just have price level effects and that this method clearly does not do so, one must conclude that the BQ method does not yield a measure of core inflation of interest to the monetary authority.

7 Conclusions

The Quah-Vahey method is not generally useful for deriving a measure of core inflation. This method imposes restrictions that are inconsistent with the hypothesis of a short-run Phillips curve, thus imposing undesirable properties.

The Blanchard-Quah restriction appears to be more useful for deriving core inflation based on the theory of a vertical long-run Phillips curve. One must consider two criteria when judging the results of this method. Non-core shocks should not have a significant long-run impact on inflation, and results should not be sensitive to reasonable changes in the definition of the long run.

The model using CPI inflation does not meet one of these criteria, but the model using the GDP deflator does. Although this method is consistent with the identifying assumption of a vertical long-run Phillips curve, the specification using the GDP deflator does not exclude shocks which only have price level effects. Because of this limitation, the value to the monetary authority of measuring core inflation with this method seems to be very limited.

Bibliography

- Bank of Canada, 1991. "Targets for reducing inflation: Announcements and background material." *Bank of Canada Review* (March): 3 - 21.
- _____, 1991. "Targets for reducing inflation: Further operational and measurement considerations." *Bank of Canada Review* (September): 3 - 23.
- _____, 1993-1994. "Statement of the Government of Canada and the Bank of Canada on monetary policy objectives" *Bank of Canada Review* (Winter): 85-86.
- _____, 1995. *Monetary Policy Report* (November).
- Blanchard, O. and Quah, D., "The Dynamic Effects of Aggregate Demand and Supply Disturbances," *The American Economic Review*, September 1989.
- Crawford, A., *Measurement Biases in the Canadian CPI*, Technical Report No. 64, Bank of Canada, September 1993.
- DeSerres, A., and Guay, A., "Selection of the Truncation Lag in Structural VARs (or VECMs) with Long-Run Restrictions," Working Paper 95-9, Bank of Canada, October 1995.
- Doan, Thomas, *RATS 4.0 Users Manual*, Estima, 1992.
- Efron, B. and Tibshirani, R.J., *An Introduction to the Bootstrap*, New York: Chapman & Hall, Inc., 1993.
- Fischer, I., *The Purchasing Power of Money*, New York: MacMillan, 1922 reprinted 1971.
- Fortin, P., "Do We Measure Inflation Correctly," in *Zero Inflation: The Goal of Price Stability*, ed. R.G. Lipsey, C.D. Howe Institute, 1990.
- Friedman, C., "Formal Targets for Inflation Reduction: The Canadian Experience," Presented at Conference on a Framework for Monetary Stability, de Nederlandsche Bank, Oct. 1993.
- Fuller, W. A., *Introduction to Statistical Time Series*, New York: John Wiley & Sons, Inc., 1976.
- Harvey, A.C., *Time Series Models*, Oxford: Philip Allan Publishers Limited, 1981.
- Hostland, D., "Changes in the Inflation Process in Canada: Evidence and Implications," Working Paper 95-5, Bank of Canada, 1995.

Howitt, P., "Zero Inflation as a Long Term Target for Monetary Policy," in *Zero Inflation: The Goal of Price Stability*, ed. R.G. Lipsey, C.D. Howe Institute, 1990.

Paquet, A., "A Guide to Applied Modern Macroeconometrics," Working Paper 94-05, Department of Finance, 1994.

Quah, D. and Vahey, S. P., "Measuring Core Inflation", *The Economic Journal*, September 1995.

Selody, J., *The Goal of Price Stability: A Review of the Issues*, Technical Report No. 54, Bank of Canada, May 1990.

Simon and Blume, *Mathematics for Economists*, New York: W.W. Norton & Company, 1994.

Sims, "Macroeconomics and Reality", *Econometrica*, Vol. 48 No. 1, January 1980.

Wolf, M., "A Gamble with Stability", *The Financial Times (U.K.)*, January 16, 1996.

APPENDIX 1

Lag length Selection Criteria

Choose the lag that minimizes the absolute value of one of the following criteria:

$$\text{akaike criteria} = \log\det(\Sigma) + (2 * n_{\text{reg}} * n_{\text{reg}} * \text{lags} / \text{nobs})$$

$$\text{Hannan-Quinn criteria} = \log\det(\Sigma) + (n_{\text{reg}} * n_{\text{reg}} * \log(\text{nobs}) / \text{nobs})$$

$$\text{schwartz criteria} = \log\det(\Sigma) + (2 * n_{\text{reg}} * n_{\text{reg}} * \log(\log(\text{nobs})) / \text{nobs})$$

Likelihood Ratio tests

For lag length tests, the unrestricted model is that with n lags.

The restricted model is that with $n-k$ lags.

The following tests the null hypothesis that the restriction(s) is(are) valid, i.e.

Ho: restrictions cannot be rejected, i.e. coefficients on last k lags = 0

H1: restrictions can be rejected

The test statistic is distributed as Chi-Squared, with degrees $(k * \text{number of variables})^{**2}$

The test statistic = $(\text{number of observations} - (\text{number of regressors in unrestricted}))$

* $(\text{Log of the determinant of the restricted covariance matrix}$

- $\text{Log of the determinant of the unrestricted covariance matrix})$

as proposed by Sims(1980).

Interpreting Tables 5 through 8

Akaike, Hannan-Quinn, Schwartz criteria¹ point to using between three and five lags for all models tested. However, DeSerres and Guay(1995) find that these information criteria generally lead to choosing lag lengths that are too small, which can lead to estimation bias of the permanent and/or temporary components of the infinite moving average representation. They recommend using sequence based tests to determine the lag length to use, either a Wald test or a likelihood ratio test. Thus decisions regarding the appropriate lag length to use in models were based on likelihood ratio tests, although the information criteria are presented as well.

1. Paquet, 1994

Table 5a: tests for lag length of VARs with $\Delta \log$ CPI and $\Delta \log$ Output(quarterly)

lags	Selection Criteria		
	akaike	HQ	schwartz
1	-1.23300	-1.05419	-0.95312
2	-1.33466	-0.83795	-0.55724
3	-0.40678	-0.43322	0.11696
4	1.55853	0.16788	1.07737
5	5.51549	0.91957	2.27820
6	10.44262	1.80039	3.69797
7	17.39264	2.86305	5.38941
8	26.36399	4.10597	7.35095

Table 5b: Likelihood Ratio Tests

Lags	4vs 2	6vs4	8vs6	10vs8	10vs6
Chi-Squared	(8) 20.82	(8) 16.80	(8) 10.76	(8) 8.12	(16) 17.71
Significance	0.0076	0.032	0.215	0.422	0.341

Conclusion: 6 lags

Table 6a: tests for lag length of VARs with $\Delta \log$ PGDP and $\Delta \log$ Output(quarterly)

	Selection Criteria		
lags	akaike	HQ	schwartz
1	-0.69258	-0.51377	-0.41271
2	-0.94383	-0.44712	-0.16642
3	-0.02475	-0.05120	0.49899
4	1.85429	0.46363	1.37312
5	5.83541	1.23949	2.59811
6	10.81349	2.17126	4.06884
7	17.79294	3.26335	5.78971
8	26.73300	4.47499	7.71996

Table 6b: Likelihood Ratio Tests

Lags	4vs 2	6vs4	8vs6	8vs4	10vs8
Chi-Squared	(8) 20.06	(8) 15.02	(8) 14.19	(8) 25.98	(8) 12.54
Significance	0.010	0.059	0.077	0.054	0.129

Conclusion: 8 lags

Table 7a: tests for lag length of VARs with $\Delta\Delta\log$ CPI and $\Delta\log$ Output (quarterly)

lags	Selection Criteria		
	akaike	HQ	schwartz
1	-1.51710	-1.31039	-1.19760
2	-1.55753	-0.98334	-0.67003
3	0.37178	-0.50281	0.11127
4	2.31017	0.17054	1.18565
5	6.25968	1.03876	2.55516
6	12.22980	2.11132	4.22927
7	20.20784	3.37555	6.19530
8	31.19826	4.83589	8.45771

Table 7b: Likelihood Ratio Tests

Lags	4vs 2	6vs4	8vs6	10vs8	10vs6
Chi-Squared	(8) 15.43	(8) 18.42	(8) 7.65	(8) 9.05	(16) 18.60
Significance	0.051	0.018	0.469	0.338	0.290

Conclusion: 6 lags

Table 8a: tests for lag length of VARs with $\Delta\Delta\log$ PGDP and $\Delta\log$ Output(quarterly)

lags	Selection Criteria		
	akaike	HQ	schwartz
1	-0.96767	-0.78789	-0.68642
2	-1.11033	-0.61094	-0.61094
3	-0.23046	-0.25165	0.30079
4	1.70335	0.32138	1.23460
5	5.68987	1.10692	2.47112
6	10.66485	2.04073	3.94610
7	17.62271	3.11722	5.65396
8	26.59529	4.36824	7.62654

Table 8b: Likelihood Ratio Tests

Lags	4vs 2	6vs4	8vs6	10vs8	10vs6	10vs4
Chi-Squared	(8) 23.76	(8) 6.36	(8) 11.76	(8) 9.92	(16) 24.43	(24) 36.15
Significance	0.0025	0.607	0.162	0.272	0.081	0.053

Conclusion: 8 lags

APPENDIX 2**1 Impulse Responses (model Δ Log of Output, Δ Inflation (CPI))**

2a Impulse Responses (model Δ Log of Output, Δ Inflation (CPI))

2b with 90% Confidence bands

2c

Decomposition of CPI (in logs)

2d y/y Inflation

CPI

3a Impulse Responses (model Δ Log of Output, Δ Inflation (PGDP))

3b with 90% Confidence bands

3c

Decomposition of pgdp (in logs)

3d y/y inflation

PGDP

4a Impulse Responses (model Δ Log of Output, Inflation (CPI))

4b with 90% Confidence bands

4c

Decomposition of CPI (in logs)

4d y/y Inflation

5a Impulse Responses (model ΔLog of Output, Inflation (PGDP))

5b with 90% Confidence bands

5c

Decomposition of PGDP (in logs)

5d y/y Inflation

6a Impulse Responses (model Δ Log of Output, Inflation (CPI))

6b y/y CPI Inflation

6c with 90% Confidence bands (40 quarters)

6d Decomposition of CPI Price Measures (logs)

7a Impulse Responses (model Δ Log of Output, Inflation (PGDP))

7b y/y PGDP Inflation

7c with 90% Confidence bands (40 quarters)

7d Decomposition of PGDP Price Measure (logs)

8a PGDP Price Measures Comparisons (logs)

Annual Percent Changes

APPENDIX 3: Details of Decomposition Methodology

The first step in implementing this technique is to estimate a VAR. Following Quah and Vahey, a VAR consisting of the first difference in the log of output (ΔY) and the first difference of inflation ($\Delta\pi$) is estimated:

$$X = \begin{bmatrix} \Delta Y \\ \Delta\pi \end{bmatrix}, \quad X = B(L)X + e.$$

The moving average representation of the VAR is as follows:

$$\begin{aligned} X_t &= B(L) X_t + e_t \\ [I - B(L)] X_t &= e_t \\ X_t &= [I - B(L)]^{-1} e_t \\ (1) \quad X_t &= e_t + C(1)e_{t-1} + \dots + C(\infty)e_{t-\infty} \\ X_t &= \left(\sum_{j=0}^{\infty} C(j)e_{t-j} \right) \quad \text{Var}(e) = \Omega. \end{aligned}$$

In this case, one wants to identify two shocks: core shocks (η_1) and non-core shocks (η_2).¹ This is accomplished by finding a transformation of the VAR from which one can recover these shocks. The moving average representation of the transformed VAR would be:

$$\begin{aligned} SX_t &= SB(L) X_t + Se_t \\ S[I - B(L)] X_t &= Se_t \\ X_t &= [I - B(L)]^{-1} S^{-1} Se_t \\ \text{define: } S^{-1} &= D(0), \quad (S^{-1})(S^{-1})^T = \Omega, \quad \eta_t = Se_t \\ X_t &= [I - B(L)]^{-1} D(0) \eta_t \\ (2) \quad X_t &= D(0)\eta_t + D(1)\eta_{t-1} + \dots + D(\infty)\eta_{t-\infty} \end{aligned}$$

1. Core shocks are those that have minimal long-run effects on output. This is slightly different than the better known Blanchard-Quah technique, which identifies core shocks as those that have a zero effect on output in the long run.

$$X_t = \left(\sum_{j=0}^{\infty} D(j) \eta_{t-j} \right) \quad \text{Var}(\eta) = I.$$

From (1) and (2) one can see that

$$X_t = \left(\sum_{j=0}^{\infty} [C(j)D(0)] D(0)^{-1} e_{t-j} \right)$$

$$e = D(0)\eta \quad \text{or} \quad \eta = D(0)^{-1}e, \quad \text{and}$$

$$D(j) = C(j)D(0).$$

$d_{11}(j)$ will be the effect of shock 1 on output growth after j periods.

$d_{12}(j)$ will be the effect of shock 2 on output growth after j periods.

$d_{21}(j)$ will be the effect of shock 1 on the change in measured inflation after j periods.

$d_{22}(j)$ will be the effect of shock 2 on the change in measured inflation after j periods.

$$\text{Thus } \Delta\pi(t) = \sum_j d_{21}(j) \eta_1(t-j) + \sum_j d_{22}(j) \eta_2(t-j) .$$

With a constant, the moving average representation of the transformed VAR would be:

$$(3) \quad X_t = \alpha + \left(\sum_{j=0}^{\infty} D(j) \eta_{t-j} \right) \quad \text{Var}(\eta) = I.$$

$$\text{Thus } \Delta\pi(t) = \alpha_2 + \sum_j d_{21}(j) \eta_1(t-j) + \sum_j d_{22}(j) \eta_2(t-j) , \text{ and}$$

$$\Delta Y(t) = \alpha_1 + \sum_j d_{11}(j) \eta_1(t-j) + \sum_j d_{12}(j) \eta_2(t-j) .$$

How does one derive the transformation matrix?

In order to derive the transformation matrix S , Quah and Vahey (1995) propose picking a matrix which minimizes the long run effect on output of core inflationary shocks.

$$\begin{array}{ll} D(0) D(0)^T = \Omega & \text{yields three restrictions, and} \\ \min. \sum d_{11}(j)^2 & \text{yields fourth restriction.} \end{array}$$

d_{11} is the effect of a shock on the change in output, so this is minimizing the sum of the squared effects on the change in output.

To impose this fourth restriction, one does the following:

$$\begin{aligned} \min_{D(0)} \sum_{j>N} d_{11}(j)^2 &\iff \min_{D(0)} \sum_{j>N} \left(\begin{bmatrix} c_{11}(j) & c_{12}(j) \end{bmatrix} \begin{bmatrix} d_{11}(0) \\ d_{21}(0) \end{bmatrix} \right)^2 \\ &\iff \min_{D(0)} \begin{bmatrix} d_{11}(0) & d_{21}(0) \end{bmatrix} \sum_{j>N} \begin{bmatrix} c_{11}(j)^2 & c_{11}c_{12}(j) \\ c_{11}c_{12}(j) & c_{12}(j)^2 \end{bmatrix} \begin{bmatrix} d_{11}(0) \\ d_{21}(0) \end{bmatrix} \end{aligned}$$

A standard property of symmetric matrices proves that $\begin{bmatrix} d_{11}(0) \\ d_{21}(0) \end{bmatrix}$ is an eigenvector

associated with an eigenvalue of $\sum_{j>0} \begin{bmatrix} c_{11}(j)^2 & c_{11}c_{12}(j) \\ c_{11}c_{12}(j) & c_{12}(j)^2 \end{bmatrix}$.

Let A be a $k \times k$ symmetric matrix²

- (a) all k roots of the characteristic equation $\det(A - \lambda I) = 0$ are real numbers
- (b) eigenvectors corresponding to distinct eigenvalues are orthogonal
- (c) even if A has multiple eigenvalues, there is a non-singular matrix P whose columns $w_1, \dots, w_k$ are eigenvectors of A such that
 - (i) $w_1, \dots, w_k$ are mutually orthogonal to each other
 - (ii) $P^{-1} = P^T$

2. Theorem 23.16 (Simon and Blume, pg 621)

$$(iii) P^{-1}AP = P^TAP = \begin{bmatrix} \lambda_1 & 0 & \dots & 0 \\ 0 & \lambda_2 & \dots & 0 \\ \dots & \dots & \dots & \dots \\ 0 & 0 & \dots & \lambda_k \end{bmatrix}$$

The resulting eigenvector associated with the smallest eigenvalue gives us the desired relationship between $d_{11}(0)$ and $d_{21}(0)$ in the $D(0)$ matrix, and imposes the fourth restriction. Coupled with the three restrictions that $D(0)D(0)^T = \Omega$, $D(0)$ can be uniquely determined and is the inverse of the transformation matrix S .

$$\begin{bmatrix} d_{11} & d_{12} \\ d_{21} & d_{22} \end{bmatrix} \begin{bmatrix} d_{11} & d_{21} \\ d_{12} & d_{22} \end{bmatrix} = \begin{bmatrix} d_{11}d_{11} + d_{12}d_{12} & d_{11}d_{21} + d_{12}d_{22} \\ d_{11}d_{21} + d_{12}d_{22} & d_{21}d_{21} + d_{22}d_{22} \end{bmatrix} = \begin{bmatrix} \Omega_{11} & \Omega_{12} \\ \Omega_{12} & \Omega_{22} \end{bmatrix}$$

$$d_{11} = b \cdot d_{21}$$

$$d_{11}^2 + d_{12}^2 = \Omega_{11}$$

$$d_{11}d_{21} + d_{12}d_{22} = \Omega_{12}$$

$$d_{21}^2 + d_{22}^2 = \Omega_{22}$$

Thus the solution to this problem is (used MAPLE):

$$d_{11} = b \cdot d_{21}$$

$$d_{21} = ((\Omega_{22} \cdot \Omega_{11} - \Omega_{12}^2)^{0.5}) \cdot (\Omega_{22} \cdot b^2 - 2b \cdot \Omega_{12} + \Omega_{11})^{-0.5}$$

$$d_{12} = (\Omega_{11} - b \cdot \Omega_{12}) \cdot (\Omega_{22} \cdot b^2 - 2b \cdot \Omega_{12} + \Omega_{11})^{-0.5}$$

$$d_{22} = (\Omega_{12} - b \cdot \Omega_{22}) \cdot (\Omega_{22} \cdot b^2 - 2b \cdot \Omega_{12} + \Omega_{11})^{-0.5}$$

Alternately, a decomposition that imposed neutrality could be identified by using the methodology described in Blanchard and Quah (Sept. 1989):

$$D(0)D(0)^T = \Omega \quad \text{yields three restrictions, and}$$

$$\sum_{j=0}^N d_{11}(j) = 0 \quad \text{yields the fourth restriction}$$

$$\text{where } \Sigma D(j) = \begin{bmatrix} \sum d_{11}(j) & \sum d_{12}(j) \\ \sum d_{21}(j) & \sum d_{22}(j) \end{bmatrix}.$$

This fourth restriction would be that core inflationary shocks (π_1) have no long run impact on output, i.e. inflation is output-neutral in the long run. This is because one is setting the sum of the changes in output equal to zero.

$$\sum d_{11}(j) = \sum [c_{11}(j) \ c_{12}(j)] \begin{bmatrix} d_{11}(0) \\ d_{21}(0) \end{bmatrix} = \sum c_{11}(j) d_{11}(0) + \sum c_{12}(j) d_{21}(0) = 0$$

Thus the fourth restriction is again regarding the relationship between $d_{11}(0)$ and $d_{21}(0)$, and is easily derived from the infinite moving average representation of the untransformed VAR.

Thus the solution is the same,

$$\begin{bmatrix} d_{11} & d_{12} \\ d_{21} & d_{22} \end{bmatrix} \begin{bmatrix} d_{11} & d_{21} \\ d_{12} & d_{22} \end{bmatrix} = \begin{bmatrix} d_{11}d_{11} + d_{12}d_{12} & d_{11}d_{21} + d_{12}d_{22} \\ d_{11}d_{21} + d_{12}d_{22} & d_{21}d_{21} + d_{22}d_{22} \end{bmatrix} = \begin{bmatrix} \Omega_{11} & \Omega_{12} \\ \Omega_{12} & \Omega_{22} \end{bmatrix}$$

$$d_{11} = b \cdot d_{21}$$

$$d_{11}^2 + d_{12}^2 = \Omega_{11}$$

$$d_{11} d_{21} + d_{12} d_{22} = \Omega_{12}$$

$$d_{21}^2 + d_{22}^2 = \Omega_{22}$$

the only difference is how b is determined.

APPENDIX 4: Confidence Intervals using the Bootstrapping Technique

In order to get confidence intervals using the bootstrapping technique for a particular impulse response:

- (1) Estimate the VAR: $X = \hat{\alpha} + \hat{\beta}(L)X + \hat{\varepsilon}.$
- (2) Calculate the decomposition matrix, generate and save the impulse responses.
- (3) Do n times:
 - (i) Draw random ε' shocks using the estimated variance/covariance matrix of $\hat{\varepsilon}$, and assuming a normal distribution for the random number generator.
 - (ii) Generate: $X' = \hat{\alpha} + \hat{\beta}(L)X' + \varepsilon'.$
*((i) and (ii) are done with the **simulate** command in RATS.)*
 - (iii) Estimate a VAR: $X' = \tilde{\alpha} + \tilde{\beta}(L)X' + \tilde{\varepsilon}.$
 - (iv) Calculate the decomposition matrix, generate and save impulse responses as rows in a matrix.

One ends up with a matrix of n rows (n iterations), and t columns (t is the time horizon chosen) for each impulse response. To get the confidence bands, sort each column of the impulse response matrix, then save the appropriate rows depending on what confidence level is desired.

In this case, 1000 draws were performed ($n=1000$), and a 90% confidence band was desired, so the 50th and the 950th rows were saved and used as the lower and upper confidence bands.

APPENDIX 5: Data Sources

The data used for this paper was obtained from Statistics Canada. The following series are all available in Statistic Canada's CANSIM database.

Seasonally adjusted Consumer Price Index

Monthly: Matrix 7454, series P719500 from September 1978 on.

Before September 1978, seasonal adjustments calculated at the Bank of Canada are applied to unadjusted series D484000.

Quarterly: average of the monthly series.

Seasonally adjusted Consumer Price Index excluding Food, Energy, and Indirect Taxes

Monthly: Matrix 903, series B3312.

Quarterly: average of the monthly series.

Seasonally adjusted GDP at Factor Cost

Monthly: Matrix 4671, series I37026.

Seasonally adjusted National Accounts GDP

Quarterly: Matrix 6829, series D20463.

Implicit GDP deflator

Quarterly: Matrix 6836, series D20556.

END

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FIN