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Abstract

Since World War II, permanent interest rate shocks have driven nearly all of the fluctuations of U.S. M1 velocity, which is cointegrated with the short rate, and most of the long-horizon variation in the velocity of M2-M1. Permanent velocity shocks specific to M2-M1, on the other hand, have played a minor role. Further, counterfactual simulations show that, absent permanent interest rate shocks, M1 velocity would have been broadly flat, and fluctuations in the velocity of M2-M1 would have been more subdued than they have historically been. We show that failure to distinguish between M1 and M2-M1 causes a significant distortion of the inference, erroneously pointing towards a dominant role for M2 velocity shocks.

Keywords: Money demand; structural VARs; unit roots; cointegration; long-run restrictions.

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1 Introduction

In his classic investigation of the dynamics of U.S. money velocity since the times of the Civil War (1861-1865), Richard Selden (1956) pointed out that

> '[e]conomists have been talking about the velocity of circulation of money and related concepts for nearly three hundred years. [...] Prior to the Great Depression most economists [assumed] velocity to be essentially constant for short normal periods. Since the early 1930s, however, there has been a growing conviction that the velocity of money is highly volatile and undependable [...].'

Selden summarized his main findings as providing

> 'little support to the hypothesis that velocity movements are mainly a result of changes in the cost of holding money. Whatever role the cost of holding money may have had during some periods of our history, it cannot account for the major velocity changes between 1919 and 1951.'

Six decades after the publication of Selden's work, the conventional wisdom in the macroeconomics profession is quite remarkably little changed: As John Cochrane (1998) put it in his exploration of the fiscal theory of the price level,

> '[m]oney demand relations are dominated by *velocity shocks* [...]'.[1]

The main reason behind this view is the alleged disappearance, starting from the early 1980s, of any previously identified stable relationship between monetary aggregates, GDP, and interest rates. For the United States, for example, researchers such as Friedman and Kuttner (1992) documented the breakdown, during those years, of any stable long-run demand for several alternative monetary aggregates.[2] The standard explanation for such evidence of widespread instability in money-demand relationships is that velocity shocks play a sizeable, or even a dominant role.

The literature[3] discusses three main sources of velocity shocks:

(*i*) *financial deepening*, defined as the increase in the size of the financial sector as a fraction of GDP[4] which is associated with the early stages of economic development. Since, *ceteris paribus*, financial deepening causes an increase in both the non interest-bearing demand deposits which are part of M1, and the interest-bearing components which are part of the non-M1 portion of broader aggregates (e.g., savings deposits), it automatically causes a decline in money velocity.

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[1] Emphasis in the original.

[2] By the same token, in the Euro area, the European Central Bank's so-called 'monetary pillar' (a 'reference value' for the annual growth rate of M3 derived from a money demand equation) has come to be seen as too unreliable to be of any use at all.

[3] See e.g. Bordo and Jonung (2009).

[4] And therefore in the ratios between its nominal assets and liabilities, and nominal GDP.

(*ii*) *Technological advances* in the payments and, more generally, financial system. Innovations such as credit cards or electronic cash management techniques, for example, reduce the transactions demand for money for any level of the interest rate, thus causing a corresponding increase in velocity. By the same token, the introduction of new financial instruments which satisfy asset demand motives previously met by (demand or savings) deposits decreases the demand for the latter, thus causing, again, an increase in velocity.

(*iii*) *Institutional changes* such as the introduction of unemployment benefits and public pension schemes decrease the precautionary demand for monetary assets for any level of the interest rate, thus causing, again, an increase in velocity.

In advanced countries such as the United States the process of financial deepening had largely been completed by World War I, but in other countries it either had been going on until recently, or it is still ongoing. Since in the present work we focus on the United States (and to a lesser extent Canada) since World War I, velocity shocks originating from financial deepening are, for our own purposes, essentially irrelevant, and technological advances in the financial system, and institutional changes, are therefore the main source of exogenous variation in velocity.

The view we take in this paper is at odds with today's conventional wisdom about the dominant role of velocity shocks in money-demand relationships. Specifically, we argue that most of the low-frequency fluctuations in U.S. and Canadian money velocity since World War I have *not* been caused by exogenous velocity shocks, and they have rather originated from the permanent interest rate fluctuations which, historically, have been one of the defining features of the period following the collapse of the Classical Gold Standard, in August 1914.[5] We argue that the permanent variation in nominal interest rates of the post-Gold Standard era has been mostly, or even entirely unrelated to 'authentic' velocity shocks (i.e. shocks originating from either financial deepening, technological advances, or institutional changes). In particular, conceptually in line with Friedman and Schwartz (1963), and with the most recent analysis of Benati and Ireland (2017), we show that during the interwar period fluctuations in U.S. interest rates had been driven, to a dominant extent, by shocks to the money multiplier (in particular, shocks to the reserves/deposits ratio) associated with the Great Depression episode. By the same token, during the post-WWII period permanent fluctuations in U.S. interest rates have been largely caused by the permanent inflation shocks mostly associated with the Great Inflation episode, and by shocks to the real interest rate.

Our main substantive results can be summarized as follows.

[5]In fact, marking the exact date of the end of the metallic standards era is all but impossible, as Richard Nixon's closing of the 'gold window' in August 1971 was the culmination of a decades-long unravelling process which had started with WWI. (For a fascinating discussion of such progressive unravelling, see e.g. Barro (1982).) We take August 1914 as the date marking the end of metallic standard mostly because we regard World War I as the single most important shock to the Gold Standard.

Since World War II, permanent interest rate shocks unrelated to 'authentic' velocity disturbances have driven nearly *all* of the fluctuations of U.S. M1 velocity—which is cointegrated with the short rate (see Benati, Lucas, Nicolini, and Weber, 2018; henceforth, BLNW)—and most of the long-horizon variation in the velocity of the M2-M1 aggregate. Permanent velocity shocks specific to M2-M1, on the other hand, have played a *minor* role. Further, counterfactual simulations show that, absent such permanent interest rate shocks, M1 velocity would have been broadly *flat*, and fluctuations in the velocity of M2-M1 would have been more subdued than they have historically been.

We also show that failure to distinguish between M1 and M2-M1 causes a significant distortion of the inference, erroneously pointing towards a dominant role for M2 velocity shocks. The reason for this is straightforward: Since, as we document, permanent interest rate shocks have an *opposite* effect on the velocities of M1 and M2-M1—due to the permanent portfolio reallocations they induce out of (into) non interest-bearing M1, and into (out of) interest-bearing M2-M1—failure to split M2 into its two components causes the shocks' impacts to largely cancel out in the aggregate. As a result, this spuriously creates the need for another 'shock' in order to explain the long-horizon dynamics of M2 velocity.

As for the period between the two World Wars, although evidence is more complex, and different under a number of dimensions—in particular, all identified shocks induced similar responses in the velocities of either M1, or M2-M1—a consistent finding is that, once again, 'authentic' velocity shocks played a uniformly minor role in driving velocity series, as well as other macroeconomic variables.

Our main conclusion is therefore that the macroeconomic profession's widespread consensus about the dominant role played by velocity shocks in driving money demand relationships is the figment of two errors:

first—and least importantly—a dominant focus on the post-WWII period. As mentioned, based on interwar data velocity shocks play a uniformly minor-to-negligible role, no matter how you 'slide and dice' the monetary data.

Second—and crucially—failure to split broader monetary aggregates into M1, whose velocity entails a strong and stable relationship with short-term nominal rates, and the non-M1 component, which, as we will see in the case of M2, *almost* does, but not quite, thus implying the presence of 'small' velocity shocks.

Although at odds with contemporary thinking in monetary economics, our conclusions are very much in the spirit of an older literature best exemplified by the work of Milton Friedman and Anna Schwartz, stressing the broad stability of monetary relationships, and the dangers caused by the instability in the monetary regime.

We reach these conclusions by working with cointegrated structural VARs identified *via* long-run restrictions. In fact, however, the economic logic underlying our re-interpretation of post-Gold Standard monetary history is extraordinarily simple, and can be briefly outlined as follows.

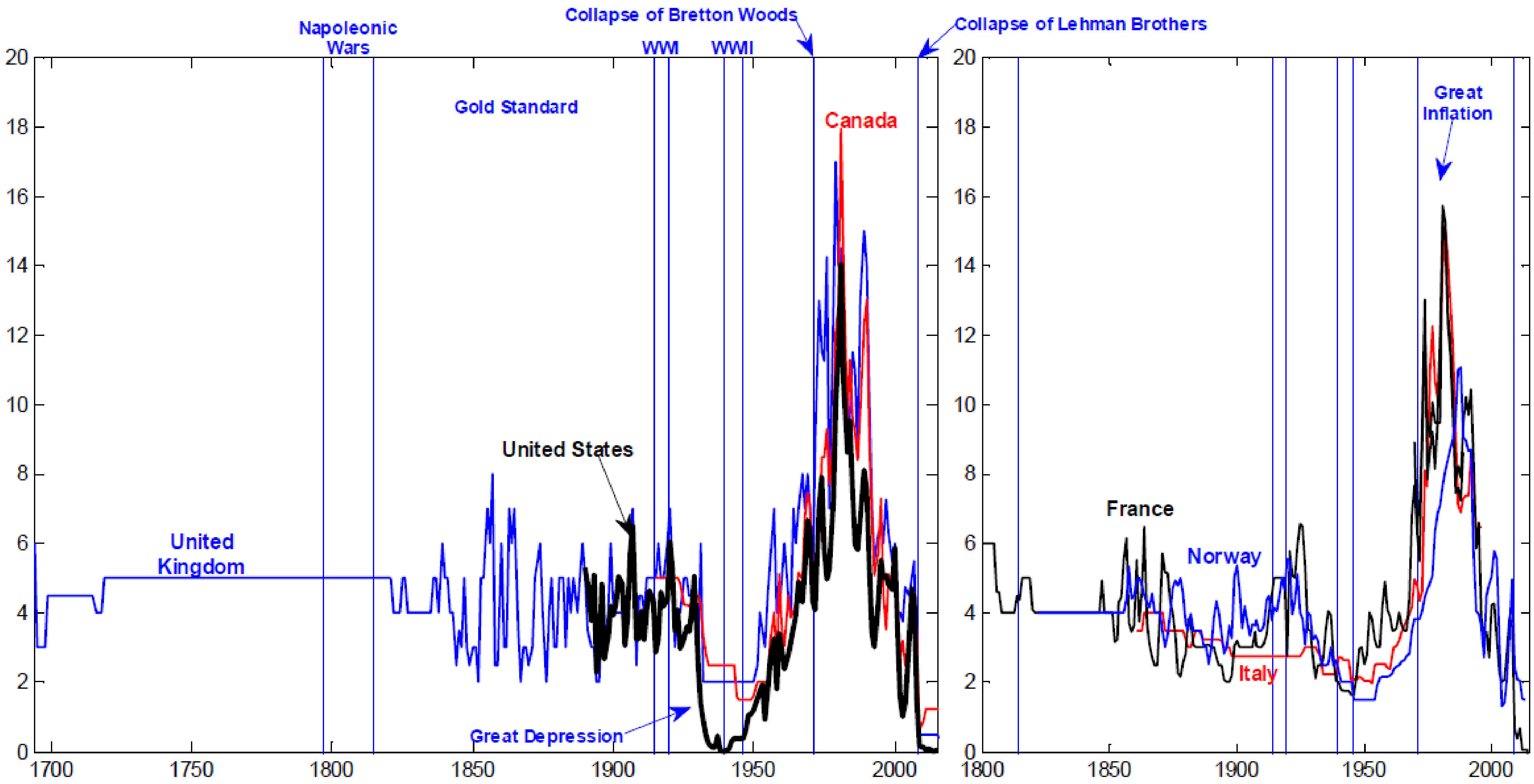

Figure 1 Short-term interest rates since the late XVII century

1.1 A summary of our argument

Before World War I, short-term interest rates had been strongly stationary for centuries,[6] reflecting the white noise character of inflation induced by monetary regimes based on metallic standards.[7] As extensively documented by BLNW (2018), on the other hand, since 1914

(*i*) short-term rates have been uniformly I(1) in all of the 32 countries in their dataset, reflecting the fact that, as first documented by Barsky (1987), under post-Gold Standard regimes inflation has typically acquired a unit root;[8] and

(*ii*) in many cases, short-term rates have been cointegrated with M1 velocity, thus pointing towards the existence of a stable long-run demand for M1. This is the case, e.g., for the United States, the United Kingdom, Canada, Australia, and Switzerland, and for several high-, or very high-inflation countries (Argentina, Bolivia, Brazil, Chile, and Israel).

Figure 1 provides a stark illustration of changes in the integration properties of short-term nominal interest rates since the late XVII century. Before World War I short rates had been either literally constant—as in the United Kingdom between 1721 and the aftermath of the Napoleonic Wars—or manifestly stationary (for statistical evidence on this, see footnote 6). Since the collapse of the Classical Gold Standard, on the other hand, visual evidence clearly suggests that—in line with the results from BLNW's (2018) unit root tests—short rates have acquired a permanent component. In particular, in all of the countries shown in Figure 1, nominal short-term rates have exhibited, over the post-WWII period, a dramatic and historically unprecedented hump-shaped fluctuation, associated with the Great Inflation episode and the subsequent disinflation. For the interwar period evidence is mixed, but in the United States the short rate had exhibited a sizeable fall from 3-5 per cent towards zero. In fact, as we will discuss in Section 2, unit root tests clearly suggest that U.S. nominal interest rates had, and have been I(1) during both the interwar and the post-WWII periods.

The presence of a permanent component in U.S. nominal interest rates during the period following the collapse of the Classical Gold Standard logically implies that, since 1914, permanent interest rates shocks have been the *only* driver of U.S. M1

[6] Table I in the Appendix reports results from Elliot *et al.*'s (1996) unit root tests for the central bank rate for the United Kingdom (1816-1913), France (1800-1913), Austria (1818-1913), Norway (1819-1913), Sweden (1856-1913), Finland (1867-1913), Spain (1874-1913), and Japan (1883-1913). (The methodology is discussed in Section 3 below.) With the single exception of Japan—for which evidence is ambiguous (possibly because of the comparatively short sample period)—in *all* other cases the tests strongly reject a unit root in the central bank rate.

[7] See in particular Barsky (1987) and Benati (2008).

[8] In fact, things are more complicated than this. In particular, for the United States evidence of a unit root in inflation is strong only for the post-WWII period. This is why, in what follows, we perform our analysis by sub-sample. Further, as documented by Benati (2008), following the end of the Great Inflation, evidence of a unit root in inflation has largely vanished. This has especially been the case for countries which have adopted explicit inflation targets.

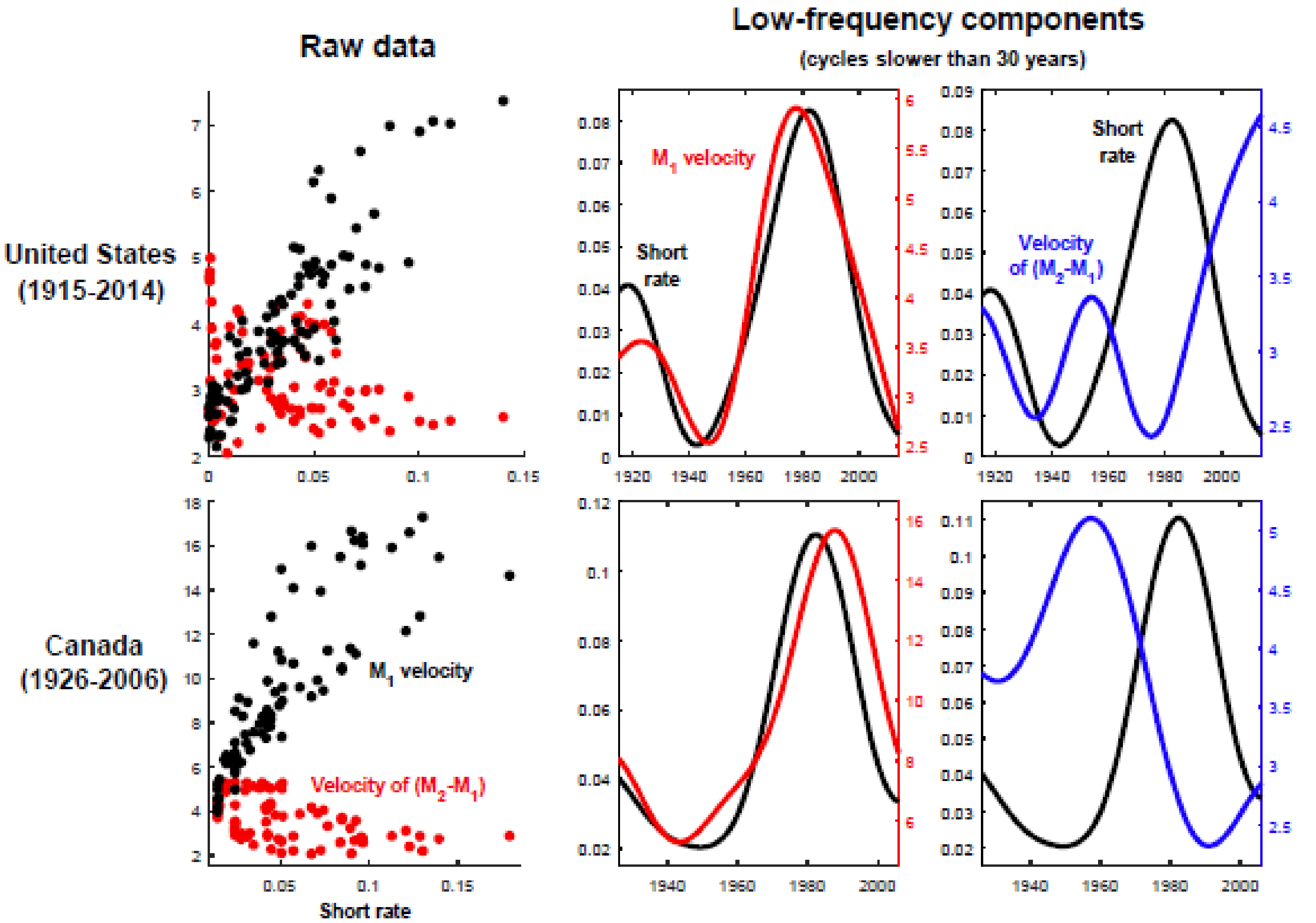

Figure 2 United States and Canada: Scatterplots of the short rate and of money velocity for M1 and M2-M1, and low-frequency components of the series

velocity at the frequency zero (i.e., in the infinite long run).

Now, suppose—just for the moment—that the long-run demand for the non-M1 component of M2 is also stable, so that, under post-Gold Standard regimes, the velocity of M2-M1 has also been cointegrated with the short rate. Under these circumstances, a positive (negative) permanent shock to the short rate would cause

(1) a permanent increase (decrease) in M1 velocity, as economic agents switch from non interest-bearing M1 to interest-bearing assets, such as those included in the non-M1 component of M2, and

(2) precisely because of this, a permanent decrease (increase) in the velocity of M2-M1.

If we relax the unrealistic (and, in fact, counterfactual) assumption of cointegration between the short rate and the velocity of M2-M1, by allowing it to also being affected by 'small' permanent velocity shocks specific to this aggregate, the negative relationship at the very low frequencies between the two series should become somehow 'blurred', but it should still be possible to recover it by applying low-frequency filtering techniques.

The evidence reported in Figure 2 is consistent with this view. The figure shows, in the first column, scatterplots of a short-term nominal interest rate and of the velocity of either M1 or M2-M1, for either the United States or Canada; and in the second and third columns, the low-frequency components of the same series.[9] The evidence in the figure speaks for itself: In particular, focusing on the low-frequency components of the data,

first, conceptually in line with BLNW (2018), for both countries the relationship between the short rate and M1 velocity appears as remarkably strong, clearly positive, and apparently stable.

Second, the relationship between the short rate and the velocity of M2-M1 is strongly and uniformly negative, and apparently stable, in Canada—thus reflecting the previously mentioned portfolio reallocation mechanism associated with permanent interest rate shocks—whereas in the United States it has been clearly negative since the 1940s, and positive before that.

The evidence in Figure 1 logically points towards two conclusions:

[I] absent permanent interest rate shocks—which, as previously mentioned, was the 'normal state of affairs' under metallic standards—the low-frequency component of M1 velocity should have been essentially flat, and fluctuations in the corresponding component of M2-M1 velocity should have been much more subdued.

[II] Since, as we show in Section 2, M2 velocity is not cointegrated with the short rate, failure to distinguish between M1 and M2-M1 *inevitably* distorts the inference, pointing towards a larger role for velocity shocks than it is in fact the case. As mentioned, the reason for this is straightforward: Since permanent interest rate shocks

[9] Low-frequency components have been extracted *via* the band-pass filter proposed by Christiano and Fitzgerald (2003), and the 'low-frequencies' have been defined as in Benati (2009), as the set of all fluctuations in the series with cycles slower than 30 years.

have an opposite effect on the velocities of the M1 and non-M1 components, their impact will partly, or even mostly cancel out in the aggregate. In turn, as a matter of logic this will spuriously create the need for *another shock* in order to explain the long-horizon dynamics of M2 velocity.

Another way of putting this is that failure to distinguish between M1 and M2-M1 *automatically* causes a fraction of permanent interest rate shocks to be mis-interpreted as velocity shocks. As we show based on cointegrated structural VARs, evidence for the United States and Canada since World War I provides very strong support for both [I] and [II], thus suggesting that a dominant portion of the fluctuations in U.S. and Canadian money velocity over the last century has originated from the permanent interest rate fluctuations which have been one of the hallmarks of post-Gold Standard monetary regimes.

The paper is organised as follows. Section 2 explores the unit root and cointegration properties of the data, whereas section 3 describes the empirical methodology we use in the main body of the paper, based on cointegrated structural VARs identified *via* long-run restrictions. Section 4 discusses the evidence for the United States, whereas Section 5 discusses that for Canada. Section 6 concludes, and discusses possible directions for future research.

2 Integration and Cointegration Properties of the Data

2.1 Unit root tests

Tables 1a and 1b report, for the periods 1959Q1-2008Q3 and January 1919-November 1941, respectively, bootstrapped p-values for Elliot, Rothenberg, and Stock (1996) unit root tests for the series in our dataset.[10] For the post-WWII period we end the sample in 2008Q3, in order to avoid possible distortions induced by the subsequent explosion in the monetary base associated with quantitative easing policies. By the same token, we end the interwar period one month before the attack on Pearl Harbour, thus avoiding the possible distortions in the inference originating from World War II and its aftermath. For all series exhibiting obvious trends the tests are based on models including an intercept and a time trend.[11] These series are the logarithms of nominal M0, and nominal M0, real GDP and real consumption *per capita* for the

[10] For either series, p-values have been computed by bootstrapping 10,000 times estimated ARIMA(p,1,0) processes. In all cases, the bootstrapped processes are of length equal to the series under investigation. As for the lag order, p, since, as it is well known, results from unit root tests may be sensitive to the specific lag order which is being used, for reasons of robustness we consider four alternative lag orders: p = 1, 2, 3, or 4 quarters for the former period, and p = 3, 6, 9, or 12 months for the latter one.

[11] The reason for including a time trend is that, as discussed e.g. by Hamilton (1994, pp. 501), the model used for unit root tests should be a meaningful one also under the alternative.

Table 1*a* United States, 1959Q1-2008Q3: Bootstrapped *p*-values for Elliot, Rothenberg, and Stock unit root tests[a]

	Lag order:			
	p=1	p=2	p=3	p=4
	In levels, without a time trend			
GDP deflator inflation	0.073	0.203	0.295	0.239
3-month Treasury bill rate	0.304	0.298	0.312	0.207
10-year government bond yield	0.583	0.580	0.530	0.542
M1 velocity	0.507	0.481	0.472	0.440
M2 velocity	0.683	0.685	0.638	0.596
Velocity of M2-M1	0.914	0.917	0.904	0.882
Multiplier of M2-M1	0.250	0.522	0.517	0.499
	In levels, with a time trend			
Log nominal M0	0.002	0.002	0.001	0.004
Log nominal M0 *per capita*	0.000	0.001	0.000	0.002
Log real GDP *per capita*	0.435	0.419	0.267	0.193
Log real consumption *per capita*	0.782	0.703	0.512	0.498
	In differences, without a time trend			
	p=1	p=2	p=3	p=4
GDP deflator inflation	0.000	0.000	0.000	0.000
3-month Treasury bill rate	0.000	0.000	0.000	0.000
10-year government bond yield	0.000	0.000	0.000	0.000
M1 velocity	0.000	0.000	0.000	0.000
M2 velocity	0.000	0.000	0.000	0.000
Velocity of M2-M1	0.000	0.000	0.000	0.000
Multiplier of M2-M1	0.000	0.000	0.000	0.000
Log real GDP *per capita*	0.000	0.000	0.000	0.000
Log real consumption *per capita*	0.000	0.000	0.000	0.000

[a] Based on 10,000 bootstrap replications of estimated ARIMA processes.

Table 1*b* United States, January 1919-November 1941: Bootstrapped *p*-values for Elliot, Rothenberg, and Stock unit root tests[a]

	Lag order:			
	p=3	p=6	p=9	p=12
	In levels, without a time trend			
CPI inflation	0.006	0.036	0.036	0.005
New York FED discount rate	0.630	0.538	0.596	0.573
High grade bond rate	0.837	0.816	0.711	0.454
Logarithm of $(1 + k)$	0.557	0.410	0.071	0.106
Logarithm of $(r + k)$	0.935	0.893	0.707	0.727
k	0.542	0.425	0.071	0.102
r	0.910	0.889	0.825	0.700
M1 velocity	0.184	0.261	0.138	0.173
M2 velocity	0.127	0.114	0.049	0.066
Velocity of M2-M1	0.285	0.176	0.103	0.115
	In levels, with a time trend			
Log M0	0.844	0.890	0.771	0.870
Log CPI	0.648	0.380	0.557	0.949
Log industrial production	0.789	0.773	0.377	0.583
Log department store sales	0.897	0.679	0.626	0.643
	In differences, without a time trend			
	p=3	p=6	p=9	p=12
Log CPI	0.007	0.037	0.036	0.004
New York FED discount rate	0.000	0.000	0.000	0.000
High grade bond rate	0.000	0.000	0.000	0.000
Logarithm of $(1 + k)$	0.000	0.000	0.042	0.018
Logarithm of $(r + k)$	0.000	0.000	0.022	0.025
k	0.000	0.000	0.039	0.017
r	0.000	0.000	0.011	0.014
M1 velocity	0.000	0.000	0.001	0.000
M2 velocity	0.000	0.000	0.003	0.002
Velocity of M2-M1	0.000	0.001	0.011	0.009
Log M0	0.000	0.003	0.077	0.030
Log industrial production	0.000	0.000	0.003	0.001
Log department store sales	0.000	0.000	0.026	0.035

[a] Based on 10,000 bootstrap replications of estimated ARIMA processes. k = currency/deposits ratio. r = reserve/deposits ratio.

Table 1*c* Canada, 1926-2006: Bootstrapped *p*-values for Elliot, Rothenberg, and Stock unit root tests[a]

	Lag order:	
	p=1	p=2
	In levels, without a time trend	
Bank of Canada rate	0.381	0.481
10-year government bond yield	0.714	0.767
M1 velocity	0.781	0.799
M2 velocity	0.386	0.216
Velocity of M2-M1	0.4811	0.351
	In levels, with a time trend	
Log real GDP *per capita*	0.671	0.350
Log real consumption *per capita*	0.851	0.775
	In differences, without a time trend	
	p=1	p=2
Bank of Canada rate	0.000	0.000
10-year government bond yield	0.000	0.000
M1 velocity	0.002	0.014
M2 velocity	0.000	0.000
Velocity of M2-M1	0.000	0.000
Log real GDP *per capita*	0.000	0.000
Log real consumption *per capita*	0.000	0.000

[a] Based on 10,000 bootstrap replications of estimated ARIMA processes.

post-WWII period; and the logarithms of nominal M0, the CPI, industrial production, and department store sales for the interwar period.[12] For all other series the tests are based on models including an intercept, but no time trend. As for the determinants of the M1 multiplier for the interwar period,[13] we report results both for the levels of the currency/deposits and reserves/deposits ratios (k and r, respectively), and for the logarithms of the numerator and denominator of the multiplier—that is: $\ln(1+k)$ and $\ln(r+k)$, respectively. The rationale for also reporting results for the two latter variables is that, in Section 4, we will identify permanent shocks to r and k by entering $\ln(1+k)$ and $\ln(r+k)$ in cointegrated VARs, and then imposing a Cholesky structure on the respective (2×2) block of the long-run impact matrix of the structural shocks. Because of this, we want to be sure that not only r and k, but also $\ln(1+k)$ and $\ln(r+k)$ are I(1).

For the interwar period the results pertaining to velocity series should be taken with a pinch of salt. As discussed in the data appendix, indeed, before 1947 U.S. GDP (or GNP) is only available at the annual frequency. Rather than resorting to using the reconstructed GNP quarterly data from Robert Gordon and his co-authors—see, e.g., Balke and Gordon (1986)—we have preferred to use industrial production as an inevitably imprecise *proxy* for GNP. As a result, we have computed the logarithms of velocity series as the difference between the log of the relevant monetary aggregate, and the sum of the logarithms of industrial production and the CPI.

At the 10 per cent significance level we take as our benchmark throughout the entire paper, the following results emerge from the two tables:

(*i*) inflation had been I(0) in the interwar period, whereas it has been I(1) after World War II.

(*ii*) The monetary base had been I(1) in the interwar period, whereas it had been trend-stationary in the post-WWII years. The latter result is robust to considering either M0, or M0 *per capita*.[14]

(*iii*) For all other series, the null of a unit root cannot be rejected.[15]

(*iv*) Finally, for all series, and for either period, tests in differences without a time trend strongly reject the null of a unit root. This is crucial because a necessary condition for performing Johansen's tests is that the series under investigation do contain a unit root, but that their order of integration is not greater than one.

Both (*i*) and (*ii*) justify our choice of performing the analysis by sub-sample,

[12] For the interwar period, the series for population is only available at the annual frequency.

[13] For the post-WWII period we ignore the M1 multiplier since Benati and Ireland's (2017) analysis suggests that shocks to this variable played a negligible role in post-WWII macroeconomic dynamics.

[14] Including the period since 2008Q3 the null of a unit root in the monetary base cannot be rejected. The problem with doing this, however, is that the explosion in the base associated with quantitative easing policies suggests that considering the period since 2008Q3 together with the previous one is incorrect.

[15] For M2 velocity in the interwar period evidence is mixed, with a unit root being rejected only for p equal to either 9 or 12. In this case, we regard we regard the null of a unit root as not having been convincingly rejected, and in what follows we will therefore consider this series as I(1).

rather than for the joint sample 1919-2007 based on annual data.

Table 1*c* reports the corresponding evidence for Canada for the period 1926-2006.[16] Due to the paucity of data at frequencies higher than annual for the period before 1961, we are here working with annual data (Appendix B.2 contains an alternative set of results based on quarterly data for the period 1961Q1-2006Q4). The null of unit root cannot be rejected for any series, with the partial exception of inflation and consumption *per capita*. In either case we regard we regard the null of a unit root as not having been convincingly rejected, and in what follows we will therefore consider both series as I(1).

2.2 Cointegration tests

Tables 2*a* and 2*b* report results from Johansen's cointegration tests for the United States, whereas Table 2*c* reports the corresponding results for Canada. In all cases we report results for both the two main systems we will work with (featuring, respectively, either the velocities of M1 and M2-M1, or the velocity of M2) and for smaller sub-systems featuring the short-term nominal rate and the velocity of either M1, M2-M1, or M2. For the post-WWII period, the two larger systems feature, beyond the velocity series, the logarithms of real GDP and consumption *per capita*, the multiplier of M2-M1, inflation, the 3-month Treasury bill rate, and the 10-year government bond yield. On the other hand, we do not include the monetary base because, as discussed in the previous sub-section, it has clearly been trend-stationary over the sample period. For the interwar period they feature, beyond the velocity series, the logarithms of sales, industrial production, M0, the CPI, $(1+k)$, and $(r+k)$, the New York FED discount rate,[17] and the high-grade bond rate,[18] a long-term interest rate. For the United States during the interwar period we also consider more flexible money demand specifications not imposing unitary income (or, to be more precise, industrial production) elasticity. The key reason for also considering these smaller systems is in order to test for the presence of stable long-run money demand relationships.

Following BLNW (2018), we bootstrap the tests[19] *via* the procedure proposed by Cavaliere *et al.* (2012; henceforth, CRT). In a nutshell, CRT's procedure is based on the notion of computing critical and p-values by bootstrapping the model which is relevant under the null hypothesis.[20] All of the technical details can be found in

[16] As discussed in the data appendix, we end the sample period in 2006 because of changes in the definitions of monetary aggregates which make it impossible to meaningfully link series corresponding to alternative definitions.

[17] The 3-month Treasury bill rate is only available starting from 1934.

[18] 'Index of Yields of High Grade Public Utility Bonds for United States'.

[19] The rationale for bootstrapping critical and p-values for Johansen's tests was provided by Johansen (2002) himself, who showed how, in small samples, trace and maximum eigenvalue tests based on asymptotic critical values typically tend to perform poorly.

[20] This means that for tests of the null of no cointegration against the alternative of one or more cointegrating vectors the model which is being bootstrapped is a simple, non-cointegrated VAR

Table 2a United States, 1959Q1-2008Q3: Results from Johansen's cointegration tests[a]

	Trace tests of the null of no cointegration against the alternative of h or more cointegrating vectors:			
	h = 1	*h = 2*	*h = 3*	*h = 4*
3-month Treasury bill rate and				
M1 velocity	20.475 (0.043)			
M2 velocity	13.176 (0.349)			
velocity of M2-M1	13.013 (0.325)			
8-variables system with the velocities of M1 and M2-M1	267.453 (0.001)	187.933 (0.000)	115.078 (0.003)	68.639 (0.022)
7-variables system with M2 velocity	169.346 (0.096)	108.688 (0.059)	66.178 (0.085)	36.149 (0.194)
	Maximum eigenvalue tests of h versus h+1 cointegrating vectors:			
	0 versus 1	*1 versus 2*	*2 versus 3*	*3 versus 4*
3-month Treasury bill rate and				
M1 velocity	15.557 (0.069)			
M2 velocity	11.913 (0.274)			
velocity of M2-M1	11.152 (0.292)			
8-variables system with the velocities of M1 and M2-M1	79.520 (0.112)	72.855 (0.001)	46.439 (0.040)	32.044 (0.195)
7-variables system with M2 velocity	60.659 (0.261)	42.509 (0.081)	30.030 (0.247)	–

[a] Bootstrapped p-values (in parentheses) are based on 10,000 bootstrap replications, based on Cavaliere *et al.*'s (2012) methodology.

Table 2*b* United States, January 1919-November 1941: Results from Johansen's cointegration tests[a]

	Trace tests of the null of no cointegration against the alternative of h or more cointegrating vectors:				
	h = 1	*h = 2*	*h = 3*	*h = 4*	*h = 5*
New York FED discount rate and					
M1 velocity	11.867 (0.310)				
M2 velocity	13.876 (0.393)				
velocity of M2-M1	11.207 (0.632)				
log industrial production, and log real M1	31.107 (0.098)				
log industrial production, and log real M2	24.755 (0.325)				
log industrial production, and log real M2-M1	32.656 (0.614)				
10-variables system with the velocities of M1 and M2-M1	446.633 (0.000)	318.473 (0.000)	227.456 (0.000)	162.230 (0.000)	111.194 (0.000)
9-variables system with M2 velocity	386.210 (0.000)	171.377 (0.000)	112.086 (0.000)	68.686 (0.000)	38.938 (0.004)
	Maximum eigenvalue tests of h versus h+1 cointegrating vectors:				
	0 versus 1	*1 versus 2*	*2 versus 3*	*3 versus 4*	*4 versus 5*
New York FED discount rate and					
M1 velocity	9.990 (0.285)				
M2 velocity	11.220 (0.307)				
velocity of M2-M1	8.007 (0.643)				
log industrial production, and log real M1	17.411 (0.272)				
log industrial production, and log real M2	17.775 (0.256)				
log industrial production, and log real M2-M1	20.037 (0.536)				
10-variables system with the velocities of M1 and M2-M1	128.160 (0.002)	91.017 (3.0e-4)	65.226 (0.013)	51.036 (0.087)	38.383 (0.268)
9-variables system with M2 velocity	132.440 (1.0e-4)	82.394 (3.0e-4)	59.290 (0.012)	43.400 (0.110)	–

[a] Bootstrapped *p*-values (in parentheses) are based on 10,000 bootstrap replications, based on Cavaliere *et al.*'s (2012) methodology.

Table 2*c* Canada, 1926-2006: Results from Johansen's cointegration tests[a]

	Trace tests of the null of no cointegration against the alternative of h or more cointegrating vectors:			
	h = 1	*h = 2*	*h = 3*	*h = 4*
Bank of Canada rate and				
M1 velocity	23.244 (0.015)			
M2 velocity	11.802 (0.369)			
velocity of M2-M1	12.121 (0.338)			
6-variables system with the velocities of M1 and M2-M1	129.446 (0.009)	82.102 (0.010)	41.597 (0.108)	
5-variables system with M2 velocity	92.983 (0.009)	46.278 (0.064)	13.445 (0.843)	
	Maximum eigenvalue tests of h versus h+1 cointegrating vectors:			
	0 versus 1	*1 versus 2*	*2 versus 3*	*3 versus 4*
Bank of Canada rate and				
M1 velocity	21.714 (0.008)			
M2 velocity	7.650 (0.564)			
velocity of M2-M1	8.928 (0.425)			
6-variables system with the velocities of M1 and M2-M1	47.344 (0.069)	40.505 (0.053)	26.570 (0.209)	
5-variables system with M2 velocity	46.704 (0.010)	32.833 (0.044)	8.570 (0.941)	

[a] Bootstrapped p-values (in parentheses) are based on 10,000 bootstrap replications, based on Cavaliere *et al.*'s (2012) methodology.

CRT, which the reader is referred to. We select the VAR lag order as the maximum[21] between the lag orders chosen by the Schwartz and the Hannan-Quinn criteria[22] for the VAR in levels, for a maximum allowed lag order of $p = 12$ for the interwar period, and $p = 4$ for the post-WWII one.

As for the post-WWII period, the following results emerge from Table $2a$:

(i) in line with BLNW (2018), M1 velocity is cointegrated with the 3-month Treasury bill rate, thus pointing towards the presence of a stable long-run demand for M1.

(ii) On the other hand, in line with Altermatt (2018), it is not possible to reject the null of no cointegration between the 3-month Treasury bill rate and M2 velocity. (As she stresses there, in stark contrast to BLNW's (2018) results for M1, absence of cointegration between M2 velocity and a short-term nominal rate is an extraordinarily robust result, holding for nearly all countries and sample periods since the XIX century.) This, together with (i), logically suggests that the absence of a stable long-run demand for M2 in the post-WWII United States originates from permanent velocity shocks specific to the M2-M1 component. Indeed, as Table $2a$ shows, lack of cointegration with the short rate also pertains to the velocity of M2-M1.

(iii) As for the two larger systems, we adopt a conservative approach, and we take the identified number of cointegration vectors to be the smaller between those identified by the trace and maximum eigenvalue tests, respectively. This points to three cointegration vectors for the system featuring the velocities of M1 and M2-M1, and two for the system featuring the velocity of M2. For either system, basic economic logic suggests that two cointegration vectors pertain to GDP and consumption, and to the 3-month Treasury bill rate and the 10-year government bond yield, respectively. By the same token, as for the system featuring the velocities of M1 and M2-M1, both basic economic logic, and the evidence of cointegration between M1 velocity and the 3-month Treasury bill rate, suggest that the the third cointegration vector pertains to these two series.

Turning to the interwar period, for the reason we mentioned in the previous subsection the evidence from cointegration tests should be taken, once again, with a pinch of salt. At face value, however, the results in Table $2b$ point towards the presence of four cointegration vectors in the baseline, 10-variables system we will work with in Section 3.2, featuring the New York FED discount rate and the high grade bond rate; the velocities of M1 and M2-M1; and the logarithms of the CPI, the monetary

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in differences. For the maximum eigenvalue tests of h versus $h+1$ cointegrating vectors, on the other hand, the model which ought to be bootstrapped is the VECM estimated under the null of h cointegrating vectors.

[21] We consider the maximum between the lag orders chosen by the SIC and HQ criteria because the risk associated with selecting a lag order smaller than the true one (model mis-specification) is more serious than the one resulting from choosing a lag order greater than the true one (over-fitting).

[22] On the other hand, we do not consider the Akaike Information Criterion since, as discussed (e.g.) by Luetkepohl (1991), for systems featuring I(1) series the AIC is an inconsistent lag selection criterion, in the sense of not choosing the correct lag order asymptotically.

base, industrial production, sales, $(1+k)$, and $(r+k)$. As for smaller systems featuring the New York FED discount rate and the velocity of either M1, M2, or M2-M1; or the New York FED discount rate, log industrial production, and the logarithm of either real M1, real M2, or real M2-M1, there is essentially no evidence of a stable long-run demand for either of the three monetary aggregates. In line with Engle and Granger (1987), and with the Monte Carlo evidence reported by BLNW (2018), a possible interpretation of these results is however that they simply reflect the short sample period and, possibly, the high persistence of the cointegration residual.[23] For example, based on the same data used herein, Benati and Ireland (2017) detect strong evidence of cointegration between the New York FED discount rate and the logarithms of the CPI, M1, and industrial production based on the longer period January 1919-December 1960.

Finally, as for Canada the following findings emerge from Table 2c:

(i) in line with the results for the post-WWII United States, there is very strong evidence of cointegration between the Bank of Canada rate and M1 velocity, whereas there is no evidence of cointegration with either M2 velocity, or the velocity or M2-M1. Once again, this points towards the presence of a stable long-run demand for M1, and of permanent velocity shocks specific to M2-M1 which prevent cointegration between the velocities of either M2-M1, or M2, and the short rate.

(ii) As for the larger systems, we detect two cointegration vectors for both the system featuring the velocities of M1 and M2-M1, and the one featuring the velocity of M2.

We now turn to an analysis based on cointegrated structural VARs.

3 Evidence for the United States

We start by discussing the evidence for the post-WWII period, and we then turn to the interwar years, for which, as mentioned, the lack of official high-frequency data for either GDP or GNP makes our results less reliable.

3.1 The post-WWII period

We estimate either the baseline 8-variables system featuring the velocities of M1 and M2-M1, or the alternative 7-variables system featuring the velocity of M2, based on Johansen's estimator of the VECM, imposing in estimation three and, respectively, two cointegration vectors. We characterize the uncertainty around all estimated objects of interest by bootstrapping the estimated cointegrated VAR as in CRT (2012),

[23] For example, Hansen (1999) 'grid bootstrap' estimates of the sum of the autoregressive coefficients in AR(p) representations for the 'candidate cointegration residual' (defined as in BLNW, 2018), are equal to (bootstrapped 90%-coverage confidence interval in parentheses) 0.96 [0.94; 0.99] for the system featuring the 3-month Treasury bill rate and M1 velocity; and to 0.97 [0.95; 0.99] and to 0.98 [0.97; 1.00] for the corresponding systems featuring the velocities of M2 and of M2-M1.

and imposing upon the bootstrapped data the same identifying restrictions we impose upon the actual data.

3.1.1 Identification of the structural disturbances

We identify four permanent shocks by imposing restrictions on the matrix of the shocks' long-run impacts.

The first three shocks are the same which had been identified by King, Plosser, Stock, and Watson (1991) in the expanded, six-variables system including nominal variables of the second part of the paper (see pages 831-836): a 'balanced-growth shock', a 'neutral inflation shock', and a 'real interest-rate shock'.

(1) We start by identifying a permanent shock to GDP and consumption *per capita* (ϵ_t^y), by imposing the restriction that it is the only shock affecting consumption *per capita* in the infinite long run. We focus on consumption, rather than GDP, in order to obtain a better identification of the shock. This choice is motivated by the evidence reported, e.g., by Cochrane (1994), of consumption being, to a first approximation, the permanent component of GDP, which is an obvious time-series implication of the permanent income hypothesis under rational expectations, as first outlined by Hall (1978).

(2) Conditional on having identified ϵ_t^y, we identify a residual permanent inflation shock (ϵ_t^π), as the only other shock permanently impacting upon inflation in the infinite long run. Since, as we will see, the permanent GDP shock has a statistically insignificant long-run impact on inflation, ϵ_t^π is, in fact, the *only* shock permanently impacting upon inflation in the infinite long run. In Appendix B we report results from an alternative identification scheme in which we aim at providing a more structural interpretation of ϵ_t^π, by identifying a permanent shock to the multiplier of M2-M1, which turns out to be the main driver of the unit root in inflation. To anticipate, results are in line with those produced by the scheme we are using herein. Our preference for King *et al.*'s (1991) scheme, in which no (more) structural interpretation of the unit root in inflation is provided, is motivated by the fact that it represents the simplest possible way of implementing, within a structural VAR context, the argument we laid out in Section 1.1: Failure to distinguish betweeen M1 and M2-M1 automatically causes the permanent portfolio reallocations between the two aggregates associated with the Great Inflation episode to be largely misinterpreted as permanent M2 velocity shocks. As we will see, this is indeed what evidence based on King *et al.*'s (1991) scheme suggests.

(3) Conditional on having identified ϵ_t^y and ϵ_t^π, we identify a residual permanent shock to the nominal interest rate (ϵ_t^r), as the only other shock permanently impacting upon the 3-month Treasury bill rate in the infinite long run. This shock has the natural interpretation of a shock to the real rate.

Finally, (4) beyond the three shocks identified by King *et al.* (1991), we identify a residual permanent shock to the velocity of either M2-M1, or M2, as the only other

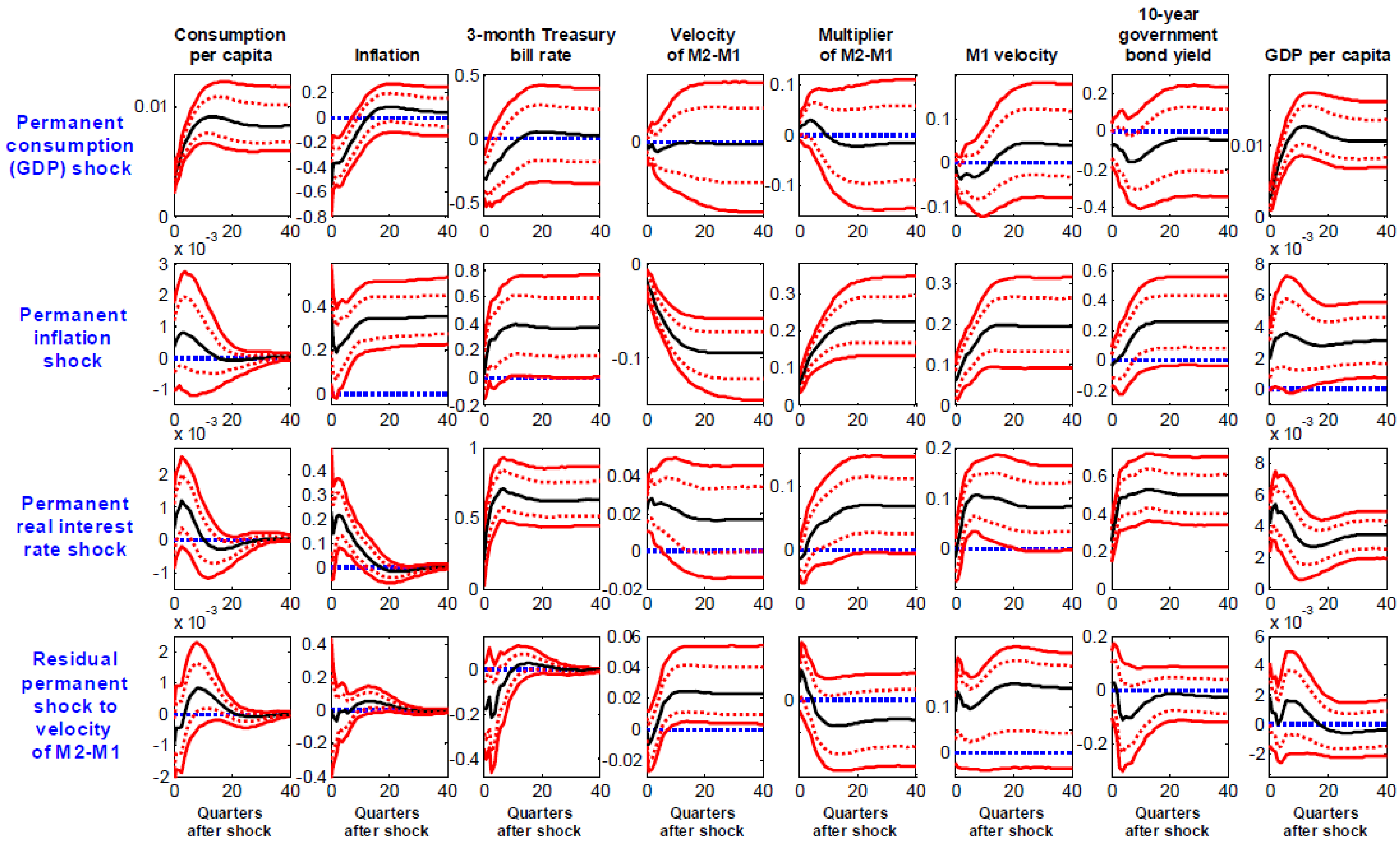

Figure 3 United States, 1959Q2-2008Q3: Impulse-response functions to the permanent shocks, with 16-84 and 5-95 bootstrapped confidence bands

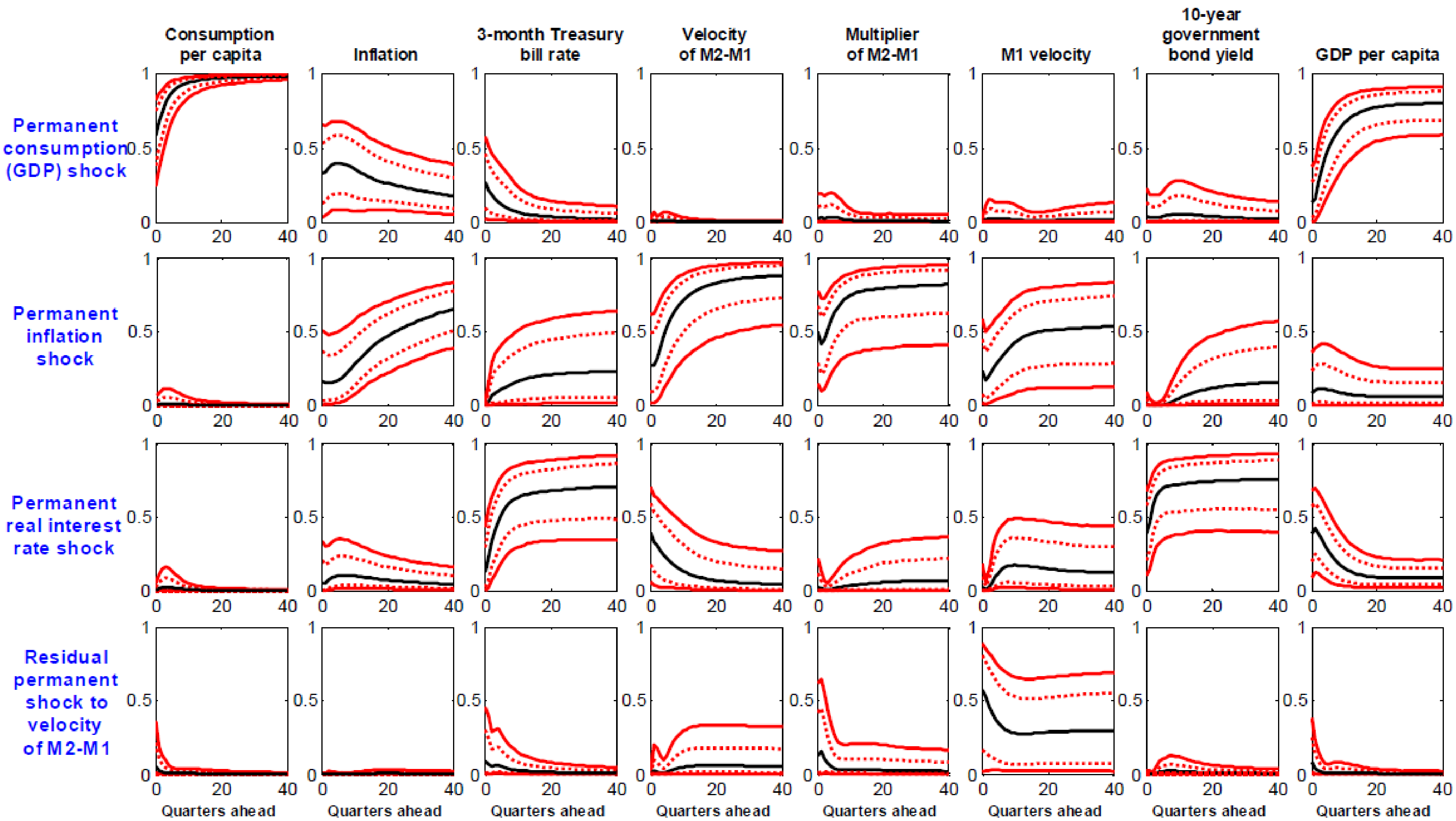

Figure 4 United States, 1959Q2-2008Q3: Fractions of forecast error variance explained by either of the permanent shocks, with 16-84 and 5-95 bootstrapped confidence bands

shock permanently impacting upon the relevant velocity series in the infinite long run. The importance of this shock at driving the relevant velocity series—in terms of the fraction of its FEV it explains—is a main objective of our investigation.

We now turn to the evidence.

3.1.2 Evidence

Figures 3 to 5 show, based on the system featuring the velocities of M1 and M2-M1, the impulse-response functions (IRFs) to the four shocks; the fractions of FEV of the series they explain; and the series' counterfactual paths obtained by killing off one shock at a time (here we do not show results for the permanent GDP shock because they are not especially interesting). Figure 6 shows the fractions of FEV of the series explained by any of the four shocks based on the system featuring the velocity of M2.

Impulse-response functions Most of the IRFs are not especially interesting, as they simply exhibit the pattern we would expect *ex ante*. Permanent GDP shocks, for example, have a positive and statistically significant impact on both GDP and consumption, and a statistically insignificant impact on all other series.

The most interesting results pertain to the permanent inflation shocks, which cause a permanent increase in inflation itself; as a consequence of this they cause, by the Fisher effect, permanent increases in both the 3-month Treasury bill rate and the 10-year bond yield which are borderline significant at the 90 per cent level, but are clearly significant at the 68 per cent level; they cause a strongly statistically significant increase in the multiplier of M2-M1; and—because of the portfolio reallocation mechanism illustrated in Figure 2—they therefore cause a permanent increase in M1 velocity, and a permanent decrease in the velocity of M2-M1. Finally, permanent inflation shocks also have, by construction, no long-run impact on consumption. As for the long-run impact on GDP, it is, strictly speaking, statistically significant, but it is quantitatively negligible. Further, as shown in Figure 4 these shocks explain essentially nothing of the FEV of GDP (and consumption) at any horizon, so that, all considered, the finding of a very small statistically significant impact of these shocks on GDP should be heavily discounted. The reason for this is that, as discussed e.g. by Canova and Paustian (2011), reliably estimating the IRFs to 'small' shocks—i.e., to shocks which explain little-to-nothing of the variance of the data—is typically difficult.

As expected, the real interest rate shock has a positive and statistically significant impact on both nominal interest rates. As for the long-run impact on the multiplier and the two velocity series, it is almost uniformly insignificant, either clearly, as in the case of the velocity of M2-M1, or in a borderline fashion, for the other two series at long horizons. As shown in Figure 4, however, these shocks explain little-to-*nil* of the FEV of the three series at long horizons, so that, based on Canova and Paustian's previously mentioned argument, the results for the IRFs should be discounted.

Finally, the residual permanent shock to the velocity of M2-M1 has a statistically significant impact *only* on the velocity series itself.

Fractions of forecast error variance Turning to the fractions of FEV, the most important result in Figure 4 pertains to the permanent inflation shocks, which explain the bulk of the FEV of inflation itself at long horizons; explain about one-fifth of the long-horizon FEV of the 3-month Treasury bill rate; and explain the dominant portion of both M1 velocity, and especially the velocity of M2-M1 and the multiplier of M2-M1. By contrast, residual shocks to the velocity of M2-M1 explain virtually nothing of all series—in particular, of velocity itself. The contrast with the corresponding set of results produced by the system featuring M2 velocity—instead of the velocities of M1 and M2-M1—is stark: As the fourth panel in the fourth row of Figure 6 shows, in this case the SVAR 'identifies' a large role for shocks to M2 velocity, which explain almost everything of the long-horizon FEV of M2 velocity itself. As previously mentioned, the explanation for this result is straightforward: Since, as documented in Figure 3, inflation shocks have *opposite* effects on the velocities of M1, and of M2-M1, failure to split M2 into its two components logically implies that the impact of these shocks will largely cancel out in the aggregate. As a result, this spuriously creates the need for another 'shock' in order to explain its long-horizon dynamics. Another way of putting this is that failure to split M2 into M1, and M2-M1, automatically causes a sizeable portion of the permanent inflation shocks lagely associated with the Great Inflation episode to be erroneously classified as shocks to M2 velocity.

These results, together with those pertaining to the IRFs in Figure 3, provide an interpretation of shifts in U.S. money velocity over the post-WWII period in which permanent inflation shocks caused, *via* the Fisher effect, permanent fluctuations in nominal interest rates. This, in turn, triggered permanent portfolio reallocations, first out of M1 and into M2-M1, and subsequently, with the Volcker disinflation, in the opposite direction, thus causing first an increase, and then a decrease in M1 velocity, and the opposite pattern of variation in the velocity of M2-M1.

As for other disturbances, permanent GDP shocks explain, as expected, essentially all of the long-horizon FEV of consumption, and—again as expected—a dominant, but slightly smaller fraction of the FEV of GDP. Finally, shocks to the real rate have played an important role only for the 3-month Treasury bill rate[24] and the 10-year bond yield.

Counterfactual simulations Evidence from counterfactual simulations in which we 'kill off' one shock at a time provide additional validation to the previously discussed interpretation of post-WWII fluctuations in U.S. money velocity. Whereas, absent the residual shocks to the velocity of M2-M1, essentially nothing would have

[24] This result is the same as King *et al.*'s (1991).

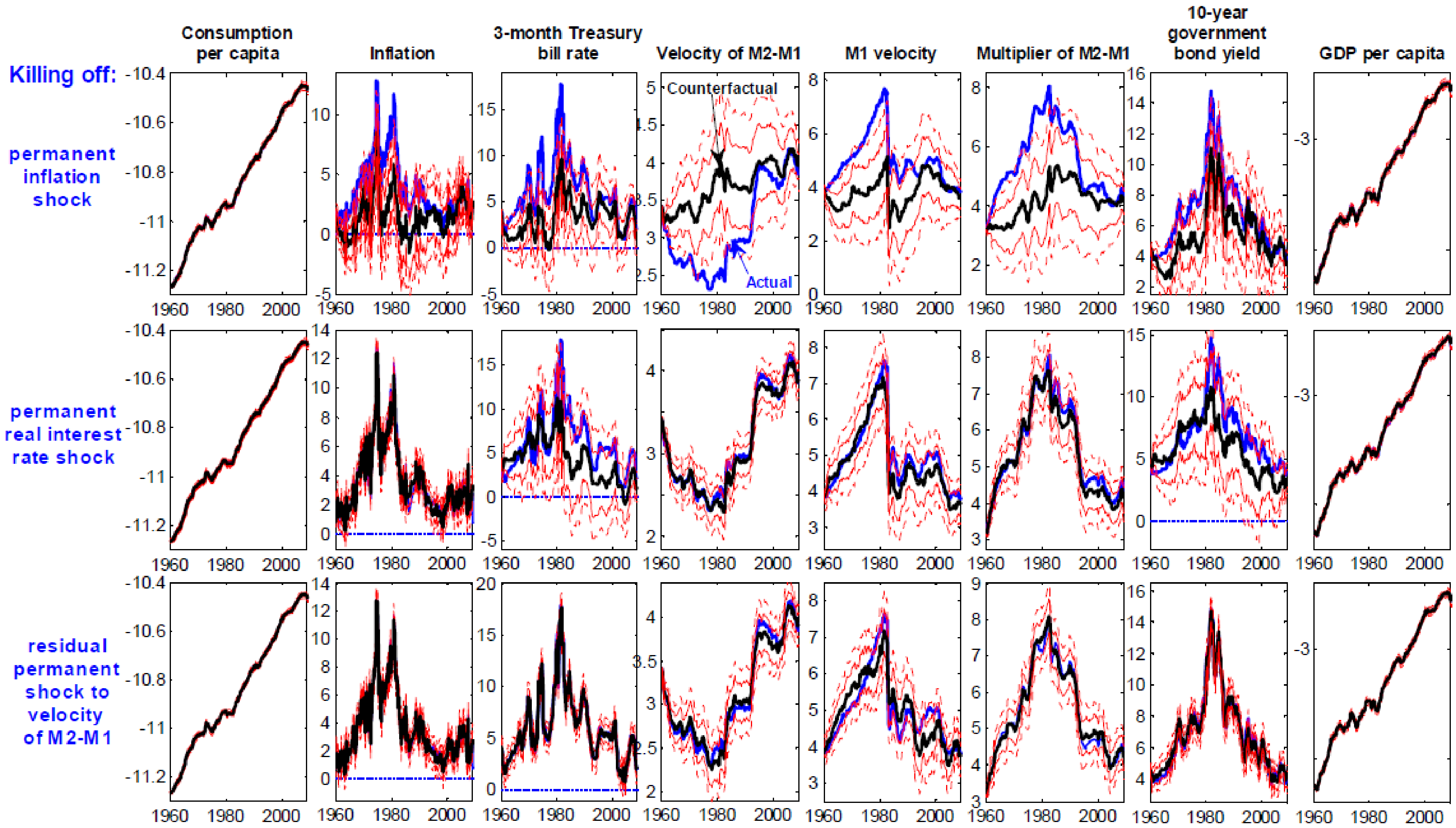

Figure 5 United States, 1959Q2-2008Q3: Counterfactual simulations killing off permanent shocks, with 16-84 and 5-95 bootstrapped confidence bands

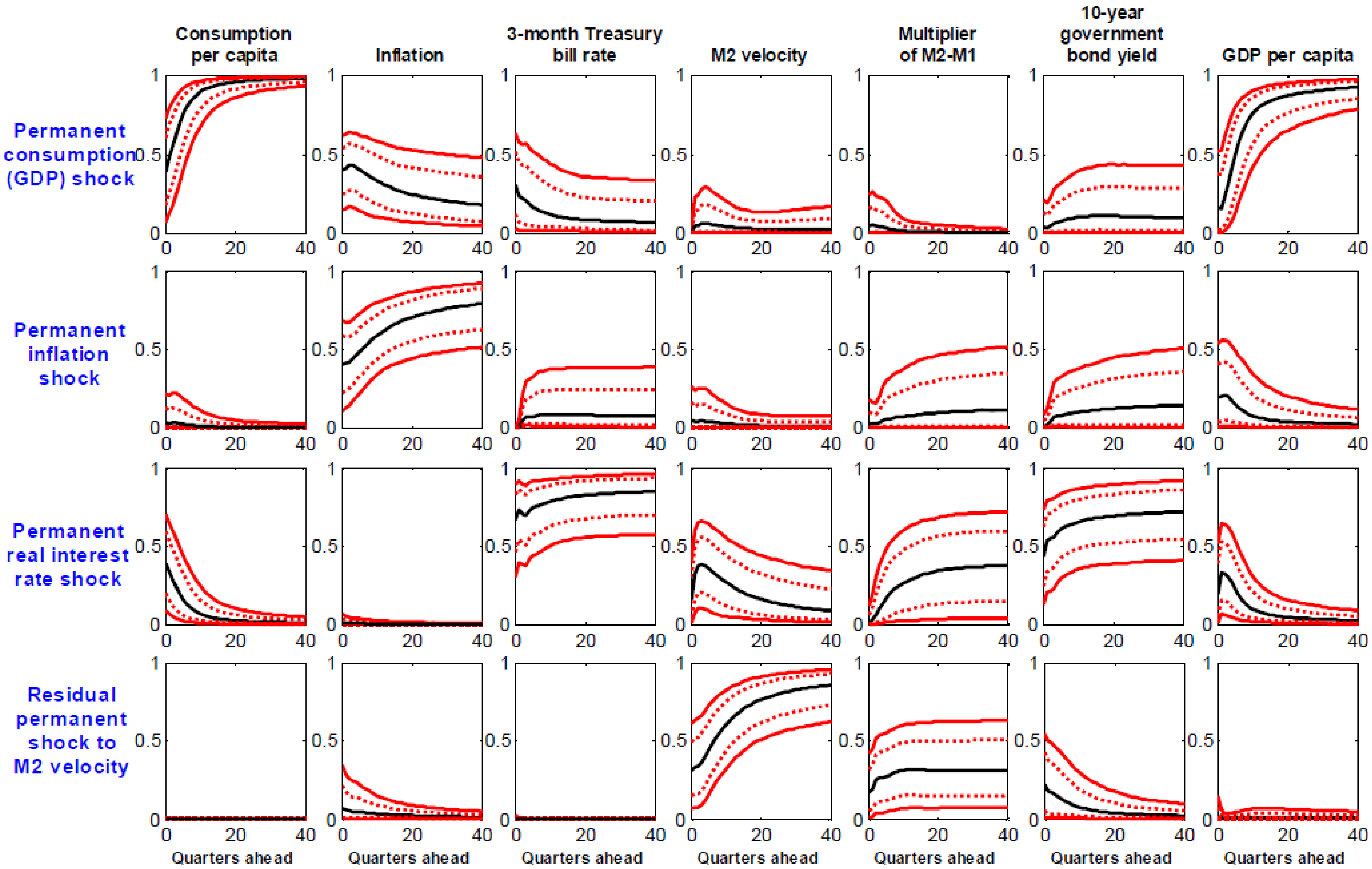

Figure 6 United States, 1959Q2-2008Q3: Fractions of forecast error variance explained by either of the permanent shocks, with 16-84 and 5-95 bootstrapped confidence bands

changed compared to the actual historical outcomes,[25] eliminating the inflation shocks would have produced dramatic changes in all series except—as is logically to be expected—GDP and consumption. Specifically, absent such shocks, the Great Inflation would not have taken place, and both inflation and the 3-month Treasury bill rate would have exhibited a flat overall trend, although with highly persistent transitory fluctuations. Because of this, M1 velocity and the multiplier of M2-M1 would also have exhibited much less variation, and they would have been broadly flat, whereas the velocity of M2-M1 would have exhibited a steady increase over the entire sample period, as opposed to its U-shaped actual historical evolution.

We now turn to the interwar period.

3.2 The period January 1919-November 1941

As before, we estimate either the baseline 10-variables system featuring the velocities of M1 and M2-M1, or the corresponding 9-variables system featuring M2 velocity, based on Johansen's estimator of the VECM, imposing in estimation four and respectively three cointegration vectors. In what follows we only report and discuss results based on the larger system because, as we will see, the velocities of M1 and M2-M1 co-moved *positively*—rather than negatively, as in the post-WWII period—in response to the structural disturbances driving the permanent component of the New York FED's discount rate. As a result, the system featuring M2 velocity produces qualitatively the same results.[26] We characterize the uncertainty around all estimated objects of interest by bootstrapping the estimated cointegrated VAR as in CRT (2012), and imposing upon the bootstrapped data the same identifying restrictions we impose upon the actual data.

3.2.1 Identification of the structural disturbances

We identify six permanent shocks by imposing restrictions on the matrix of the shocks' long-run impacts.

(1) We start by identifying a permanent shock to the currency/deposits ratio, k (ϵ_t^k), and a permanent shock to the reserves/deposits ratio, r (ϵ_t^r), by imposing the restrictions that (*i*) ϵ_t^k is the only shock which is allowed to have a permanent impact on $\ln(1+k)$, and (*ii*) ϵ_t^r is the only other shock, beyond ϵ_t^k, which is allowed to have a permanent impact on $\ln(r+k)$.

(2) Conditional on having identified ϵ_t^k and ϵ_t^r, we then identify the permanent shocks to sales (ϵ_t^s), as the only other shock having a permanent impact on sales.[27]

[25] As mentioned, the counterfactual paths obtained by killing off permanent GDP shocks are even closer to the actual historical paths, to the point that they are essentially indistinguishable. Because of this we do not report them, but they are available upon request.

[26] The results produced by the 9-variables system featuring M2 velocity are reported in the online appendix.

[27] We use sales as a *proxy* for consumption, which is unavailable at a frequency higher than annual.

We identify this disturbance *after* having previously identified the shocks to k and r because, given the peculiarity of the Great Depression episode, we want to allow for the *possibility* that shocks to either the currency/deposits or the reserve/deposits ratio—i.e., the two key disturbances which, historically, had driven the Depression—may have had a permanent impact on consumption and output levels (here proxied by sales and industrial production). This choice is, in our own view, not only easy to rationalize, but in fact a logical one: Just to mention a single piece of supporting evidence, it is well known that by the time Franklin D. Roosevelt became President, in March 1933, about one-third of the U.S. banking system had gone bankrupt (to the point that he introduced a week-long banking holiday in order to stabilize the system). So the notion that the key shocks driving the Depression—ϵ_t^k and ϵ_t^r—may have had a permanent impact on output and consumption levels not only is not far-fetched, but it is, in fact, a logical one.

(3) Conditional on having identified ϵ_t^k, ϵ_t^r, and ϵ_t^s, we then identify a residual permanent shock to the monetary base ($\epsilon_t^{M_0}$), as the only other shock having a permanent impact on M0. The fact that we identify this shock after disturbances to k, r, and sales implies that any of these three disturbances is allowed to impact upon the monetary base. As for sales, since they here proxy for consumption, the reason is obvious: Any shock permanently impacting upon consumption, and therefore GDP, should be expected to also permanently impact M0 in the same direction. As for k and r, the rationale is that, in the face of contractionary shocks to either k or r—and therefore contractionary shocks to the M1 multiplier—it can be reasonably expected that the Fed might try to counteract the recessionary impact on the economy by expanding the monetary base. At the same time, we also want to allow for autonomous variation in M0. The rationale for this is not only the strict conceptual one about the sheer implausibility that the monetary base might have exhibited no random, autonomous permanent variation over the sample period. Rather, Friedman and Schwartz (1963) discusses several instances in which, during those years, the base was affected by manifestly exogenous disturbances unrelated to variation in k and r.[28]

(4) Conditional on having identified ϵ_t^k, ϵ_t^r, ϵ_t^s, and $\epsilon_t^{M_0}$, we then identify a residual permanent shock to the New York FED discount rate (ϵ_t^r), as the only other shock having a permanent impact on the discount rate.

(5) Finally, conditional on having identified the previous five shocks, we identify a residual permanent shock to the velocity of M2-M1 ($\epsilon_t^{V_{2-1}}$).

We now turn to discussing the evidence. As already stressed, it is important to keep in mind that, because of the previously discussed limitations pertaining to the quality of interwar data, all of these results should be taken with some caution.

[28]The starkest example is provided by the large gold inflows, mainly from Britain, during the period of U.S. neutrality from September 1939 through November 1941, which as discussed by Friedman and Schwartz (1963, p. 551) led to a cumulative 29 percent increase in both the monetary base and broader monetary aggregates and a coincident 23 increase in the wholesale price level, translating into an inflation rate of 9 percent per year.

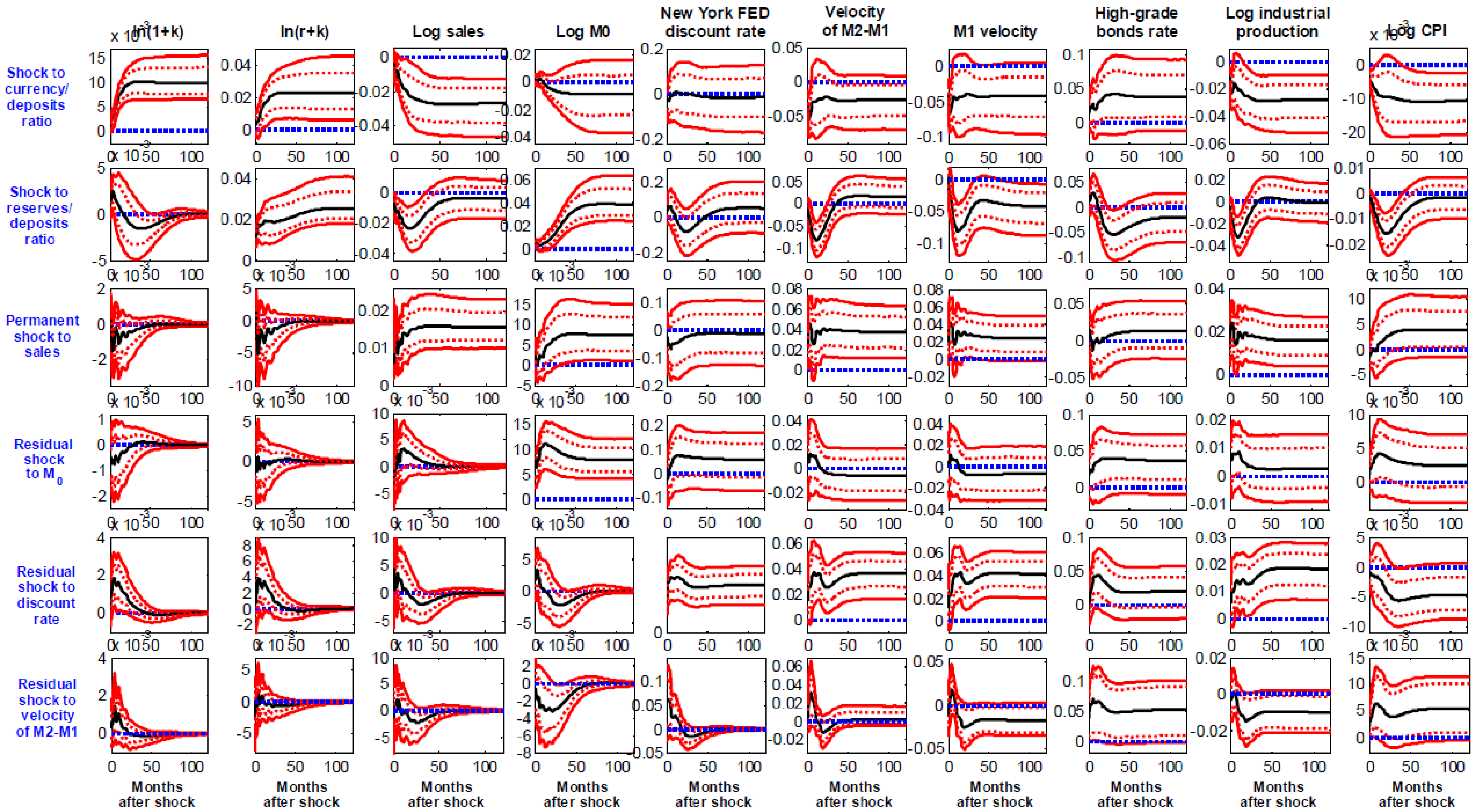

Figure 7 United States, January 1919-November 1941: Impulse-response functions to the permanent shocks, with 16-84 and 5-95 bootstrapped confidence bands

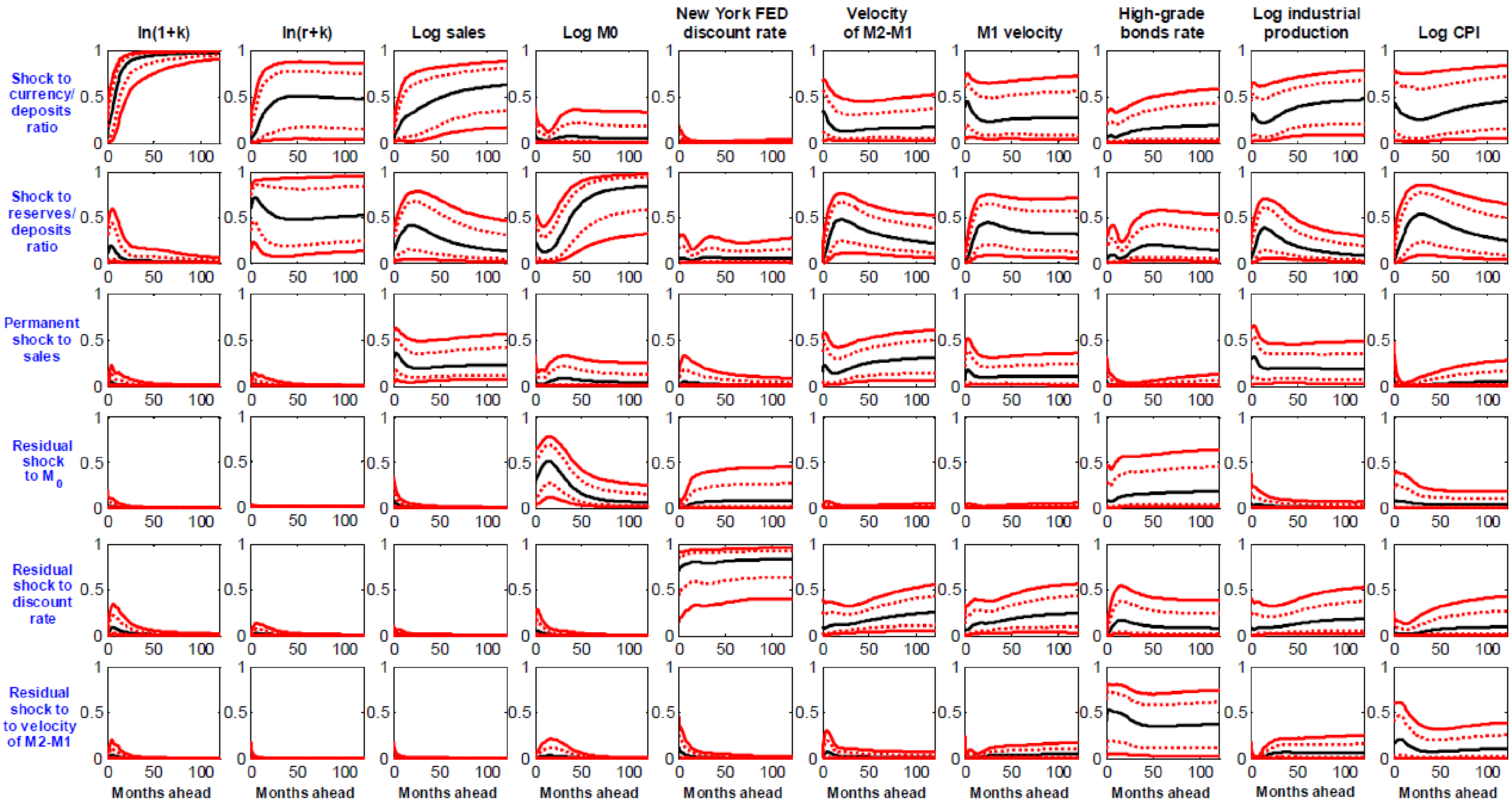

Figure 8 United States, January 1919-November 1941: Fractions of forecast error variance explained by either of the permanent shocks, with 16-84 and 5-95 bootstrapped confidence bands

3.2.2 Evidence

Impulse-response functions Starting from the IRFs, the main finding in Figure 7 is that—in stark contrast to the post-WWII period—*all* disturbances induce qualitatively the same response in the velocity of either M1 or M2-M1. This logically implies that, different from the latter period, failure to split M2 into its M1 and non-M1 portions does not lead to any distortion of the inference pertaining to the role played by velocity shocks: Quite simply, rather than largely cancelling out in the aggregate, the responses of the two velocity series to any of the shocks get added up, so that focusing on M2 velocity produces, qualitatively, the same results (this additional set of results is reported in the online appendix).

Entering into details, shocks to the currency/deposits ratio have a *negative permanent* impact on both sales and industrial production, thus providing support to our previous conjecture that some of the key disturbances which had historically driven the Great Depression episode had a permanent impact on output levels. By the same token, these shocks are estimated to have had a negative permanent impact on the CPI. This, together with the fact that shocks to k explain dominant portions of the FEV of either sales, industrial production, or the CPI (see the first row of Figure 8), point towards these disturbances having been a key driver of the Great Depression and of the associated deflation. On the other hand, shocks to the currency/deposits ratio have had statistically insignificant impacts on all other series (in the case of the two velocity series, insignificance at the 90 per cent level is borderline, whereas both impacts are clearly negative at the one standard deviation level of significance). In particular, the monetary base does not react in a statistically significant way to shocks to the currency/deposits ratio, thus suggesting that, during the interwar period, the FED did not react to contractionary shocks to k.

Shocks to the reserve/deposits ratio, on the other hand, triggered a strong and statistically significant response in the monetary base, thus suggesting that the FED attempted to cushion the blow for the economy by expanding M0. This is the most logical explanation for the fact that—different from shocks to k—these disturbances only had a *temporary* negative impact on either sales, industrial production, or the CPI. Finally, the impact on either velocity series is negative and statistically significant, being transitory for M2-M1, and permanent for M1.

The residual permanent shocks to sales cause, as expected, permanent increases in industrial production and the monetary base. They are also estimated to cause an increase in the velocity of M2-M1, and a borderline statistically insignificant increase in M1 velocity. The residual shocks to the monetary base have no statistically significant impact on anything other than the base itself at any horizon. A *caveat* to these results is that these shocks are estimated to explain essentially nothing of all series (other than the base itself) at all horizons, so that everything pertaining to these shocks should be taken with some caution. The residual shock to the discount rate causes a highly statistically significant increase in either of the two velocity series, and a puzzling increase in industrial production, which is, possibly, just a figment of the idiosyncratic nature of the interwar period. Finally, the residual shocks to the velocity of M2-M1 are *transitory* for all series, including the velocity of M2-M1 itself.

Fractions of forecast error variance Turning to the fractions of FEV, the most important result emerging from Figure 8 pertains to the dominant role played by shocks to either the currency/deposits or the reserves/deposits ratio in driving the velocities of both M1 and M2-M1: Considered together, the two shocks explain about half of the FEV of M1 velocity, and 40-45 per cent of the FEV of the velocity of M2-M1, at all horizons. By contrast, the residual shock to the velocity of M2-M1 explains virtually nothing of all series—including velocity itself—with the single exception of the long-term rate, thus showing that, in fact, this disturbance is a residual shock to the long rate. Shocks to the monetary base explain little of the FEV of all series, with the single exception of the base itself at short-to-medium horizons. This points towards the long-horizon dynamics of the base as being driven, to a dominant extent, by other exogenous influences, first and foremost shocks to the reserves/deposits ratio. Finally, permanent shocks to sales explain one fourth to one fifth of the long-horizon FEV of sales themselves, but other than that they play a minor to begligible role for all other series.

We now discuss the evidence for Canada.

4 Evidence for Canada

Figures 9 to 12 show, for Canada for the period 1926-2006, evidence from cointegrated structural VARs featuring either the velocities of M1 and M2-M1, or the velocity of M2. We identify three shocks; (*i*) a permanent consumption (i.e., GDP) shock, (*ii*) a residual permanent shock to the Bank of Canada's discount rate, and (*iii*) a residual permanent shock to the velocity of either M2-M1, or M2. The IRFs reported in Figure 9 do not require any particular comment, as they are uniformly in line with what we should expect, with (e.g.) the permanent GDP shock only permanently impacting upon GDP and consumption; the residual permanent interest rate shock having no impact on GDP and consumption, and causing a statistically significant increase in the Bank rate, the long rate, and M1 velocity, and a decrease in the velocity of M2-M1; and the residual shock to the velocity of M2-M1 only permanently impacting upon velocity itself. A comparison between Figures 10 and 12 shows that based on either system, velocity shocks are estimated to have played a uniformly minor role, although, in line with the the evidence for the post-WWI United States, failure to split M2 into M1 and M2-M1 leads, once again, to a larger role for velocity shocks at long horizons. Finally, eliminating permanent interest rate shocks produces counterfactual paths which are uniformly significantly flatter then the actual historical series for the discount rate, the long rate, and M1 velocity, whereas the impact is more subdued for the velocity of M2-M1.

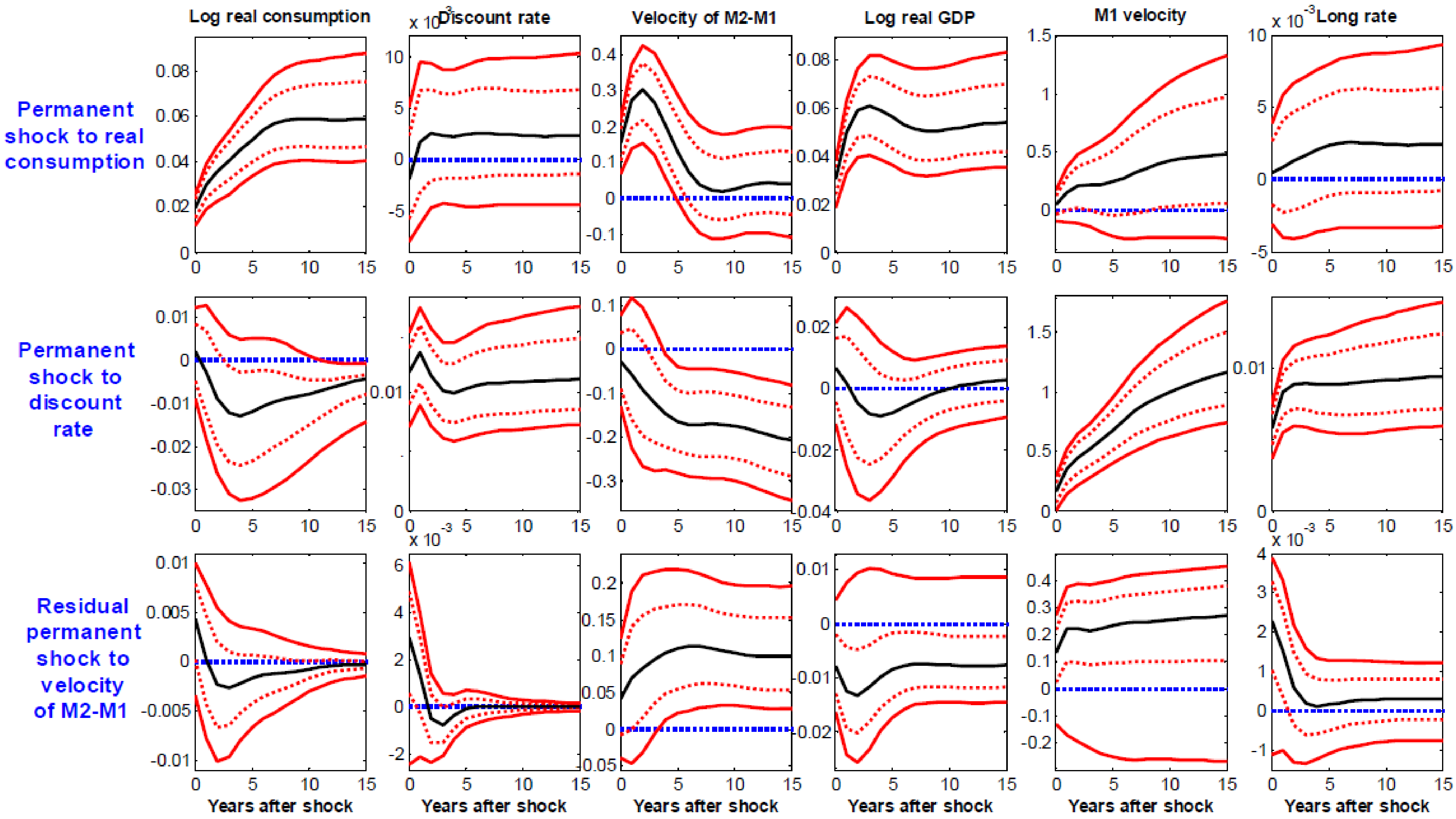

Figure 9 Canada, 1926-2006: Impulse-response functions to the permanent shocks, with 16-84 and 5-95 bootstrapped confidence bands

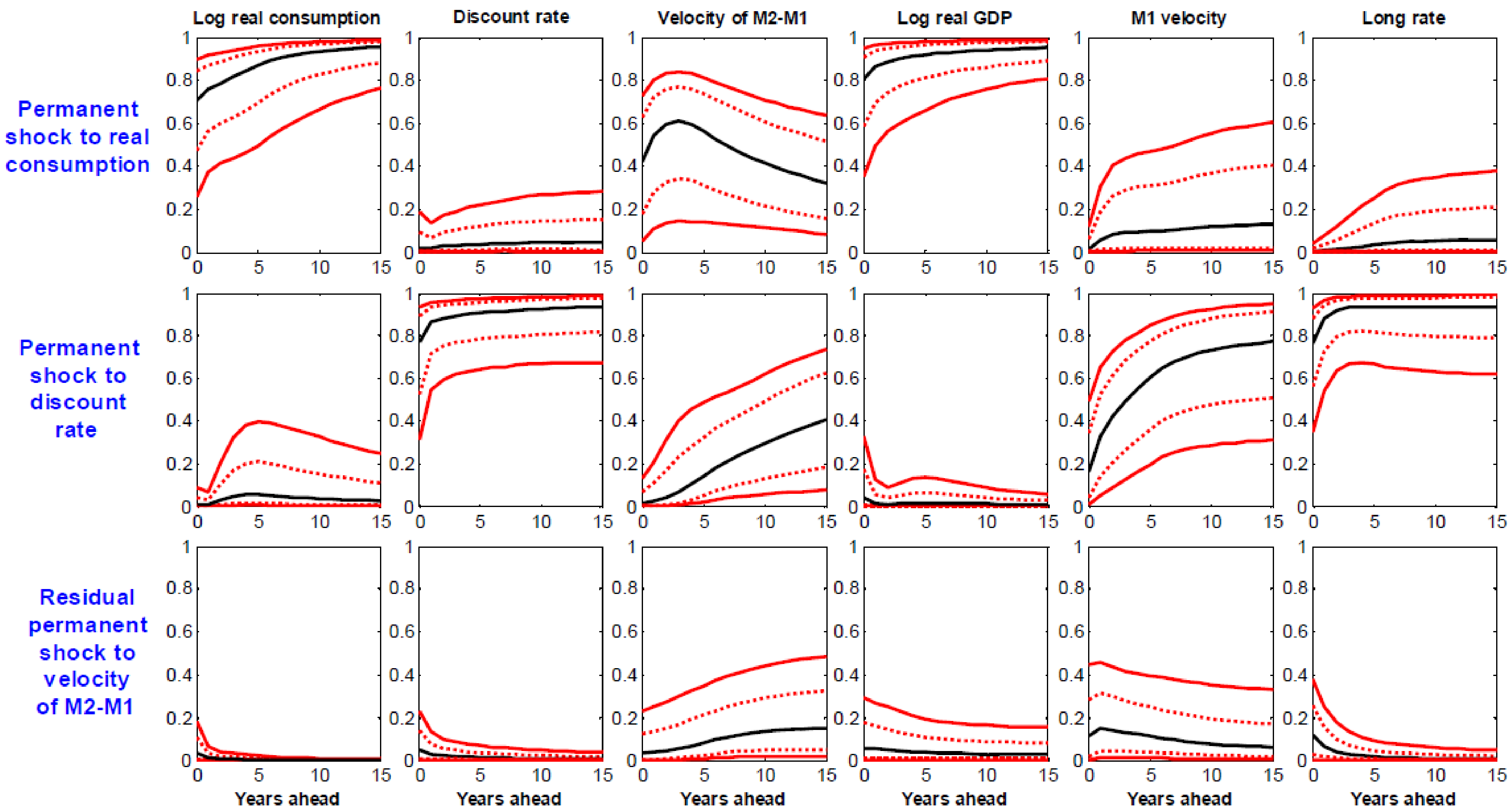

Figure 10 Canada, 1926-2006: Fractions of forecast error variance explained by either of the permanent shocks, with 16-84 and 5-95 bootstrapped confidence bands

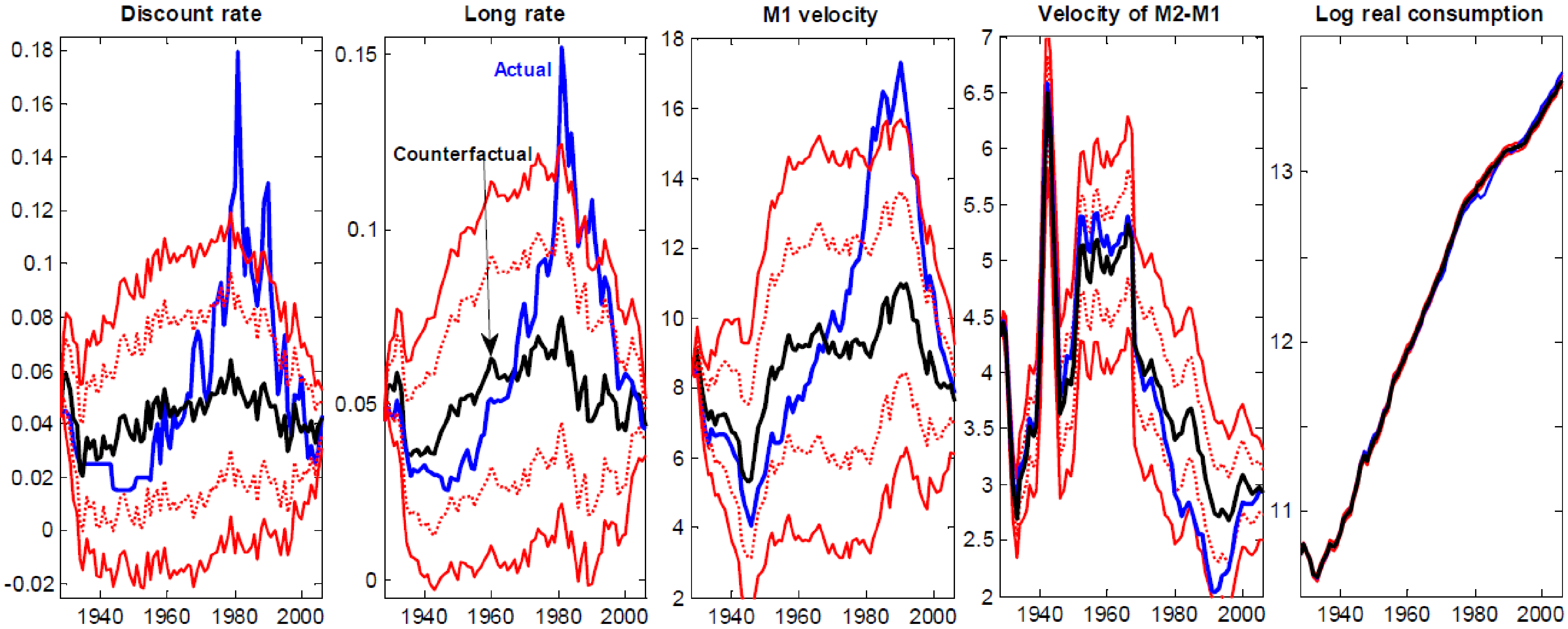

Figure 11 Canada, 1926-2006: Counterfactual simulations killing off permanent interest rate shocks, with 16-84 and 5-95 bootstrapped confidence bands

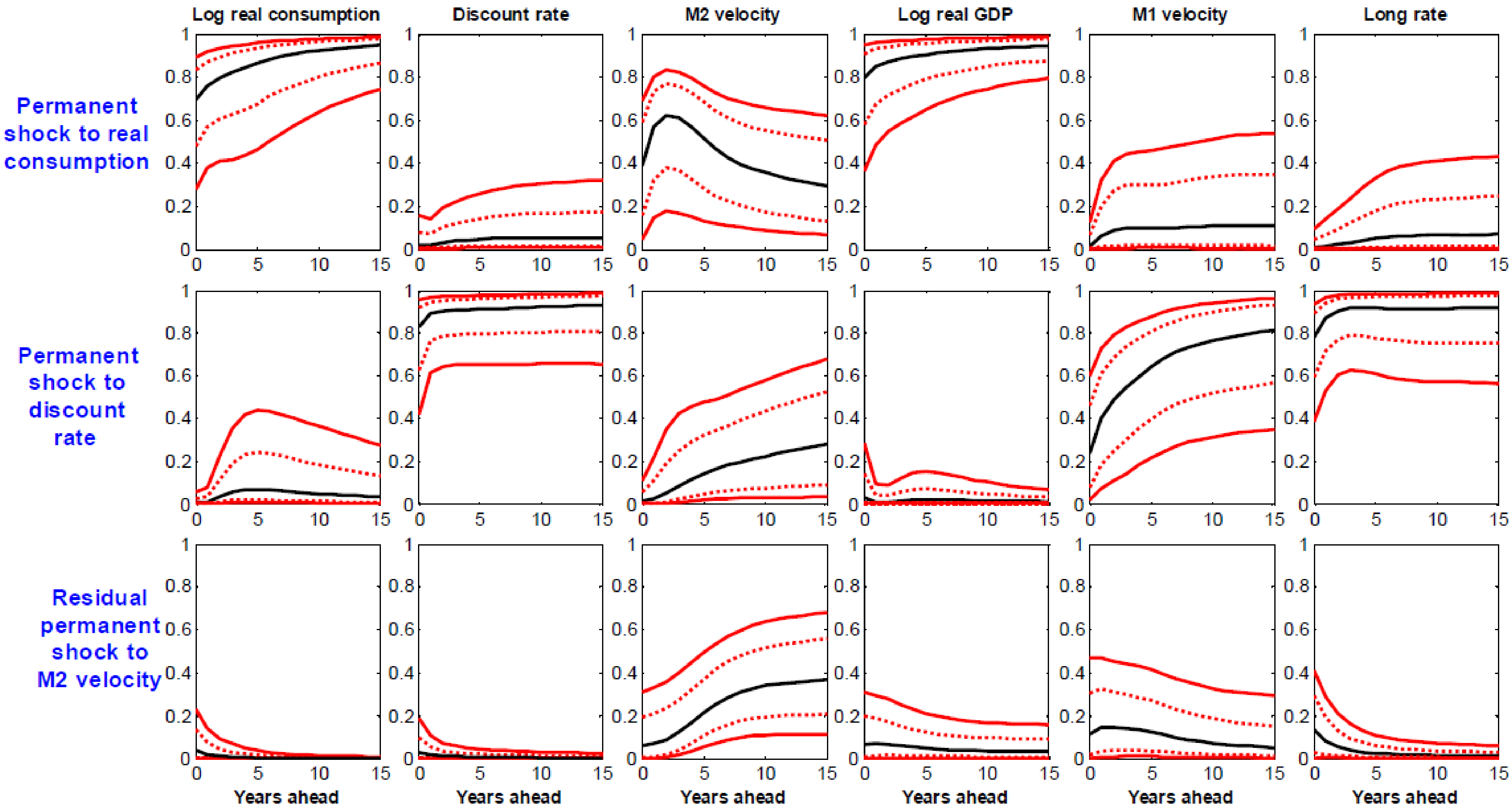

Figure 12 Canada, 1926-2006: Fractions of forecast error variance explained by either of the permanent shocks, with 16-84 and 5-95 bootstrapped confidence bands

5 Conclusions

Since World War I, in the United States permanent interest rate shocks have driven nearly all of the fluctuations of M1 velocity (which is cointegrated with the short rate), and most of the movements in the velocity of the M2-M1 aggregate. Velocity shocks specific to M2-M1 have played a minor role.

Failure to distinguish between M1 and M2-M1 causes a dramatic distortion of the inference, erroneously pointing towards a dominant role for M2 velocity shocks: In fact, since interest rate shocks have an opposite effect on the velocity of M1 and M2-M1, failure to split M2 into its two components causes the shocks' impacts to largely cancel out in the aggregate, thus spuriously creating the need for another shock in order to explain the dynamics of M2 velocity.

Our evidence suggests that most of the fluctuations in U.S. money velocity since World War I have not been caused by exogenous velocity shocks, and they have rather originated from the instability of U.S. post-Gold Standard monetary regimes (i.e., they have been an empirical manifestation of the Lucas critique). By introducing a unit root in inflation—and therefore in interest rates—these regimes have caused fluctuations in money velocity which, otherwise, would have not been there.

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A The Data

A.1 Austria

An annual series for the policy rate of the *Oesterreichische Nationalbank* (Austria's central bank), available for the period 1818-1998, is from the central bank's website.

A.2 Canada

Annual series for the period 1926-2006 An annual series for nominal GDP, available since 1870, has been constructed by linking the Urquhart series (available from *Statistics Canada*, which is Canada's national statistical agency), for the period 1870-1924; series 0380-0515, v96392559 (1.1) from *Statistics Canada*, for the period 1925-1980; and series 0384-0038, v62787311 (1.2.38) from *Statistics Canada*, for the period 1981-2013. A series for the official discount rate, available since 1926, has been constructed as follows. Since 1934, when the Bank of Canada was created, it is simply the official bank rate ('Taux Officiel d'Escompte') from the Bank of Canada's website. Before that, we use the Advance Rate, which had been set by the Treasury Department for the discounting of bills, from Table 6.1 of Shearer and Clark (1984). To be precise, Shearer and Clark (1984) do not provide the actual time series for the Advance Rate, but rather the dates at which the rate had been changed (starting from August 22^{nd}, 1914), together with the new value of the rate prevailing starting from that date. Based on this information, we constructed a daily series for the rate starting on January 1^{st}, 1915 *via* a straightforward MATLAB program, and we then converted the series to the annual frequency by taking annual averages. Monthly series for M1 and M2 starting in January 1872 are from Metcalf, Redish, and Shearer (1996), and they have been extended as follows. As for M2, we use the series from Metcalf *et al.* (1996) until December 1967. Then, starting from January 1968, we use the series labelled as 'M2 (net) (currency outside banks, chartered bank demand and notice deposits, chartered bank personal term deposits, adjustments to M2 (net), v37198' from *Statistics Canada*. As for M1, we use the series from Metcalf *et al.* (1996) until December 1952; after that, we link it *via* splicing to the series labelled as 'Currency and demand deposits, M1 (x 1,000,000), v37213' until November 1981 from *Statistics Canada*; finally, from December 1981 until December 2006, we use the series from *Statistics Canada* labelled as 'M1 (net) (currency outside banks, chartered bank demand deposits, adjustments to M1 (continuity adjustments and inter-bank demand deposits) (x 1,000,000), v37200'. An important point to stress is that over the periods of overlapping, the three series are near-identical (up to a scale factor), which justifies their linking. On the other hand, for the period after December 2006 we were not able to find an M1 series which could be reliably linked to the one we use for the period December 1981-December 2006 (over the last several decades, Canada's monetary aggregates have undergone a number of redefinitions, which complicates the task of constructing consistent long-run series for either of them). As a result, we decided to end the sample period in 2006. We convert the monthly series to the annual frequency by taking simple annual averages.

Quarterly series for the period 1961Q1-2006Q4 The monthly series for M1 and M2 are the same discussed in the previous section, and they have been converted to the quarterly frequency by taking simple quarterly averages. A series for the monetary base, available since January 1955, is from the Bank of Canada (Table 176-0020: Currency outside banks and chartered bank deposits, monthly average, dollars x 1,000,000). Either M0, M1, or M2 have been seasonally adjusted *via* ARIMA X-12, as implemented in *EViews*, and they have been converted to the quarterly frequency by taking averages within the quarter. A quarterly series for population since 1960Q1 is from Ohanian and Raffo (2011), and it has been updated based on the series 'Working Age Population: Aged 15-64: All Persons for CanadaPersons, Quarterly, Seasonally Adjusted' (acronym is LFWA64TTCAQ647S) from the St. Louis FED's website. Monthly series for the 3-month Treasury bill rate and the 10-year government bond yield are from *Statistics Canada*. They have been converted to the quarterly frequency by taking averages within the quarter. Quarterly seasonally adjusted series for nominal and real GDP, real consumption, and the GDP deflator are from *Statistics Canada*.

A.3 Finland

A series for Bank of Finland's monetary policy rate (labelled as the 'Base rate'), available since January 1867, is from *Suomen Pankki Finlands Bank*, i.e., Finland's central bank (henceforth, *Suomen Pankki*). To be precise, *Suomen Pankki* does not provides the actual time series for the base rate, but rather the dates at which the rate had been changed (starting from January 1^{st}, 1867), together with the new value of the base rate prevailing starting from that date. Based on this information, we constructed a daily series for the base rate starting on January 1^{st}, 1867 *via* a straightforward MATLAB program, and we then converted the series to the annual frequency by taking annual averages.

A.4 France

An annual series for the *Banque de France*'s discount rate for the period 1800-1989 is from Tables 27 and 63 of Homer and Sylla (2005). An annual series for the 3-month Treasury bill rate for the period since 1971 is from the St. Louis FED's website (acronym is INTGSTFRM193N).

A.5 Japan

A monthly series for the *Bank of Japan*'s (henceforth, *BoJ*) discount rate, available since January 1883, is from the *BoJ*'s long-run historical statistics, which are available at its website (the series is labelled as: 'BJ'MADR1M: The Basic Discount Rate and Basic Loan Rate'). The series has been converted to the annual frequency by taking annual averages.

A.6 Norway

A series for the central bank's official discount rate, available since 1819, is from the Historical Statistics of *Norges Bank* (Norway's central bank), which are available at its website.

A.7 Spain

An annual series for the official discount rate of the *Banco de Espana* (Spain's central bank, henceforth, *BdE*), available for the period 1930-1989, is from Table 74, pp. 541-542, of Homer and Sylla (2005).

A.8 Sweden

An annual series for the *Riksbank*'s discount rate available for the period 1856-1989 is from Tables 35 and 72 of Homer and Sylla (2005, p. 268, and pp. 531-533, respectively).

A.9 United Kingdom

The *Bank of England*'s official discount rate is from version 2.3 of the *Bank of England*'s dataset of long-run historical statistics, which is available from the *Bank of England*'s website (the Excel spreadsheet is called threecenturies_v2.3.xlsx; henceforth, TC). The first version of the dataset was discussed in detail in Hills and Dimsdale (2010).

A.10 United States

The annual series for the short-term nominal rate since 1890 The series for the 3-month Treasury Bill since 1915 rate is from Benati *et al.* (2018). The series' original source is the *Economic Report of the President.* For the period 1890-1914, we use the series for the nominal rate on stock exchange loans (series Cj1226), linked to the series for bankers' acceptances rate (series Cj1230).

Monthly series for the period January 1919-December 1960 Seasonally adjusted series for currency held by the public, demand deposits, bank reserves, and M2 are from Tables A.1 and A.2 of Friedman and Schwartz (1963). We compute high-powered (i.e., base) money as the sum of currency held by the public and bank reserves. A seasonally adjusted series for the industrial production index is from the Board of Governors of the Federal Reserve System. A seasonally adjusted series for the CPI has been constructed by linking the seasonally adjusted CPI series for all urban consumers, all items (acronym is CPIAUCSL) from the U.S. Department of Labor: Bureau of Labor Statistics, which is available since January 1947, to the CPI all items series (NBER series 04128 from NBER Historical database), which is, originally, seasonally unadjusted, and we seasonally adjusted *via* ARIMA X-12. A seasonally unadjusted series for the discount rate of the Federal Reserve Bank of New York is from the NBER Historical database (acronym is M13009USM156NNBR). The seasonally unadjusted series for Moody's seasoned Baa corporate bond yield is Moody's. A seasonally unadjusted series for the index of yields of high grade public utility bonds for United States is from the NBER Historical database (acronym is M13025USM156NNBR). A seasonally unadjusted series for department store sales is from the NBER Historical database (acronym is M06F2BUSM350NNBR), and it has been seasonally adjusted *via* ARIMA X-12.

Quarterly series for the period 1959Q1-2008Q3 A monthly seasonally adjusted M2 series is from the St. Louis FED's website (acronym is M2SL). Monthly seasonally unadjusted series for the Federal Funds rate and the 10-year government bond yield are from the St. Louis FED's website (acronyms are FEDFUNDS and GS10). A monthly seasonally unadjusted series for the St. Louis Source Base (SBASENS) is from the St. Louis Fed's website. The series has been seasonally adjusted *via* ARIMA X-12 as implemented in EViews. A monthly seasonally unadjusted series for civilian non-institutional population (CNP16OV) is from the U.S. Department of Labor, Bureau of Labor Statistics. All of the monthly series have been converted to the quarterly frequency by taking averages within the quarter.

A quarterly seasonally adjusted version of Lucas and Nicolini's (2015) M1 aggregate has been kindly provided by Juan-Pablo Nicolini. Specifically, the series is equal to M1SL from the St. Louis FED's website (converted to the quarterly frequency by taking averages within the quarter) until 1981Q4, and it is equal to M1SL plus MMDAs for the period 1982Q1-2008Q3. As discussed by LucasJr. and Nicolini (2015), the rationale for including MMDAs (which were introduced in 1982) into M1 is that, although they have traditionally been classified as part of the M2-M1 component, in fact, the economic function they perform is very similar to that performed by the bank deposits which are part of M1. Seasonally adjusted series for real and nominal GDP (GDPC96 and GDP, respectively) are from the U.S. Department of Commerce, Bureau of Economic Analysis. The seasonally adjusted series for real chain-weighted consumption of non-durables and services have been computed based on the data found in Tables 1.1.6, 1.1.6B, 1.1.6C, and 1.1.6D of the National Income and Product Accounts. A seasonally adjusted chain-type price index series for the gross domestic product (GDPCTPI) is from the U.S. Department of Commerce: Bureau of Economic Analysis.

B The Post-WWII Period: Evidence from Alternative Identification Strategies

In this appendix we report results for the post-WWII United States and Canada, based on alternative identification strategies compared to those we used in the main text.

B.1 United States

B.1.1 Identification of the structural disturbances

We identify four permanent shocks by imposing the following restrictions on the matrix of the shocks' long-run impacts.

(1) As in the main text, we start by identifying a permanent shock to GDP and consumption *per capita* (ϵ_t^y), by imposing the restriction that it is the only shock affecting consumption *per capita* in the infinite long run.

(2) Conditional on having identified ϵ_t^y, we identify a residual permanent shock to the multiplier of M2-M1 (ϵ_t^m), as the only other shock permanently impacting upon the multiplier in the infinite long run. Since, as we will see, the permanent GDP shock (*i*) explains essentially nothing of the forecast error variance (FEV) of the multiplier of M2-M1 at any horizon, and (*ii*) it has a statistically insignificant impact on it at all horizons, ϵ_t^m is, in fact, the *only* shock permanently impacting upon the multiplier in the infinite long run. Our motivation for identifying this shock is twofold. First, we aim at providing an explicitly *monetary interpretation* of the permanent inflation shocks we identified in Section 3.1. In doing this, we are motivated by evidence, such as that discussed by Lucas (2006, 2014), of a remarkably strong and stable correlation, over time and across monetary regimes, between the low-frequency components of inflation and of the rates of growth of alternative monetary aggregates. Second, in deciding which specific monetary aggregate to focus upon, our choice of M2-M1—and, in particular, of its *multiplier*—is motivated by the fact that (*i*) since, as discussed in Section 2.1, M0 has been trend-stationary, as a matter of logic it cannot possibly have been the source of the permanent variation in post-WWII U.S. inflation; and (*ii*) as shown by Benati and Ireland (2017), in the post-WWII United States, shocks to the M1 multiplier have played a uniformly negligible role across the board. Our interpretation of the Great Inflation episode, and of the Volcker disinflation, is therefore that, for a given, trend-stationary path of the monetary base, they had been caused first by an expansion, and then by a contraction, of the multiplier of M2-M1,

that is, of the amount of M2-M1 the financial system creates for a given 'input' of monetary based provided by the central bank. As we will see, this shock explains the dominant portion of the FEV of the velocities of both M1, and M2-M1, especially at long horizons.

(3) Conditional on having identified ϵ_t^y and ϵ_t^m, we identify a residual permanent inflation shock (ϵ_t^π), as the only other shock permanently impacting upon inflation in the infinite long run. The reason for identifying this shock is in order to allow for the possibility of some additional permanent influence on inflation beyond permanent monetary shocks.

(4) Conditional on having identified ϵ_t^y, ϵ_t^m, and ϵ_t^π, we identify a residual permanent shock to the nominal interest rate (ϵ_t^r), as the only other shock permanently impacting upon the 3-month Treasury bill rate in the infinite long run. This shock has the natural interpretation of a shock to the real rate.

Shocks (1) and (4), together with a 'quasi reduced-form' permanent inflation shock, were the same disturbances originally identified by King, Plosser, Stock, and Watson (1991) in the largest (i.e., six-variable) system they had considered. Then,

(5) conditional on having identified the previous four disturbances, we identify a residual permanent shock to the velocity of either M2-M1, or M2, as the only other shock permanently impacting upon the relevant velocity series in the infinite long run. The importance of this shock at driving the relevant velocity series—in terms of the fraction of its FEV it explains—is a main objective of our investigation.

We now turn to the evidence.

B.1.2 Evidence

Figures B.1 to B.3 show, based on the system featuring the velocities of M1 and M2-M1, the impulse-response functions (IRFs) to the five shocks; the fractions of FEV of the series they explain; and the series' counterfactual paths obtained by killing off one shock at a time (here we do not show results for the permanent GDP shock because they are not especially interesting). Figure B.4 shows the fractions of FEV of the series explained by any of the five shocks based on the system featuring the velocity of M2.

Impulse-response functions Most of the IRFs are not especially interesting, as they simply exhibit the pattern we would expect *ex ante*. Permanent GDP shocks, for example, have a positive and statistically significant impact on both GDP and consumption, and a statistically insignificant impact on all other series.

The most interesting results pertain to the permanent shocks to the M2-M1 multiplier, which cause a permanent increase both in the multiplier itself and, as expected, in inflation; as a consequence they cause, by the Fisher effect, a permanent increase in both the 3-month Treasury bill rate and the 10-year bond yield; and—because of the portfolio reallocation mechanism illustrated in Figure 2—they therefore cause a permanent increase in M1 velocity, and a permanent decrease in the velocity of M2-M1. Finally, permanent shocks to the M2-M1 multiplier also have, by construction, no long-run impact on consumption, whereas their impact on GDP is borderline statistically insignificant. Since, as shown in Figure B.2, these shocks explain essentially nothing of the FEV of GDP (and consumption) at any horizon, this result should however be heavily discounted.

The residual permanent inflation shock has a statistically significant impact only on inflation itself, and on the velocity of M2-M1, which it permanently affects negatively.

The real interest rate shock has a positive and statistically significant impact, as expected, on both nominal interest rates. It also has a positive and statistically significant impact on M1 velocity, whereas its impact on the velocity of M2-M1 is insignificant. Finally, it also has, at face value, a statistically significant impact on GDP, but since this shock explains a compaatively small fraction of its FEV, this result should be discounted.

Finally, the residual permanent shock to the velocity of M2-M1 has a statistically significant impact *only* on the velocity series itself.

Fractions of forecast error variance Turning to the fractions of FEV, the most important result in Figure B.2 pertains to the shocks to the multiplier of M2-M1, which explain essentially all of the FEV of the multiplier itself at nearly all horizons; explain about half of the long-horizon FEV of inflation, thus providing support to our presumption that low-frequency fluctuations in post-WWII U.S. inflation have had a monetary origin; explain about one-fourth of the FEV of either nominal rate at almost all horizons; and explain the dominant portion of both M1 velocity, and especially the velocity of M2-M1. By contrast, residual shocks to the velocity of M2-M1 explain virtually nothing of all series—in particular, of velocity itself. The contrast with the corresponding set of results produced by the system featuring M2 velocity—instead of the velocities of M1 and M2-M1—is stark: As the fifth panel in the fifth row of Figure B.4 shows, in this case the SVAR 'identifies' a large role for shocks to M2 velocity, which explain slightly more than 40 per cent of the long-horizon FEV of M2 velocity itself. As previously mentioned, the explanation for this result is straightforward: Since, as documented in Figure B.1, shocks to the multiplier of M2-M1 have *opposite* effects on the velocities of M1, and of M2-M1, failure to split M2 into its two components logically implies that the impact of these shocks will largely cancel out in the aggregate. As a result, since M2 velocity—different from M1 velocity—is not cointegrated with the short rate (see Table 2a), this spuriously creates the need for another 'shock' in order to explain its long-horizon dynamics. Another way of putting this is that failure to split M2 into M1, and M2-M1, automatically causes a sizeable portion of the monetary shocks associated with the unit root component of post-WWWII U.S. inflation to be erroneously classified as shocks to M2 velocity.

These results, together with those pertaining to the IRFs in Figure B.2, provide an interpretation of shifts in U.S. money velocity over the post-WWII period in which permanent inflation shocks caused by permanent disturbances to the multiplier of M2-M1 caused, *via* the Fisher effect, permanent fluctuations in nominal interest rates. This, in turn, triggered permanent portfolio reallocations, first out of M1 and into M2-M1, and subsequently, with the Volcker disinflation, in the opposite direction, thus causing first an increase, and then a decrease in M1 velocity, and the opposite pattern of variation in the velocity of M2-M1.

As for other disturbances, permanent GDP shocks explain, as expected, essentially all of the long-horizon FEV of consumption, and—again as expected—a dominant, but slightly smaller fraction of the FEV of GDP. Shocks to the real rate have played an important role only for the 3-month Treasury bill rate,[29] and, to a lesser extent, for the 10-year bond yield and M1 velocity. Finally, the residual permanent inflation shock only plays a sizeable role for the 10-year bond yield.

Counterfactual simulations Evidence from counterfactual simulations in which we 'kill off' one shock at a time provide additional validation to the previously discussed interpretation of post-WWII fluctuations in U.S. money velocity. Whereas, absent the residual shocks to the velocity of M2-M1, essentially nothing would have changed compared to the actual historical outcomes,[30] eliminating the shocks to the multiplier of M2-M1 would have produced signifiacnt changes in all series except—as is logically to be expected—GDP and consumption. Specifically, absent such shocks, the large, hump-shaped fluctuation in the multiplier of M2-M1 over the post-WWII period would have disappeared, and the multiplier would have been essentially flat. With a trend-stationary monetary base, this, in turn, logically implies that the Great Inflation should not have taken place: And in fact, as the third panel in the first row of Figure B.3 shows, counterfactual inflation would have peaked at about *5 per cent*, compared to the actual historical peak in excess of 12 per cent. In turn, nominal interest rates—once again, because of the Fisher effect—would have been significantly lower, and very broadly flat, than they have historically been. Finally, because of this, M1 velocity would also hae exhibited much less variation, and it would have been broaly flat, whereas the velocity of M2-M1 would have exhibited a steady increase over the entire sample period, as opposed to its U-shaped actual historical evolution. By contrast, killing off either permanent inflation shocks, or permanent shocks to the real rate, would have produced minor-to-negligible changes compared to the actual historical paths.

[29] This result is the same as King *et al.*'s (1991).

[30] As mentioned, the counterfactual paths obtained by killing off permanent GDP shocks are even closer to the actual historical paths, to the point that they are essentially indistinguishable. Because of this we do not report them, but they are available upon request.

B.2 Canada

B.2.1 Results from unit root and cointegration tests

Table B.1 reports results from unit root tests for Canada for the period 1961Q1-2006Q4.16 The null of unit root cannot be rejected for any series, with the partial exception of inflation and consumption *per capita*. In either case we regard we regard the null of a unit root as not having been convincingly rejected, and in what follows we will therefore consider both series as I(1).

Table B.2 reports results from cointegration tests. The following findings emerge from the table:

(*i*) in line with the results for the post-WWII United States, there is very strong evidence of cointegration between the 3-month Treasury bill rate and M1 velocity, whereas there is no evidence of cointegration with either M2 velocity, or the velocity or M2-M1. Once again, this points towards the presence of a stable long-run demand for M1, and of permanent velocity shocks specific to M2-M1 which prevent cointegration between the velocities of either M2-M1, or M2, and the short rate.

(*ii*) As for the larger systems, we detect two cointegration vectors for the system featuring the velocities of M1 and M2-M1, and one for the system featuring the velocity of M2. In fact, based on the economic logic we previously mentioned for the post-WWII United States, we should have expected to detect one more cointegration vector in either system. In practice, however, imposing for Canada the identified number of cointegration vectors, or further imposing an additional one, makes no material difference to the results,[31] so that in what follows we have chosen to work with the number of cointegration vectors which has been identified by Johansen's tests.

B.2.2 Evidence

Figures B.5 to B.8 show, for Canada for the period 1961Q1-2006Q4, the same evidence reported in Figures B.1 to B.4 for the post-WWII United States. For reasons of space, in what follows we exclusively focus upon, and discuss, the main similarities and differences between these results and the corresponding evidence for the United States.

As for the identification of the structural disturbances, the only difference with the post-WWII United States has to do with the fact that, as discussed in Section 2.1, the Canadian monetary base exhibits strong evidence of a unit root. As a result, after having idetified, as for the United States, a permanent shock to log real consumption *per capita*, we subsequently identify a residual permanent shock to log nominal M0 *per capita*,[32] as the only other shock which is allowed to have a permanent impact

[31] This alternative set of results is reported in the online appendix.

[32] 'Residual' because, quite obviously, permanent shocks to GDP and consumption should be expected to have a corresponding permanent impact on the monetary base.

on the monetary base. Then, conditional on these two shocks, we identify, exactly as before, the remaining four shocks to the multiplier of M2-M1, inflation, the real interest rate, and to the velocity of either M2-M1 (in the baseline system), or M2 (in the alternative system).

Turning to the main substantive findings, our key results for the post-WWII United States—pertaining to (*i*) a uniformly minor role played by velocity shocks specific to M2-M1, and (*ii*) the distortions in the inference produced by failing to split M2 into its M1 and non-M1 components—still hold here (compare the sixth panels in the sixth rows of Figures 10 ad 12). Once again, the reason for (*ii*) is that permanent shocks to the multiplier of M2-M1—as well as shocks to the monetary base, and to the real interest rate—have an opposite impact on the velocities of M1 and M2-M1,[33] so that failure to split M2 into its two components causes such impacts to largely cancel out in the aggregate, thus spuriously creating the need for another shock in order to explain the dynamics of M2 velocity. Other results are almost uniformly in line with those for the United States. Finally, these results are also robust to imposing three cointegration vectors instead of two (this alternative set of results is reported in the online appendix).

[33] As for the shock to the real rate, the response of M1 velocity is only significant at the one standard deviation level.

Table A.1 Bootstrapped *p*-values for Elliot, Rothenberg, and Stock unit root tests[a] on the central bank rate

	Lag order	
	p=1	p=2
United Kingdom, 1816-1913	0.00	0.00
France, 1800-1913	0.00	0.01
Austria, 1818-1913	0.08	0.04
Norway, 1819-1913	0.01	0.02
Sweden, 1856-1913	0.05	0.03
Finland, 1867-1913	0.07	0.04
Spain, 1874-1913	0.06	0.02
Japan, 1883-1913	0.03	0.15

[a] Based on 10,000 bootstrap replications of estimated ARIMA processes. Tests are with an intercept and no time trend.

Table B.1 Canada, 1961Q1-2006Q4: Bootstrapped *p*-values for Elliot, Rothenberg, and Stock unit root tests[a]

	Lag order:			
	p=1	p=2	p=3	p=4
	In levels, without a time trend			
GDP deflator inflation	0.001	0.025	0.090	0.117
3-month Treasury bill rate	0.302	0.263	0.235	0.264
10-year government bond yield	0.687	0.692	0.637	0.589
M1 velocity	0.889	0.930	0.875	0.925
M2 velocity	0.587	0.505	0.563	0.570
Velocity of M2-M1	0.215	0.224	0.260	0.258
	In levels, with a time trend			
Log nominal M0 *per capita*	0.965	0.971	0.963	0.969
Log real GDP *per capita*	0.297	0.282	0.326	0.374
Log real consumption *per capita*	0.006	0.058	0.046	0.102
	In differences, without a time trend			
	p=1	p=2	p=3	p=4
GDP deflator inflation	0.000	0.000	0.000	0.000
3-month Treasury bill rate	0.000	0.000	0.000	0.000
10-year government bond yield	0.000	0.000	0.000	0.000
M1 velocity	0.000	0.000	0.000	0.000
M2 velocity	0.000	0.000	0.000	0.000
Velocity of M2-M1	0.000	0.000	0.000	0.000
Log real GDP *per capita*	0.000	0.000	0.000	0.000
Log real consumption *per capita*	0.000	0.000	0.000	0.000

[a] Based on 10,000 bootstrap replications of estimated ARIMA processes.

Table B.2 Canada, 1961Q1-2006Q4: Results from Johansen's cointegration tests[a]

	Trace tests of the null of no cointegration against the alternative of h or more cointegrating vectors:			
	h = 1	*h = 2*	*h = 3*	*h = 4*
3-month Treasury bill rate and				
M1 velocity	40.137 (2.0E-4)			
M2 velocity	15.388 (0.226)			
velocity of M2-M1	12.301 (0.270)			
9-variables system with the velocities of M1 and M2-M1	285.466 (0.000)	207.724 (0.000)	145.541 (0.000)	98.761 (0.003)
8-variables system with M2 velocity	196.391 (0.037)	133.401 (0.081)	97.926 (0.032)	68.486 (0.017)
	Maximum eigenvalue tests of h versus h+1 cointegrating vectors:			
	0 versus 1	*1 versus 2*	*2 versus 3*	*3 versus 4*
3-month Treasury bill rate and				
M1 velocity	38.456 (1.0E-4)			
M2 velocity	12.790 (0.245)			
velocity of M2-M1	8.301 (0.437)			
9-variables system with the velocities of M1 and M2-M1	77.742 (0.008)	62.183 (0.035)	46.780 (0.195)	—
8-variables system with M2 velocity	62.990 (0.050)	35.475 (0.815)	—	—

[a] Bootstrapped p-values (in parentheses) are based on 10,000 bootstrap replications, based on Cavaliere *et al.*'s (2012) methodology.

Figures for appendix B

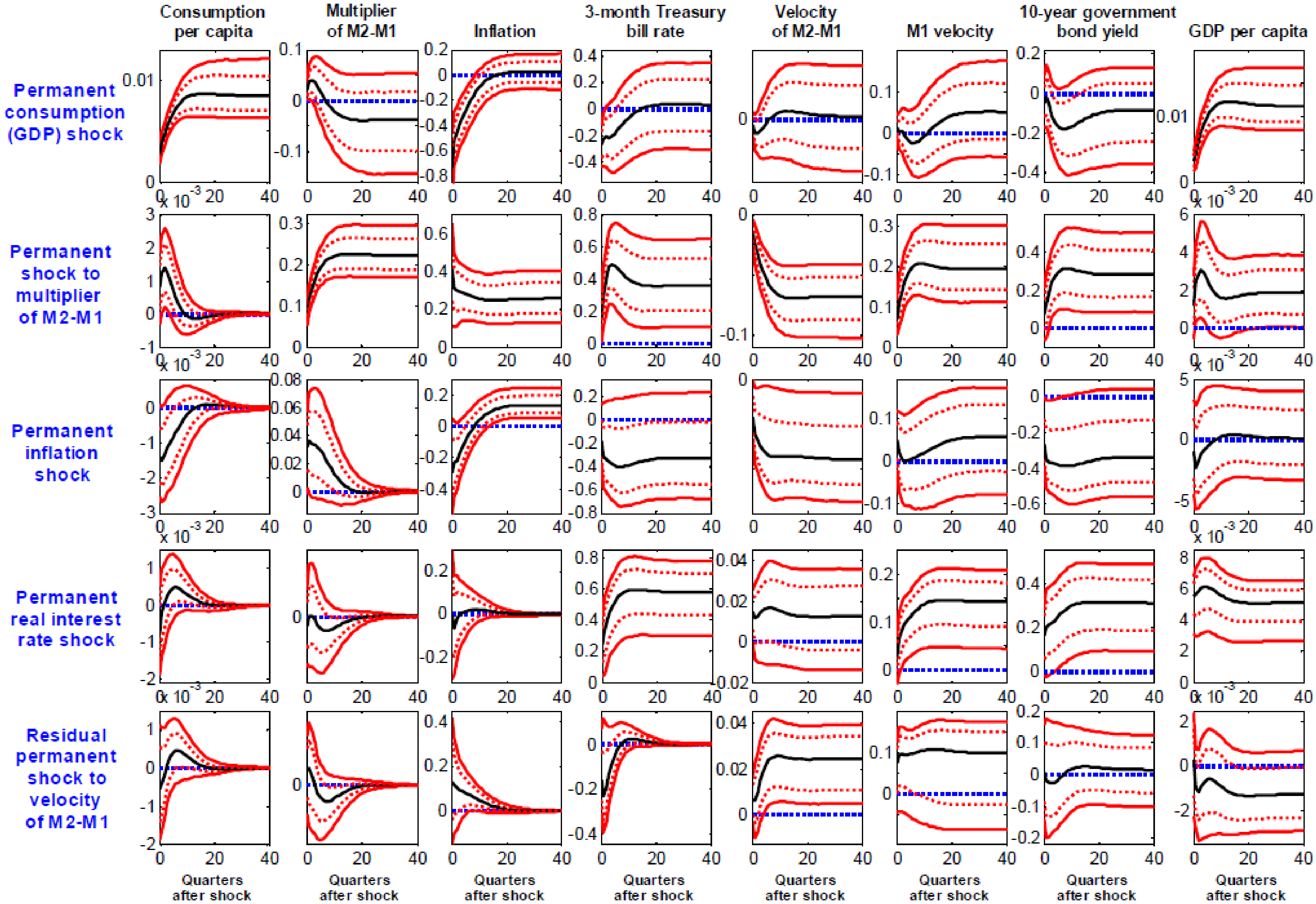

Figure B.1 United States, 1959Q2-2008Q3: Impulse-response functions to the permanent shocks, with 16-84 and 5-95 bootstrapped confidence bands

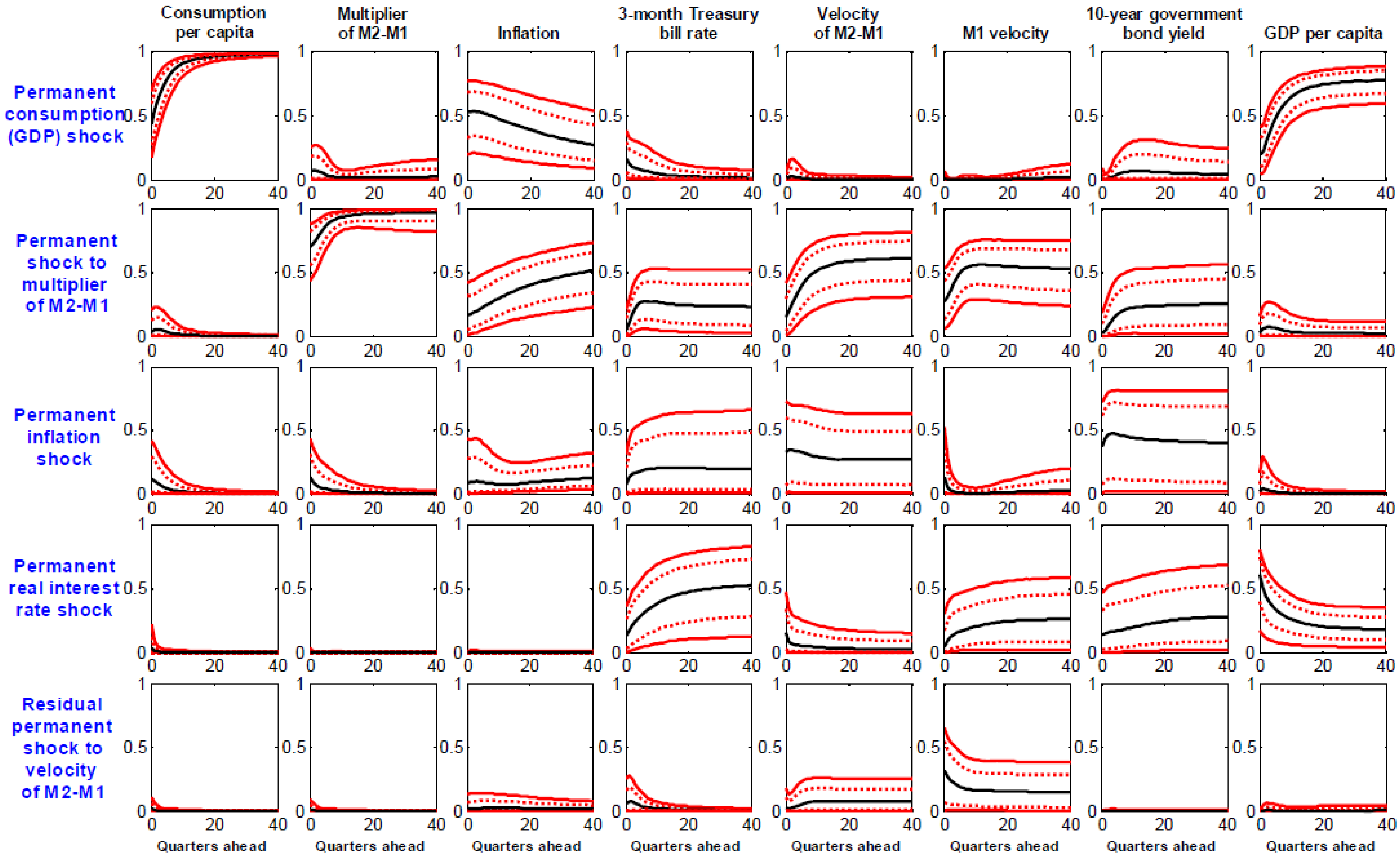

Figure B.2 United States, 1959Q2-2008Q3: Fractions of forecast error variance explained by either of the permanent shocks, with 16-84 and 5-95 bootstrapped confidence bands

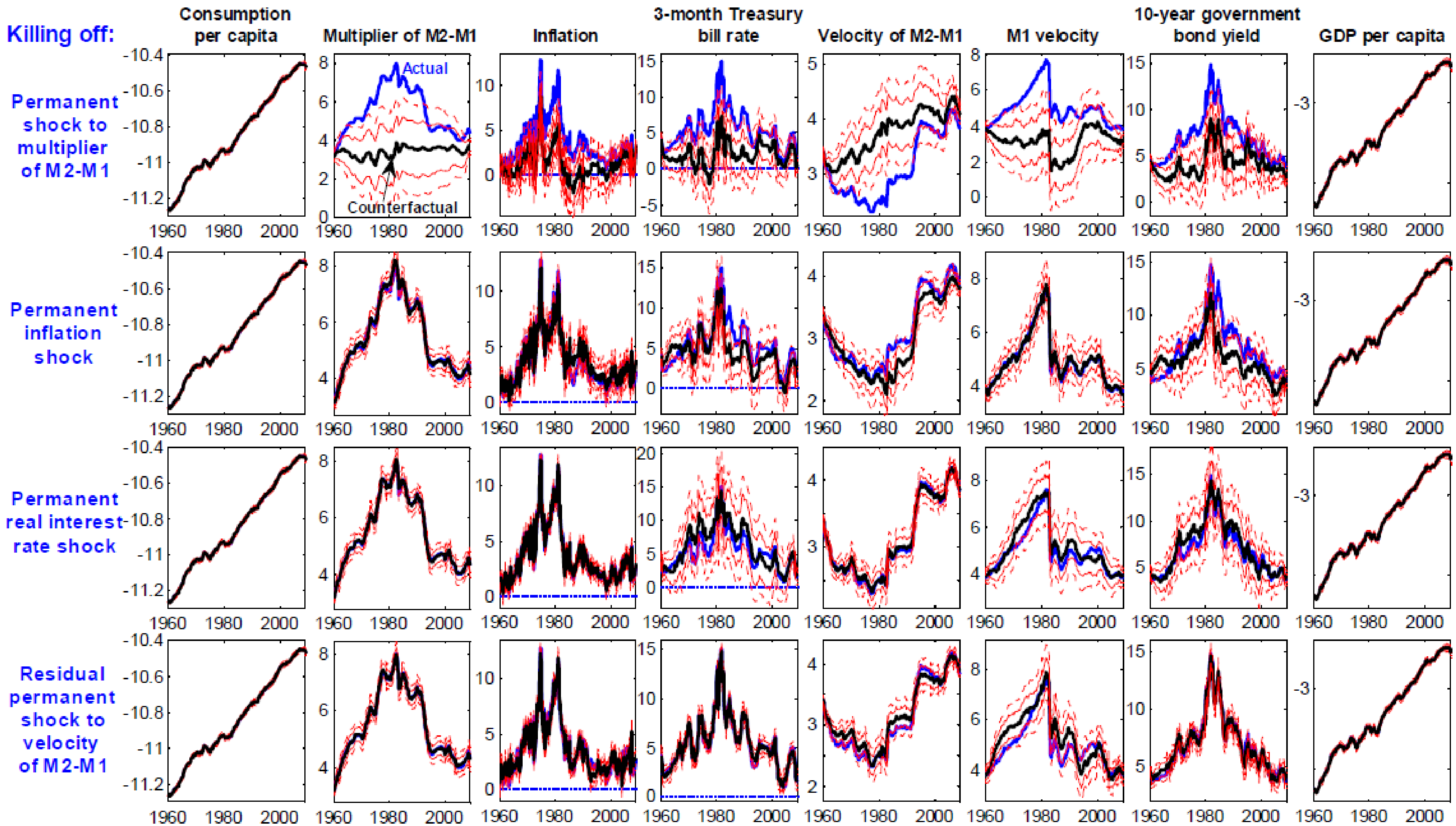

Figure B.3 United States, 1959Q2-2008Q3: Counterfactual simulations killing off permanent shocks, with 16-84 and 5-95 bootstrapped confidence bands

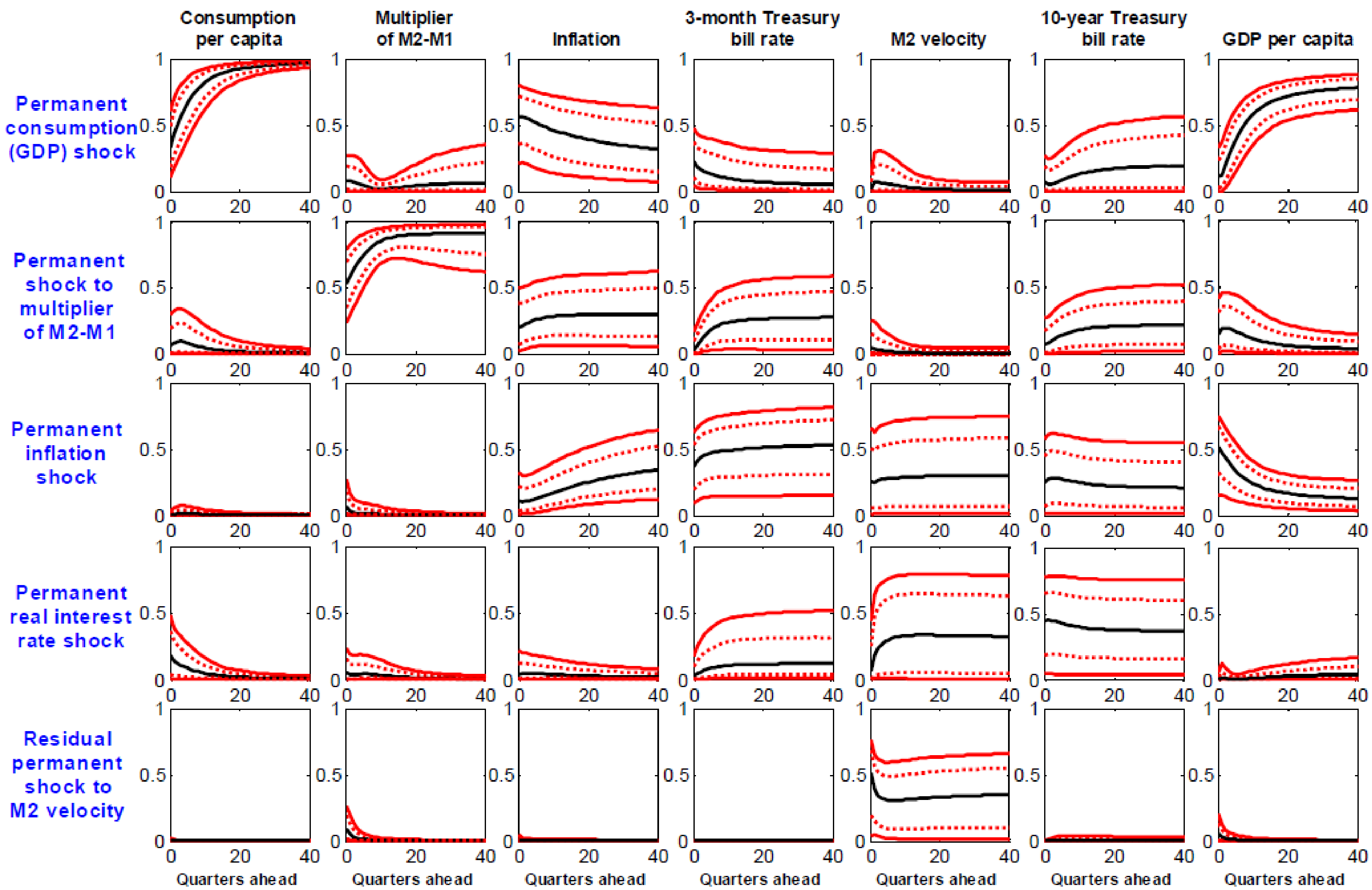

Figure B.4 United States, 1959Q2-2008Q3: Fractions of forecast error variance explained by either of the permanent shocks, with 16-84 and 5-95 bootstrapped confidence bands

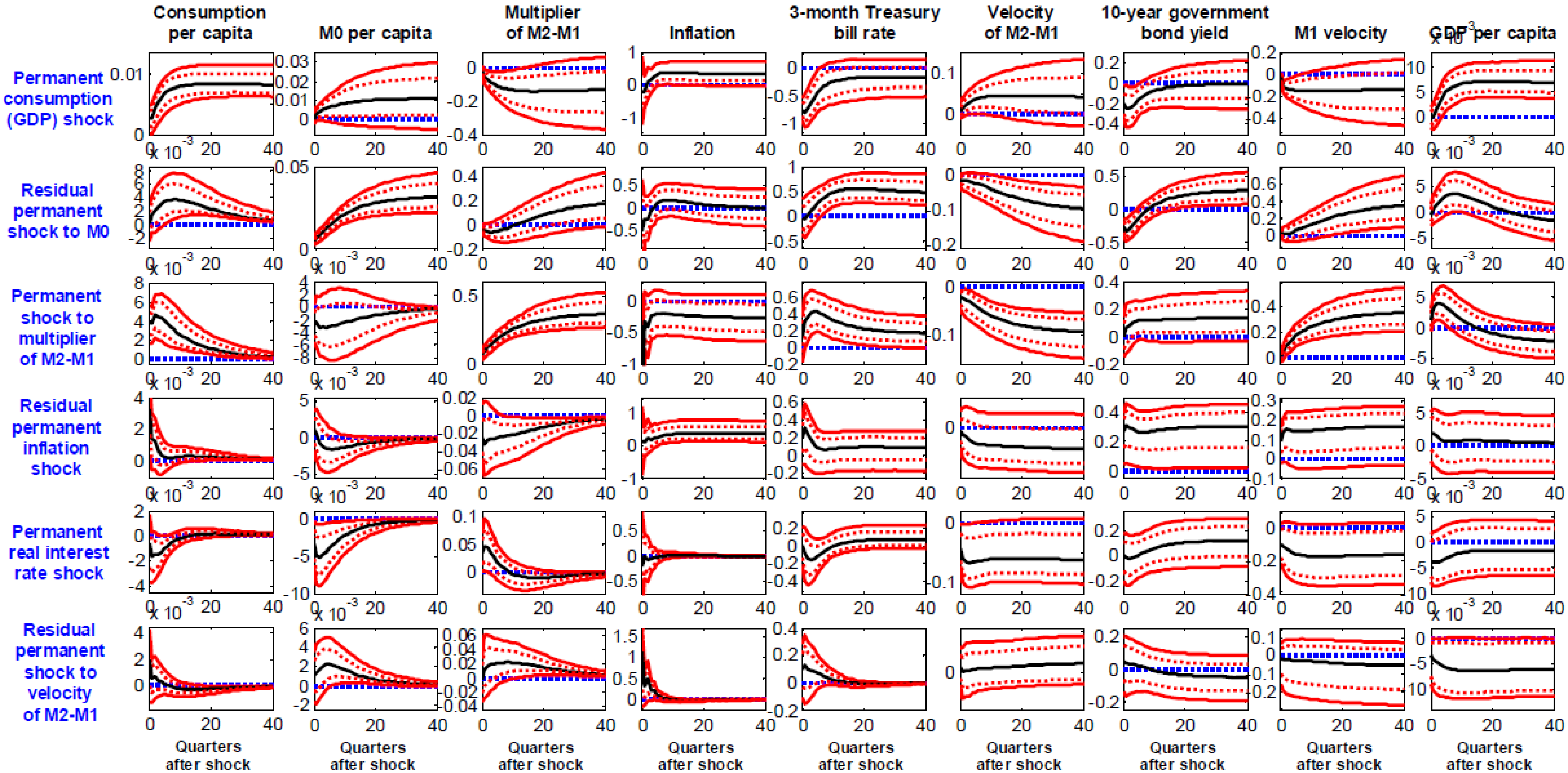

Figure B.5 Canada, 1961Q1-2006Q4: Impulse-response functions to the permanent shocks, with 16-84 and 5-95 bootstrapped confidence bands

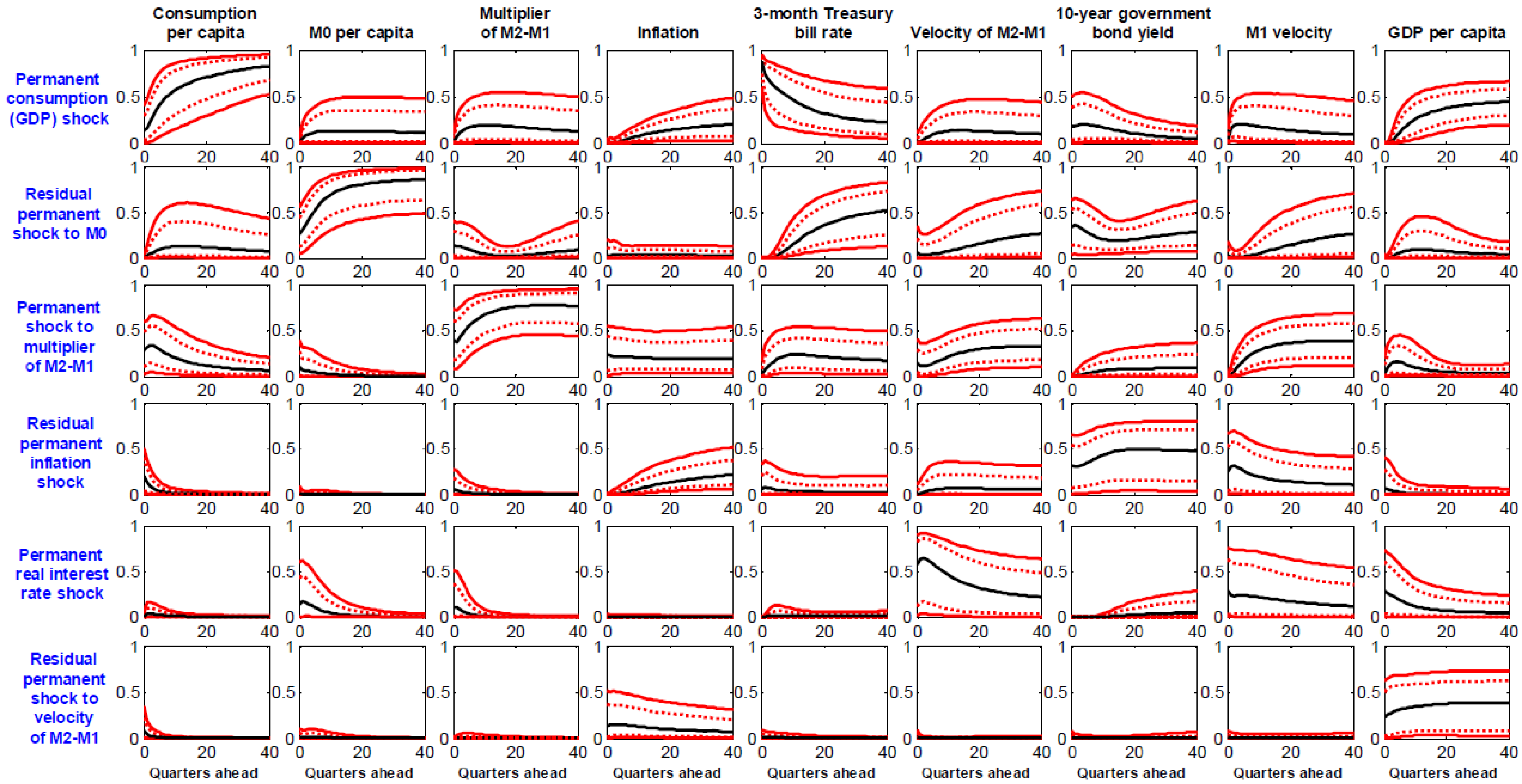

Figure B.6 Canada, 1961Q1-2006Q4: Fractions of forecast error variance explained by either of the permanent shocks, with 16-84 and 5-95 bootstrapped confidence bands

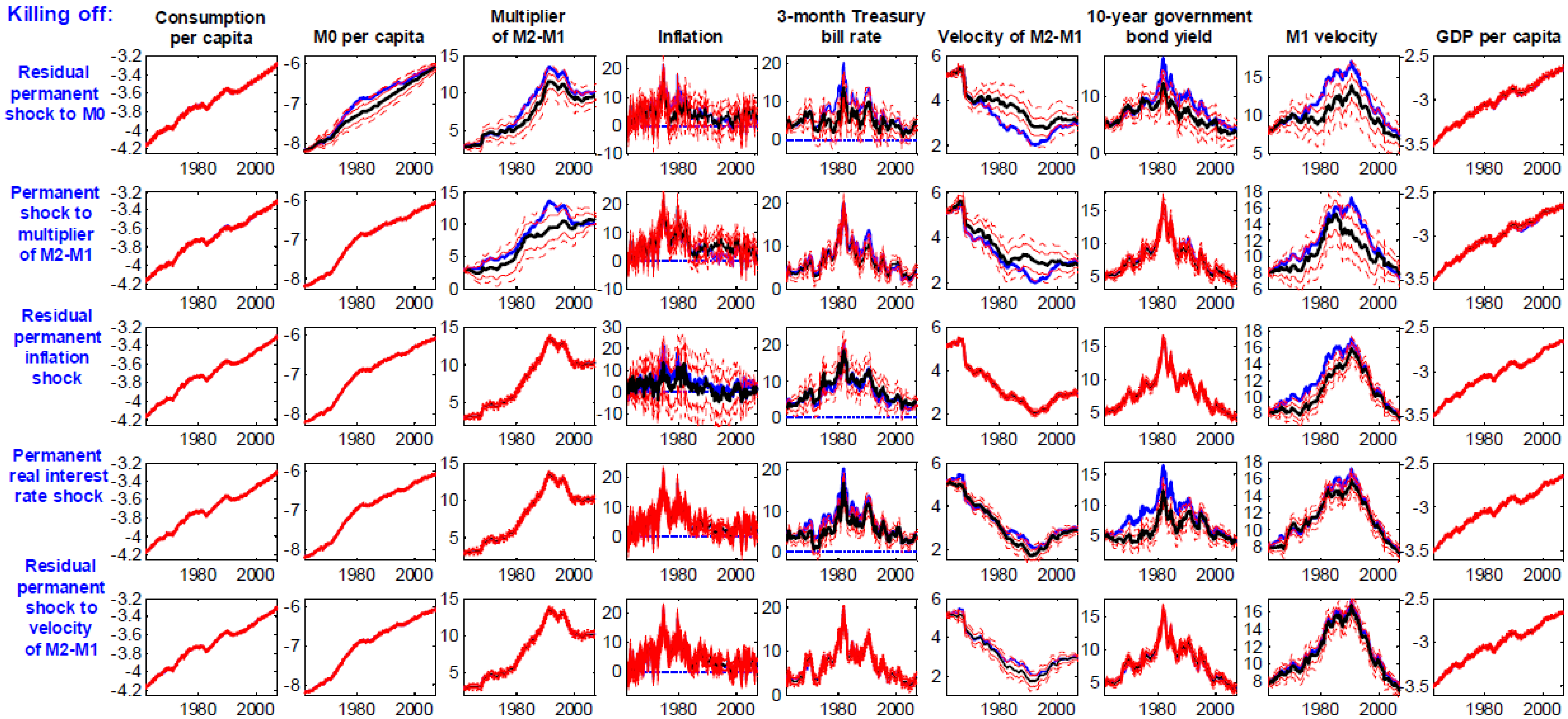

Figure B.7 Canada, 1961Q1-2006Q4: Counterfactual simulations killing off permanent shocks, with 16-84 and 5-95 bootstrapped confidence bands

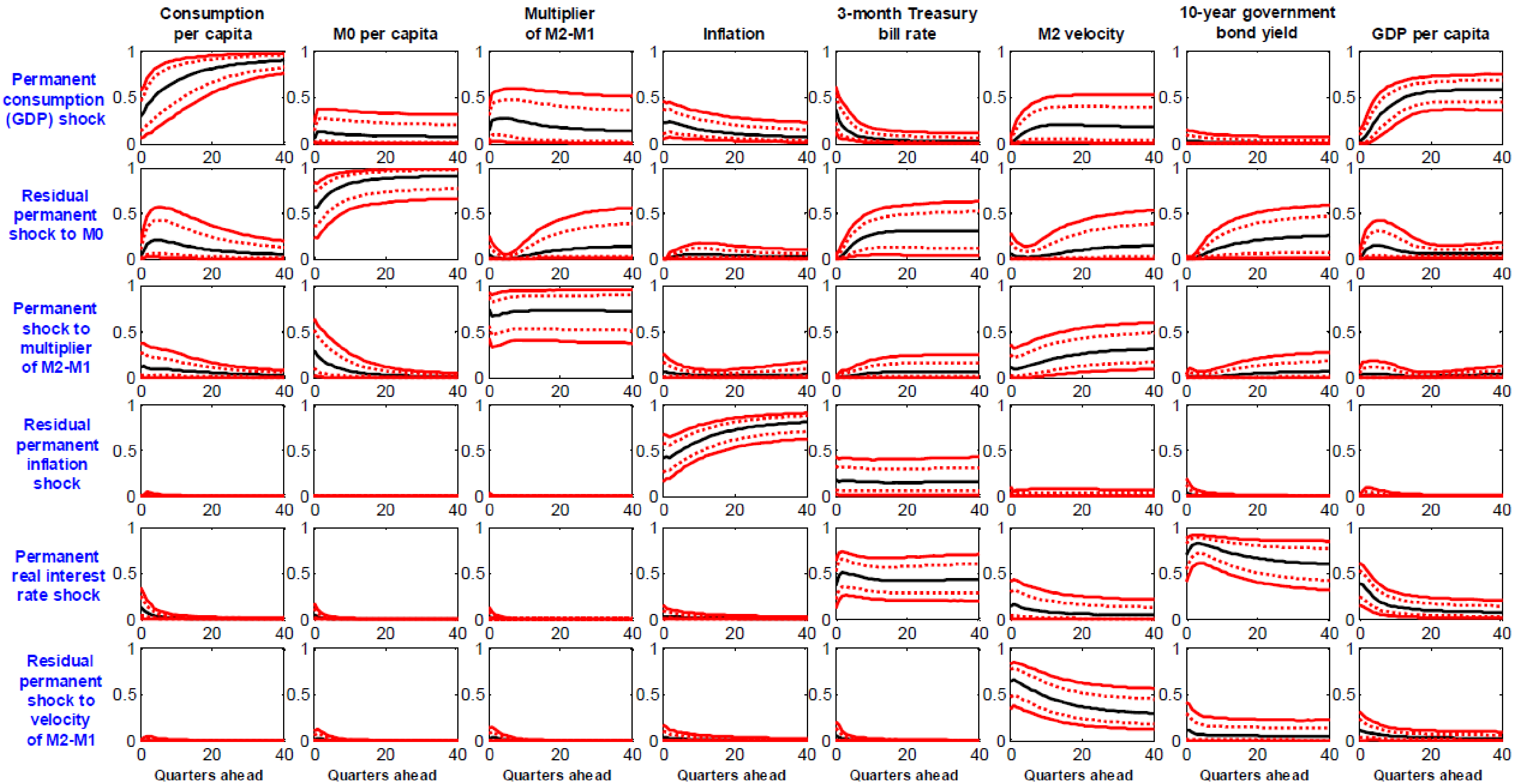

Figure B.8 Canada, 1961Q1-2006Q4: Fractions of forecast error variance explained by either of the permanent shocks, with 16-84 and 5-95 bootstrapped confidence bands