Historical Performance of Rule-Like Monetary Policy

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Abstract

I construct the differences between rule-based monetary policy for multiple interest rate rules and the actual interest rates for nine countries using real-time data available to policymakers at the time. Using structural break analysis, regressions at the country level, and panel regressions, which are robust to different measures of output and inflation, I document that more rule-like policy is associated with greater economic stability primarily though improved inflation stability. Additionally, I find evidence that the association between rule-like policy and greater economic stability is causal by examining the timing of the structural breaks and the changes in central bank policy and Granger causality testing.

Keywords: Monetary policy; Rules versus discretion; Taylor rules

JEL codes: E52; E60

1 Introduction

Debates over the merits of rule-based and discretionary monetary policy have been an integral part of macroeconomics for almost a century. Henry Simons (1936) framed it as a choice between rules, such as in the form of a clearly defined law, and a monetary authority with discretion in achieving broad goals. He argued that a rule-based monetary policy is essential to an economy based on the freedom of enterprise and emphasized the need for a stable and predictable policy in minimizing uncertainty. Milton Friedman (1948) argued for rules because of uncertainty about the timing and magnitude of the effects of monetary policies. Kydland and Prescott (1977) provided a theoretical argument for rules based on the time inconsistency of discretionary policy. The predominant arguments against rule-based monetary policy emphasize its rigidity, along with critiques of individual rules. Throughout the debate, research on policy rules has exploded, and a variety of policy rules have been proposed, critiqued, and evaluated in a myriad of models, including feedback rules to the interest rate such as Taylor (1993).

Despite an enormous amount of literature on model evaluations, very few direct empirical evaluations of rule-based policy have been conducted. Meltzer (2012) identified 1985 through 2003 as a period of stable growth and low inflation and as a period when monetary policy was rule-based. Taylor (2012) qualitatively identified the pre-1985 and post-2003 periods as ad hoc and found that economic performance in the rule-based era in between was significantly better. Nikolsko-Rzhevskyy, Papell, and Prodan (2014) applied econometrics by measuring deviations from policy-rule recommendations. They tested for structural breaks and identified discretionary and rule-based eras; they found that, as measured by six loss functions and three policy rules, economic performance in rule-based eras was uniformly better.

The results in Meltzer (2012), Taylor (2012) and Nikolsko-Rzhevskyy et al. (2014) are striking, but they rely on comparisons of economic performance across only a few distinct eras. Additionally, as Piazzesi (2014) points out the results do not prove that economic performance in the Great Recession would have been improved had policy been more rule-based. More generally, the results do not establish causation.

To explore these questions, I first expand upon Nikolsko-Rzhevskyy et al.'s (2014) econometric analysis for the United States by showing that the findings are robust across different measures of inputs into the policy rules and do not hinge on specific estimates of the output gap. Then I use real-time data from eight additional countries to document that more rule-like policy is consistently associated with greater economic stability, whether one uses structural break analysis or examines the relationship between the moving averages of deviations from policy rules and measures of economic stability.

To explore causality, I examine the timing of the structural breaks and the associated changes in central bank policy, which provides evidence for the dual-causality of this relationship. I also test for Granger causality both in the time series and panel setting.

An important assumption in this literature is the definition of rule-based and discretionary monetary policy. In principle, a policy rule can be highly complicated and made to fit almost any observed policy ex post. Hence, empirical evaluations of rule-like and discretionary policy must be restricted to some set of policy rules. I adopt the literature's convention to consider variations of interest rate rules in the Taylor rule style as the set of rule-based policies and to classify deviations from these rules as discretionary.

The next section briefly considers the underling theory informing the empirical estimation. Sections three presents the methodology of the empirical analysis. Section four presents the results for the main specifications for each country, with additional details for the United States, and I summarize these results in section five. In sections six, I examine the homogenous relationships and panel-data results, and I conclude in section seven.

2 Theoretical Background

There is considerable theoretical research showing that rule-based monetary policy affects economic stability. Variants of the Taylor rule have been shown to be optimal or near optimal in large classes of models, as well as robust across models.[1] Woodford's (2001) theoretical analysis of the Taylor rule illustrates the features of optimal monetary policy incorporated in to the Taylor rule, its potential for optimality, and its limitations. In the context of a simple and highly stylized "neo-Wicksellian" model, the Taylor rule is optimal under certain conditions. An essential aspect of optimal policy is determinacy. In forward-looking models, determinacy is ensured by

[1] Levin et al. (1999) show that within-model performance of simple policy rules is nearly identical to more complex policy rules while having greater robustness across models.

the Taylor principle, which requires interest rates to be sufficiently responsive to inflation.[2] This typically means interest rates must respond more than one-for-one with inflation.[3] The standard parametrizations of the Taylor rule satisfy the Taylor principle, ensuring the determinacy of the equilibrium and the stabilization of inflation and output.[4] While the Taylor rule has appealing features, Woodford (2001) argues that under relaxed assumptions, optimal policy should react to additional variables, such as the lagged interest rates, which allows policy to stabilize the economy by influencing expectations.[5]

Levin, Wieland, and Williams (1999) find that in forward-looking models, Taylor rules with inertia outperform those without inertia, generate nearly identical policy frontiers as more complicated rules, and are much more robust than more complicated rules. Levin, Wieland, and Williams (2003) finds that forecast-based policy rules do not "provide substantial gains in stabilization performance compared with simple outcome-based rules." Levin and Williams (2003) look across both forward- and backward-looking models.[6] They find that losses with optimized Taylor rules with inertia are not significantly greater than under the optimal policy, and optimal policy has significant inertia in forward-looking models and low to negative inertia in the backward-looking model. Also, while lower inertia increases losses in forward-looking models, high inertia in backward-looking models may lead to infinite losses.[7] More recent work has also considered modifications of the Taylor rule that may be optimal during financial crises, such as including a response to credit spreads (Curdia and Woodford, 2010) and credit growth (Christiano et al. 2007).

Not only can monetary policy regimes affect economic stability, but economic stability, or lack thereof, may affect monetary policy regimes. Monetary policy, like all policies, is more likely to come under scrutiny in a crisis than in an economic boom. Floating exchange rates typically replaced fixed exchange rates after currency crises, inflation targeting was adopted following repeated surges in inflation, and monetary-easing policies have largely been adopted during the financial crisis. The direction of this effect is ambiguous; bad economic conditions may lead to the adoption of policy

[2]Cochrane (2011, 2016) argues that this is an implausible assumption for central bank policy and for "Neo-Fisherian" dynamics.

[3]The formal condition is model dependent and relates the coefficients on inflation and the output gap in the policy rule to model parameters. See Woodford (2001) for simple examples, or see Davig and Leeper (2007) for a more comprehensive treatment.

[4]See Woodford (2001) for a discussion of inflation and output stability as monetary policy objectives.

[5]See Woodford (2001) for a further discussion on the role of inertia.

[6]The three models are from Woodford (2003), Fuhrer (2000), and Rudebusch and Svensson (1999).

[7]These results are consistent with findings in Taylor (1999) and Orphandies and Williams (2002, 2008).

that is more consistent with a Taylor rule, such as with the adoption of inflation targeting,[8] or policy that is less consistent with the Taylor rule, such as a major recession leading to a looser monetary policy.

3 Methodology

3.1 Estimating Discretion Relative to Policy Rules

In order to examine the relationship between deviations from policy rules and economic stability, we need historical estimates of deviations from policy rules. In light of the critiques against the use of ex-post data,[9] I use real-time data. The real-time data comes from three types of sources: country-specific data sets, OECD Release Data and Revisions Database, and the Real-Time Historical Database for the OECD (Fernandez, 2011)[10]. Policy recommendations for a particular quarter are calculated using the most recently available data at the time. As data for economic aggregates is released with a one- to two-quarter lag, policy recommendations are based on lagged economic conditions. All dates refer to the vintage the data comes from.[11]

The policy rules considered are variations of the Taylor rule, and they necessitate real-time estimates of inflation and the output gap. The output gap for a given vintage is calculated by detrending GDP or GNP from a country-specific starting date through the vintage date. The choice among detrending methods has a significant impact on the results, and there is a lack of consensus in the literature on the appropriate method. For example, the Congressional Budget Office (CBO) estimates that the output gap in the US in 2011 was negative five percent, while the standard Hodrick-Prescott (HP) filter suggests that the economy had already fully recovered from the financial crisis.

If a central bank chooses to follow a policy rule, it will implement the policy using its estimate of the output gap. Therefore a natural metric for real-time output-gap estimates in monetary policy

[8] Inflation targeting was usually adopted during periods of high inflation volatility. Typically the inflation targeting regime is much more consistent with rule-based policy than the preceding monetary policy regime.

[9] Orphanides (2001) shows that monetary policy rule estimates and recommendations depend on whether real-time or ex-post data is used. Orphanides and Norden (2002) show that real-time data is subject to large revisions and that end-of-sample estimates of the trend in output are unreliable.

[10] Additional detail about the data are provided in the supplemental appendix.

[11] 2000:Q1 refers to the policy recommendation based of the most recent data known in 2000:Q1 and is compared to the actual interest rate in 2000:Q1 to obtain the deviation from the policy rule in 2000:Q1.

Table 1: Comparison Between Different HP Filters and Real-Time Federal Reserve and 2014 CBO Estimates of the Output Gap

	Greenbook - Realtime			CBO - Ex Post		
Filter (λ))	Correlation	Average Absolute Difference	Average Difference Squared	Correlation	Average Absolute Difference	Average Difference Squared
100	-0.297	1.572	3.844	0.536	1.982	6.193
400	-0.057	1.591	3.804	0.620	1.890	5.356
800	0.113	1.555	3.558	0.660	1.833	4.916
1200	0.226	1.508	3.310	0.683	1.796	4.652
1600	0.309	1.463	3.089	0.698	1.766	4.464
Quadratic	0.762	2.316	6.643	0.781	1.579	4.861
2500	0.436	1.368	2.690	0.722	1.713	4.176
5000	0.611	1.195	2.043	0.754	1.617	3.757
10000	0.732	1.032	1.532	0.780	1.553	3.417
25000	0.807	0.893	1.234	0.800	1.506	3.160
30000	0.813	0.891	1.223	0.803	1.498	3.135
35000	0.817	0.895	1.223	0.805	1.492	3.119
40000	0.819	0.900	1.228	0.806	1.487	3.110
45000	0.820	0.906	1.236	0.808	1.483	3.106
50000	0.820	0.913	1.246	0.808	1.479	3.104
55000	0.821	0.920	1.255	0.809	1.475	3.105
60000	0.821	0.927	1.264	0.810	1.471	3.107
65000	0.821	0.934	1.273	0.810	1.467	3.111
70000	0.821	0.940	1.281	0.811	1.463	3.116
75000	0.821	0.945	1.289	0.811	1.460	3.122
100000	0.820	0.965	1.315	0.812	1.451	3.162

Note: Each row shows how close an HP filters with a specific smoothing parameter (λ) or quadratic detrending matches the Federal Reserve and CBO estimates of the output gap. The left panel shows how they match with real-time Federal Reserve estimates, while the right panel shows how they match with ex-post CBO estimates. Highlighted in red (yellow) are values that signal the closest (a close) match.

analysis for the United States is the Federal Reserve's own real-time estimates which are available from 1987 through 2007.[12] The real-time Federal Reserve estimates are similar to the CBO ex-post model-based estimates but differ significantly with real-time estimates from the standard HP filter or a quadratic trend. The standard HP filter estimates are characterized by very quick recoveries, and the estimates have a correlation of only .309 with the Federal Reserve estimates.

Alternate univariate filters produce output-gap series that are more consistent with the Federal

[12] A similar approach is taken in Nikolslo-Rzhevsky (2011) where various univariate method are compared in their ability to match Greenbook estimates. The author's findings favor quadratic detrending among the simple measures and a 20 year rolling window quadratic detrending as the overall preferred measure. However, the paper only considered HP detrending with the standard smoothing parameter, but as seen in Table 1, HP filters with higher smoothing parameters substantially outperform quadratic detrending.

Reserve's estimates. Table 1 shows how the quadratic filter and the HP filter, for numerous values of the smoothing parameter (λ), perform in matching the real-time Federal Reserve estimates in real-time and ex-post CBO estimates from an ex-post perspective. HP filters with higher values of the smoothing parameter does much better in real time than the standard HP filter or a quadratic trend. Relative to the standard HP filter, the correlation more than doubles, and the differences in the series are reduced by a third. Differences in the ex-post results are much smaller, but even for much higher values of the smoothing parameter, estimates of the output gap do not become less consistent with the CBO estimates.

These results lead me to focus on the HP filter with $\lambda = 50000$, which makes the trend far smoother than with the standard HP filter and does much better at matching the real-time estimates by the Federal Reserve.[13] Inflation is measured by the annual percent change in a price index as measured by total CPI.

I consider policy recommendations for two interest rate rules.[14] Both rules are of the form:

$$i_t = 1.0 + \theta_\pi * \pi_t + \theta_y * y_t. \tag{1}$$

The first, proposed in Taylor (1993), sets θ_π to 1.5 and θ_y to .5. The most common modification to this rule is to increase the coefficient on output, θ_y, to one, as described in Yellen (2012). I refer to this as the modified Taylor rule. For both rules, the inflation target and the equilibrium interest rate are implicitly assumed to equal two and this is maintained across all countries. Hence the analysis asks if monetary policy consistent with these two standard formulations of the Taylor rules outperform policy inconsistent with these rules in maintaining output stability and inflation near two percent. Notably, in multiple countries monetary policy in the late 1960s and early 1970s was broadly consistent with these rules even though monetary policy wasn't thought of in terms of these rules. If in these and other periods where policy looks rules-based, despite not being based in the framework of the particulars of monetary policy conduct at the time, and outperforms periods where policy is inconsistent with the rules, then this provides new evidence that these policy rules

[13]For robustness, I also consider the results with the standard HP filter.

[14]A third rule often considered in the literature is a country specific estimated rule; however, the estimated rules for most countries, other than the United States, violate the Taylor principle and would result in a multiplicity of equilibria in standard models. Furthermore even for the United States, it is unclear what a policy rule estimated over both the 1970s and the 1990s would indicate a rule that is either theoretically appealing or was actually followed.

are robust in delivering good though likely not optimal outcomes.

For each country-rule pair, I calculate the absolute deviation between the policy-rule recommendation using real-time data and the actual central bank rate. Higher values are times of greater discretion relative to the rule, while smaller values suggest a more rule-like monetary policy. When central bank rates are near the zero lower bound, I use a measure of the shadow interest rate as an approximation of the true monetary-policy position.

3.2 Structural Break Analysis

In order to compare economic stability across eras of rule-like and discretionary monetary policy, I use the Bai and Perron (1997, 2003) tests for structural breaks on all recursively determined partitions on the series of absolute deviations from a policy rule to identify the eras. The first structural break date, k, is estimated by running the linear regression:

$$y_t = \mu_1 * D_{t\leq k} + \mu_2 * D_{t>k} + \epsilon_t, \tag{2}$$

where y_t is the absolute deviation from the policy-rule, and $D_{t\leq k}$ and $D_{t>k}$ are dummy variables, with the first equal to one through the structural break and the latter after the structural break for all possible structural-break dates $k \in T$. The estimated structural break, $\hat{k}$, is the one that minimizes the sum of squared residuals, with $\hat{\mu}_1$ being the average absolute deviation from the policy rule prior to the break and $\hat{\mu}_2$ being the average absolute deviation from the policy rule after the break. An F-test is used to test if the null hypothesis of no structural breaks can be rejected. If the null hypothesis cannot be rejected, I find no evidence for multiple eras. If the null hypothesis is rejected, then $\hat{k}$ is a structural break, and the procedure is repeated on the two subsets of the data partitioned by $\hat{k}$. The procedure ends when the null hypothesis cannot be rejected on any partition. Additional refinements are used to ensure that the results are asymptotically equivalent to a global optimization procedure.[15]

This procedure identifies the number of structural breaks, the monetary-policy regimes they separate, and when the breaks occur. For each country-rule pair, I classify each identified monetary-policy regime as either a discretionary, rule-based, or intermediate era. The regime with the highest

[15] All tests are done with a trimming percentage of 15%, a maximum of five breaks, and at a 5% significance level.

average absolute deviation is classified as discretionary, and the regime with the lowest average absolute deviation is classified as rule based. For a single structural break and two eras, classifying eras as discretionary or rule based is clear, and the unrestricted test for structural breaks confirms that monetary policy is consistent with two distinct eras. With multiple structural breaks, two concerns arise: (1) multiple regimes may be part of the same era and (2) the difficulty of classifying regimes with intermediate levels of deviations.

Separate regimes that are part of the same era will have different average absolute deviations, but the test identifies the regimes and not the eras. A plausible and testable definition of an era is a set of policy regimes with a single level of average deviations, which can be imposed via a restricted version of the test for structural breaks documented in Bai and Perron (2006). However, this restriction may be inappropriate for discretionary eras, since different discretionary eras may have different levels of average absolute deviations from a policy rule.

In principle, intermediate eras can also be classified by imposing restrictions that allow for only two era types. However, this is often inconclusive, with both possible classifications better than the null hypothesis of no structural breaks. Additionally, the test can result in nonsensical results in the presence of a single highly discretionary period, such as in the case of Mexico, where an intermediate period with an average deviation of almost 8% is classified as rule like due to the presence of a discretionary period with an average deviation of 23%. For these reasons, the restricted tests are mentioned only when they provide additional insight, and the results primarily rely on the unrestricted tests, qualitative classifications of the eras, and robustness checks for the classifications of the intermediate eras.

3.3 Loss Functions

Economic stability and performance comparisons across eras are done via seven loss functions calculated with ex-post data. The loss functions are:

Modified misery index:	$\pi_t - y_t$	Linear absolute loss:	$\|\pi_t - 2\| + \|y_t\|$
First quadratic loss:	$(\pi - 2)^2 + y^2$	Second quadratic loss:	$1.5(\pi - 2)^2 + .5y^2$
Third quadratic loss:	$.5(\pi - 2)^2 + 1.5y^2$	Fourth quadratic loss:	$(\pi - 2)^2$
Fifth quadratic loss:	y^2		

Welfare comparisons across eras are made by comparing average losses across era types, with robustness checks for alternate classifications of intermediate eras.

3.4 Regression Analysis and Causality

The structural break analysis identifies long periods of rule-like and discretionary policy and compares average losses across those periods. An alternative approach is to estimate the relationship between deviations from a rule-like policy over a period and current economic performance. This uses all the variation in the data and measures how an increase in discretion is associated with economic stability. The degree to which monetary policy is inconsistent with a policy rule is captured by a three-year backward-looking moving average and a weighted moving average with a smoothing factor of .1 of deviations from a policy rule. The relationship is estimated by regressing the loss measures on a constant and a measure of deviations from the policy rule.

The preceding methods document a correlation between various measures of deviations and economic stability, but they fail to provide guidance for the causality of the relationship which may run in either direction. Additionally, the measure of the degree of discretion is relative to a theoretical policy rule rather than the actual rule. This opens an additional avenue of causality; greater economic instability may cause more discretionary policy. To see this channel, assume that monetary policy has no effect on the economy and the central bank follows a less responsive policy rule than the specified rule. Then, with greater economic instability, inflation and the output gap will be larger, implying a larger difference between the specified rule and the less responsive central bank policy, and therefore, deviations from the policy rule will increase as instability increases.

I take two approaches to explore causality in the country-specific data sets. The first approach is to examine the timing of the structural breaks within the context of economic stability and stated policy changes. Transitions to discretionary eras during periods of instability suggest that economic performance affects the degree of discretion from the policy rule. In the absence of official policy changes, this likely exemplifies the measurement channel rather than a shift to a more discretionary policy. Stated policy shifts near structural-break dates suggest that the policy changes are affecting economic stability in the following era. A common example suggesting that rule-like policy is improving economic stability is the adoption of a floating exchange rate near the beginning of a highly inflationary, discretionary era. Typically, such eras conclude with the adoption of inflation targeting, which leads to a low inflation, rule-like era. An alternative approach is to look for Granger causality between rule-like policy and economic stability. To test for Granger causality, I run a VAR with the chosen measures of losses and deviations and a constant, select lag length using the Schwartz information criterion, and run the Granger causality test.

3.5 Panel Data

Alternatively to looking for robust relationships in the country-specific results, they can be estimated directly in the panel data. While the structural break analysis cannot be done in a panel-data setting, the regression analysis and Granger causality tests are directly extendable. The panel data set is unbalanced with nine cross sections.[16] To estimate the homogenous relationship between deviations from a policy rule and economic losses, I estimate the equation:

$$Losses_{i,t} = \beta_0 + \beta_1 Deviation_{i,t} + \alpha_i + \delta_{year} + \epsilon_{i,t}, \tag{3}$$

where $Losses_{i,t}$ are the economic losses in country i for quarter t according to one of the seven loss functions, $Deviation_{i,t}$ are the deviations from the policy rule captured by one of the three measures explained in the preceding section, α_i represent country fixed effects, and δ_{year} represents yearly fixed effects.

As will be seen in the next section, the country-specific analysis shows a great degree of heterogeneity in the Granger causality results. I use the Dimitrescu and Hurlin (2012) test for homogenous non-causality to confirm the heterogeneous relationship. The Dimitrescu and Hurlin (2012) test amounts to running the standard Granger causality test on each cross section and using a weighted average of the individual Wald statistics as a new test statistic. The null hypothesis of the test is that there is homogenous non-causality between the variables. The alternative is heterogeneous non-causality; that is, there exists a subgroup of countries for which there is Granger causality between the variables.[17]

[16] All countries with real time data for at least 20 years outside of a monetary union are included. The countries are the U.S., the U.K., Australia, Canada, Japan, Italy, Mexico, New Zealand, and Norway.

[17] An alternative approach is to estimate a causal relationship in the panel data though this must overcome endogeneity in the measure of discretion which can potentially be done by using lagged values of the measure of discretion in a restricted VAR. The results from such an approach are consist to the findings reported in the paper and shown in the supplemental appendix.

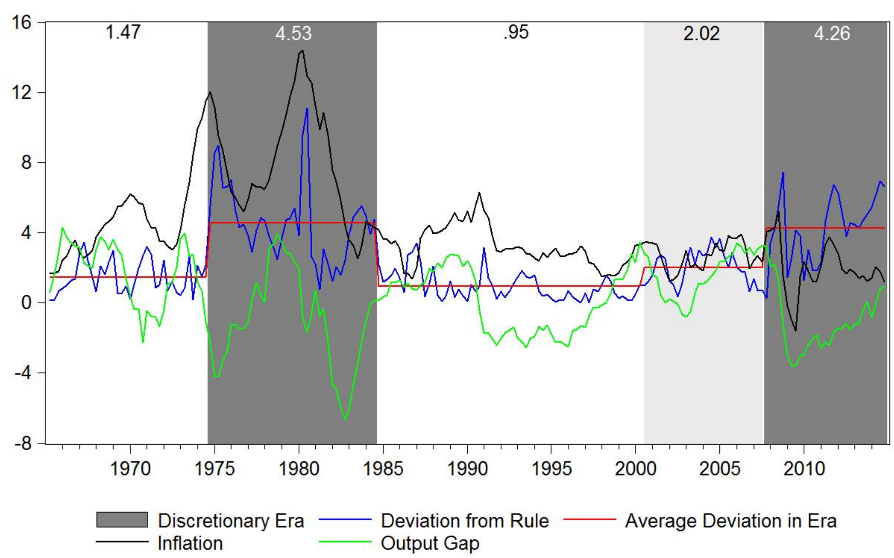
4 Country-Specific Results

In this section I focus on results for deviations from the original Taylor rule with the modified HP filter output gaps. Figures 1 and 2 show the structural break analysis results for all the countries along with how inflation and output perform. Complete results for the loss-function comparisons, the Granger causality testing, and the regressions are available as supplemental material for deviations relative to the original and the modified Taylor rules.

4.1 United States

For comparison with Nikolsko-Rzhevskyy et al. (2014) and for robustness, the results for the United States are presented for all output gap measures and for both policy rules. Real-time data is available for 1965:Q2 through 2014:Q4, and output detrending starts from 1947:Q1.[18]

Figure 1: Structural Breaks in the Absolute Deviations from the Original Taylor rule with Modified HP Filter Output Gaps



Note: The numbers indicate the average absolute deviation in each period.

Figure 1 shows the structural break analysis for the original Taylor rule with the modified HP filter output gaps and table 2 summarizes the structural break analysis for all the specifications.

[18]Output data post 1965:Q3 and CPI data starting in 1994 comes from the Philadelphia Federal Reserve's Real-Time Data Set for Macroeconomists and is supplemented by the OECD data sets prior to this. The federal funds rate is replaced by the Wu and Xia shadow interest rate staring in 2009:Q3.

Table 2: Eras, Average Deviations, and Structural Breaks across Policy Rules and Output-Gap Measures

Policy Rule	Output Gap Measure	1st Era		2nd Era		3rd Era		4th Era		5th era		6th era	
		Average Deviation	End Date	Average Deviation	End Date	Average Deviation	End Date	Average Deviation	End Date	Average Deviation	End Date	Average Deviation	End Date
Original	Quadratic	1.72	1974Q3	4.52	1984Q3	1.7	1993Q1	1.05	2000Q2	3.16	2014Q4		
	HP λ=1600	1.34	1973Q3	5.46	1980Q4	1.56	2007Q3	5.16	2014Q4				
	HP λ=50000	1.47	1974Q3	4.53	1984Q3	0.95	2000Q2	2.02	2007Q3	4.26	2014Q4		
	CBO	2.44	1974Q3	4.48	1987Q2	0.92	2003Q1	2.87	2014Q3				
Modified	Quadratic	2.85	2014Q4										
	HP λ=1600	1.29	1974Q4	5.24	1981Q4	1.55	2007Q3	5.51	2014Q4				
	HP λ=50000	1.64	1974Q4	4.3	1984Q3	1.3	1992Q2	0.68	1999Q4	2.05	2007Q3	3.82	2014Q4
	CBO	4.21	1987Q2	0.68	1994Q4	1.4	2004Q2	2.05	2014:Q3				
		Rule Like				Intermediate				Discretioanry			

Note: Each row shows the average deviation in and end date of each period identified by the unrestricted test for structural breaks for the output-gap measure specified in column two and relative to the policy rule specified in column one.

There are significant differences across the various measures of the output gap, demonstrating the significance of the measurement choices, especially in relating structural breaks to policy changes at central banks. Despite the differences, the broad trends are similar across most filters. Relative to the original Taylor rule, policy is the most inconsistent between 1975 and the mid 1980s. In the following period, though the early 2000s, policy is the most consistent with the Taylor rule. In the early 2000s, and especially since the financial crisis, policy became increasingly inconsistent with the Taylor rule. Finally, the initial period from the mid 1960s till the mid 1970s, while not nearly as rule like as the 1990s, is also less discretionary than either of the discretionary periods. Relative to the modified Taylor rule, the overall trend is the same, but the initial and final periods are trickier to classify.

With quadratic output gaps, the structural break analysis relative to the original Taylor rule is consistent with Nikolsko-Rzhevskyy et al. (2014), but I find no structural breaks for deviations from the modified Taylor rule.[19] This difference occurs from the use of the total CPI rather than the GDP deflator.[20] However, minor modification to the specification of the test, such as reducing the significance level to 90% or reducing the trimming percentage to 10%, results in qualitatively

[19]The eras are nearly identical aside from an additional structural break in 1993:Q2, which separates an intermediate and a rule-like era. However, under the assumption of only rule-like and discretionary eras, the intermediate eras become rule like, and I have the same four eras with near-identical structural breaks. This is confirmed by the test for multiple restricted structural changes when imposing this restriction at the 99% confidence level; the structural break dates are 1974:Q3, 1984:Q4, and 2000:Q3 with average deviations of 1.52 and 3.72 in the rule-like and discretionary periods, respectively.

[20]With a GDP-deflator based inflation measure, the results are nearly identical to those in Nikolsko-Rzhevskyy et al. (2014).

similar results with CPI inflation as with a GDP-deflator based inflation measure.

The preceding results are consistent with findings in the literature that the Federal Reserve's policy was close to the Taylor rule starting in the mid 1980s and began to deviate from the Taylor rule in the early 2000s.[21] The initial period of rule-like policy transitioned into discretionary policy in the mid 1970s. The transition is likely to have been caused by a belief in the Phillips Curve, which led the Federal Reserve to expand the monetary supply excessively, while the collapse of the Bretton Woods system in August of 1971 and of the Smithsonian Agreement in early 1973 removed the dollar's tenuous anchor to gold. Thus, the expansion of the monetary supply without outside restrictions became both desired and possible. However, despite the expansion of the monetary supply, policy remained relatively rule like though 1974:Q3. Monetary policy became rule like again in 1984:Q4, more than five years after Volcker raised interest rates to bring down inflation. Although a significant time gap, it was a transition period in which the public needed to adjust its expectations of future monetary policy and inflation. The transition is masked in the results due to the use of absolute values of deviations. Through 1979, interest rates were consistently too low, whereas after 1979 interest rates were consistently too high. The next structural break of the early 2000s occurred as policy became increasingly easy and has been well documented. However, this was a time of consistent leadership and no formal policy changes. The final structural break at the beginning of the financial crisis can initially be attributed to the zero lower bound, as interest rates were reduced too slowly. However, as quantitative easing became a significant policy instrument and the economy recovered, the Federal Reserve has not raised interest rates or reversed quantitative easing. Together, this amounts to a long term shift to increasingly more accommodating policy since 2000.

Table 3 shows the loss-function comparison across eras for the main specification. Losses are much higher in discretionary periods than in rule-like periods but are even lower in the short intermediate period. For both Taylor rules, average losses are greater in the discretionary periods by at least 47% and as much as 434% regardless of how the intermediate period is classified. The loss-function comparisons with the three alternative measures of the output gap all provide the same qualitative results of greater losses in discretionary periods regardless of how intermediate periods are classified. While qualitatively the classification of intermediate eras does not matter, an

[21] See Taylor (2012), Nikolsko-Rzhevskyy et al. (2014), Poole (2007), and Meltzer (2011).

Table 3: Loss-Function Comparison for United States with Modified HP Filter Output Gaps

Type of Taylor Rule	Average Loss During: Rules-Based Eras (1)	Discretionary Eras (2)	Intermediary Eras (3)	Rule and Intermediary Eras (4)	Discretionary and Intermediary Eras (5)	Ratio (2)/(1)	Ratio (2)/(4)	Ratio (5)/(1)
	Misery Index: $L = Inflation -$ Output Gap							
Original	3.09	6.54	1.10	2.64	4.93	2.12	2.48	1.60
Modified	3.14	6.54	1.05	2.64	4.84	2.08	2.48	1.54
	Linear Absolute Loss Function: $L = \|Inflation - 2\%\| + \|Output\ Gap\|$							
Original	3.64	6.07	2.59	3.40	5.04	1.67	1.78	1.39
Modified	3.63	6.07	2.69	3.40	5.03	1.67	1.78	1.38
	Quadratic Loss Function: $L = (Inflation - 2\%)^2 + (Output\ Gap)^2$							
Original	10.55	34.58	5.34	9.39	25.93	3.28	3.68	2.46
Modified	10.56	34.58	5.65	9.39	25.62	3.28	3.68	2.43
	Quadratic Loss Function $L = 1.5 * (Inflation - 2\%)^2 + .5 * (Output\ Gap)^2$							
Original	11.64	44.94	3.74	9.87	32.75	3.86	4.55	2.81
Modified	11.74	44.94	3.93	9.87	32.23	3.83	4.55	2.75
	Quadratic Loss Function: $L = .5 * (Inflation - 2\%)^2 + 1.5 * (Output\ Gap)^2$							
Original	9.47	24.23	6.94	8.90	19.11	2.56	2.72	2.02
Modified	9.38	24.23	7.38	8.90	19.00	2.58	2.72	2.03
	Quadratic Loss Function: $L = (Inflation - 2\%)^2$							
Original	6.36	27.65	1.07	5.18	19.78	4.35	5.34	3.11
Modified	6.46	27.65	1.10	5.18	19.42	4.28	5.34	3.01
	Quadratic Loss Function: $L = (Output\ Gap)^2$							
Original	4.19	6.93	4.27	4.21	6.15	1.65	1.65	1.47
Modified	4.10	6.93	4.55	4.21	6.19	1.69	1.65	1.51

Note: Columns 1 through 5 show the average losses in each era type for each loss function and relative to deviations from both Taylor rules, where each period from the test for structural break is classified as rule based, discretionary, or intermediate (see text for classifications). The final three columns show the ratio of average losses in discretionary to rule-based periods for the three possible classifications of intermediate periods.

average deviation from the rule of greater than 2% is sizable and is a benchmark for intermediate eras being practically discretionary. Although this guideline is not helpful for the main specification, where the intermediate eras are on the borderline, the intermediate eras for the original Taylor rule with quadratic output gaps can be thought of as rule like, and all other intermediate eras are close to being discretionary.

Similarly, the regression analysis shows that larger deviations from the original Taylor rule are consistently associated with greater losses for the misery index, linear absolute loss function, and the first four quadratic loss functions across all measures of the output gap. For the fifth quadratic loss function, which only values output stability, the results are less robust with consistently positive but not necessarily significant coefficients. Larger deviations from the modified Taylor rule, for most output-gap measures, are associated with greater losses for all loss functions, and the relationship is weakest for the fifth quadratic loss function. The exception to this result occurs with output

Table 4: P-values for Granger Causality Tests for the United States: Deviations Cause Losses

Taylor Rule	Output Gap	Measure of Deviations	MI	LAL	QLF1	QLF2	QLF3	QLF4	QLF5
Original	Quadratic	MA - 3 year	0.140	0.357	0.090	0.051	0.409	0.051	0.781
		MA - 5 year	0.104	0.780	0.562	0.521	0.523	0.439	0.929
		WMA	0.028	0.123	0.343	0.088	0.152	0.043	0.602
		Instant	0.091	0.233	0.383	0.027	0.886	0.011	0.854
Original	HP (λ=1600)	MA - 3 year	0.038	0.069	0.005	0.004	0.007	0.006	0.222
		MA - 5 year	0.092	0.292	0.200	0.156	0.243	0.116	0.368
		WMA	0.009	0.313	0.038	0.021	0.122	0.018	0.139
		Instant	0.056	0.375	0.017	0.010	0.574	0.009	0.854
Original	HP (λ=50000)	MA - 3 year	0.231	0.118	0.031	0.018	0.084	0.021	0.286
		MA - 5 year	0.224	0.703	0.359	0.360	0.312	0.266	0.266
		WMA	0.045	0.104	0.341	0.036	0.067	0.019	0.107
		Instant	0.123	0.510	0.540	0.016	0.739	0.009	0.915
Original	CBO	MA - 3 year	0.108	0.172	0.014	0.016	0.303	0.015	0.893
		MA - 5 year	0.120	0.251	0.084	0.089	0.186	0.101	0.896
		WMA	0.016	0.007	0.045	0.030	0.066	0.018	0.512
		Instant	0.141	0.093	0.523	0.134	0.802	0.077	0.714
Modified	Quadratic	MA - 3 year	0.749	0.609	0.881	0.257	0.931	0.165	0.815
		MA - 5 year	0.757	0.514	0.869	0.540	0.919	0.368	0.845
		WMA	0.384	0.419	0.600	0.317	0.824	0.152	0.779
		Instant	0.389	0.552	0.668	0.249	0.780	0.118	0.924
Modified	HP (λ=1600)	MA - 3 year	0.136	0.392	0.011	0.004	0.105	0.003	0.335
		MA - 5 year	0.304	0.119	0.249	0.168	0.307	0.116	0.530
		WMA	0.075	0.568	0.162	0.056	0.304	0.034	0.183
		Instant	0.295	0.132	0.018	0.008	0.283	0.006	0.518
Modified	HP (λ=50000)	MA - 3 year	0.931	0.731	0.908	0.328	0.902	0.241	0.646
		MA - 5 year	0.745	0.709	0.892	0.611	0.908	0.419	0.553
		WMA	0.458	0.566	0.971	0.161	0.726	0.064	0.525
		Instant	0.535	0.616	0.877	0.100	0.903	0.042	0.855
Modified	CBO	MA - 3 year	0.837	0.216	0.095	0.456	0.235	0.555	0.842
		MA - 5 year	0.752	0.4553	0.441	0.651	0.559	0.667	0.942
		WMA	0.191	0.028	0.200	0.035	0.407	0.097	0.931
		Instant	0.148	0.143	0.558	0.041	0.255	0.124	0.328

Note: P-values are for the null hypothesis that deviations from the Taylor rule specified in column one do not Granger cause economic losses. Economic losses are captured by the seven loss functions introduced in section 3.3. MI stands for the misery index, LAL stands for linear absolute loss, and QLF1-QLF5 are the five quadratic loss functions. The measures of deviations from the rule are captured by the three and five year moving averages, a weighted moving average, and a single quarter deviation.

gaps from quadratic detrending, where the relationships exist only for a subset of the loss functions and measures of deviations.

The Granger causality results shown in tables 4 and 5 are mixed. The most robust result

Table 5: P-values for Granger Causality Tests for the United States: Losses Cause Deviations

Taylor Rule	Output Gap	Measure of Deviations	Loss Functions MI	LAL	QLF1	QLF2	QLF3	QLF4	QLF5
Original	Quadratic	MA - 3 year	0.026	0.002	0.000	0.000	0.002	0.000	0.118
		MA - 5 year	0.012	0.001	0.001	0.003	0.004	0.003	0.067
		WMA	0.006	0.000	0.000	0.000	0.000	0.000	0.158
		Instant	0.000	0.000	0.000	0.000	0.000	0.000	0.060
Original	HP (λ=1600)	MA - 3 year	0.102	0.447	0.002	0.001	0.013	0.000	0.228
		MA - 5 year	0.018	0.490	0.128	0.074	0.088	0.061	0.925
		WMA	0.002	0.008	0.000	0.000	0.005	0.000	0.105
		Instant	0.000	0.033	0.000	0.000	0.000	0.000	0.169
Original	HP (λ=50000)	MA - 3 year	0.035	0.038	0.000	0.000	0.008	0.000	0.144
		MA - 5 year	0.019	0.030	0.002	0.006	0.036	0.005	0.569
		WMA	0.005	0.002	0.002	0.000	0.001	0.000	0.130
		Instant	0.000	0.000	0.000	0.000	0.000	0.000	0.152
Original	CBO	MA - 3 year	0.001	0.001	0.000	0.000	0.004	0.000	0.526
		MA - 5 year	0.008	0.014	0.016	0.028	0.057	0.056	0.064
		WMA	0.001	0.000	0.000	0.000	0.001	0.000	0.237
		Instant	0.000	0.000	0.000	0.000	0.000	0.000	0.127
Modified	Quadratic	MA - 3 year	0.507	0.003	0.000	0.001	0.000	0.000	0.006
		MA - 5 year	0.431	0.001	0.010	0.009	0.015	0.006	0.106
		WMA	0.320	0.004	0.016	0.000	0.000	0.000	0.003
		Instant	0.385	0.000	0.000	0.000	0.000	0.000	0.001
Modified	HP (λ=1600)	MA - 3 year	0.449	0.338	0.003	0.001	0.008	0.000	0.018
		MA - 5 year	0.413	0.247	0.224	0.101	0.089	0.072	0.787
		WMA	0.104	0.047	0.001	0.000	0.164	0.001	0.373
		Instant	0.012	0.240	0.002	0.000	0.007	0.000	0.358
Modified	HP (λ=50000)	MA - 3 year	0.508	0.001	0.000	0.000	0.002	0.000	0.087
		MA - 5 year	0.125	0.002	0.001	0.002	0.002	0.001	0.118
		WMA	0.125	0.003	0.039	0.000	0.002	0.000	0.014
		Instant	0.166	0.000	0.000	0.000	0.000	0.000	0.012
Modified	CBO	MA - 3 year	0.005	0.001	0.001	0.001	0.000	0.005	0.008
		MA - 5 year	0.032	0.027	0.037	0.003	0.006	0.006	0.023
		WMA	0.063	0.000	0.001	0.000	0.000	0.000	0.000
		Instant	0.034	0.000	0.000	0.000	0.000	0.000	0.000

Note: P-values are for the null hypothesis that economic losses do not Granger cause deviations from the Taylor rule specified in column one. Economic losses are captured by the seven loss functions introduced in section 3.3. MI stands for the misery index, LAL stands for linear absolute loss, and QLF1-QLF5 are the five quadratic loss functions. The measures of deviations from the rule are captured by the three and five year moving averages, a weighted moving average, and a single quarter deviation.

is that losses Granger-cause deviations from policy rules, although there are some exceptions, typically occurring for either the misery index or the fifth quadratic loss function. Deviations from the modified Taylor rule do not Granger-cause losses except with standard HP filter output gaps, where deviations Granger-cause losses for functions emphasizing inflation stability.

The original Taylor rule is the only policy rule for which there is clear evidence of Granger causality of deviations on losses. Across all measures of the output gap, the various moving averages of deviations usually Granger cause the fourth but not the fifth quadratic loss function. This means that deviations from the original Taylor rule Granger-cause losses from inflation but not from output fluctuations. For the other loss functions that combine the two objectives of monetary policy, the results are mixed with a lot of variance between various measures of output gaps and deviations. Throughout, it is important to note that the deviation measure is of the absolute value of deviations, which masks important policy changes in this analysis. In examining Granger causality, the pre-Volker and the early Volker period look very similar with high absolute deviations, thereby hiding the most important change in U.S. monetary policy over the sample period.

Overall deviations from the original Taylor rule Granger-cause losses from inflation and some of the other loss functions. The timing argument of the structural breaks does not provide new insights; clearly, the monetary policy in the 1970s was flawed, led to inflation instability, and was highly inconsistent with either policy rule. Drawing insight from the more recent transition to policy that is inconsistent with the policy rules is fraught with debatable assumptions and controversy.

4.2 United Kingdom

The available real-time data sets for the United Kingdom cover the period from 1966:Q1 through 2014:Q4.[22] The structural break analysis identifies five periods, but they can be grouped into three distinct eras. The second period from 1974:Q2 to 1981:Q2 and the fourth period from 1995:Q2 to 2007:Q3 are clearly discretionary and rule like, respectively, as they have average deviations of 11.83 and .86, respectively. The three remaining periods have average deviations of 2.86, 2.17, and 2.79, respectively, and are all classified as intermediate, but from an economic perspective these are all discretionary periods. This implies an interpretation of a single rule-like era surrounded by two discretionary eras, which is confirmed by a restricted structural breaks test.

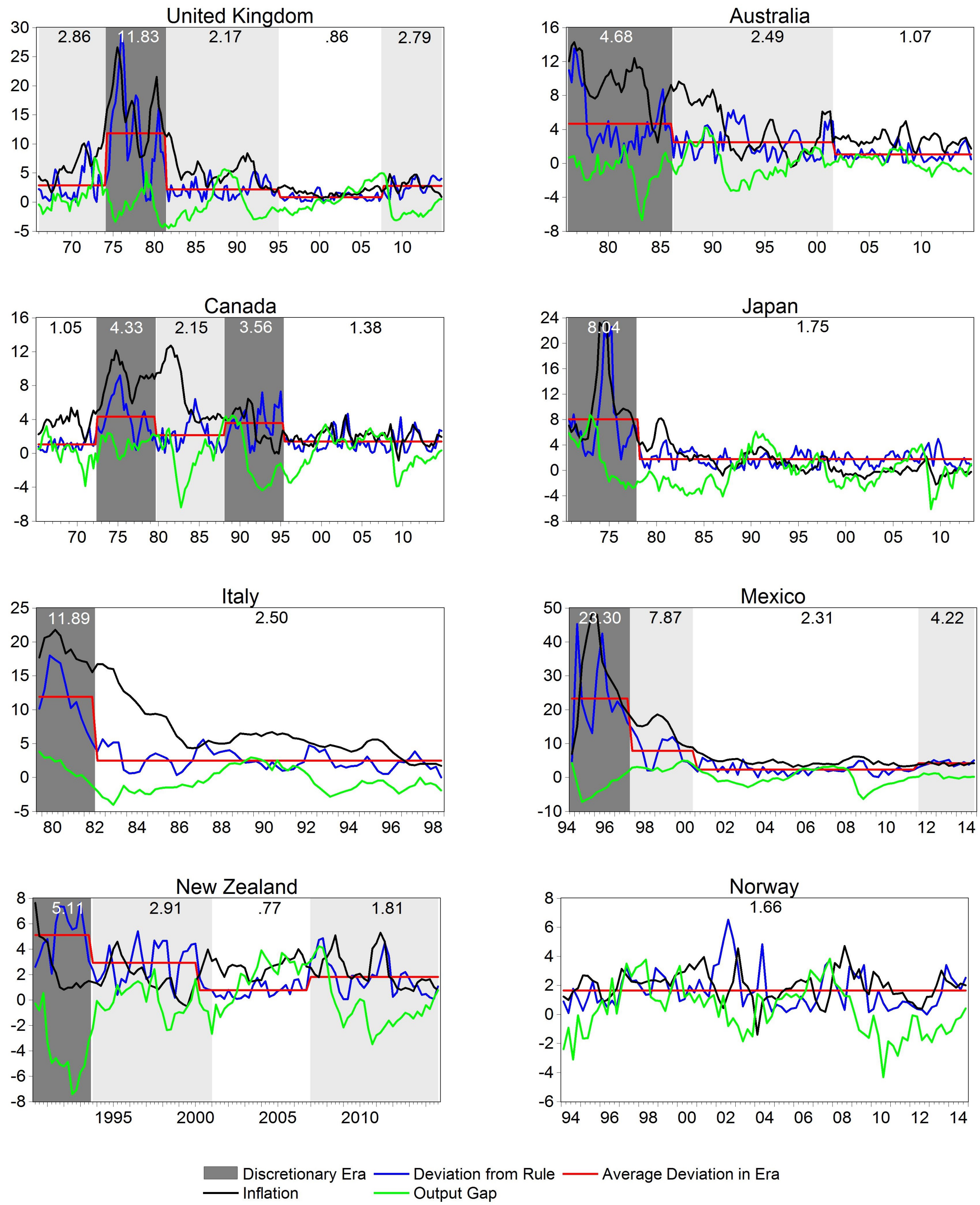
The periods broadly correspond to changing approaches to monetary policy. The first intermediary period occurred largely prior to the 1971 collapse of the Bretton Woods system. After the collapse there were no real monetary targets, and both inflation and deviations from the Taylor rules jumped to huge levels in the mid 1970s. In the late 1970s and throughout the 1980s, monetary targets (growth of money supply or narrow money) were adopted, and both inflation and deviations from policy rules dropped significantly (aside from 1980-81, which was a period of major financial deregulation). In the early 1990s, a formal inflation target was adopted, which led to rule-like monetary policy and a slow reduction of inflation to 2% by 2003. Since the start of the great recession, policy became less consistent with the policy rules.[23]

The loss-function comparison across discretionary and rule-based eras, for all but the fifth quadratic loss function, shows that average losses are smallest in the period most consistent with the Taylor rule, slightly higher in intermediate periods, and much higher in the period that is least consistent with the Taylor rule. For the fifth quadratic loss function, which only captures output stability, average losses are also lowest in the rule-like period but are highest in the intermediate periods. The regression analysis results are qualitatively similar. The Granger causality results show that losses Granger-cause deviations from the policy rule and that deviations from the policy rule Granger-cause losses, although the relationship is less significant for the instantaneous measure

[22]Real-time CPI inflation is constructed from the OECD data sets. The OECD data is supplemented with the Bank of England's Gross Domestic Product Real-Time Database measures of real GDP between 1975:Q1 and 2013:Q2. Interest rate data comes from the Bank of England and is replaced by the Wu and Xia shadow interest rate staring in 2009:Q1.

[23]This result relies on the specific measures of the output gap and the shadow-rate.

Figure 2: Structural Break Analysis Results



Note: Periods are identified by a test for structural breaks for deviations relative to the original Taylor rule with modified HP filter output gaps. Periods are shaded based on their category: discretionary periods are darkly shaded, intermediate periods are lightly shaded, and rule-like periods are not shaded. The numbers at the top indicate the average deviations in each period.

of deviations.

4.3 Australia

The available real-time data sets for Australia cover the period from 1976:Q2 through 2014:Q4.[24] The structural break analysis identifies three distinct periods. The initial period through 1986:Q1 is discretionary with an average deviation of 4.68. The final period from 2001:Q4 is rule like with an average deviation of 1.07. The middle period, with an average deviation of 2.49, is classified as intermediate, but from an economic perspective this is a second discretionary period.

The identified periods are only partially consistent with changes in the Reserve Bank of Australia's policy. The largest policy change occurred in 1983 with the shift to a floating exchange rate, and policy became more consistent with the original Taylor rule following the shift. A second major policy change was the replacement of a money supply target with an inflation target in 1993, but this change is not consistent with any of the identified structural breaks. Instead, the second structural break occurs in 2001:Q4 in the absence of any formal policy changes, but inflation nonetheless became significantly more stable following this structural break.

Economic stability in Australia was much better during periods of rule-like policy. Average losses are lowest in the rule-like era, two to ten times greater in the intermediate era, and four to 45 times greater in the discretionary era. The regression results are consistent with the structural break analysis; higher deviations from the policy rule are correlated with higher average losses. The Granger causality results show that losses only Granger-cause deviations when deviations are captured by the instantaneous measure and that deviations from the policy rule do not Granger-cause losses.

4.4 Canada

The available real-time data sets for Canada cover the period from 1965:Q2 through 2014:Q4.[25] The structural break analysis identifies five periods, but they can be grouped into three distinct eras. The initial period through 1972:Q2 and the final period post 1995:Q1 are rule like, as they

[24] Real-time data comes from the Australian Real-Time Macroeconomic Database maintained by the University of Melbourne. I use the bank's target rate starting in 1993:Q3 and the actual interbank overnight cash rate between 1976:Q2 and 1993:Q2.

[25] Real time data from the OECD data sets is supplemented with the Bank of Canada's historical interest rates.

have average deviations of 1.05 and 1.38, respectively. The remaining years are separated into three periods: a discretionary period from 1972:Q3 to 1979:Q3 with an average deviation of 4.33, an intermediate period from 1979:Q4 to 1988:Q1 with an average deviation 2.15, and a second discretionary period between 1988:Q2 to 1995:Q2 with an average deviation of 3.56. However, the intermediate period is not inconsistent with discretionary policy, and the entire three-period era can be viewed as discretionary.

The three main eras are consistent with three distinct policies implemented by the Bank of Canada. The first rule-like period through 1972 corresponds to the fixed exchange rate period under the Bretton Woods system. Canada transitioned to a floating exchange rate in June 1, 1970, approximately two years prior to the structural break ending the first rule-like period. During the following discretionary period, the Bank of Canada had a dual mandate of unemployment and inflation stability, largely targeted M1, and maintained a highly expansionary policy at the beginning of this period. This policy resulted in a decade of very high inflation rates. In 1991, inflation targeting was formally established as the sole policy objective, with an announced gradual reduction of inflation to its target by 1995.[26] In 1995, the transition period was at an end, and the rule-like era, as identified by the structural breaks analysis, began.

The loss-function comparison across eras shows that losses are at least two times greater in intermediate and discretionary eras than in the rule-like periods. While the intermediate period seems inconsistent with rule-like policy, even if it is classified as a rule-like period, average losses are still at least 50% higher in the discretionary eras. Consistent with the average loss comparison across eras, higher deviations from the policy rule are correlated with higher average losses.[27] The Granger causality results show that losses Granger-cause deviations, but deviations from the policy rule do not Granger-cause losses.

4.5 Japan

The available real-time data sets for Japan cover the period from 1970:Q4 through 2014:Q4. The protracted period at the zero lower bound requires alternative measures of the interest rate,

[26] Additionally, the Bank of Canada adopted an overnight rate as the target rate in 1996.

[27] The one exception to this is the quadratic loss function with a zero coefficient on inflation, which has a negative and significant relationship with average deviations.

and the results are reliant on the specific measure.[28] The structural break analysis identifies two periods. The initial period through 1978:Q1 is very discretionary with an average deviation of 8.04. The following, longer era is much closer to the Taylor rule, with an average deviation of 1.75.

The identified structural break corresponds to the transition from a fixed to a floating exchange rate. Through early 1973 and the demise of the Bretton Woods system, the Bank of Japan pegged the yen to the dollar, repeatedly faced appreciation pressures, and was forced to increase the monetary base, letting inflation grow to over 10% as a result. With the collapse of the Bretton Woods system, the Bank of Japan could actively target inflation, but in the second half of 1973 an oil shock further drove prices up and devastated the economy. The Bank of Japan responded with a commitment to reducing inflation and the growth rate of the monetary base. This transition was complete, and their initial targets for inflation were reached by the late '70s. Further changes in the Bank of Japan's policy, including all of the unconventional monetary policy of the past 20 years, has not caused additional changes to the average rate of deviations from either version of the Taylor rule.

Economic stability in Japan was much better during periods of rule-like policy. Losses in the more discretionary period are between three and 23 times greater than in the rule-like period, and the regression-analysis results mirror this. I don't find Granger causality in either direction for the fifth quadratic loss function. For the other loss functions, the instantaneous deviations but not the three-year moving averages of deviations Granger-cause losses. In the reverse direction, I find Granger causality for both measures of deviations.

4.6 Italy

As Italy joined the Euro zone, I use real-time data from 1979:Q4 through 1998:Q4 for my analysis and capture the policy rate with the discount rate.[29] A single structural break in 1982:Q3 separates an initial, discretionary period from a relatively rule-like period after the structural break. The average deviation from the Taylor rule falls from 11.89 in the first period to 2.50 in the later

[28] After 1995, I use a shadow interest rate from Christensen and Rudebusch's (2013) full two factor model which is updated through 2013:Q2. Additionally, the Bank of Japan maintains data on its call rate since 1985, but for much of the time, it is at the zero lower bound. Instead, I use the Basic Discount Rate and Basic Loan Rate as a proxy for the call rate prior to 1995. Jointly, the interest rate measure captures the direction of monetary policy but is only an approximation of its magnitude.

[29] The Bank of Italy did not target the overnight interbank or any other interest rate directly, and such rates are not available for the 1980s.

period. While the later period is classified as rule like in the loss-function comparisons, for most countries, it would be an intermediate or borderline discretionary period.

The two decades involved significant structural reform of the Bank of Italy, but the increased independence of the Bank of Italy obtained in July 1981 stands out as the catalyst for the structural break. In July 1981, the Bank of Italy ceased acting as the residual purchaser of government securities, although the link between the Bank of Italy and the treasury was not fully broken until 1994 (Sarcinelli 1995). Prior to this, despite inflation reaching 20% and strong devaluation pressure on the lira, the Bank of Italy was unwilling to raise interest rates beyond the 15% to 19% range. This implied very high deviations from the Taylor rule and did little to limit further inflation. Following the reform and despite numerous devaluations of the currency, inflation declined to under 10% by 1985, with interest rates remaining largely unchanged but far more appropriate for the new level of inflation, which would continue to drop to and remain around 5%. A variety of further reforms do not have any additional effect on the monetary policy's consistency with the Taylor rule.

Losses in the discretionary period are greater for all seven loss functions, with the magnitudes varying from 32% to 762% greater, and the regression results are similar. The Granger-causality results are mixed. For most loss functions, deviations Granger-cause loses with a three-year average of deviations but not with instantaneous deviations. In the reverse direction, quadratic loss functions with a strong emphasis on inflation Granger-cause deviations.

4.7 Mexico

Mexico is the least developed economy in the sample and the first of three countries for which real-time data is available for only approximately 20 years ending in 2014. The available real-time data sets cover the period from 1994:Q4 through 2014:Q4.[30] The structural breaks occur in 1997:Q4, 2001:Q1, and 2012:Q1. In the first three periods, policy becomes increasingly rule like with average deviations decreasing from 23.30 to 7.87 to 2.31. In the final period policy becomes more discretionary, with the average deviations increasing to 4.22. Although the two intermediate periods are classified as such, this reflects the much higher deviations in the initial period rather than an economic interpretation of these periods, which are both clearly discretionary.

Reforms at the Bank of Mexico are consistent with the structural break analysis through 2010.

[30] The interest rate used is the overnight interbank rate from the OECD data set.

The initial highly discretionary period resulted from a failed exchange rate band with managed slippage regime. The end of the discretionary and the first intermediate period are part of a transition to an inflation-targeting scheme adopted in 2001. Around the time a formal inflation target was adopted and the transition period was ending, the structural break analysis suggests the rule-like period began. The structural break in 2012:Q1 is not associated with any significant reform or change in central bank policy. Instead, the Bank of Mexico remained in the same inflation-targeting framework, but its board decided that inflation was sufficiently stable to allow them to lower the interest rates to stimulate demand and account for a global low-interest-rate climate.

The loss-function comparison across discretionary and rule-based eras, for all but the fifth quadratic loss function, shows that average losses are highest in the period least consistent with the Taylor rule, lower in the intermediate periods, and lowest in the period that is most consistent with the Taylor rule. For the fifth quadratic loss function, losses are highest in the discretionary period and approximately the same across rule-like and intermediate periods. The regression results are qualitatively similar. Granger causality testing reveals that deviations Granger-cause losses for most of the loss functions, but the reverse relationship is found only with the instantaneous measure of deviations.

4.8 New Zealand

Real-time data for New Zealand is available from 1990:Q2 through 2014:Q4.[31] The structural break analysis identifies four periods. In the first three periods, policy shifts from discretionary to intermediate in 1993:Q4, and then it becomes rule like in 2000:Q2, as the average deviations fall from 5.11 to 2.91 to .77. The final period, between 2007:Q1 and 2014:Q4, has an average deviation of 1.81 and is classified as an intermediate period.

Relating the structural breaks to changes in the Reserve Bank of New Zealand's approach to monetary policy is challenging, as the most significant policy change occurred a year prior to the sample period. The Reserve Bank of New Zealand Act of 1989 adopted inflation targeting, and the initial era was a transition period, as inflation was reduced. The target band for inflation was adjusted from 0-2% to 0-3% in 1996 and to 1-3% in 2002, and a greater focus on medium

[31] Real-time GDP data comes primarily from the real-time database for GDP from the Reserve Bank of New Zealand and is supplemented by OECD data for the most recent vintages. The interest rate from 1999:Q3 is the official cash rate target, while prior to 1999:Q3, I use the OECD-reported overnight interbank rate.

over short-term inflation measures was placed in 2002. However, these policy changes do not seem related to the structural breaks; rather, a significant contribution to the deviations from the policy rules comes from the output gaps. Relative to the policy-rule, New Zealand's monetary policy, which barely responded to output gaps, was too tight most of the time, and the economic boom in the mid-2000s made the interest rate consistent with the Taylor rules. However, the presence of Granger causality is inconsistent with this interpretation. Notably, deviations from the Taylor rule declined prior to the boom due to increased inflation, and the economy recovered and grew when policy was already consistent with the policy rule.

The loss-function comparison across discretionary and rule-based eras shows that average losses in discretionary periods are greater than in rule-like periods for all seven loss functions and regardless of how intermediate periods are classified. Regression results confirm this relationship for the instantaneous measures of deviations, while the three-year moving average of deviations does not have a significantly relationship to most of the loss functions. The Granger causality testing shows that deviations Granger-cause losses, and that losses Granger-cause deviations as captured by the instantaneous but not the three-year moving average of deviations.

4.9 Norway

The available real-time data sets for Norway cover the period from 1994:Q1 through 2014:Q4, and the interest rate is captured by the sight deposit rate.[32] Unlike the structural break results for most other countries, the results for Norway vary significantly across specifications. With modified HP filter output gaps, there are no structural breaks for deviations relative to the original Taylor rule, and the average deviation in the sole period is 1.66.

Over the sample period, the Norges Bank had one formal switch to its policy objective. A fixed exchange rate was abandoned on December 12, 1992, but the stable-exchange-rate mandate remained until the Regulations on Monetary Policy were established on March 29, 2001, which mandated an inflation-targeting regime with a target rate of 2.5%. While the formal change occurred in March 2001, the actual change in policy was significantly more gradual as exemplified by interest rates remaining unchanged for more than two quarters following the change.

[32] Since June 1993, the official interest rate is the sight deposit rate, which is the rate on deposits at the Norges Bank up to a certain limit. The sight deposit rate is very close to the overnight interbank rate; since 2011:Q3, for which the NOWA rate is provided by the Norges Bank, the two differ by an average of two basis points.

Similar to the structural break analysis, the regression analysis finds no relationship between most measures of losses and deviations from the original Taylor rule. The exceptions to this are the third and fifth quadratic loss functions, which emphasize output stability, and are negatively correlated with the three-year moving average of deviations from the policy rule. Consistent with no correlation between the variables, neither losses nor deviation Granger cause each other.

5 Summary of Results

To be informative of aggregate patterns and robust relationships, results should hold across countries and specifications. Table 6 provides a summary of the structural break and regression analysis for the original and modified Taylor rule and for output gaps from both the standard and modified HP filter.

The first two columns of the structural-breaks-analysis panel report the number of loss functions for which average losses are greater by at least 20% in discretionary and rule-like eras for each country, rule, and output-gap combination. Intermediate eras are classified as rule based or discretionary by two methods. The first approach is to classify the intermediate eras in a qualitatively reasonable manner, as was done for the main specification. An alternative method is to use the worst case for the main hypothesis; intermediate eras are classified in a manner that leads to the lowest ratio of average losses in discretionary to rule-like periods. The method of classifying intermediate eras matters only in four cases, and when the results differ, the alternative method's results are listed in parentheses.

The next column reports if losses according to most loss functions are lowest in a rule-like eras or discretionary eras or are roughly equivalent. For the main specification, economic performance was more stable during rule-like periods for all countries except Norway, for which the results are indeterminate. The results are similar for the standard HP filter, except that economic stability in Norway for the modified Taylor rule is greater in discretionary periods. Finally, combining the standard HP filter with intermediate eras classified in a manner to minimize support for the main hypothesis changes the results for New Zealand to be indeterminate for both policy rules. Hence, the structural break analysis across countries extends the Nikolsko-Rzhevskyy et al. (2014) results for the United States; economic stability is better when monetary policy is rule like.

Table 6: Summary of Country-Specific Results

Country	λ	Taylor Rule	Structural breaks analysis*				Correlation between deviations from policy rules and economic losses**							
			# of loss functions for which average loss is greater in:		In which eras are economic losses smallest?	Is there a low deviation period?	Loss functions							
			discretionary eras	rule based eras			MI	LAL	QLF1	QLF2	QLF3	QLF4	QLF5	Overall
US	50000	Original	7	0	Rule	Yes	+	+	+	+	+	+		+
		Modified	7	0	Rule	Yes	+	+	+	+	+	+	+	+
	1600	Original	7	0	Rule	Yes	+	+	+	+	+	+	+	+
		Modified	7	0	Rule	Yes	+	+	+	+	+	+	+	+
UK	50000	Original	7(6)	0	Rule	Yes	+	+	+	+	+	+		+
		Modified	7(6)	0	Rule	Yes	+	+	+	+	+	+		+
	1600	Original	7	0	Rule	Yes	+	+	+	+	+	+	+	+
		Modified	7	0	Rule	Yes	+	+	+	+	+	+	+	+
Australia	50000	Original	7	0	Rule	Yes	+	+	+	+	+	+	+	+
		Modified	7	0	Rule	Yes	+	+	+	+	+	+	+	+
	1600	Original	7	0	Rule	Yes	+	+	+	+	+	+	+	+
		Modified	7	0	Rule	Yes	+	+	+	+	+	+	+	+
Canada	50000	Original	7	0	Rule	Yes	+	+	+	+	+	+	-	+
		Modified	7	0	Rule	Yes	+	+	+	+		+		+
	1600	Original	7	0	Rule	Yes	+	+	+	+	+	+	-	+
		Modified	5	0	Rule	Yes	+	+	+	+	+	+	-	+
Japan	50000	Original	7	0	Rule	Yes	+	+	+	+	+	+		+
		Modified	7	0	Rule	No	+	+	+	+	+	+		+
	1600	Original	7	0	Rule	Yes	+	+	+	+	+	+		+
		Modified	7	0	Rule	No	+	+	+	+	+	+		+
Italy	50000	Original	7	0	Rule	No	+	+	+	+	+	+	+	+
		Modified	7	0	Rule	No	+	+	+	+	+	+	+	+
	1600	Original	7	0	Rule	Yes	+	+	+	+	+	+	+	+
		Modified	7	0	Rule	Yes	+	+	+	+	+	+	+	+
Mexico	50000	Original	7	0	Rule	No	+	+	+	+	+	+		+
		Modified	7	0	Rule	No	+	+	+	+	+	+		+
	1600	Original	7	0	Rule	No	+	+	+	+	+	+		+
		Modified	7	0	Rule	No	+	+	+	+	+	+		+
New Zealand	50000	Original	6	0	Rule	Yes	+							
		Modified	7	0	Rule	Yes								
	1600	Original	6(0)	1	Rule (Equiv.)	Yes		+	+		+		+	+
		Modified	6(0)	1	Rule (Equiv.)	Yes		+	+		+		+	+
Norway	50000	Original	N/A	N/A	N/A	N/A					-		-	
		Modified	3	1	Equivalent	Yes					-		-	
	1600	Original	3	1	Equivalent	Yes	+	+		+				
		Modified	1	5	Discretionary	Yes	+							

*Average loss must be at least 20% greater in one era type to be considered here. When results differ according to the way intermediate eras are jointly classified, the numbers reported are for the prefered classification and in parentheses for the classification leading to the greatest losses in rule like eras. **Deviations from rule-like policy are captured by a three-year moving average of deviations from the policy rule. A positive and significant relationship is denoted by a + and a negative and significant relationship is denoted by a -.

The regressions document a similar cross-country result. The second panel of Table 6 shows if losses, as measured by the seven loss functions, are correlated with the three-year backward-looking moving average of deviations from the policy rules. A positive and significant relationship it is denoted by a +, a negative and significant relationship is denoted by a −, and if there is no significant relationship in either direction, the entry is left blank. For the U.S., U.K., Australia, Canada, Japan, Italy, and Mexico there is a significant positive relationship between loss functions and average deviations for at least six of the seven loss functions. For Norway, there is no consistent, significant relationship between the moving averages of deviations and losses, while for New Zealand, the result depends on the choice of output gap with either no or a positive relationship.

The one consistent exception to the positive relationship between deviations and losses in the second panel of Table 6 occurs for the fifth quadratic loss function (QLF5) for which the relationship is less robust and in some cases reversed. The fifth quadratic loss function is the sole loss function that does not place a weight on inflation stability and captures losses purely from output fluctuations. Hence, this implies that rule-like policy is more effective at stabilizing inflation rather than the real side of the economy. Additionally, the relationship seems to hold regardless of the magnitude of deviations from the policy rules. Column four of the structural-breaks-analysis panel reports if there is at least one rule-like period with an average deviation below two percent, and the results are not contingent on this.

The Granger causality tests exhibit significant variation in results both within and across countries. The only clear result is the heterogeneity of the results. For the U.K. there is Granger causality in both directions, while in Mexico, there is clear Granger causality of deviations on losses and partial evidence for losses causing deviations. The reverse is true for the U.S. and Japan, with there being only partial evidence for Granger causality of deviations on losses but clear evidence for losses Granger-causing deviations. For New Zealand and Italy, there is partial evidence in both directions, and in Canada, there is strong evidence of losses Granger-causing deviations and no evidence of the reverse relationship. Finally, in Norway and Australia, neither variable Granger-causes the other. Furthermore, the timing of the structural breaks suggests that causality runs in both directions.

6 Panel-Data Results

The panel regressions confirm the patterns from the preceding section and emphasize the robustness of the results. Table 7 shows the results of regressions of economic losses on a constant and a measure of deviations from a policy rule with country and yearly fixed effects.[33] A 1% increase in deviation from either policy rule is associated with a .5 to .75 increase in the misery index and

[33] The results with quarterly or no fixed effects are qualitatively similar.

the linear absolute loss function, which is equivalent to a combined increase in deviations from the output gap and inflation targets summing to approximately .6. Similarly, it is associated with a 10 to 30 increase in quadratic loss functions one, two, and four and a five to ten increase in the third quadratic loss function. The results for the fifth quadratic loss function, which only captures output volatility, are less robust. With output gaps from the HP filter with $\lambda = 50000$, the coefficients are positive and significant, while with standard HP filter output gaps, the coefficients are generally not statistically distinguishable from zero.

Table 7: Panel Data Regression of Economic Losses on Deviations from Policy Rules

λ	Taylor Rule	Measure of Deviations	Loss Functions						
			MI	LAL	QLF1	QLF2	QLF3	QLF4	QLF5
50000	Original	MA - 3 year	.5372***	.6608***	10.9121***	16.2097***	5.6145***	10.7537***	.1584**
			(.0490)	(.0481)	(.9436)	(1.4151)	(.4810)	(.9444)	(.0799)
		WMA	.7317***	.8460***	15.5377***	23.0576***	8.0178***	15.2887***	.2490**
			(.0699)	(.0583)	(1.9153)	(2.9108)	(.9291)	(1.9543)	(.1194)
		Instant	0.6263***	.6581***	19.1795***	28.5518***	9.8073***	18.9620***	.2275**
			(.0953)	(.0952)	(4.2055)	(6.2603)	(2.1522)	(4.1578)	(.0856)
	Modified	MA - 3 year	.5002***	.6597***	10.9501***	16.2321***	5.6680***	10.7571***	.1930**
			(.0532)	(.0499)	(.9773)	(1.4724)	(.4907)	(.9849)	(.0796)
		WMA	.7105***	.8690***	15.7697***	23.3830***	8.1564***	15.4981***	.2716**
			(.0728)	(.0587)	(1.8613)	(2.8316)	(.8997)	(1.9020)	(.1155)
		Instant	.5312***	.5965***	16.5697***	24.6083***	8.5311***	16.3234***	.2462***
			(.0854)	(.0866)	(3.6943)	(5.5027)	(1.8876)	(3.6558)	(.0813)
1600	Original	MA - 3 year	.5230***	.5766***	9.5456***	14.3178***	4.7734***	9.5450***	.0006
			(.0478)	(.0433)	(.8888)	(1.3418)	(.4394)	(.8978)	(.0494)
		WMA	.7087***	.7391***	14.0776***	21.1372***	7.0180***	14.0984***	-.0208
			(.0733)	(.0639)	(1.9797)	(2.9833)	(.9785)	(1.9937)	(.0603)
		Instant	.6576***	.6397***	18.4509***	27.5123***	9.3893***	18.2870***	.1639**
			(.0998)	(.0977)	(4.2307)	(6.2979)	(2.1646)	(4.1827)	(.0750)
	Modified	MA - 3 year	.5091***	.5815***	9.5654***	14.3422***	4.7886***	9.5595***	.0059
			(.0506)	(.0443)	(.8903)	(1.3492)	(.4353)	(.9045)	(.0522)
		WMA	.7098***	.7591***	14.3450***	21.5363***	7.1536***	14.3638***	-.0189
			(.0779)	(.0669)	(2.0264)	(3.0559)	(.9995)	(2.0430)	(.0639)
		Instant	.5917***	.5868***	16.3198***	24.3516***	8.2881***	16.1917***	.1282*
			(.0990)	(.0979)	(4.0169)	(5.9796)	(2.0552)	(3.9713)	(.0735)

Coefficients (and White cross-section standard errors) of the deviations from a policy rule on the loss functions with country and yearly fixed effects.

The country-specific analysis suggests that the presence of Granger causality differs greatly across countries. In the panel data, I can confirm this conclusion through the Dimitrescu and Hurlin (2012) test for homogenous non-causality. Table 8 shows the p-values for the null hypothesis of homogenous non-causality of deviations from a policy rule on losses. Aside from a couple of exceptions, the null of homogenous non-causality of deviations on losses can be rejected for all but the fifth quadratic loss function. In the case of the fifth quadratic loss function, the results are

Table 8: Dumitrescu Hurlin Panel Causality Tests P-values: Deviations Homogeneously do Not Cause Losses

(a) Lag of 2 periods

λ	Taylor Rule	Measure of Deviations	MI	LAL	QLF1	QLF2	QLF3	QLF4	QLF5
50000	Original	MA - 3 year	.0014	.0000	.0000	.0000	.0000	.0000	.0355
		WMA	.0000	.0005	.0000	.0000	.0000	.0000	.3638
		Instant	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	Modified	MA - 3 year	.0591	.0446	.0000	.0000	.0023	.0000	.6914
		WMA	.0452	.5281	.0058	.0108	.0035	.0061	.7425
		Instant	.0000	.0000	.0000	.0000	.0000	.0000	.0000
1600	Original	MA - 3 year	.0000	.0000	.0000	.0000	.0000	.0000	.1126
		WMA	.0000	.0000	.0000	.0000	.0000	.0000	.7993
		Instant	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	Modified	MA - 3 year	.0000	.0000	.0000	.0000	.0000	.0000	.0169
		WMA	.0000	.0000	.0000	.0000	.0000	.0000	.3481
		Instant	.0000	.0000	.0000	.0000	.0000	.0000	.0000

(b) Lag of 5 periods

λ	Taylor Rule	Measure of Deviations	MI	LAL	QLF1	QLF2	QLF3	QLF4	QLF5
50000	Original	MA - 3 year	.1189	.1042	.0000	.0000	.0001	.0000	.9210
		WMA	.0280	.9120	.0000	.0000	.0000	.0000	.0051
		Instant	.0144	.6239	.0000	.0000	.0000	.0000	.3073
	Modified	MA - 3 year	.0697	.6342	.1098	.0118	.8822	.0034	.4133
		WMA	.0078	.1049	.0474	.0093	.4152	.0009	.8879
		Instant	.0430	.8506	.0000	.0000	.0000	.0000	.4252
1600	Original	MA - 3 year	.0094	.0009	.0000	.0000	.0000	.0000	.0639
		WMA	.0009	.0092	.0000	.0000	.0000	.0000	.0058
		Instant	.0077	.0047	.0000	.0000	.0000	.0000	.0139
	Modified	MA - 3 year	.0017	.0157	.0000	.0000	.0002	.0000	.0629
		WMA	.0000	.0885	.0000	.0000	.0000	.0000	.0376
		Instant	.0000	.0020	.0000	.0000	.0000	.0000	.0515

mixed with the null typically rejected with standard HP filter output gaps but not with modified HP filter output gaps. Similarly, aside from four exceptions, the null of homogenous non-causality of losses on deviations can be rejected, implying that there is a subset of the panel for which there is causality.[34] Hence, there are perhaps different subsets of the sample for which Granger causality runs in each direction. As panel Granger causality tests do not specify what the subgroup is or how large it is, to ascertain for which countries the causality holds, we must look to the standard Granger causality tests.

A variety of homogenous causality tests exist in the panel setting, and the results differ across the tests. Under the assumption that the effect is the same across countries, for most specifications I find that deviations homogeneously Granger-cause losses; but if the effects are allowed to differ across countries, then for most specifications I find evidence against Granger-causality of deviations on losses.

The direction of the Granger causality, when it occurs, can be explored with the impulse-response functions associated with the VAR for the Granger causality tests. The specifics vary greatly across countries and in the panel data depending on the specifications. However, the broad trend is similar except for instantaneous change in deviations. An increase in deviations from the policy rule initially decreases losses for one two three years. After the initial period, there is a longer period with higher losses. The length of the two periods, the magnitude and significance of each effect, and which effect dominates depends on the specification.

7 Conclusion

Nikolsko-Rzhevskyy et al. (2014) document that economic stability in the United States was far better in eras during which monetary policy was consistent with a Taylor rule. I expand upon the findings for the United States by showing the robustness of the results across different measures of inputs into the Taylor rules and that the results are not reliant on the use of a quadratic output gap. By using moving averages of deviations, I can additionally estimate the correlation between economic stability and the degree to which policy is inconsistent with the Taylor rules over the past few years. Extending this methodology to nine countries, I find that more rule-like policy is

[34] A table showing the p-values for the null hypothesis of homogenous non-causality of losses on deviations from a policy rule is available in the supplemental appendix.

consistently associated with greater economic stability. This finding is robust across output gap measures, specifications of the Taylor rule, both the structural break and the regression approaches, and is confirmed in the panel data. The analysis also reveals that the relationship between Taylor rule-like monetary policy and welfare losses is primarily driven by changes in inflation stability rather than output stability.

Beyond documenting the relationship, I find evidence that Taylor rule-like policy causes greater economic stability. Many of the structural breaks can be related to formal policy changes, such as a switch to a floating exchange rate or the adoption of inflation targeting. Typically, transitions to floating exchange rates were associated with more discretionary monetary policies and occurred at the beginning of discretionary eras with high inflation. The adoption of inflation targeting usually occurred near the beginning of a more rule-like periods that, after a transition period, had lower and more stable inflation rates. A timing argument of this sort suggests a causal relationship with more rule-like policy causing greater inflation stability. The analysis of Granger causality further supports the presence of a causal relationship between the variables, albeit only for a subset of the countries and with the caveats of Granger causality. Finally, the unbalanced panel regression analysis finds a significant and positive effect of a lagged measure of consistency with the Taylor rules on economic performance, but it relies on the assumption that the degree to which policy is consistent with the Taylor rule one to four years ago is exogenous to current economic stability.

In my analysis, the choices of inflation and potential output measures have a significant role in the intermediate results, but the final results are generally robust across various measures. However, to find meaningful results from structural break dates within this study, or to determine if policy in the early to mid 2000s experienced a significant change requires a clear consensus on the measures of inflation and the output gap. In the absence of a consensus, the choices across these variables allow authors to find drastically different answers to these questions as in Bernanke (2015) and Poole (2007). The cross-countries comparison and robustness check for an alternative output-gap measure alleviate these concerns in this paper, as the primary results are insensitive to the choice of output gap, and the larger sample should make the choices generally less significant.

In my methodology, deviations from policy rules are considered without concern for direction. There are compelling reasons to consider positive and negative deviation separately, as the effects may be asymmetric. Because the degree of deviations affects inflation stability far more than output stability, it is possible that overly easy policy relative to a rule may be associated with far worse outcomes than too-tight policy. The direction of the deviations also play a role in the structural break analysis. The current approach does not distinguish the pre-Volcker overly easy monetary policy with the Volcker period policy, but these policies are widely believed to have had significant and very different effects on the economy.

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