THREE ESSAYS ON THE

TAYLOR CURVE

by

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A DISSERTATION

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ABSTRACT

This dissertation contains three essays regarding the Taylor curve. Taylor (1979) posited a permanent tradeoff between the volatility of output gap and the volatility of inflation. The first essay explores the empirical relationship between the volatility of inflation and the output gap. The last two essays implement optimal control techniques to construct Taylor curves for the United States and countries in the European Union. In the first essay,

The Taylor curve necessitates that the correlation between the volatilities of inflation and the output gap be non-positive for optimal monetary policy. In essay one, the correlation between the second moments of inflation and the output gap are investigated using time-varying correlations, variance impulse response functions, and a time-varying parameter model. We find that macroeconomic performance is substantially better during time periods in which the correlation is negative as the Taylor curve suggests.

In the second essay, we use data from 1875 examine the efficiency of U.S. monetary policy by measuring the orthogonal distance between the observed volatilities of the output gap and inflation from the Taylor curve. In addition, we identify time periods in which the variability of the U.S. economy changed by observing shifts in this efficiency frontier. We find that since 1940 the Taylor curve has trended towards the origin. Moreover, the cost of stabilizing inflation in terms of output gap volatility has steadily decreased through time. The Taylor curve also necessitates that the correlation between the volatilities of inflation and the output gap be non-positive for optimal monetary policy.

In essay three, the efficiency a historical analysis of the European Monetary System and the monetary policy of European Central Bank (ECB) is conducted. Using data from European Union countries I measure the orthogonal distance between the observed volatilities of the output gap and inflation from their optimal levels. In addition, I identify time periods in which the variability of the E.U. economies changed by observing shifts in this efficiency frontier. I find in most EU countries, the Taylor curve has shifted towards the origin. In addition, stage II of the Maastricht Treaty was more instrumental in macroeconomic stabilization for EU countries than the beginning of ECB monetary policy. Policy by the ECB appears to be more conducive for France than any other countries in our sample.

DEDICATION

To my parents: Joe and Ramona Olson.

LIST OF ABBREVIATIONS AND SYMBOLS

Std	Standard Deviation
S.E.	Standard Error
ρ	Correlation
$\sim N$	Random variable which follows a normal distribution
p-value	Probability associated with the occurrence under the null hypothesis
$\forall$	For all
$+$	Addition
Σ	Summation
$=$	Equal to
EU	European Union
ECB	European Central Bank
EMS	European Monetary System
ECU	European Currency Unit
DEM	German Mark
BEF	Belgian Franc
NLG	Dutch Guilder
FRF	French Franc
ITL	Italian Lira
U.S.	United State of America

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While I dedicate this dissertation to my parents, I also would like to thank my immediate family, Anna, Leah, Adam, Amanda, Walker, and Jennings, for the encouragement, thoughts, and prayers you have provided. Specifically, I would like to thank Anna for her patience, help, and support while living here in Tuscaloosa.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Taylor (1979) posited that a central bank faces a tradeoff between the volatility of the output gap and volatility of inflation; this trade-off has become known as the Taylor curve. The Taylor curve serves as an efficiency envelope for policy makers. Thus, the Taylor curve can be used to evaluate the efficacy of monetary policy. However, Chaterrjee (2002) argues that the Taylor Curve can also serve as a policy menu from which central banks may choose the levels of inflation and output gap volatilities desired. Friedman (2006) challenged Chatterjee (2003) and Taylor's (2006) view that the Taylor curve may only be used as an efficiency frontier.

In the first essay, the empirical relationship between the volatility of inflation and volatility of the output gap is explored. Results indicate that macroeconomic performance is better during time periods in which the relationship between the volatilities is negative.

The second essay uses quarterly data from 1875-2009 to gauge the efficiency of U.S. monetary policy by calculating the distance the observed volatilities are from their optimal values. Friedman's well known claim that monetary policy has been sub-optimal for extended periods is substantiated by our results. Results also indicate that macroeconomic stability is improved during time periods in which interest rates exhibit mean reverting behavior.

The third essay historically evaluates macroeconomic stability for six EMS countries. The ECB began setting monetary policy for EMS countries beginning in 1999. Thus, Taylor (1979) curves are estimated to explore if monetary policy is better for some member countries.

Results show that Stage II of the Maastricht Treaty played a substantial role in stabilizing EMS economies. ECB policy does not appear to influence each member country equally.

An Empirical Investigation of the Taylor Curve

1.1 Introduction

There is large and important literature concerning the behavior of the price-output correlation over the course of the business cycle. Earlier papers, such as Mankiw (1989) and Cooley and Ohanian (1991), debated whether or not the correlation was positive. However, the more recent literature, see Pakko (2000) and Cover and Hueng (2003), makes the point that the correlation is actually time-varying.[1] As such, the correlation can be positive in some periods but not in others. Although this literature is vast––EconLit lists no fewer than 80 papers containing the phase "price-output correlation" in the title and/or abstract––relatively little has been done concerning the higher moments of the joint distribution of prices and output. Nevertheless, Taylor (1979) argues that the relationship between the *variance* of prices and the *variance* of output is important for policy.

Unlike the traditional Phillips curve, that posits a temporary tradeoff between the level of inflation and output, Taylor (1979) argues for the existence of a "second order Phillips curve" such that there is a permanent tradeoff between the variance of inflation and the variance of the output gap. The tradeoff arises because monetary policy cannot simultaneously offset both types of variability. In discussing a hypothetical increase in petroleum prices resulting from a supply disruption, Bernanke (2004) states:

> … in the standard framework, the periodic occurrence of shocks to aggregate supply (such as oil price shocks) forces policymakers to choose between stabilizing output and stabilizing inflation. This apparent tradeoff between output variability and inflation variability faced by policymakers gives rise to what has been dubbed the *Taylor curve*…. (p. 3)

[1] Cover and Hueng (2003) provide an excellent summary of the literature on the price-output correlation.

Taylor (2006) and Chatterjee (2002) argue that the so-called Taylor curve has replaced the Phillip's curve as a policy menu since the former is more compatible with current mainstream macroeconomic theory. In their view, a central bank can choose to reduce the variance of inflation (output) only if it is willing to tolerate a greater variance of output (inflation). Nevertheless, the view that the central bank actually operates on the Taylor curve is not universally accepted. Milton Friedman (2006) points out that that the Taylor curve is an efficient frontier yielding the tradeoff for optimal monetary policy. As such, the economy will operate on this efficiency locus only if the central bank pursues an optimal monetary policy. He presents evidence showing that the correlation between U.S. output variability and inflation variability is positive, not negative, over the 1879 – 2005 period; the estimated correlation coefficient is 0.81. As such, Friedman (2006) claims that there is substantial evidence supporting his well-known view that monetary policy has been suboptimal for long periods of time.

In contrast to the vast literature on the price-output correlation, relatively few studies have empirically verified the negative relationship between the volatility of output and volatility of inflation. Although there are a number of theoretical papers that rely on the Taylor curve—see Fuhrer (1997), Castelnuovo (2006), Mishkin and Hebbel (2007), and Bodenstein, Erceg and Guerrieri (2008)—the empirical evidence is scanty. To our knowledge, Lee's (1999, 2002) seminal work represents the only evidence that the volatility of inflation and volatility of output are negatively correlated. However, he never allows the correlation to be time-varying and never examines the contemporaneous relationship between the two variances.

Our aim is to empirically estimate the relationship between output volatility and inflation volatility without the need to assume that the economy is always operating on the Taylor curve. Towards this end, we develop a variant of Mishkin and Hebbel's (2007) macroeconometric model in order to obtain estimates of the multivariate GARCH interactions between the volatilities of the output gap and inflation. We then characterize the relationship between the two volatilities using rolling correlations, impulse responses, and a time-varying parameter model. The paper proceeds as follows: Section 2 discusses background; Section 3 discusses the estimation strategy of our multivariate GARCH model of the macroeconomy; Section 4 estimates the Taylor curve relationship; and Section 5 concludes.

1.2. Background

The standard derivation of the Taylor curve begins with a central bank trying to minimize the expected value of its loss function (*L*):

$$L = \lambda(\pi_t - \pi_t^*)^2 + (1-\lambda)(y_t - y_t^*)^2$$

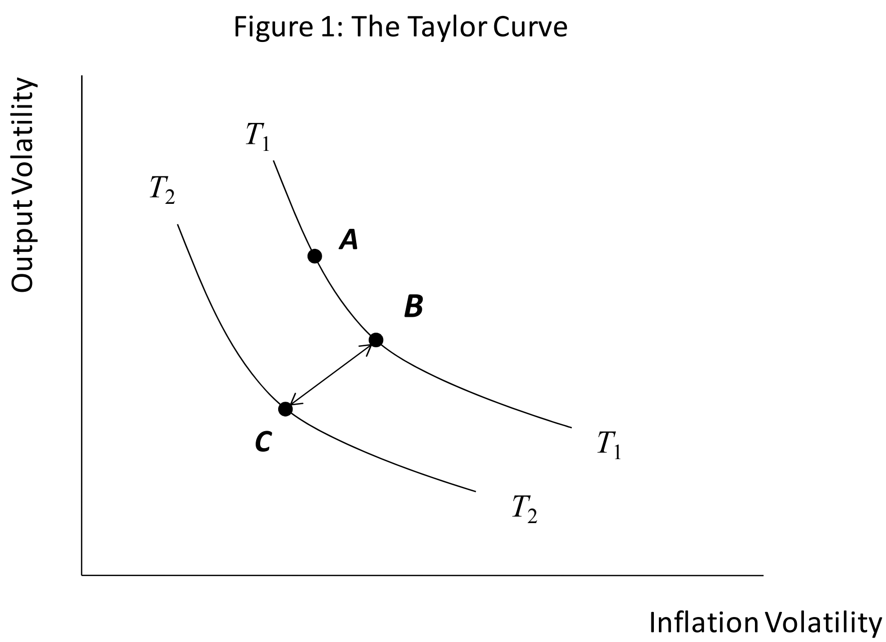
where π_t is the inflation rate, π_t^* is the inflation target, λ is the central bank's weight given to inflation, y_t is output, and y_t^* is the target level of output.

Given the structural equations of the economy, and the weight assigned to inflation, it is possible obtain a point on the Taylor curve. This point represents the optimized values of the variance of inflation and the variance of output for the given value of λ. Varying λ allows one to plot out an efficiency frontier as the locus of points indicating the smallest variance of inflation obtainable for any given variance of the output gap.[2] Consider the Taylor curve depicted by the negatively sloped line T_1T_1 shown in Figure 1.1. An efficient central bank that weights price stability quite heavily will operate on its Taylor curve at a point such as *A*. To the extent that the Taylor curve is binding, a change in policymakers' preferences towards output stability will necessitate a movement towards a point such as *B*. Hence, in such circumstances a negative trade-off between the two volatilities would be observed. A positive correlation could only arise

[2] The same type of derivation also results in the so-called Taylor Rule yielding the central bank's target interest rate as a function of output and the inflation rate.

if the underlying variability of the economy changed. For example, a positive correlation would be observed if the Taylor curve shifted inward from T_1T_1 to T_2T_2 such that the economy moved from *B* to *C*.[3] However, as Friedman (2006) points out, a positive relationship could also result if the economy is operating off of the efficiency frontier as a result of suboptimal monetary policy. Movements toward (or away from) the Taylor resulting from a change in the efficacy of monetary policy would be expected to cause both volatilities to move in the same direction. Nevertheless, if the Taylor curve is a stable function, positive correlations due to shifts of the curve would be observed infrequently.

Figure 1.1. The Taylor Curve



[3] Of course, if the economy moves from *C* to *B*, a positive correlation would also be observed.

1.3. Multivariate GARCH Model

Unlike a traditional Phillips curve estimation, our task is to estimate the *volatilities* of output and inflation. Towards this end, we implemented the type of multivariate GARCH model discussed in Engle and Kroner (1995). In order to avoid being *ad hoc*, we used the aggregate demand and supply model developed in Mishkin and Hebbel (2007). Consider:

$$y_t = \alpha_{1,0} + \sum_{i=1}^{n} \alpha_{1,i}\, y_{t-i} + \sum_{i=1}^{n} \beta_{1,i}\, \pi_{t-i} + \sum_{i=1}^{n} \phi_{1,i}\, i_{t-i} + \sum_{i=0}^{n} \gamma_{1,i+1}\, \mathrm{oil}_{t-i} + \varepsilon_{1,t} \quad (1)$$

$$\pi_t = \alpha_{2,0} + \sum_{i=1}^{n} \alpha_{2,i}\, y_{t-i} + \sum_{i=1}^{n} \beta_{2,i}\, \pi_{t-i} + \sum_{i=0}^{n} \gamma_{2,i+1}\, \mathrm{oil}_{t-i} + \varepsilon_{2,t}. \quad (2)$$

Equation (1) represents an aggregate demand function, where the output gap (y_t) is a function of its own lags, lags of the nominal interest rate (i_t), lags of the inflation rate (π_t), and lags of the deviation of oil prices from a Hodrick-Prescott (HP) trend (oil_t). Equation (2) represents a Phillips curve, in which inflation is a function of its own lags, lags of the deviation of oil prices from a HP trend (oil_t), and lags of the output gap.

In order to estimate a model in the form of (1) and (2), we obtained data from the Federal Reserve of St. Louis FRED database for the 1955Q1 – 2008Q3 period. The output gap was measured as 100 times the log difference of real GDP from the CBO's measure of real potential GDP. Inflation was defined as 400 times the logarithmic first-difference of the CPI. As a preliminary diagnostic we performed standard augmented Dickey-Fuller tests to determine whether or not the variables are stationary; all variables in the form represented by (1) and (2) were found to be stationary at the 5% significance level.[4]

[4] Details and results of the various unit root tests are available from the authors upon request. Although some authors have argued that the inflation rate (as measured by the CPI), is *I*(1), we do not pursue that possibility here.

Unlike Mishkin and Hebbel (2007), we are especially concerned about the variances of the regression residuals $\varepsilon_{1,t}$ and $\varepsilon_{2,t}$. Denote the conditional variances of output and inflation as $h_{1,t}$ and $h_{2,t}$ and let the conditional covariance between the two be $h_{12,t}$. As discussed in more detail below, after some experimentation, we found that the following parsimonious BEEK specification using two ARCH terms worked quite well:

$$H_t = \Gamma'\Gamma + A' e_{t-1} e'_{t-1} A + B' e_{t-2} e'_{t-2} B \qquad \forall t = 1, \dots \dots \dots . T \qquad (3)$$

where H_t is a symmetric 2 x 2 matrix containing the conditional (co)variances of the output gap and inflation. We denote the elements of H_t as $h_{1,t}$, $h_{2,t}$ and $h_{12,t} = h_{21,t}$ where subscripts 1 and 2 refer to the output gap and inflation, respectively. Γ, A, B are 2 x 2 upper triangular matrices of parameters; and $e_t \equiv [\varepsilon_{1,t} \;\; \varepsilon_{2,t}]'$ is a 2 x 1 vector of output gap and inflation innovations.

The multivariate ARCH(2) specification enables us to avoid the type of spurious persistence (i.e., ZILC) often present in GARCH models. In particular, our multivariate GARCH estimates implied that the conditional volatilities were highly persistent. We followed Ma, Nelson, and Startz's (2007) recommendation and examined the estimated correlograms of the best-fitting univariate GARCH (*p, q*) and ARCH(*q*) models. Since these ARCH correlograms implied far less persistence than the GARCH estimates, we settled on the ARCH specification. Diagnostic checking indicated that the models of the mean and the conditional variances represented by the simultaneous estimation of equations (1), (2), and (3), were all well-behaved.[5]

Equation (3) allows for a rich interaction among the variances $h_{1,t}$ and $h_{2,t}$ in that shocks to one conditional variance can "spill-over" to the other. Note that it would be a mistake to confuse $h_{12,t}$ with the Taylor curve relationship in that $h_{12,t}$ is the conditional covariance between

[5] The multivariate ARCH(2) specification, yielded the lowest value of the AIC and resulted in no significant residual correlations in the standardized residuals and squared standardized residuals. Details and the programming code for other specifications of the conditional variance are available from us upon request.

the *level* of inflation and *level* of the output gap. It is the relationship between $h_{1,t}$ and $h_{2,t}$ that is at the heart of the Taylor curve.

Convergence of the likelihood function in BEKK models is particularly problematic due to the number of parameters to estimate as well as the quadratic form the parameters take to ensure a positive definite covariance matrix. As such, we first estimated equations (1) and (2) as a near-VAR with seemingly unrelated equations (SUR) to implement lag-length tests to eliminate any insignificant parameters. We estimated the near-VAR beginning with eight lags of each variable. F-tests were performed to determine the appropriate number of lags for each variable in each equation. The results from near-VAR and lag-length tests are reported in Table 1. Once the model was pared down, we estimated the entire system using the BEKK model reported in Table 2. All coefficients were found to imply characteristic roots inside the unit circle. As a diagnostic check, the residuals in $\mathbf{e}_t$ were standardized by dividing each estimated value of ε_{it} by the estimate of the conditional standard deviation $(h_{i,t})^{0.5}$. All Ljung-Box Q-statistics for the standardized and squared standardized residuals were found to be insignificant up to the sixteenth lag.

Table 1.

Near-VAR Estimates and Lag-Length Tests

Observations 206
Log Likelihood –554.94

Output Gap	Coefficient	S.E.	1957Q2 – 2008Q3	Inflation	Coefficient	S.E.
Constant	0.1817	0.1336		Constant	0.062	0.1871
$y_{1,t-1}$	1.1007	0.0798		$\pi_{2,t-1}$	0.3641	0.0756
$y_{1,t-2}$	-0.0602	0.1151		$\pi_{2,t-2}$	0.0667	0.0816
$y_{1,t-3}$	-0.0816	0.1125		$\pi_{2,t-3}$	0.4189	0.0813
$y_{1,t-4}$	0.0352	0.1119		$\pi_{2,t-4}$	-0.0623	0.0863
$y_{1,t-5}$	-0.1315	0.1118		$\pi_{2,t-5}$	0.1802	0.0871
$y_{1,t-6}$	0.1082	0.1145		$\pi_{2,t-6}$	0.1109	0.0839
$y_{1,t-7}$	0.0231	0.1119		$\pi_{2,t-7}$	0.1098	0.0846
$y_{1,t-8}$	-0.0678	0.0768		$\pi_{2,t-8}$	-0.1927	0.0787
$\pi_{1,t-1}$	0.0401	0.0496		$y_{2,t-1}$	0.326	0.1216
$\pi_{1,t-2}$	-0.0464	0.0519		$y_{2,t-2}$	-0.0602	0.1801
$\pi_{1,t-3}$	-0.0575	0.0531		$y_{2,t-3}$	-0.005	0.1776
$\pi_{1,t-4}$	-0.0327	0.0551		$y_{2,t-4}$	0.1428	0.1767
$\pi_{1,t-5}$	-0.0239	0.056		$y_{2,t-5}$	-0.3057	0.1762
$\pi_{1,t-6}$	-0.023	0.0546		$y_{2,t-6}$	0.0521	0.1772
$\pi_{1,t-7}$	0.1185	0.0538		$y_{2,t-7}$	0.1238	0.1783
$\pi_{1,t-8}$	0.0224	0.0499		$y_{2,t-8}$	-0.1478	0.1164
$i_{1,t-1}$	0.0646	0.0814		$Oil_{2,t}$	0.0869	0.0311
$i_{1,t-2}$	-0.424	0.1176		$Oil_{2,t-1}$	-0.0402	0.0424
$i_{1,t-3}$	0.4137	0.1203		$Oil_{2,t-2}$	-0.1756	0.0597
$i_{1,t-4}$	-0.2024	0.1234		$Oil_{2,t-3}$	0.0038	0.0657
$i_{1,t-5}$	0.0529	0.1237		$Oil_{2,t-4}$	0.0033	0.066
$i_{1,t-6}$	0.0967	0.1229		$Oil_{2,t-5}$	-0.0516	0.0668
$i_{1,t-7}$	-0.0281	0.1237		$Oil_{2,t-6}$	0.0341	0.0672
$i_{1,t-8}$	-0.0079	0.0832		$Oil_{2,t-7}$	-0.0989	0.0675
$Oil_{1,t}$	0.002	0.0187		$Oil_{2,t-8}$	0.0688	0.0529
$Oil_{1,t-1}$	-0.0612	0.0255				
$Oil_{1,t-2}$	0.0373	0.0357				
$Oil_{1,t-3}$	0.0119	0.0394				
$Oil_{1,t-4}$	-0.0052	0.0393				
$Oil_{1,t-5}$	0.0065	0.0401				

Table 1 (*Continued*).

Output Gap	Coefficient	S.E.	1957Q2 – 2008Q3	Inflation	Coefficient	S.E.
$Oil_{1,t-6}$	-0.0357	0.0403				
$Oil_{1,t-7}$	-0.0727	0.0405				
$Oil_{1,t-8}$	0.0156	0.0324				

Dependant Variable	Explanatory Variables	Lags	F-Test	P-Value
Output Gap	Output Gap	3 to 8	0.722	0.632
	Inflation	1 to 8	1.193	0.305
	Interest Rates	4 to 8	0.968	0.438
	Oil	0 to 8	1.823	0.067
Inflation	Output Gap	2 to 8	1.81	0.087
	Oil	3 to 8	1.30	0.25

Table 2.

Multivariate Garch: BEKK Model

Log Likelihood –572.646

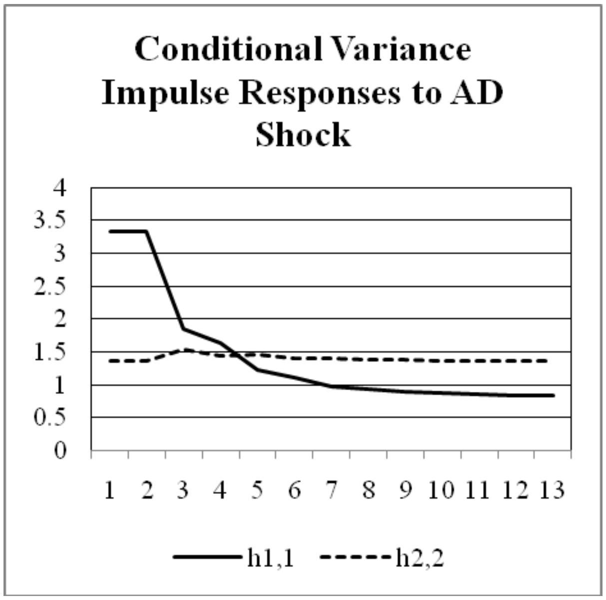
Means	Coefficient	S.E.	1957Q2 –2008Q3	Variances	Coefficient	S.E.
Output Gap				Matrix Γ		
Constant	0.314	0.119		Y_{11}	0.614	0.052
$y_{1,t-1}$	1.204	0.071		Y_{21}	-0.09	0.143
$y_{1,t-2}$	-0.273	0.069		Y_{22}	1.005	0.109
$\pi_{1,t-1}$	0.025	0.06				
$\pi_{1,t-2}$	-0.165	0.095				
$\pi_{1,t-3}$	0.08	0.06				
Inflation				Matrix $\mathbf{A}$		
Constant	0.174	0.158		α_{11}	0.346	0.096
$\pi_{2,t-1}$	0.354	0.077		α_{12}	-0.205	0.189
$\pi_{2,t-2}$	0.186	0.076		α_{21}	0.144	0.08
$\pi_{2,t-3}$	0.334	0.064		α_{22}	0.405	0.164
$\pi_{2,t-4}$	-0.064	0.058				
$\pi_{2,t-5}$	0.167	0.064				
$\pi_{2,t-6}$	0.086	0.059				
$\pi_{2,t-7}$	0.055	0.063				
$\pi_{2,t-8}$	-0.155	0.058		Matrix B		
$y_{2,t-1}$	0.203	0.045		β_{11}	0.489	0.102
$Oil_{2,t}$	0.088	0.027		β_{12}	0.056	0.161
$Oil_{2,t-1}$	0.004	0.036		β_{21}	0.017	0.063
$Oil_{2,t-2}$	-0.268	0.043		β_{22}	0.529	0.162

Q-Statistics	Output Residuals			Inflation Residuals	
Lags	Residuals	Squared Residuals		Residuals	Squared Residuals
	7.11	2.35		3.11	1.64
4	(0.13)	(0.67)		(0.53)	(0.80)
	10.02	8.18		10.80	7.77
8	(0.26)	(0.41)		(0.21)	(0.45)
	13.97	15.48		16.61	19.26
12	(0.30)	(0.21)		(0.16)	(0.08)
	20.89	19.07		18.62	25.57
16	(0.18)	(0.26)		(0.18)	(0.06)

We are particularly interested in how shocks to the structural equations of the model of the economy affect each of the conditional variances. As described in Enders (2010), taking the conditional expectation of H_t results in what can be thought of as a VAR system of conditional variances. As such, we are able to trace out the effects of a one-unit aggregate demand or aggregate supply shock on the conditional variances given in $H_{t.}$ However, since the conditional covariances are time varying, the orthogonalization is not straightforward. The first panel of Figure 1.2 shows the effect of a shock that has a contemporaneous effect on $h_{1,t}$ but no contemporaneous effect on $h_{2,t}$. The second panel reverses the causality and shows the effect of a shock that has a contemporaneous effect on $h_{2,t}$ but no contemporaneous effect on $h_{1,t}$. Although other orthogonalizations would result in slightly different patterns, the results are clear. First, the effects of the respective shocks on the conditional variances of each variable are short-lived. Since the conditional variances are not especially persistent, departures from the Taylor curve should be short-lived if the central bank operates efficiently. Moreover, there is little spillover from shocks in one conditional variance to the other conditional variance.

Figure 1.2. Impulse Response Functions

Panel 1



Panel 2

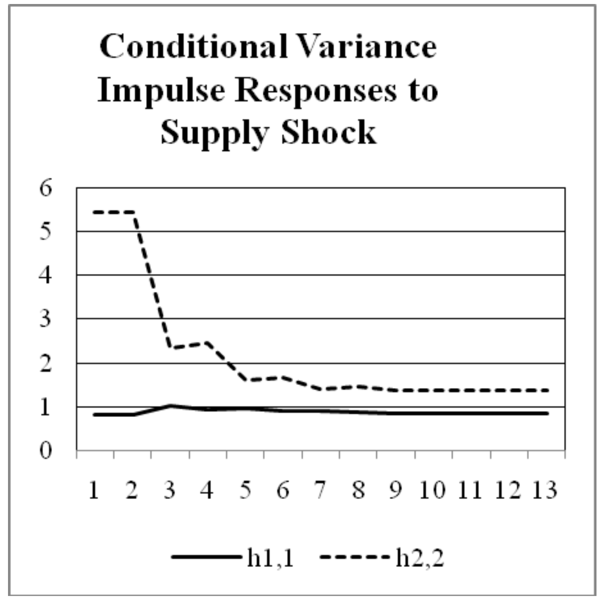
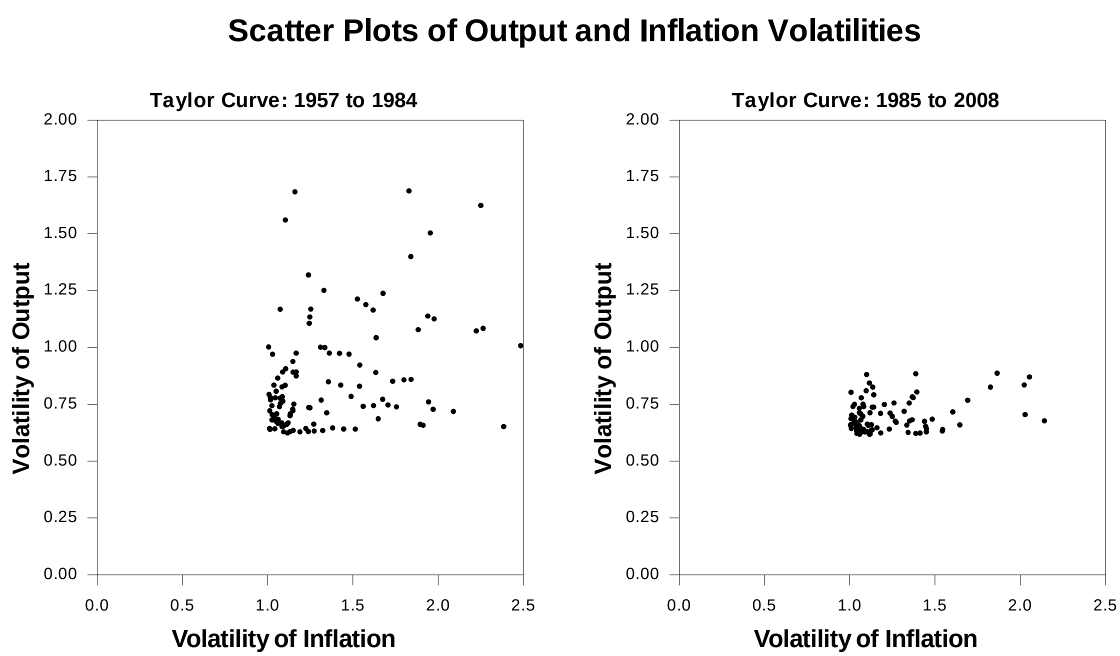


Figure 1.3 displays scatter plots of the conditional volatilities for the 1957Q1 – 1984Q4 and 1985Q1 – 2008Q3 periods.[6] As noted in Section 2, it is possible that positive correlations could occur as a result of an inward shift in the efficiency frontier. However, a comparison of the two panels of Figure 1.3 is not suggestive of such a shift. It is true that the *average* level of $h_{1.t}$ fell from 0.861 (1957–1984) to 0.694 (1985–2008) and that the *average* level of $h_{2.t}$ fell from 1.37 (1957–1984) to 1.24 (1985–2008). However, the boundaries (or envelopes) containing the volatilities seem to be very similar across the two periods.

Figure 1.3. Scatter Plots of Output and Inflation Volatilities



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[6] The result is quite robust to alternative specifications. For example, little changed when we constructed scatter plots using univariate GARCH models such that each mean equation consisted only of ARMA terms. These results can be obtained on us upon request.

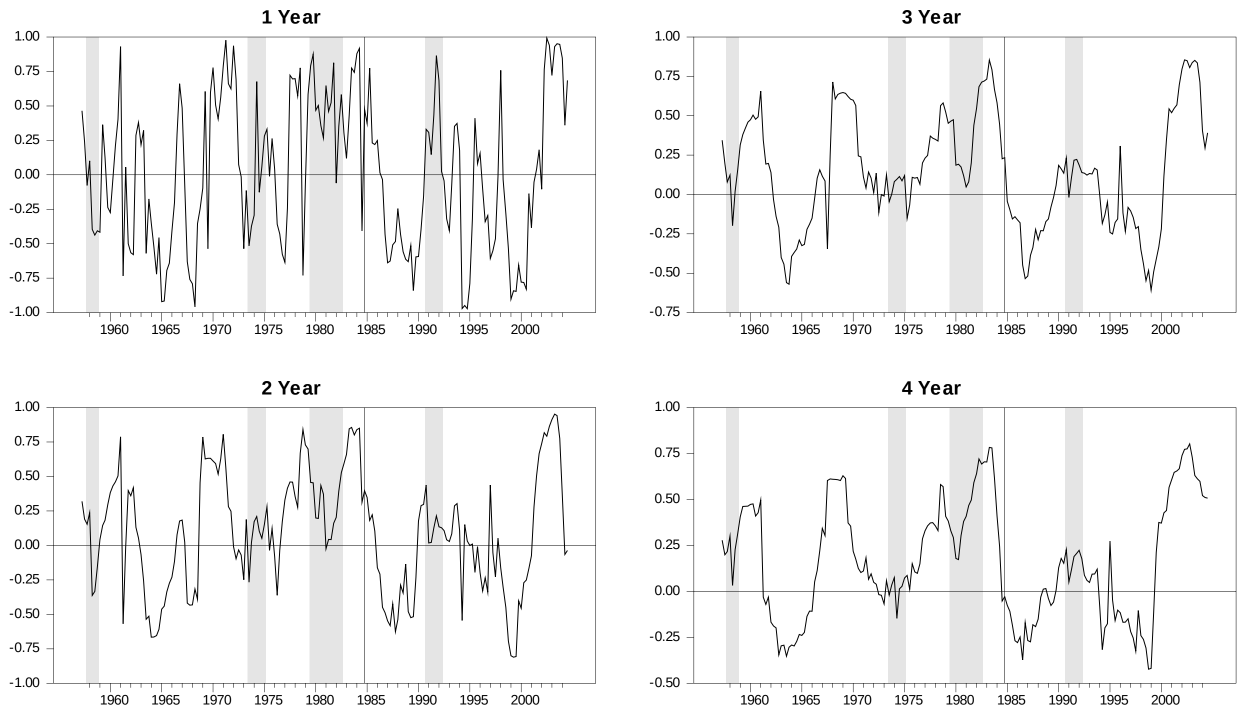
1.4. Taylor Curve Relationship

1.4.1. Rolling Correlation Windows

As a preliminary step to understanding the Taylor curve relationship, we computed the simple correlation coefficients between $h_{1,t}$ and $h_{2,t}$. In order to better interpret the results, Figure 1.4 shows the smoothed correlations using rolling windows of 1-year through 4-years. The vertical line at 1984Q4 marks the beginning of the so-called Great Moderation and the shaded bars denote Hamilton's (2003, 2009) dating of the periods during which the U.S. economy experienced adverse effects of oil price shocks. Clearly, time-varying correlations are as likely to be positive as they are to be negative. In particular, the correlations generally fell throughout the early 1960s and rose during the buildup of the Viet Nam War. The correlation was near zero around 1973 and steadily increased through 1979 reflecting the fact that the 1970s was period of general inflation and output instability. Notice that the economy reacted to the 1973 oil price shock differently from the other price shocks in that the correlations generally declined after the other three oil price shocks. After the twin recessions of the early 1980s, the correlation started to decline, fell sharply at the onset of the Great Moderation, and jumped strongly upward near the end of 2000.

In a sense, the smoothed volatilities shown in Panels 1 through 4 correspond to Friedman's (2006) historical volatility averages. As such, our results are somewhat contrary to Friedman's (2006) argument and to the argument of Taylor (2006) and Chatterjee (2002). We find that there are long periods during which the economy U.S. seemed to operate near the boundary of its Taylor curve. However, there are also long periods during which monetary policy appears to be suboptimal.

Figure 1.4. Rolling Correlations



1.4.2. Time Varying-Parameter Model

To be a bit more formal, we now estimate the relationship between $h_{1,t}$ and $h_{2,t}$ using a time-varying parameter model in the form $h_{1,t} = a_t + \beta_t h_{2,t} + \varepsilon_t$. The nature of the model is such that the volatilities, $h_{1,t}$ and $h_{2,t}$, are the observables and the time-varying regression coefficients, a_t and b_t, are the unobservables. Hence, the time-varying relationship between the two volatilities is captured by a_t and b_t. The vector of state variables is $[a_t, b_t]^{\mathrm{T}}$ and each variable follows a random walk such that changes in the coefficients only occur as new volatilities are observed. The state equation is written as

$$\begin{bmatrix} a_t \\ b_t \end{bmatrix} = \begin{bmatrix} \alpha_1 & 0 \\ 0 & \beta_1 \end{bmatrix} \begin{bmatrix} a_{t-1} \\ b_{t-1} \end{bmatrix} + \begin{bmatrix} v_{1t} \\ v_{2t} \end{bmatrix} \quad \begin{matrix} v_{1t} \sim N(0, \sigma^2_{v1t}) \\ v_{2t} \sim N(0, \sigma^2_{v2t}) \end{matrix} \tag{4}$$

and the measurement equation as

$$[h_{1,t}] = [1 \quad h_{2,t}] \begin{bmatrix} a_t \\ b_t \end{bmatrix} + \varepsilon_t \qquad \varepsilon_t \sim N(0, \sigma_\varepsilon^2). \tag{5}$$

where $h_{1,t}$ and $h_{2,t}$ are the previously estimated volatilities of the output gap and inflation, respectively. The innovations $\{\varepsilon_t, v_{1t}, v_{2t}\}$ are assumed to be serially uncorrelated and independent of each other. Once the system was estimated using the Kalman filter, we used Kalman smoothing to obtain the unobserved time-varying coefficients. For robustness, we also allowed a_t and b_t to follow AR(1) processes instead of the random-walk processes given by (5).[7] To account for the possibility of endogeneity, we also estimated the time-varying coefficients using inflation volatility as our left-hand side variable rather than output gap volatility.

Figures 5 and 6 display the time-varying parameters, b_t.[8] Figure 1.5 shows the values of b_t using the volatility of the output gap as the dependant variable and inflation volatility as the independent variables. Figure 1.6 uses inflation volatility as the dependant variable and the volatility of the output gap as the independent variable. The dashed in each figure is the expected inflation rate as measured by the Federal Reserve Bank of Philadelphia Survey of Professional Forecasters from 1970-present. The value of the coefficient b_t is measured on left-hand axis while expected inflation is measured on the right-hand axis.

[7] The univariate results and the AR(1) time varying parameter are not reported but may be obtained from the authors upon request. Not only was convergence an issue, but the lagged values did not add significant explanatory power to the model.
[8] Care must be used in constructing confidence intervals for the time-varying parameter model since the volatilities are actually generated regressors.

Figure 1.5. Time Varying Coefficient: Output Gap

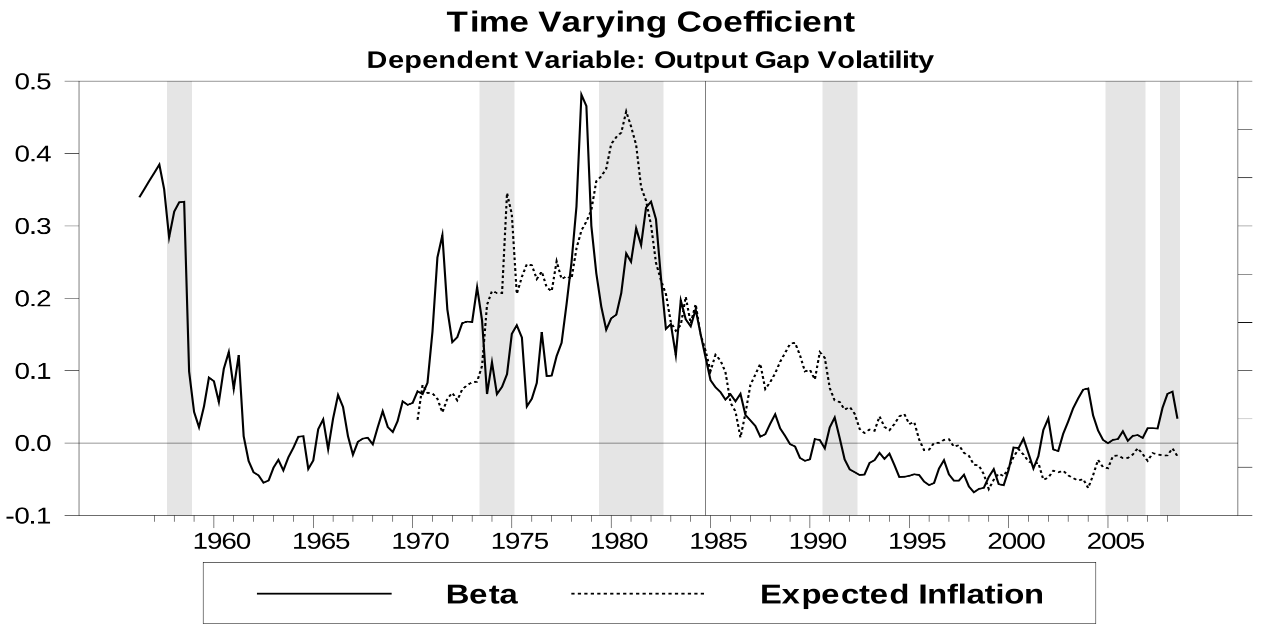
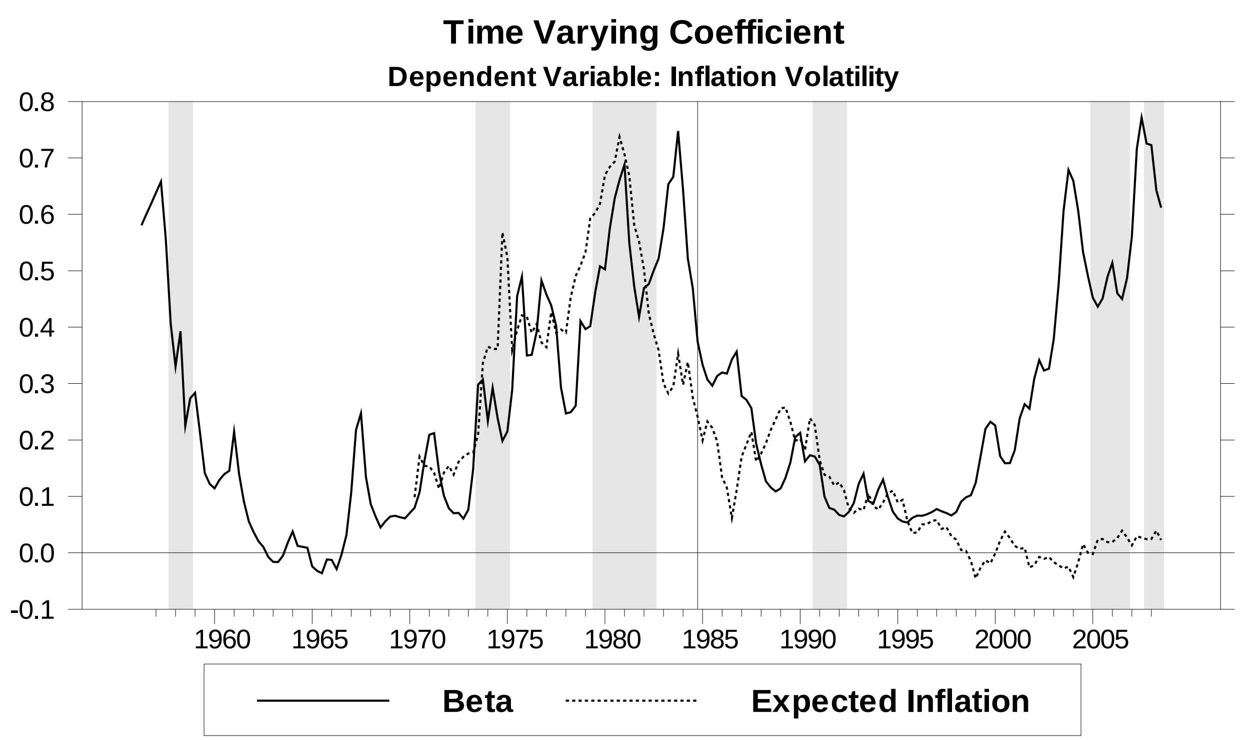


Figure 1.6. Time Varying Coefficient: Inflation



Note that the results are generally consistent which those shown in Figure 1.4. The consistent picture that emerges from Figures 4, 5, and 6 is that the relationship between the volatilities was generally positive for the 1960–1985 period and for the 2000–present periods. The fact that they are strongly positive supports Friedman's (2006) notion of suboptimal monetary policy. There is little evidence supporting a binding Taylor curve in the period prior to the Great Moderation in that b_t is almost always positive. Under the tenures of Fed chairmen William Martin, Arthur Burns, and William Miller (1960–1979) the relationship between the volatilities is positive and strong. These chairman's tenures are generally regarded as eras in which monetary policy was suboptimal resulting in macroeconomic instability. As noted by Clarida, Gali, and Gertler (2000) policy under Martin, Burns, and Miller suffered from the defect that bursts of inflation and output could result from self-fulfilling changes in expectations. Prior to Volker, individuals surmised that the Federal Reserve would accommodate rises in expected inflation by easing monetary policy which stimulated aggregate demand. Thus, the volatility of inflation and volatility of the output gap shifted together resulting in positive correlations.

Table 3 lists the summary statistics for inflation and growth for several different time periods. The periods were selected based on the sign of the 4-year rolling correlation shown in Figure 1.4. The key result is that macroeconomic performance is clearly better during time periods in which the correlation is negative. Prior to the Great Moderation, when the correlation was positive, the mean growth rates of output were 2.34 and 3.01 with variances of 12.03 and 7.64 for the 1957Q2–1966Q1 and 1966Q2–1984Q2 time periods compared to a mean growth rate of 5.32 and variance of 2.86 for 1961Q2–1966Q1. Inflation rates exhibit similar pattern. Inflation rates during times in which the correlation was consistently positive (1957Q2–1966Q1 and 1966Q2–1984Q2) were 1.79 and 6.42 with variances of 2.02 and 10.65 compare to an inflation rate of 1.42 with a variance of 0.69 for the 1961Q2–1966Q1.

Table 3.

Macroeconomic Performance

		Growth (GDP)		Average of the 4 Year Rolling Correlation Between Conditional Volatilities	Inflation (CPI)	
Time Period	Obs	Mean	Variance	ρ	Mean	Variance
1957Q2 – 1966Q1	36	2.34	12.03	0.35	1.79	2.02
1961Q2 – 1966Q1	20	5.32	2.86	–0.209	1.42	0.699
1966Q2 – 1984Q2	73	3.01	7.64	0.310	6.42	10.65
1984Q3 – 1989Q3	21	3.93	0.80	–0.14	3.53	2.57
1989Q4 – 1993Q4	17	1.94	2.12	0.127	3.72	2.42
1994Q1 – 1999Q2	22	3.75	0.64	–0.185	2.33	0.67
1999Q2 – Present	38	2.50	1.37	0.548	2.97	2.43

Perhaps most striking are the results corresponding to the tenures of Paul Volcker, Alan Greenspan, and Ben Bernanke. The stability of b_t for 1985–2000 is supportive of a very stable monetary regime. The near zero relationship between the volatilities suggests substantial improvements in monetary policy as well as a consistent weight assigned to inflation stability. After the onset of the Great Moderation, during time periods in which the correlation was positive (1989Q4–1993Q4 and 1999Q2–present), the mean growth rates were 1.94 and 2.50 with variances of 2.12 and 1.37, respectively. When the correlation was negative, the growth rates were 3.93 and 3.75 and variances of 0.80 and 0.64 for the 1984Q2–1989Q3 and 1994Q1–

1999Q2 time periods. Inflation rates exhibit much the same pattern; however, the difference in the means and variances is much smaller after 1984Q2 suggesting that the central bank placed a higher weight on price stability.

Figures 7a and 7b redisplay the values of $h_{1,t}$ and $h_{2,t}$ shown in Figure 1.3 in such a way as to correspond to the time periods listed in Table 3. Notice that the time periods during which the correlations are negative, the volatilities appear to cluster around a particular point. In contrast, in time periods in which the correlations are positive, the volatilities are scattered and large. The positive relationship between the volatilities in Figures 4, 5, 6 does not appear to be a result of an inward shift of the efficiency frontier but rather destabilizing monetary policy which resulted high levels of inflation and output gap volatilities.

Figure 1.7a. Pre-1984

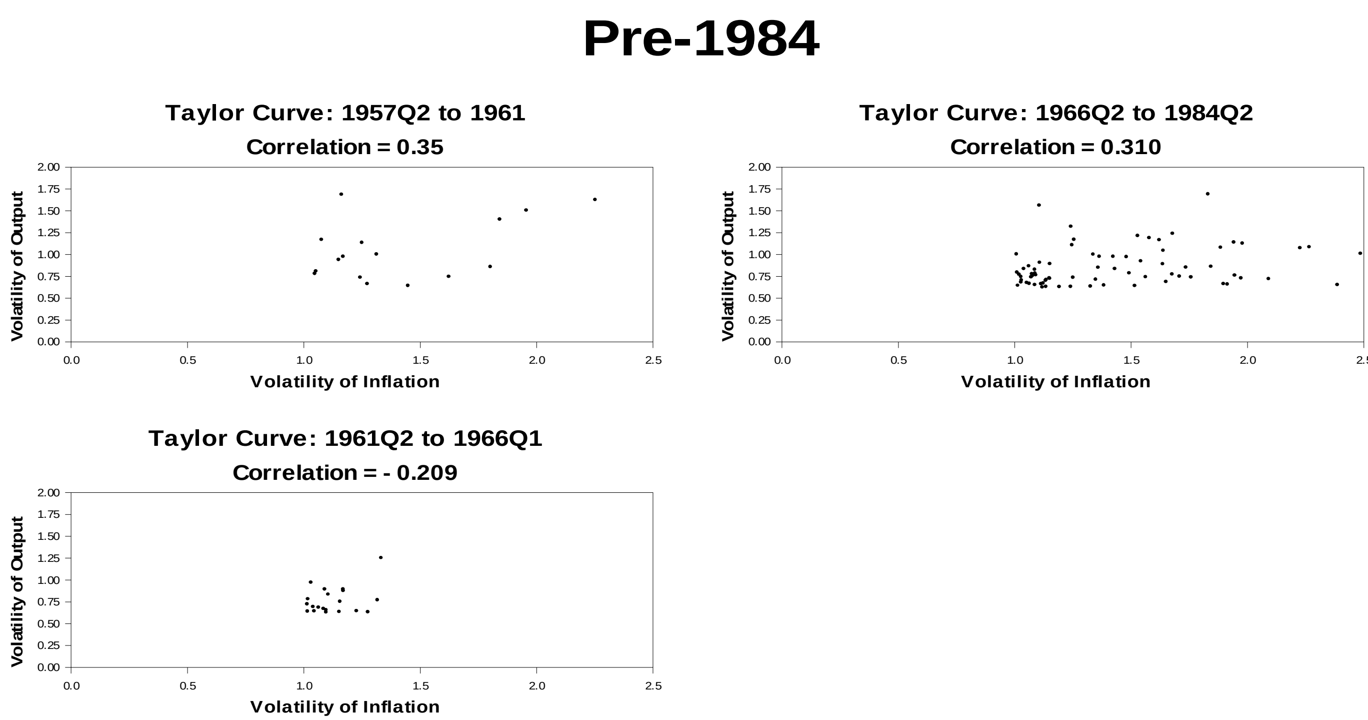
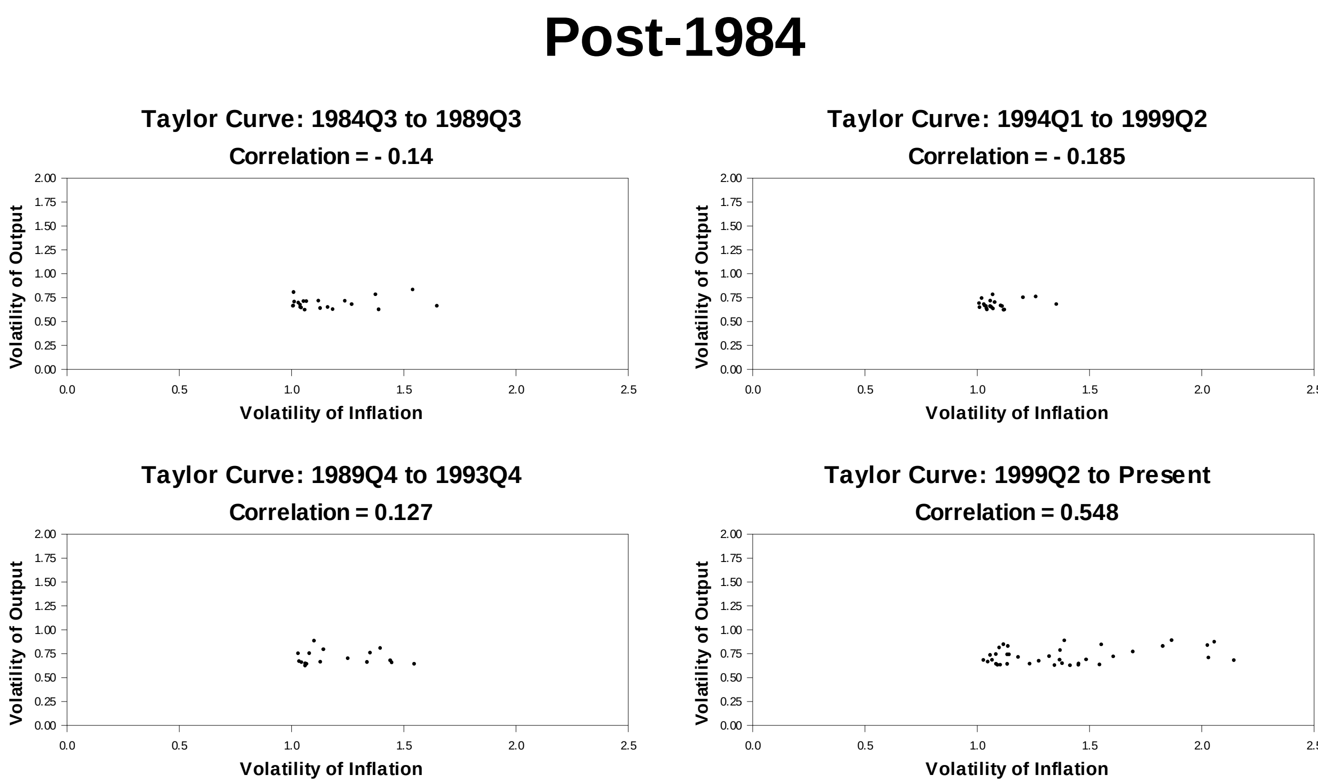


Figure 1.7b. Post-1984



1.4.3. The Taylor Rule and the Taylor Curve

Taylor's (1979) original paper showed that monetary policy using the Friedman rule would have led to better macroeconomic performance than actual policy from 1945–1979. In that spirit, we thought it would be insightful to examine the correlations between the volatilities when the behavior of the Federal Reserve is well-characterized by the *Taylor rule*. Specifically, we examine whether large values of the 4-year rolling correlations shown in the last panel of Figure 1.4 are associated with of the large discrepancies of the federal funds rate from the level suggested by the Taylor rule. Towards this end, we constructed a variable, called d_t, equal to the absolute value of the discrepancy between the federal funds rate and the rate that is consistent with a simple version of the Taylor rule.[9] Figure 1.8 displays the time-series plots of the $\{d_t\}$ sequence and the time-varying correlation between the volatilities ($corr_t$). Note that the left-hand axis is scaled for the time-varying correlations and the right-hand axis is scales for the d_t series. Even though causation is likely to be bidirectional, it is interesting that $corr_t$ and values of d_t were both large in the 1970s, fell around the time of the Great Moderation, and rose in the late 1990s. Moreover, the relationship is quite strong during the tenure of Alan Greenspan; the correlation between the two series is 0.36. Panel 2 displays similar information for the Greenspan period in that it shows the actual and fitted values of d_t obtained from the regression equation

$$\underset{}{d_t} = \underset{(3.74)}{0.376} + \underset{(3.75)}{0.820}corr_t + \underset{(5.06)}{0.542}d_{t-1}$$

where $corr_t$ is the rolling correlation, robust *t*-statistics are in parentheses, and diagnostic checking indicates that no additional lagged terms of either variable are significant at conventional levels.

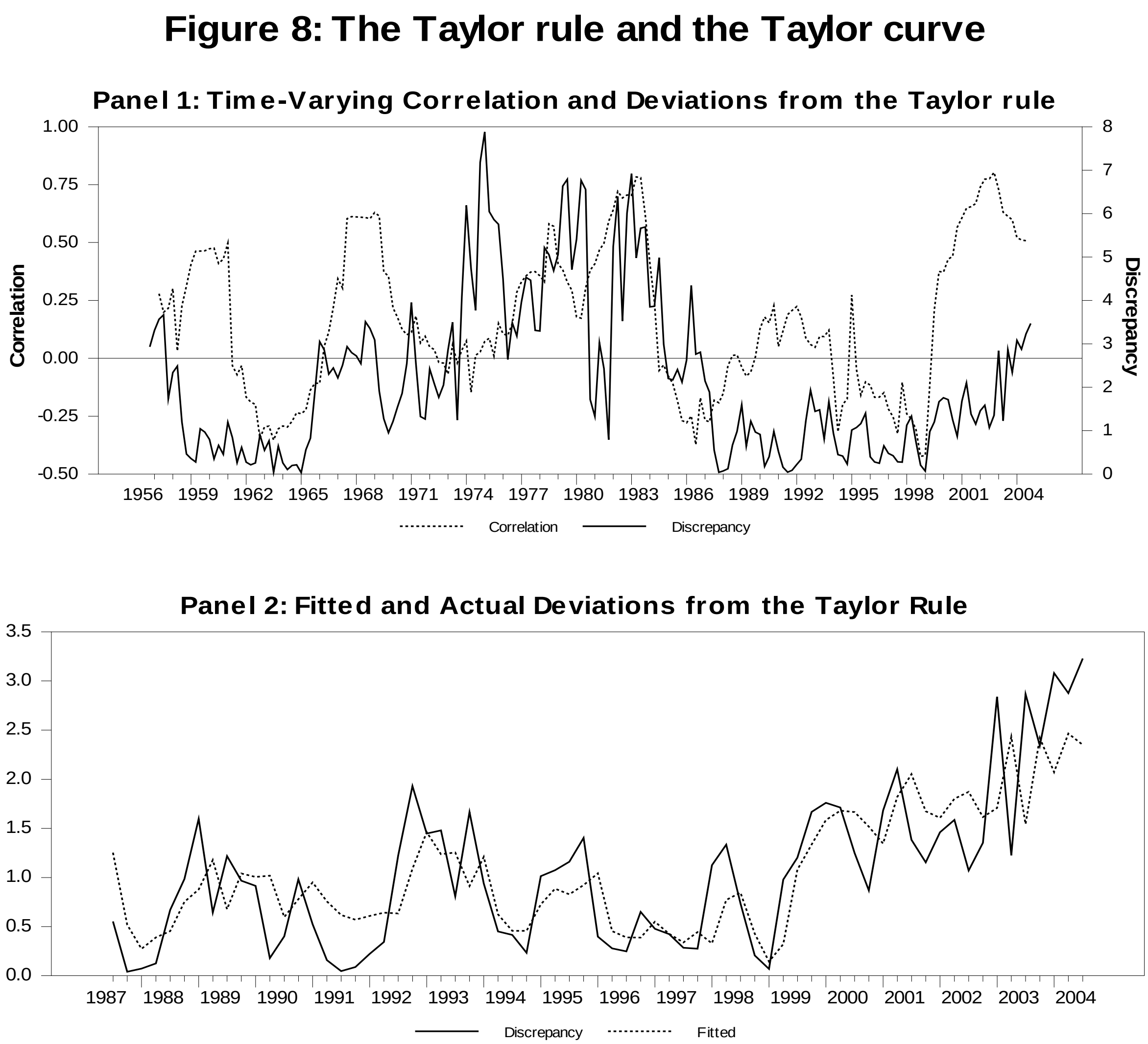
[9] There is a vast literature on the appropriate estimation of the Taylor rule and our aim is not to add to that here. Instead, our intent is to indicate periods during which the federal funds rate is generally deemed to be consistent with periods of prudent monetary policy. As such, the Taylor rule consistent federal funds was constructed as:

$$i_t^* = 0.02 + \pi_t + 0.5\, y_t + 0.5(\pi_t - 0.2)$$

and $d_t = | i_t - i_t^* |$.

Adding lagged values of the interest rate (so as to capture any interest rate smoothing by the Fed) does little to affect the shape of the d_t series.

Figure 1.8. The Taylor Rule and the Taylor Curve



1.5 Conclusion

In this paper we attempted to characterize the nature of monetary policy by empirically estimating the relationship between the Taylor curve variables over the 1955 – 2008 period. In an economy with a well-functioning monetary regime, the existence of the Taylor curve necessitates that there be a trade-off between the volatility of inflation and the volatility of output. Using a multivariate GARCH model, we presented evidence that the relationship is positive for those periods in the federal funds rate deviated from the Taylor rule. In particular, we find a positive relationship between the volatilities of output of inflation in the early 1960s, from the late-1960s through early 1980s, and beginning in 2000. In this sense, we confirm Friedman's (2006) view that monetary authorities did not operate along the Taylor curve. However, there are other long periods during which the correlation is near zero or negative. The correlation was negative (or small) in the mid-1960s, the early 1970s, and during most of Alan Greenspan's tenure as Federal Reserve chairman. During the Greenspan period, deviations from the Taylor rule were small, output volatility was small, and the correlation between the volatilities of output and inflation were generally small or negative.

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CHAPTER 2

A HISTORICAL ANALYSIS OF U.S. MONETARY POLICY

Using the Taylor Curve

2.1. Introduction

Unlike the traditional Phillips curve, that posits a temporary tradeoff between the level of inflation and output, Taylor (1979) argues for the existence of a "second order Phillips curve" such that there is a permanent tradeoff between the variance of inflation and the variance of the output gap. The tradeoff arises because monetary policy cannot simultaneously offset both types of variability during time periods in which the economy undergoes shocks to aggregate supply. A central bank can choose to reduce the variance of inflation (output) only if it is willing to tolerate a greater variance of output (inflation). Taylor (2006) and Chatterjee (2002) argue that the so-called Taylor curve has replaced the Phillip's curve as a policy menu since the former is more compatible with current mainstream macroeconomic theory. However, the view that the central bank actually operates on the Taylor curve is not universally accepted. Milton Friedman (2006) is skeptical that the Taylor curve can or should be used as such. Friedman (2006) points out that the Taylor curve is an efficient frontier yielding the tradeoff for optimal monetary policy. As such, the economy will operate on this efficiency locus only if the central bank pursues optimal monetary policy. He presents evidence showing that the correlation between U.S. output variability and inflation variability is positive, not negative, over the 1879 – 2005 period; the estimated correlation coefficient is 0.81. As such, Friedman (2006) claims that there is substantial evidence supporting his well-known view that monetary policy has been suboptimal for long periods of time.

The position of the Taylor curve depends upon the variability of aggregate supply shocks which the economy experiences. The smaller (larger) the size of the shocks the economy experiences the closer (further) the efficiency frontier will be to the origin. As a result, the Taylor curve will shift when the underlying variability of supply shocks change. For example, the well documented decline in the variance of most macroeconomic variables since the 1980s implies that the Taylor curve has shifted towards the origin. Thus, one possible explanation of the positive correlation reported in Friedman (2006) is due to inward shifts of the Taylor curve.

This paper does not seek to comment on the validity of the Taylor curve as a policy menu. Our primary purpose is to use the Taylor curve as a lens through which to historically gauge the efficiency of U.S. monetary policy. Our objectives are threefold: first, we seek to evaluate the optimality of monetary policy through time; second, we identify time periods in which the underlying variability of the economy changed; third, identify determine whether the opportunity cost of stabilizing inflation or output has changed. Towards this end, we estimate a VAR using data dating from 1875-2009 to obtain structural parameters necessary to construct the Taylor curve. We characterize the historical efficacy of monetary policy by calculating the minimum orthogonal distance between the observed volatilities of inflation and the output gap from their optimal levels. A change in the variability of shocks the economy has experienced is determined by observing the location of the efficiency frontier relative to the origin. Lastly, we identify changes in the opportunity cost of stabilizing each variable by examining changes in the curvature of the Taylor curve.

2.2. Background

The standard derivation of the Taylor curve begins with a central bank trying to minimize the expected value of a standard loss function (L):

$$L = \lambda(\pi_t - \pi_t^*)^2 + (1-\lambda)(y_t - y_t^*)^2 \quad (1)$$

where π_t is the inflation rate, π_t^* is the target inflation rate, λ is the central bank's preference for inflation stability, y_t is output, and y_t^* is the target level of output. Given the structural equations of the economy and the weight assigned to inflation, it is possible obtain a point on the Taylor curve. This point represents the optimized values of the variance of inflation and the variance of output for a given value of λ. Varying λ allows one to plot out an efficiency frontier as the locus of points indicating the smallest variance of inflation obtainable for any given variance of the output gap.[10]

Consider the Taylor curve $T_1 T_1$ depicted in Figure 2.1a. Monetary policy that is optimal would result in the economy operating on its efficiency frontier (point A). Policy which is sub-optimal would result in the observed volatilities being observed in space to the right of the Taylor curve (point B). Thus, movement towards the Taylor curve represents an improvement in monetary policy. Shifts in the Taylor curve itself, such as a movement from Taylor curve $T_1 T_1$ to $T_2 T_2$, are indicative of changes in the variability of shocks the economy experiences. Thus, decreases in macroeconomic volatility results in shifts of the efficiency frontier towards the origin whereas volatility increases result in outward shifts. The curvature of the Taylor curve can change as well. The curvature of the Taylor curve represents the cost of stabilizing inflation in terms of output gap volatility. Consider Figure 2.1b. The degree of curvature in $T_3 T_3$ is clearly high than that of $T_4 T_4$. A central bank which confronts the efficiency frontier $T_3 T_3$ will have to

[10] The same type of derivation also results in the so-called Taylor Rule yielding the central bank's target interest rate as a function of output and the inflation rate.

tolerate greater output volatility than one which faces T_4 T_4. This relative price of inflation stability will primarily be determined by the composition of the economy. Thus, changes in the composition of the economy will change the relative cost of output and inflation stabilization.

Figure 2.1a. The Taylor Curve

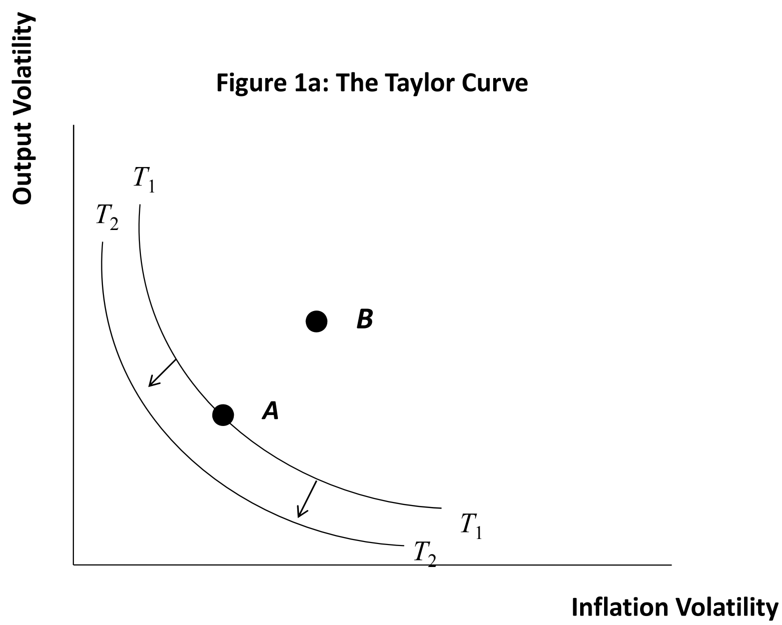
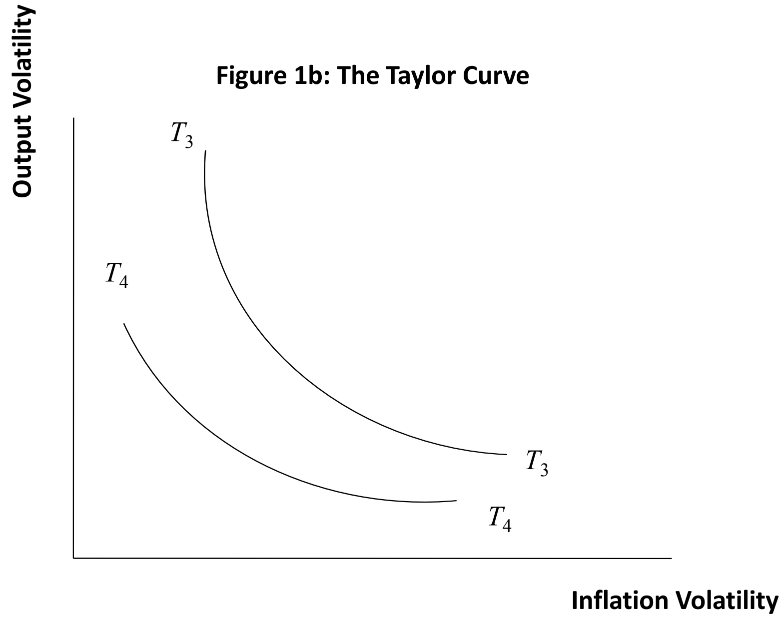


Figure 2.1b. The Taylor Curve



2.3. *Estimating the Efficiency Frontier*

2.3.1. *VAR*

In order to obtain the structural parameters for the economy necessary for construction of Taylor curve, we estimate a variant of the aggregate demand and supply model developed in Mishkin and Hebbel (2007). Consider:

$$y_t = \sum_{i=1}^{n} \alpha_{1,i}\, y_{t-i} + \sum_{i=1}^{n} \beta_{1,i}\, \pi_{t-i} + \sum_{i=1}^{n} \phi_{1,i}\, i_{t-i} + \varepsilon_{1,t} \qquad (2)$$

$$\pi_t = \sum_{i=1}^{n} \alpha_{2,i}\, y_{t-i} + \sum_{i=1}^{n} \beta_{2,i}\, \pi_{t-i} + \sum_{i=1}^{n} \phi_{1,i}\, i_{t-i} + \varepsilon_{2,t} \qquad (3)$$

Equation (1) represents an aggregate demand function, where the output gap (y_t) is a function of its own lags, lags of the nominal interest rate (i_t), and lags of the inflation rate (π_t). Equation (2) represents a Phillips curve, in which inflation is a function of its own lags, lags of the output gap, and lags of the nominal interest rate (i_t). In order to estimate a VAR in the form of (1) and (2), we obtained data from Balke and Gordon (1988) for the period 1875Q1-1947Q1 and from the St. Louis FRED database for 1947Q1-2009Q3. The data were spliced together such that values of real and nominal GNP in the Balke and Gordon (1988) in 1947Q1 were multiplied by a constant so as to equal the 1947Q1 values from the St. Louis FRED database. Balke and Gordon data pre-1947Q1 were then multiplied by the same constant. The interest rate used for the 1947Q1-1983Q4 time period was the 6-month commercial paper rate as reported in Balke and Gordon (1988); however, due to the lack of data after 1983 the 6-Month Treasury Constant Maturity Rate was obtained from FRED database for the 1984Q1-2009Q3 time period. The output gap was measured as 100 times the log difference of real GNP from a Hodrick-Prescott (HP) filter. Inflation was defined as 400 times the log first-difference of the GNP deflator. The VAR was estimated using the deviation of inflation from an HP trend.

As a preliminary diagnostic we performed standard augmented Dickey-Fuller tests to determine whether or not the variables are stationary; all variables in the form represented by (2) and (3) were found to be stationary at the 5% significance level. The lag length of the VAR was selected according to two criteria. First, the adequacy of the model was checked by calculating Ljung-Box Q-statistics for the diagonal elements of the residual covariance matrix to ensure the absence of serial correlation. Second, the multivariate generalizations of the Akaike Information Criterion (AIC) and Schwartz Bayesian Criterion (BIC) were used to measure the overall fit of the alternative models. All Ljung-Box Q-statistics tests were found to be insignificant up to the twelfth lag. Using the above criteria we found that 9 lags of inflation, 9 lags the output gap, and 2 lags of the interest rate fit the data best.

2.3.2. Constructing the Taylor Curve

In construction of the efficiency frontier we follow the methodology outlined in Taylor (1979) and Cecchetti, Flores-Lagunes, Krause (2006). The optimization procedure is best described by rewriting the structural model in (2) – (3) in its state-space representation,

$$Y_t = B\,Y_{t-1} + c\,i_{t-1} + v_t \qquad (4)$$

where

$$Y_t = \begin{bmatrix} y_t \\ \vdots \\ y_{y-8} \\ \pi_t \\ \vdots \\ \pi_{t-8} \\ i_{t-1} \end{bmatrix} \; B = \begin{bmatrix} \alpha_{11} & \cdots & \alpha_{19} & \beta_{11} & \cdots & \beta_{19} & \varnothing_{12} \\ 1 & 0 & \cdots & \cdots & \cdots & \cdots & 0 \\ 0 & \ddots & \cdots & \cdots & \cdots & \cdots & 0 \\ \alpha_{21} & \cdots & \alpha_{29} & \beta_{21} & \cdots & \beta_{29} & \varnothing_{22} \\ 0 & \cdots & \cdots & \ddots & \cdots & \cdots & 0 \\ 0 & \cdots & \cdots & \cdots & \ddots & \cdots & 0 \\ 0 & \cdots & \cdots & \cdots & \cdots & 1 & 0 \end{bmatrix} \; C = \begin{bmatrix} \varnothing_{11} \\ 0 \\ \vdots \\ \varnothing_{22} \\ 0 \\ \vdots \\ 1 \end{bmatrix} \; V = \begin{bmatrix} \varepsilon_{1t} \\ 0 \\ \vdots \\ \varepsilon_{2t} \\ 0 \\ \vdots \\ 0 \end{bmatrix} \qquad (5)$$

In matrix notation, the loss function in (1) can be as:

$$Y_t' \Lambda Y_t \qquad (6)$$

where Λ is a square weighting matrix with the first diagonal element equal to λ, the tenth diagonal element equal to $(1-\lambda)$, and the remaining elements equal to zero. The objective of the central bank is to pick the interest rate path which minimizes (6) subject to the constraints of the economy imposed by (4). Given the quadratic nature of the loss function, the solution for the interest rate will be linear which is written as:

$$i_t = g\,Y_{t-1}. \qquad (7)$$

The control vector g in the steady state is found using optimal control techniques and given by[11]:

$$g = -(c'Hc)^{-1}c'HB \qquad (8)$$

where H is the solution of the equations

[11] See Chow (1975) for further discussion

$$H = \Lambda + (B + CG)'H(B + CG). \quad (9)$$

Given the estimated values of the parameters in B and c, we can solve H and g for any value of λ. For a given set of feedback coefficients, g, the stochastic component of Y_t is described by (7). Thus, the steady state covariance matrix of Y_t is given by Σ which satisfies

$$\Sigma = \Omega + (B + CG)'\Sigma(B + CG). \quad (10)$$

where **Ω** is the covariance matrix of the residuals in V. The first and the tenth diagonal elements of **Ω** contain the steady-state variances. Given a particular weight to inflation stability, λ, this procedure determines a single point on the Taylor curve. By varying the weight assigned to inflation, an entire Taylor curve can be traced out[12].

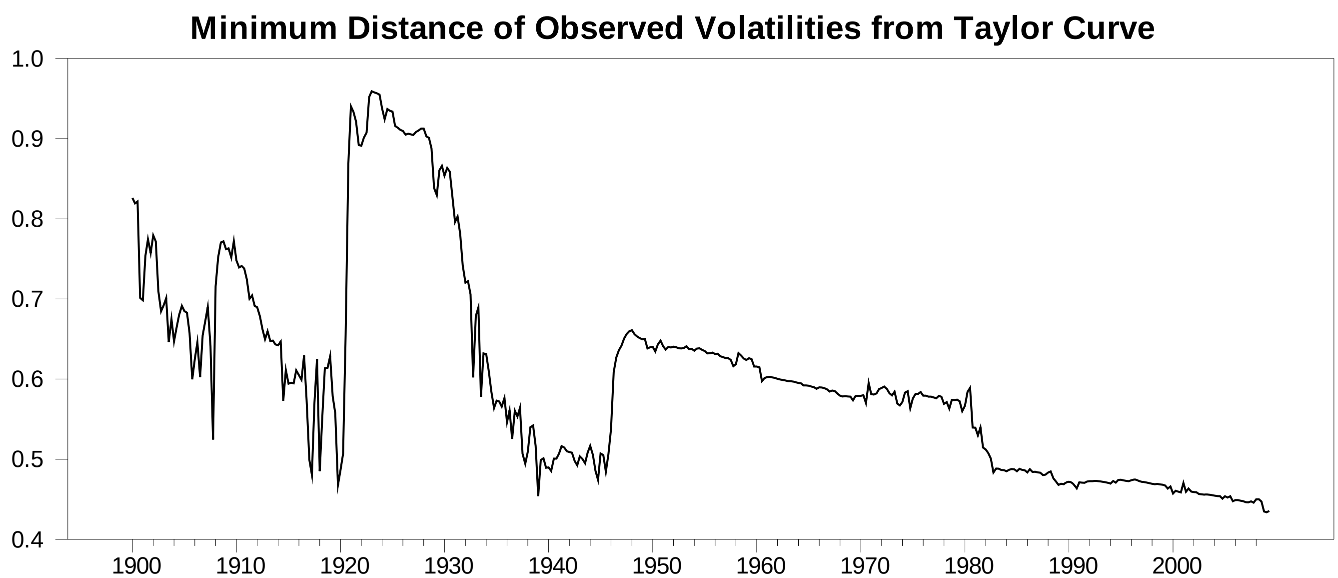
2.3.3 Constructing the Taylor Curve through Time

As noted above, we seek to use the Taylor curve to historically evaluate the efficiency of monetary policy. To that end, we re-estimated the VAR specified in section 3.1 for the 1875Q1-1900Q1 time period and subsequently derive the Taylor curve by implementing the procedure outlined in section 3.2 using the VAR coefficients estimated for the 1875Q1-1900Q1 time period. Given this efficiency frontier, we calculate the minimum orthogonal distance between the observed volatilities for the 1875Q1-1900Q1 time period and their optimal values. The above calculations are then repeated by adding one additional quarter of data, i.e. 1875Q1-1900Q2, and continued until the entire sample period is used in estimation[13]. Thus, 40 Taylor curves are estimated for each 10 year period. The resulting time series is composed of minimum orthogonal distances of observed volatilities from their optimal values for each quarter dating back to 1900Q1. However, it is important to note that this metric does not assume any knowledge about

[12] While optimal control techniques are certainly subject to the Lucas critique the empirical significance of the Lucas critique is ambiguous. See Favero and Hendry (1992), Hendry (2002), Estrella and Fuhrer (1999), and Ericsson, Hendry, & Mizon (1998) for further discussion.
[13] VAR and Taylor curve estimates can obtained upon request from the author

the preference of the central bank. We are assuming that the efficiency of monetary policy can be reasonably gauged by how close the economy operates to it efficiency frontier without any explicit knowledge of λ. Figure 2.2 displays the time series of minimum distances. Figures 2.3-2.55 displays the first Taylor curve for each decade (with the exception of 2009) and the observed volatilities for each time period labeled.

Figure 2.2. Minimum Distance of Observed Volatilities



2.4. Results

2.4.1. Monetary Policy

We divide our analysis of monetary policy into four time periods: 1875-1914, 1915-1950, 1951-1979, and 1980-present. The time period before the establishment of the Federal Reserve in 1914, commonly regarded as the international gold standard era, included 11 business cycles, deflation at the turn of the century, and one substantial financial crisis in 1907[14]. Between 1915-1951 it experienced 8 business cycles, two World Wars, and two periods of deflation: one the

[14] Cycles counted are from NBER

early 1920s and the other in the early 1930s. We pick the break date of 1951 because it marked the year in which the Federal Reserve began resumption of active monetary policy following WWII. This era experienced 5 business cycles, the Korean and Vietnam wars, the collapse of the Bretton Woods system, and the era of Great Inflation. The last time period has been documented to exhibit the most macroeconomic stability. Since 1980 the economy has experienced 5 business cycles, two Iraq Wars, the beginning of the War on Terrorism, and one substantial financial crisis.

Although, the Federal Reserve was formed 1914, WWI largely kept policy makers from pursuing policy rules until 1920-21. Much of the early policy was used in aiding Treasury keep borrowing costs low. Thus, WWI acted as a sort of policy restraint. The early 1920s were the first time policy makers could focus on developing effective monetary policy. Note in Figure 2.2 the movement away from the efficiency frontier which corresponds to the beginning of active policy. Monetary policy was clearly sub-optimal throughout much of the 1920s. However, policymakers in the 1920s did acknowledge the problems of the speculative use of Federal Reserve credit in the stock market (Orphanides, 2000). It seems reasonable to conclude that policy was too loose for much of the 1920s. Interestingly, the tight policies leading to the stock market crash in 1929 appear to move the economy towards its efficiency frontier rather than away[15]. From 1933 to the end of the 1940s, the economy steadily moved towards its efficiency frontier. However, monetary policy was essentially inactive during this time period due to short-term interest rates being zero or pegged due to WWII to ensure low borrowing costs for Treasury (Goodfriend, 1991).

[15] See Orphanides (2000) for a much more in depth discussion regarding the policy leading up the recession. He argues that it was in fact close to a Taylor type rule that led them to tighten policy.

The resumption of active policy by the Federal Reserve began with the Treasury-Federal Reserve Accord in 1951. Again notice the movement away from the efficiency frontier in Figure 2.2. If one equates active monetary policy with attempts to fine-tune the economy, the beginning of active policy in the 1920 and resumption in the 1950s are clearly associated with higher, not lower, levels of output and inflation volatilities. For the rest of the 1950s and 1960s the economy does trend towards its efficiency. Interestingly, Taylor (1998), Friedman and Schwartz (1963) both document that monetary policy was excessively tight in the early 1960s. However, this period of sub-optimal policy does not appear to cause any substantial movement of the economy away from its Taylor curve. It is not until the end of the Bretton Woods system and the Nixon price controls of the 1970s that there is any substantial movement. Clarida, Gali, and Gertler (2000) documented the serious flaws embedded in monetary policy rules in the 1970s. Misunderstanding of the Phillip's curve certainly contributed to the easy money of the 1970s and no doubt that fear of permanent rises in the unemployment rate reduced the Federal Reserve's preference towards price stability. In fact, Taylor (1998) argues that much of the cause of the Great Inflation was due to excessively loose monetary policy resulting from the above mentioned policy flaws and the collapse of the Bretton Woods system. While the minimum distance is not that much worse in the 1970s than the 1960s, the 1970s do exhibit more instability in the position of the economy relative to its Taylor curve.

In contrast to Taylor (1998) and Clarida, Gali and Gertler (1999, 2000), Orphanides (2003, 2003b) asserts that much of the policies pursued during the Great Inflation were not seriously flawed or substantially different from policy that a Taylor type rule would suggest. Rather, the poor policy was a result of inaccurate measures of potential output which led to inappropriate policy prescriptions. Thus, the instability of the economy relative to its efficiency frontier could be due to continual shifts in the Taylor curve resulting from increased supply shocks, such as the OPEC embargo and Nixon price controls, rather than a deterioration of monetary policy.

Notice the sharp decline in Figure 2.2 beginning with the Volker years in the late 1970s. While the beginning of the Great Moderation corresponds to this time period, a reduction in the size of the shocks the economy experiences has no impact on the distance the economy operates from its Taylor curve (the inward shift of the Taylor curve can be seen in Figures 2.5). The decline in the minimum distance implies that economy moved towards the Taylor curve more than the Taylor curve shifted inward. Thus, monetary policy clearly improved in the early 1980s. While there were numerous changes that contributed to better monetary policy during the 1980s, two specific improvements merit mentioning. First, increased weight assigned to inflation was crucial in taming inflationary expectations and mitigating their self-fulfilling nature. Second, the predictability of short-term interest rates improved through the adoption of Taylor type rules and increased transparency of Federal Reserve operations.

By combining the two middle time periods into one, 1915-1979, our sample period can be also split according to the changes in the characteristics of short-term interest rates: 1875-1914, 1915-1979, 1980-present. Figure 2.6 displays the interest rate for the entire sample period. Notice the change in the behavior of short term interest rates approximately beginning in 1915. Mankiw and Miron (1986, 1991) provide evidence suggesting that establishment of the Fed changed the behavior of short-term interest rates. A primary reason for the establishment of the Federal Reserve was to eliminate seasonality in short-term interest rates. Thus, interest rates changed from a mean reverting variable to one which displayed random walk characteristics. As a result, from 1915-1979 short-term interest rates exhibited little seasonality but were less predictable. Goodfriend (1991) argues that this change in the nature of short-term interest rates was required in order for the Federal Reserve to achieve their mandate. In order to affect changes in employment and prices levels, policy makers need to be able exhibit significance influence over long-term interest rates. In order to affect the long-end of the yield curve a persistent short-term rate is required. Thus, the monetary policy changes in the early 1980s had two substantial impacts. First, interest rates became more predictable due to increased transparency and the adoption of Taylor type rules; second, interest rate smoothing became a prevalent practice which maintained the persistence needed to affect long-term rates.

Two general observations regarding the time series in Figure 2.2 merit mentioning. First, time periods in which interest rates were predictable (whether because of mean reverting characteristics (1875 - 1914), interest rate pegs due to wars (1914 - 1920, late1930s - 1945), or increased transparency (1980 - present)) result in the economy operating closer to its efficiency frontier than time periods that do not. Secondly, it is interesting to note that time periods in which the position of the economy relative to its Taylor curve is most volatile are associated with time periods in which sub-optimal monetary policy is characterized as excessively easy: the 1920s and1970s. The sub-optimal tight policy in the early 1960s did not have the same effect as the sub-optimal policy of the 1920s and 1970s.

2.4.2. Shifts of the Taylor Curve

Note the shape and position of the Taylor curves in Figures 3-5. The Taylor curve shifted inward from 1900-1910 but then dramatically shifted outward in the 1920s and 1930s. No doubt that the shift in the Taylor curve outward was due in part to WWI. In each subsequent period following the 1930s, the Taylor curves shown in Figures 4 and 5 shift toward the origin. While the Great Moderation that began in the 1980s is well documented, the fact that the Taylor curve shifts inward beginning in the 1940s suggests a moderation in output that occurred post WWII. In fact, the entire 1959 AEA Presidential Address by Arthur Burns was used explaining how the decline in the volatility of output post-WWII was indicative of a more stable macroeconomy. Ironically, the stabilization of output post-WWII was debated in a series of papers beginning in the mid-1980s. Romer (1986, 1986, 1987, 1989) argued that output did not show a significant decline in volatility relative to dates before 1929; whereas and Balke and Gordon (1988) argued that output and inflation displayed significant decreases in their average level of volatilities. Figure 2.7 displays the Taylor curves from 1905, 1915, 1925, 1950, 1960, and 1970. The fact that Taylor curves for 1905 and 1915 are the closest to the origin lends credence to Romer's argument. However, there is a clear moderation in output and inflation post-WWII as evidenced in the sequential shift of the efficiency frontier towards the origin beginning in 1950.

Figure 2.3. Output-Inflation Tradeoff: 1900-1930

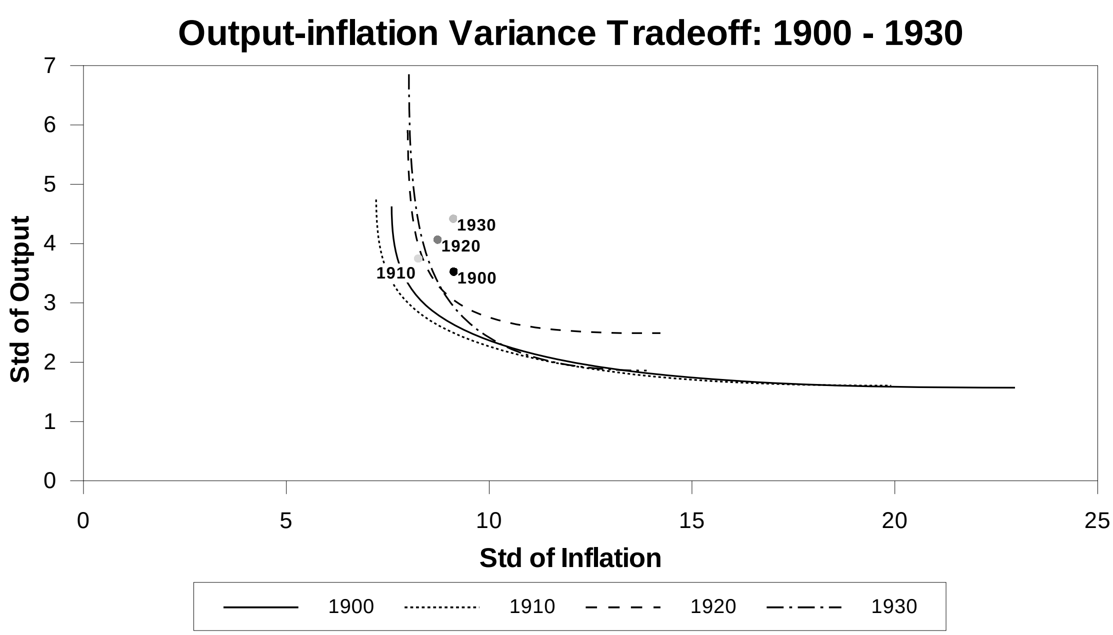


Figure 2.4. Output-Inflation Tradeoff: 1940-1970

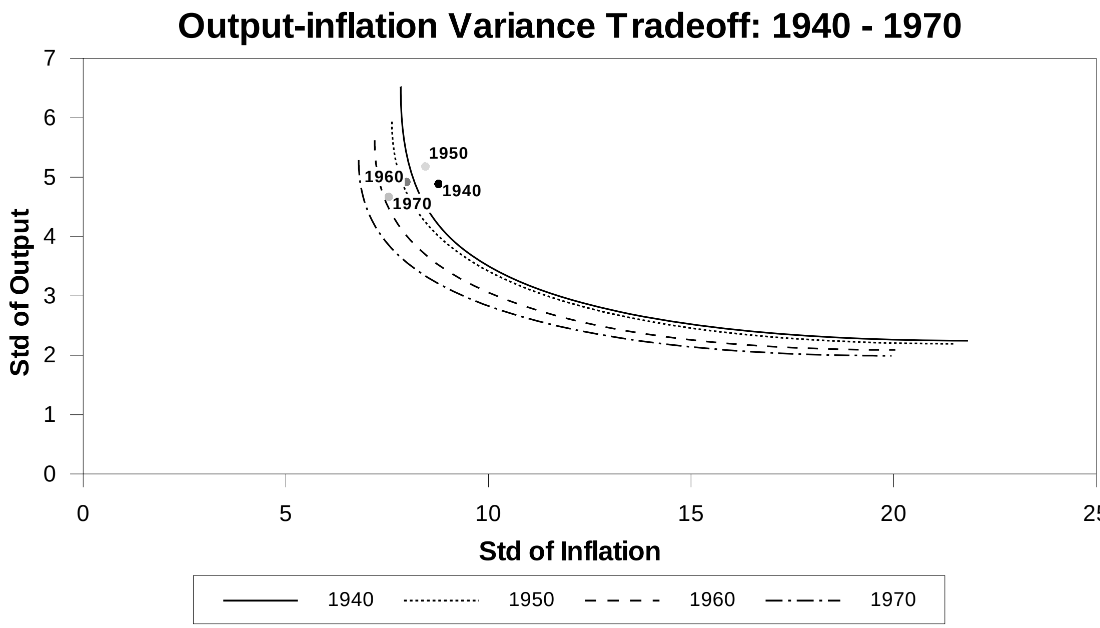


Figure 2.5. Output-Inflation Tradeoff: 1940-1970

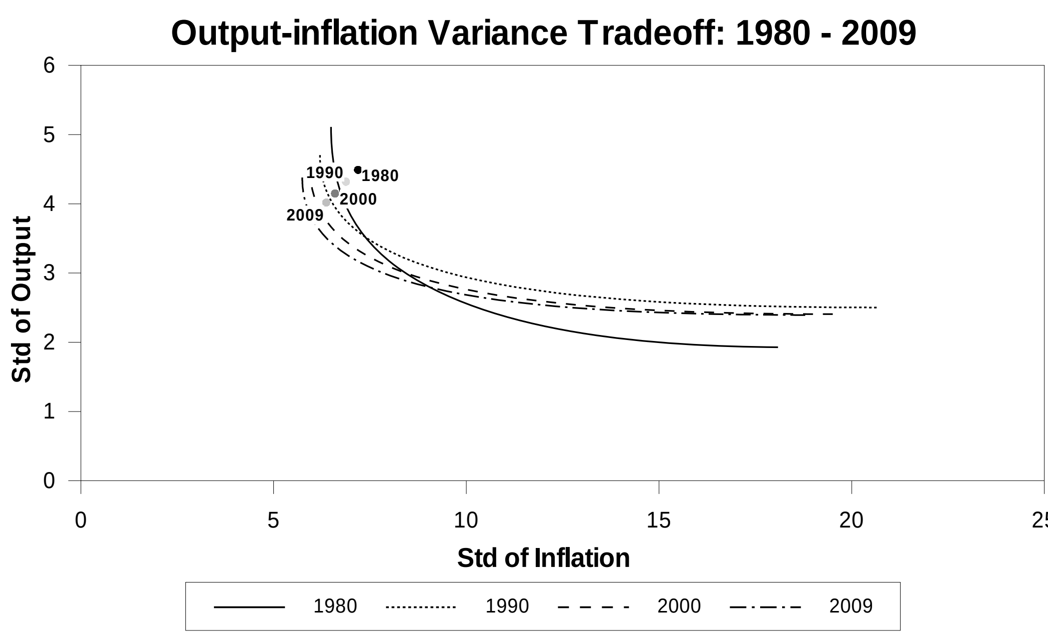


Figure 2.6. Interest Rates: 1875 – 2009

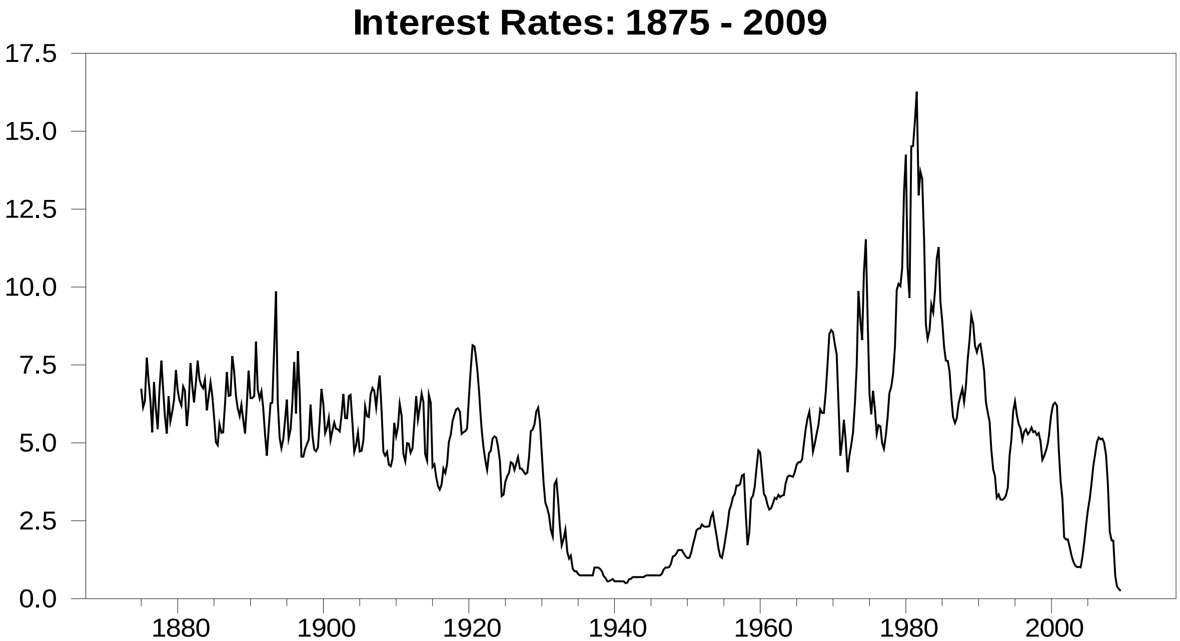
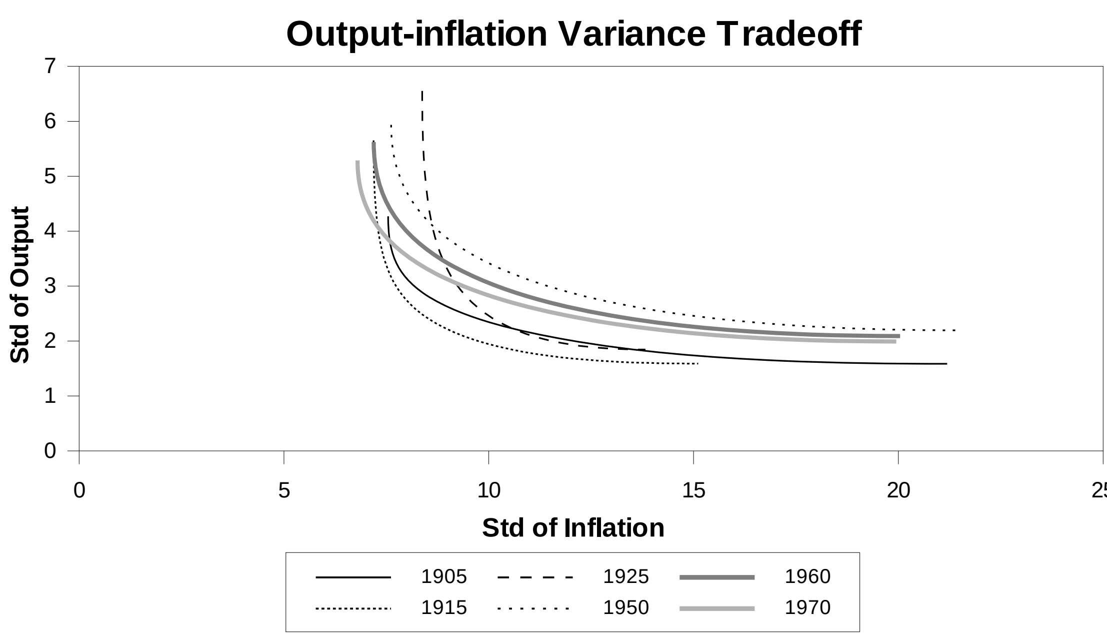


Figure 2.7. Output – Inflation Variance Tradeoff



2.4.3. Curvature of the Taylor Curve

The curvature of the Taylor curve is of interest as well. The opportunity cost of stabilizing inflation or of stabilizing output will change depending on the compositional changes the U.S. economy undergoes. Notice that the shape of the Taylor curve dramatically changed in the 1920s and 1930s. The Taylor curve actually steepened implying that the cost of stabilizing inflation in terms of output volatility increased during the 1920s and 1930s. However, after 1940 the Taylor curve continually became flatter through time. While there are certainly numerous factors that contributed to this phenomenon, we believe a significant factor was the change in the composition of the US economy. The substantial transition from a manufacturing to a service economy played a significant role in reducing the cost of stabilizing inflation.

2.5. Conclusion

By measuring the minimum orthogonal distance of the observed values of output and inflation volatilities from their optimal levels we have historically evaluated the optimality of monetary policy. Our results suggest that monetary policy has substantially improved since the inception of the Federal Reserve. However, Friedman's (2006) well known claim that monetary policy has generally been sub-optimal appears correct. We find that the beginning of active monetary policy in the 1920s and the resumption of active policy in the early 1950s resulted in higher levels of output and inflation volatilities relative to the previous 10 year time periods. The variability of supply shocks increased during the 1920s and 1930s but has steadily decreased throughout much of the rest of the century resulting in a consistent shift of the efficiency frontier towards the origin. Our results confirm the well documented decline in output and price volatility of the 1980s as well as the decline post-WWII as reported in Balke and Gordon (1988). However, the efficiency frontiers post-WWII do not appear closer to the origin than those before the Great Depression. Finally, our results suggest that the compositional change of the US economy from a manufacturing to service sector economy has contributed to the decline in the relative price of inflation stability as measured by the slope of the Taylor curve.

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CHAPTER 3

AN ANAYSIS OF THE EMS AND ECB USING EU COUNTRY TAYLOR CURVES

3.1. Introduction

Of the 11 European Union (EU) members that have not introduced the euro, eight (Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania) are obliged to yield monetary policy to the European Central Bank (ECB) when the convergence criteria of the Maastricht Treaty is met. Since the inception of the ECB in 1999, an extensive literature regarding the proficiency of its monetary policy has developed. Non-synchronized business cycles or substantial differences in countries' monetary policy transmission mechanisms can result in monetary policy which is incongruous with domestic policy goals. Thus, extensive research effort has been expended evaluating the appropriateness of ECB policy for individual member states. Much of the research regarding monetary policy in EU countries estimates Vector AutoRegressions (VAR) and impulse response functions to examine if the effects of ECB monetary policy are homogeneous across member states.

A standard method of examining central banks' monetary policy efficacy is to estimate the domestic economy's Taylor curve. Taylor (1979) argues that there exists a 'second order Phillip's curve' in which there is a permanent trade-off between the *variance* of inflation and the *variance* of the output gap for central banks which pursue optimal policies. This trade-off, the Taylor curve, serves as an efficiency frontier for optimal policy makers. Chatterjee (2002) argues that the Taylor curve has replaced the Phillip's curve as a policy menu since the former is more compatible with current mainstream macroeconomic theory. Mervyn King, of the Bank of England, (2007) describes how this relationship may be used in practice:

> The conventional wisdom is that, although there is no long-run trade-off between the levels of inflation and output growth, there is a trade-off between the stability of inflation and of output growth. Inflation can be kept closer to the target only by larger changes in interest rates and bigger fluctuations in output growth. Policy-makers thus face a choice between different combinations of inflation and output growth volatility, which, when plotted on a chart, describe a "stability possibility frontier". They can choose a point on that frontier depending on the relative importance they place on stabilising inflation and output growth, but they cannot move inside it. That is, they cannot reduce the volatility of both inflation and output growth. (pp. 6-7)

However, the view the Taylor curve should be used in policy formation is not universally accepted. The fact that policy makers cannot move inside the curve led Friedman (2006) to argue the Taylor curve is best viewed as an efficiency locus rather than a policy menu for an optimal policymaker.

The primary aim of this paper is to use member country Taylor curves' as efficiency frontiers through which to historically view the policies of the European Monetary System (EMS) and ECB. A comparison of ECB monetary policy with that of domestic monetary policy would be ideal. However, monetary policies of many EU countries were not 'truly' independent before the ECB due to participation in the EMS. Under the EMS, which began in 1979, bilateral exchange rates were fixed in a 2.5% band around the European Currency Unit (ECU). As a result, many participating members of the EMS did not have control over their domestic money supply. Moreover, inflation hawks in the Bundesbank guaranteed the strength of the German mark which resulted in significant influence on monetary policy for Europe as a whole. Thus, a comparison of independent domestic monetary policy with that of the ECB is not tenable. The effects of EMS and ECB policies are analyzed for each member state by calculating the minimum orthogonal distance between the observed volatilities of inflation and the output gap from their optimal levels. While the primary purpose of this paper is not the validity of the Taylor curve as a policy menu, the results do shed light on the issue. As a preview, I find that: (1) the frequent currency realignments of the 1980s are associated with high levels macroeconomic volatility, (2) stage II of the Maastricht Treaty resulted in significant stabilization of EU economies relative to their efficiency frontiers, (3) ECB monetary policy has not significantly decreased the distance EU countries operate from their Taylor curves, and (4) the concavity and location of the Taylor curve vary substantially, suggesting that policy makers should be cautious in using the Taylor curve as a policy menu. The paper proceeds as follows. In section 2, the intuition and background is given for the Taylor curve. In section 3, the macroeconometric model and construction of the Taylor curve is detailed. Section 4 contains results and section 5 concludes.

3.2. Background

The standard derivation of the Taylor curve begins with a central bank trying to minimize the expected value of a standard loss function (*L*):

$$L = \lambda(\pi_t - \pi_t^*)^2 + (1 - \lambda)(y_t - y_t^*)^2 \qquad (1)$$

where π_t is the inflation rate, π_t^* is the target inflation rate, λ is the central bank's preference for inflation stability, y_t is output, and y_t^* is the target level of output. Given the structural equations of the economy and the weight assigned to inflation, it is possible to obtain a point on the Taylor curve. This point represents the optimized values of the variance of inflation and the variance of output for a given value of λ. Varying λ allows one to plot out an efficiency frontier as the locus of points indicating the smallest variance of inflation obtainable for any given variance of the output gap[16]. Chairman Bernanke (2007) states that the rationale for the Taylor curve arises due to aggregate supply shocks which affect the price level. In such cases, monetary authorities must either tighten monetary policy in order to stabilize the inflation rate, which increases the output gap, or loosen monetary policy in order to mitigate the effect of the higher price level on aggregate demand, which exacerbates the impact of the supply shock on the price level.

Consider the Taylor curves depicted in Figures 1a and 1b. Monetary policy that is optimal would result in the economy operating on its efficiency frontier (point A). However, policy which is sub-optimal would result in the observed volatilities being observed in space to the right of the Taylor curve (point B). Thus, movement towards the Taylor curve represents an improvement in monetary policy. Shifts in the Taylor curve itself, such as a movement from Taylor curve $T_1 T_1$ to $T_2 T_2$, are indicative of changes in the variability of shocks the economy experiences. A decrease in macroeconomic volatility results in shifts of the efficiency frontier towards the origin whereas increases in macroeconomic volatility results in outward shifts of the Taylor curve. The concavity of the Taylor curve can change as well. The concavity of the Taylor curve represents the cost of stabilizing inflation in terms of output gap volatility. Consider Figure 3.1b. The degree of concavity in $T_3 T_3$ is clearly higher than that of $T_4 T_4$. A central bank which confronts the efficiency frontier $T_3 T_3$ will have to tolerate greater output volatility than one which faces $T_4 T_4$. This relative price of inflation stability is primarily determined by the composition of the domestic economy. Thus, changes in the composition of the economy will change the relative cost of output and inflation stabilization.

[16] The same type of derivation also results in the so-called Taylor Rule yielding the central bank's target interest rate as a function of output and the inflation rate.

Figure 3.1a. The Taylor Curve

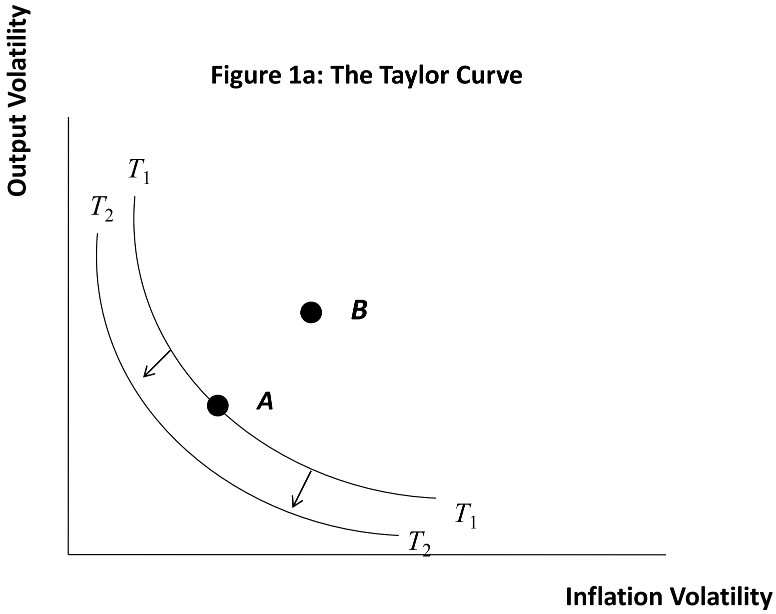
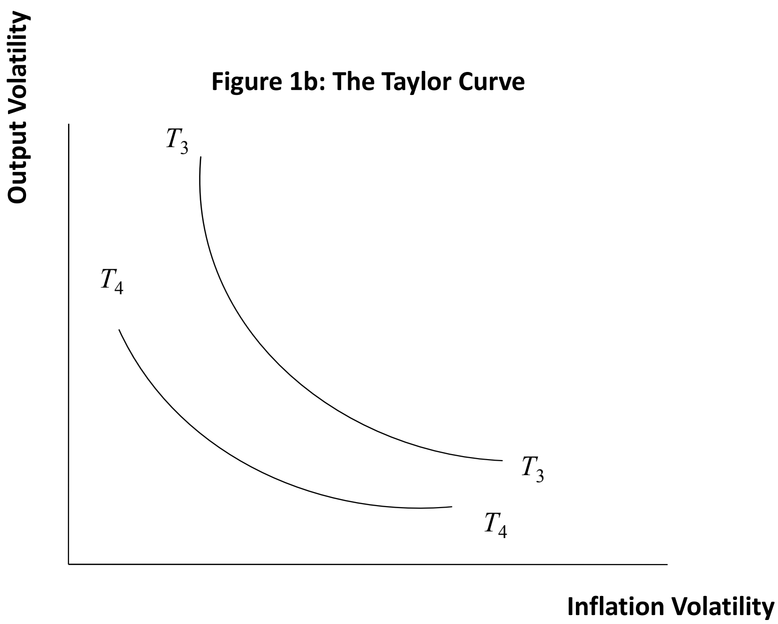


Figure 3.1b. The Taylor Curve



3.3. Estimating the Efficiency Frontier

3.3.1. VAR

In order to obtain the structural parameters for the economy necessary for construction of Taylor curve, I estimated a variant of the aggregate demand and supply model developed in Mishkin and Hebbel (2007). Consider:

$$y_t = \sum_{i=1}^{n} \alpha_{1,i}\, y_{t-i} + \sum_{i=1}^{n} \beta_{1,i}\, \pi_{t-i} + \sum_{i=1}^{n} \phi_{1,i}\, i_{t-i} + \varepsilon_{1,t} \qquad (2)$$

$$\pi_t = \sum_{i=1}^{n} \alpha_{2,i}\, y_{t-i} + \sum_{i=1}^{n} \beta_{2,i}\, \pi_{t-i} + \sum_{i=1}^{n} \phi_{1,i}\, i_{t-i} + \varepsilon_{2,t} \qquad (3)$$

Equation (2) represents an aggregate demand function, where the output gap (y_t) is a function of its own lags, lags of the nominal interest rate (i_t), and lags of the inflation rate (π_t). Equation (2) represents a Phillip's curve, in which inflation is a function of its own lags, lags of the output gap, and lags of the nominal interest rate.

The above model is estimated from 1960Q1 to 2008Q4 for 6 of the 11 original countries (Austria, Belgium, the Netherlands, France, Italy, and Spain) that yielded monetary policy to the ECB in 1999. The sample of countries was motivated by two factors. First, the above countries had reliable data on short-term interest rates; second, the sample allows comparison of large and small economies. In order to estimate a VAR in the form of (2) and (3), data was obtained from the IMF's *International Financial Statistics* for the 1960Q1 – 2008Q4 time period. The output gap was measured as 100 times the log difference of industrial production from a Hodrick-Prescott (HP) filter. Inflation was defined as the year-over-year percentage change in the consumer price index. The VAR was estimated using the deviation of inflation from an HP trend.

The interest rate series for each country was spliced with short-term money market or deposit interest rates before 1998Q4 with the Eurosystem Deposit Facility Rate post-1999Q1[17].

As a preliminary diagnostic, standard augmented Dickey-Fuller tests were calculated to determine whether or not the variables are stationary. All variables in the form represented by (2) and (3) were found to be stationary at the 5% significance level. The lag length of the VAR was selected according to two criteria. First, the adequacy of the model was checked by calculating Ljung-Box Q-statistics for the diagonal elements of the residual covariance matrix to ensure the absence of serial correlation. Second, the multivariate generalizations of the Akaike Information Criterion (AIC) and Schwartz Bayesian Criterion (BIC) were used to measure the overall fit of the alternative models[18].

3.3.2. Constructing the Taylor Curve

In construction of the efficiency frontiers, I follow the methodology outlined in Taylor (1979) and Cecchetti, Flores-Lagunes, Krause (2006). The optimization procedure is best described by rewriting the structural model in (2) – (3) in its state-space representation,

$$Y_t = B\,Y_{t-1} + c\,i_{t-1} + v_t \tag{4}$$

where

$$Y_t = \begin{bmatrix} y_t \\ \vdots \\ y_{y-n} \\ \pi_t \\ \vdots \\ \pi_{t-n} \\ i_{t-1} \end{bmatrix} \quad B = \begin{bmatrix} \alpha_{11} & \cdots & \alpha_{1n} & \beta_{11} & \cdots & \beta_{1n} & \varnothing_{12} \\ 1 & 0 & \cdots & \cdots & \cdots & \cdots & 0 \\ 0 & \ddots & \cdots & \cdots & \cdots & \cdots & 0 \\ \alpha_{2n} & \cdots & \alpha_{2n} & \beta_{21} & \cdots & \beta_{2n} & \varnothing_{22} \\ 0 & \cdots & \cdots & \ddots & \cdots & \cdots & 0 \\ 0 & \cdots & \cdots & \cdots & \ddots & \cdots & 0 \\ 0 & \cdots & \cdots & \cdots & \cdots & 1 & 0 \end{bmatrix} \quad C = \begin{bmatrix} \varnothing_{11} \\ 0 \\ \vdots \\ \varnothing_{22} \\ 0 \\ \vdots \\ 1 \end{bmatrix} \quad V = \begin{bmatrix} \varepsilon_{1t} \\ 0 \\ \vdots \\ \varepsilon_{2t} \\ 0 \\ \vdots \\ 0 \end{bmatrix} \tag{5}$$

[17] Details regarding the specific interests used before 1999 for each country may be obtained upon request of the author.

[18] All models and statistics may be obtained upon request from the author.

In matrix notation, the loss function in (1) can be as:

$$Y_t' \Lambda Y_t \quad (6)$$

where Λ is a square weighting matrix with the first diagonal element equal to λ, the n^{th} diagonal element equal to (1- λ) and the remaining elements equal to zero. The objective of the central bank is to pick the interest rate path which minimizes (6) subject to the constraints of the economy imposed by (4). Given the quadratic nature of the loss function, the solution for the interest rate will be linear which is written as:

$$i_t = g Y_{t-1}. \quad (7)$$

The control vector g in the steady state is found using optimal control techniques and given by:

$$g = -(c'Hc)^{-1} c'HB \quad (8)$$

where H is the solution of the equations

$$H = \Lambda + (B + cg)' H (B + cg). \quad (9)$$

Given the estimated values of the parameters in B and c, one can solve H and g for any value of λ. For a given set of feedback coefficients, g, the stochastic component of Y_t is described by (7). Thus, the steady state covariance matrix of Y_t is given by Σ which satisfies

$$\Sigma = \Omega + (B + cg)' \Sigma (B + cg). \quad (10)$$

where Ω is the covariance matrix of the residuals in V. The first and the n^{th} diagonal elements of Ω contain the steady-state variances. Given a particular weight to inflation stability, λ, this procedure determines a single point on the Taylor curve. By varying the weight assigned to inflation, an entire Taylor curve can be traced out[19].

3.3.3 Constructing the Taylor Curve Through Time

[19] While optimal control techniques are certainly subject to the Lucas critique, the empirical significance of the Lucas critique is ambiguous. See Favero and Hendry (1992), Hendry (2002), Estrella and Fuhrer (1999), and Ericsson, Hendry, Mizon, (1998) for further discussion.

As previously noted, the Taylor curve is used as a lens to historically evaluate country macroeconomic stability from the EMS to the EU. To that end, the VAR in section 3.1 was re-estimated for the 1960Q1-1981Q1 time period. I then subsequently derive the Taylor curve by implementing the procedure outlined in section 3.2 using the VAR coefficients estimated for the 1960Q1-1981Q2 time period. Given this efficiency frontier, the minimum orthogonal distance between the observed volatilities for the 1960Q1-1980Q1 time period and their optimal values are calculated. The above calculations are then repeated by adding one additional quarter of data, i.e. 1960Q1-1981Q2, and continued until the entire sample period is used in estimation. Thus, 40 Taylor curves are estimated for each 10 year period. The resulting time series is composed of minimum orthogonal distances of observed volatilities from their optimal values for each quarter dating back to 1981Q1. However, it is important to note that this metric does not assume any knowledge about the preference of the central bank. It is assumed that the efficiency of monetary policy can be reasonably gauged by how close the economy operates to it efficiency frontier without any explicit knowledge of λ.

3.4. Results

3.4.1. Efficiency of ECB Monetary Policy

The sample of countries was separated according to the size of the economy. France, Italy, and Spain account for approximately 40% of total output in the EMU; thus, these are considered as large countries. Austria, Belgium, and the Netherlands are considered small countries as they only account for approximately 12% of total EMU output. Figures 2a and 2b plot the output gaps for small and large countries. Interestingly, the output gaps for small countries appear more synchronized before the beginning of the EMS. While business cycles in small countries do appear somewhat more synchronized after 1999, it is not to the same degree as before 1979. Output gaps in large countries exhibit the opposite pattern. Business cycles appear more synchronized after the establishment of the EMS compared to the time period before. Figures 3a and 3b display the inflation rates for large and small countries. Note the convergence of inflation rates for small and large countries beginning in the late 1980s which corresponds to the development of the Maastricht Treaty. The Maastricht Treaty specified that unification of Europe was to be carried out in three stages. Stage I (1991-1993) called for the elimination of capital controls and induction of all EU members to the ERM. Stage II (1994-1998) began implementation of four convergence criteria meant to unify member states' economic policies. The criteria were the following. First, candidate country's average inflation rate observed during the year prior to the examination for admission to the euro could not be more than 1.5% higher than the average of the three best performing members. Second, government deficits must not exceed 3% of gross domestic product (GDP) and public debt must not exceed 60 % of GDP. Three, candidate countries must have observed the normal fluctuation bands provided in the EMS for two years without devaluing their currency. Fourth, the average long-term interest rate could not be 2% higher than the three best performing member states. Stage III (1999) introduced the euro and marked the beginning of active ECB monetary policy.

Figure 3.2a. Output Gap

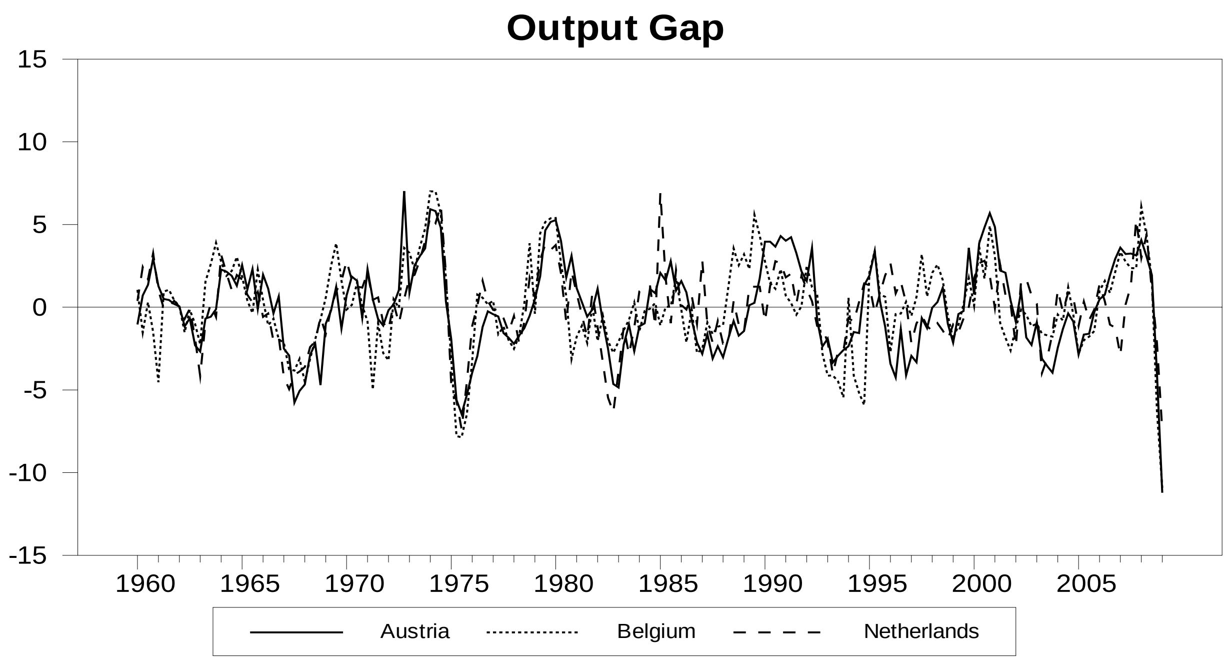


Figure 3.2b. Output Gap

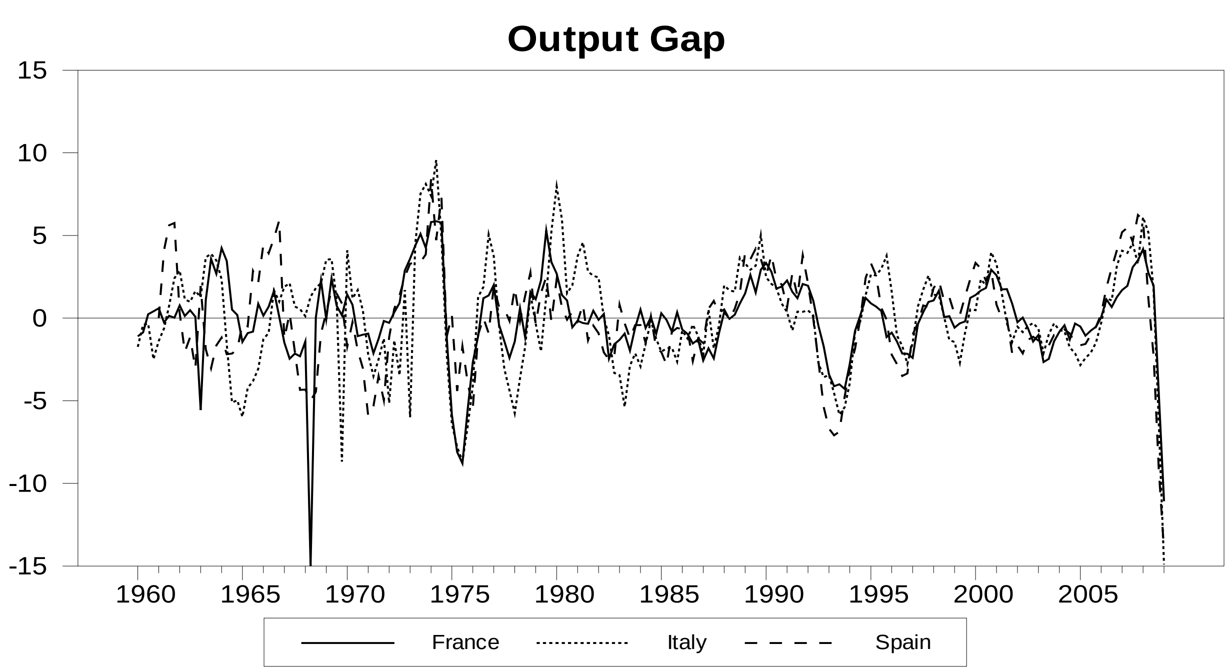


Figure 3.3a. Inflation

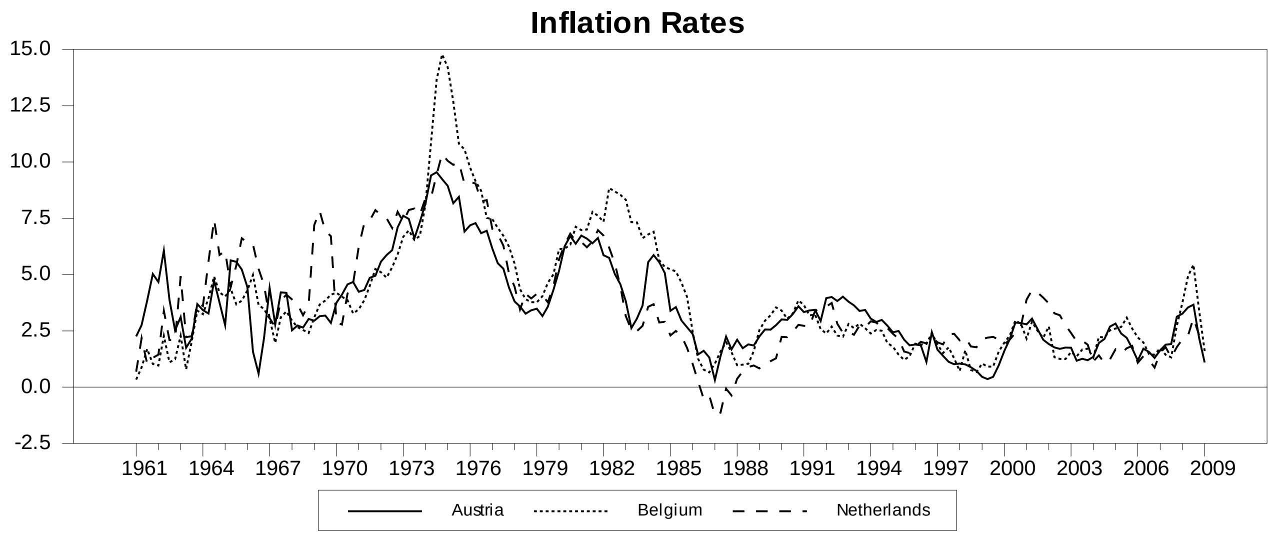
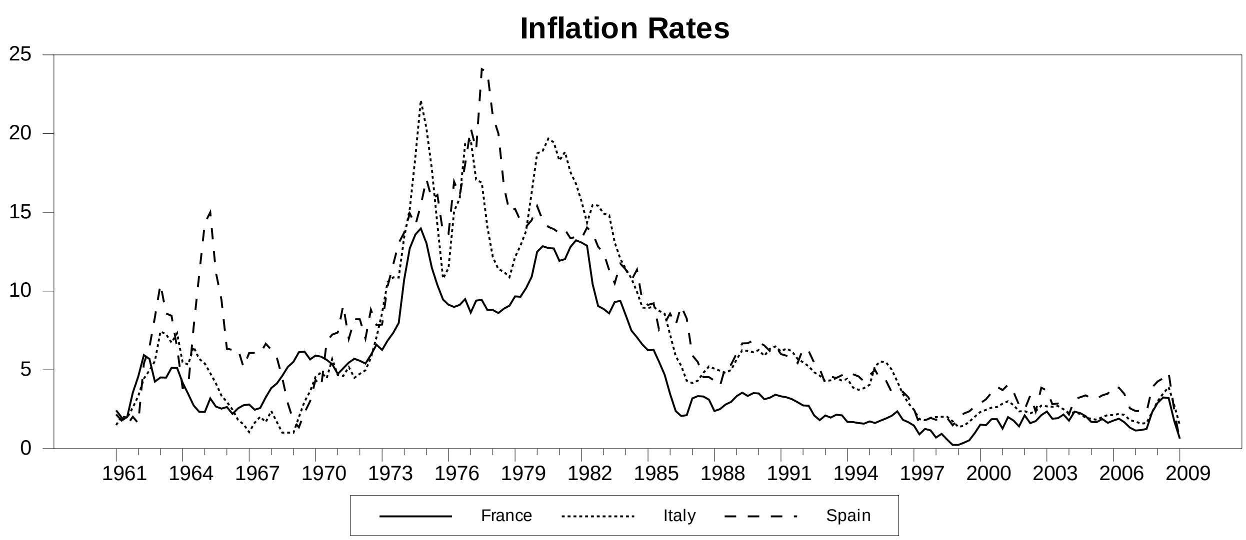


Figure 3.3b. Inflation



Figures 4a - 4f display a time series of minimum distances for each country as described in section 3.3. As noted in section 2, improvements in monetary policy move the observed volatilities towards their optimal levels. Large variations in the time series are suggestive of macroeconomic instability as the position of the economy relative to its efficiency frontier is not stable. However, as displayed in Figures 5a – 5f, the Taylor curves shift through time. Thus, changes in the minimum distances in Figures 4a – 4f could be the result of (1) the efficiency frontier shifting, (2) the economy moving towards or away from its efficiency frontier, or (3) a combination of (1) and (2)[20]. If the Taylor curve does not shift, a decrease in the distance suggests monetary policy has improved whereas an increase in the distances implies that monetary policy has worsened through time. If the Taylor curve shifts *inward*, i.e. the underlying variability of the economy declines, increases in the minimum distance suggests that the optimal levels of inflation and output gap volatility have decreased while the observed volatility levels have either remained constant or not decreased by the same amount the Taylor curve shifted inward. This situation suggests monetary policy has not fully adapted to the new economic environment. It is also possible the Taylor curve shifts outward while the observed volatility levels move inward, outward or stay constant. No assessment of monetary policy can be determined in cases in which the minimum distance decreases due to outward shifts in the Taylor curve; however, increases in the minimum distance would still suggest inappropriate monetary policy. In summary, increases in the minimum distance are always indicative of deteriorations in monetary policy whereas decreases in the minimum distance may be the result of improved monetary policy or outward shifts in the Taylor curve. Thus, Figures 4a – 4f and 5a – 5f are complementary.

[20] While a standardized or relative distance would be preferred, the author was not able to derive a consistent measure.

Notice Figures 4a – 4f suggest that the 1980s and early 1990s exhibit much more macroeconomic instability than the mid 1990s onward. While there are certainly many factors for this difference, a contributing factor was the currency realignments that took place throughout much of the 1980s. Table 1 lists the major currency realignments of Germany, Belgium, France, Italy, and the Netherlands to the ECU from 1979 - 1990. German realignments are included for two reasons. First, Austria did not join the European Economic Community until 1995. Austria entered into essentially an informal monetary union with Germany in 1981. From 1981 until the introduction of the euro in 1999, the schilling/mark exchange rate did not fluctuate by more than 0.1%. Thus, German realignments are included as a proxy for time periods in which the value of the Austrian schilling changed. Second, as noted in the introduction, the German mark was the strongest currency in the EMS. As such, German mark realignments have a significant impact on other EMS economies.

Table 3.1.

Currency Realignments to the ECU (1979-1990)

Year	DEM	BEF	NLG	FRF	ITL
1979	+2.0				
1980					
1981	+5.5		+5.5	-3.0	-6.0
					-3.0
1982	+4.25	-8.5	+4.25	-5.75	-2.75
1983	+5.5	+1.5	+3.5	-2.5	-2.5
1984					
1985	+2.0	+2.0	+2.0	+2.0	-6.0
1986	+3.0	+1.0	+3.0	-3.0	
1987	+3.0	+2.0	+3.0		
1988					
1989					
1990					-3.7

Dates are from the European Navigator's (ENA) knowledge database (www.ena.lu).
The German deutsche mark was included to establish time periods in which the Austrian schilling changed due to the schilling's peg to the mark.

The German mark appreciated by approximately 15% relative to the ECU from 1981-1983. As the German mark currency realignments became smaller in magnitude in the mid to late 1980s, the Austrian economy moved towards its efficiency frontier. The Belgian economy depreciated by 8.5% in 1982. Again note the increase in distance corresponding in 1982 in Figure 3.4b. As with Austria, as currency realignments become smaller in magnitude in the latter half of the 1980s, the Belgian economy moved towards its efficiency frontier. The relationship for the Netherlands between the distances and currency realignments in the 1980s mirrors that of Austria and Belgium.

The large currency depreciations which occurred in France and Italy during the 1980s also correspond to increases in macroeconomic volatility as displayed in Figures 4d and 4e. However, Figure 3.4d suggests that the French economy has steadily trended towards its efficiency frontier. Any currency realignments which did cause increases in macroeconomic instability appear short-lived. Unlike the French economy, the Italian economy does not significantly move towards its efficiency frontier. The Italian economy consistently is the furthest away from its efficiency frontier of any country in the sample. From 1981-1985, the Italian lira was depreciated by approximately 20% due to the large budget deficits of the Italian government. Notice the large increase in the minimum distances in the late 1980s in the Spanish economy, Figure 3.4f. Interestingly, admission to the EMS in 1986 appears to have increased the distance the Spanish economy operated from its Taylor curve.

The macroeconomic instability of the early 1990s in Figures 4a-4f is likely a result of the pound and lira currency crisis. High deficits due to reunification efforts in Germany fueled inflation and caused the Bundesbank to raise interest rates. However, high unemployment rates in much of the rest of the EU, specifically the U. K. and Italy, made maintaining exchange rate parity problematic. As a result, the Bank of England and Bank of Italy were forced to depreciate their currencies and withdraw from the ERM in 1992. In order to keep other member states from withdrawing, the EMS exchange rate bands were increased from 2.5% to 15%.

Of particular interest is macroeconomic stability that occurred in the mid-1990s in Figures 4a – 4f which corresponds to the beginning of Stage II of the Maastricht Treaty. While the convergence criteria did not cause economies to move towards their efficiency frontiers, it did provide fiscal and monetary constraints which translated to consistent monetary policy and stabilized the location of the economy relative to its Taylor curve. Notice that the beginning of active monetary policy by the ECB does not appear to have significantly affected the location of EU economies relative to its Taylor curve. While each domestic central bank has one vote on the ECB governing council, the steady movement of the French economy towards its efficiency frontier indicates that ECB policy has been more appropriate for the French economy relative to the other countries in the sample.

Figure 3.4a . Austria

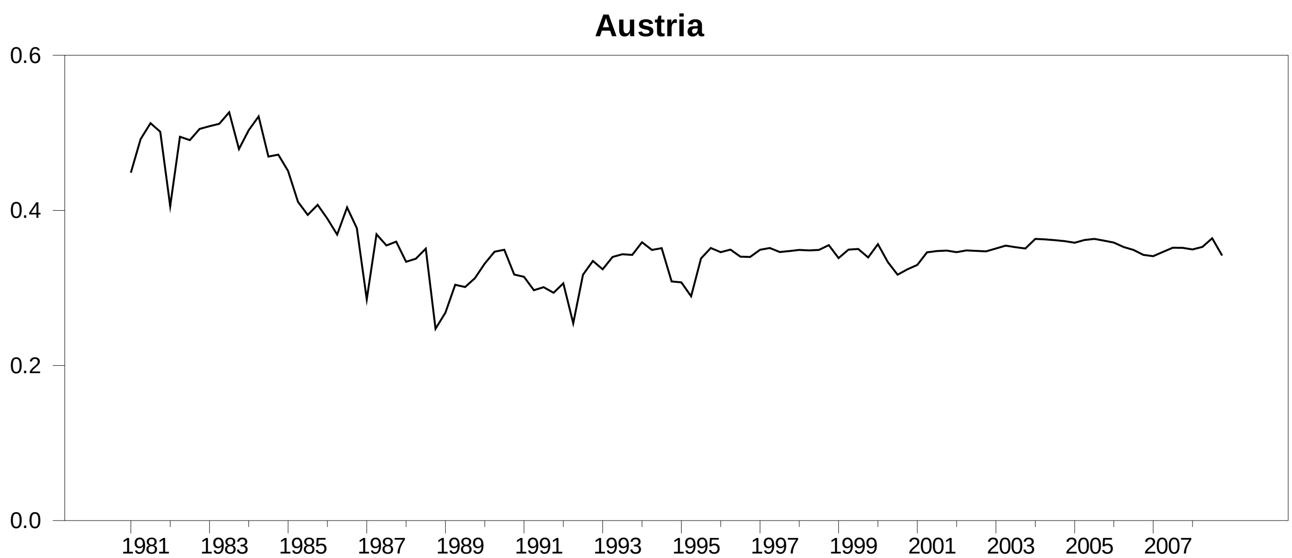


Figure 3.4b. Belgium

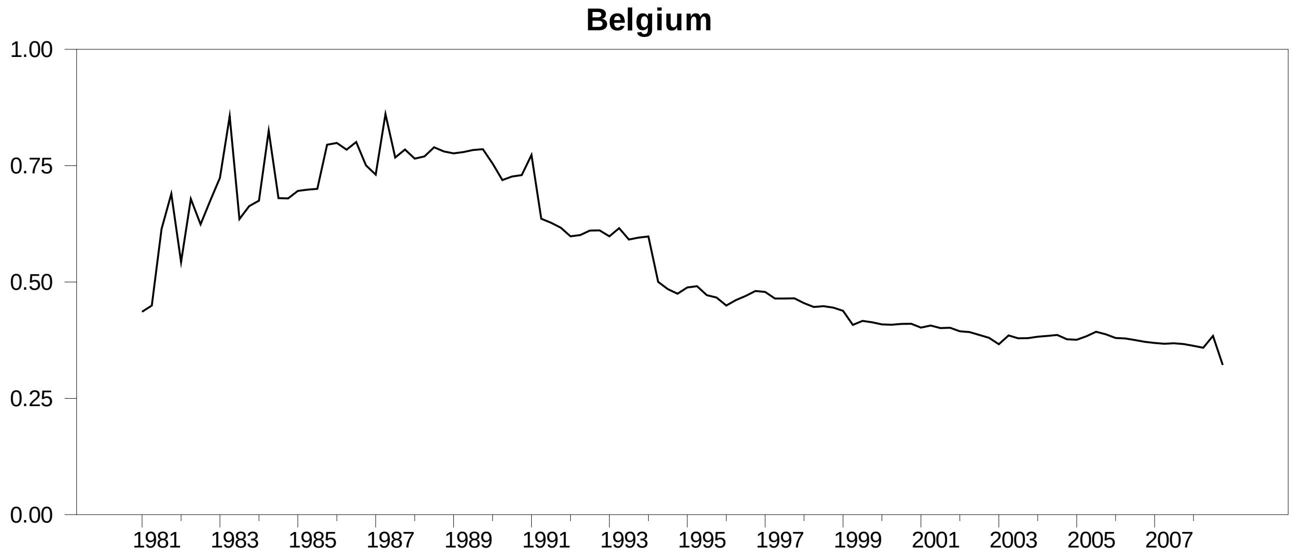


Figure 3.4c. The Netherlands

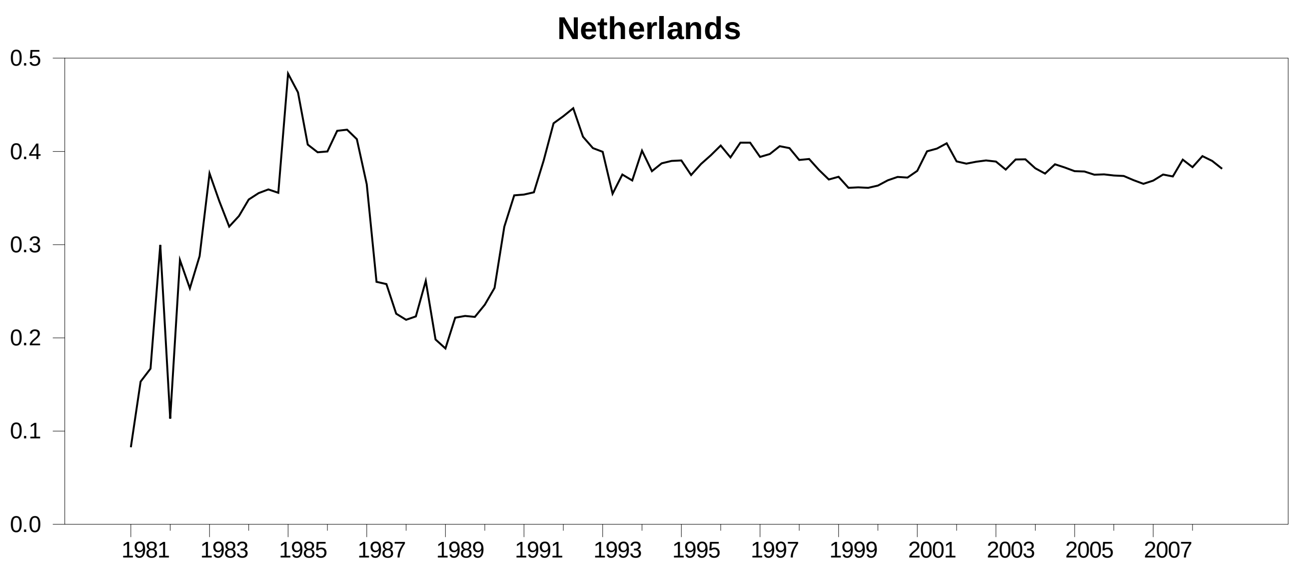


Figure 3.4d. France

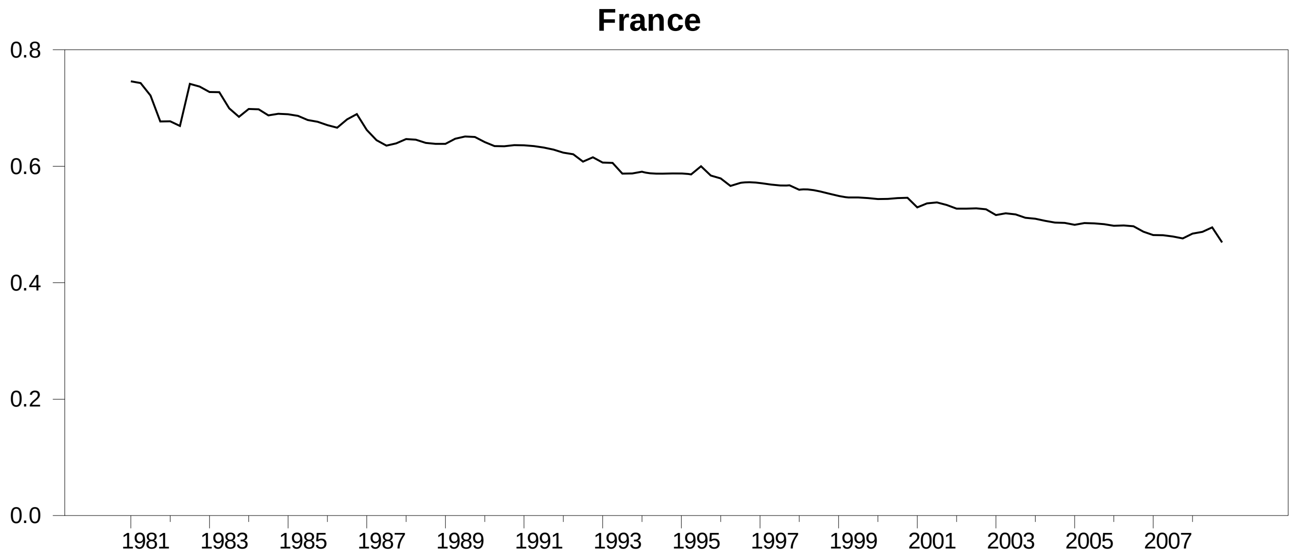


Figure 3.4e. Italy

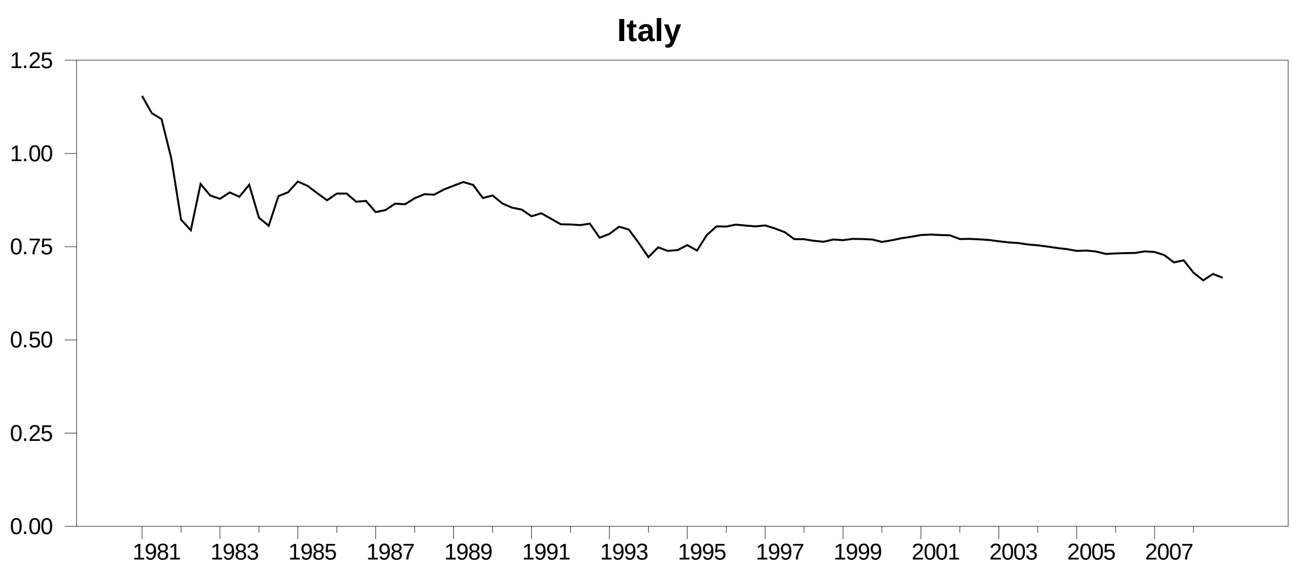
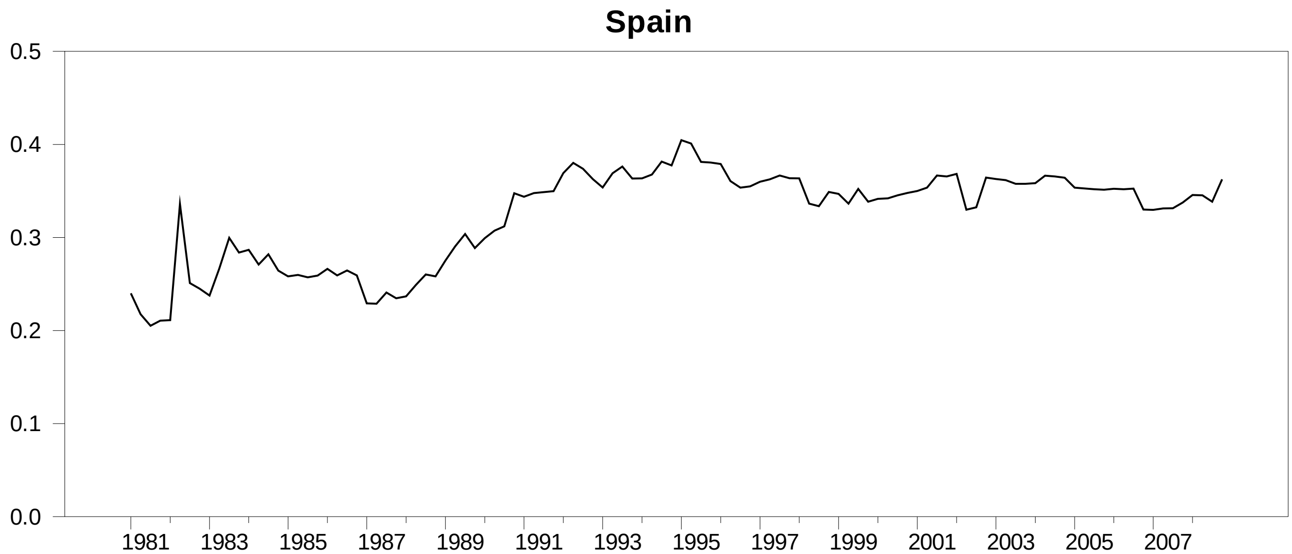


Figure 3.4f. Spain



4.2. *Taylor Curve as a Policy Menu*

As noted above, Figures 5a – 5f display Taylor curves and observed volatilities for the first quarter of 1988, 1998, and 2008 for each country[21]. The years 1988, 1998, 2008 were chosen simply to display how the Taylor curve has shifted through time[22]. With the exception of Belgium, the efficiency frontiers for all countries have shifted inward towards the origin. This inward shift is consistent with the well documented decline in the variances of output and inflation in many industrialized countries that began in the mid 1980s. Also, note the shape of the Taylor curve has changed through time. Again with the exception of Belgium, the efficiency frontier for each country has flattened out, implying the cost of stabilizing inflation in terms of output volatility has decreased since the 1980s. While there are certainly numerous factors that contributed to this phenomenon, a significant factor are the changes in the composition of EU

[21] All the Taylor curves estimated may be obtained upon request from the author
[22] The fact that the Taylor curve shifts suggests that a standardized or relative distance would be preferred to the absolute distance displayed in Figure 3.4. However, such a measure was not possible.

economies. Transition from manufacturing to service based economies has played a significant role in reducing the cost of stabilizing inflation.

As previously noted, some argue the Taylor curve has replaced the Phillip's curve as a policy menu for central banks. While the Taylor curves in Figures 5a – 5f are specific to the macroeconomic model in section 3, the significant variation in the location and concavity of the Taylor curves in Figures 3.5a – 3.5f suggests that policy makers should be particularly cautious in using the Taylor curve as a policy menu. As such, these results confirm Friedman (2006) that the Taylor curve is best viewed as an efficiency locus which may be used as a benchmark with which to gauge monetary policy rather than a menu from which to choose levels of inflation and output gap volatilities.

Figure 3.5a. Output-Inflation Tradeoff: Austria

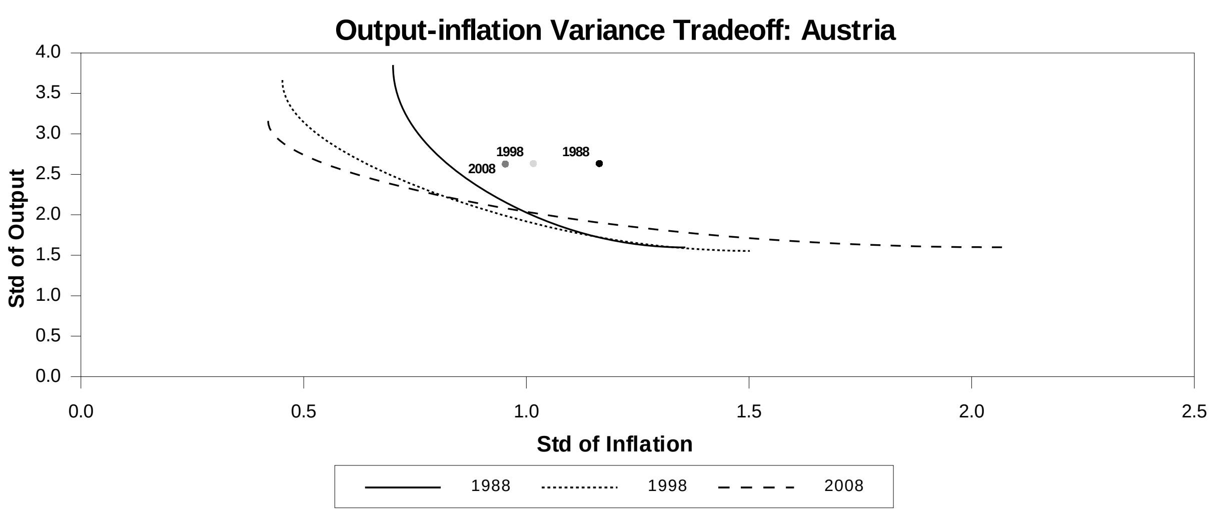


Figure 3.5b. Output-Inflation Tradeoff: Belgium

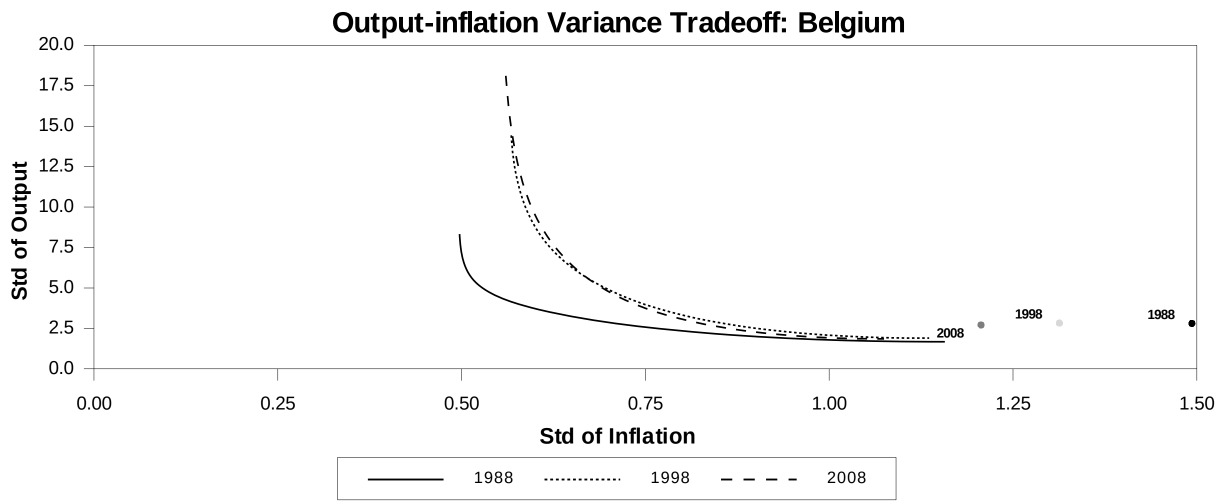


Figure 3.5c. Output-Inflation Tradeoff: the Netherlands

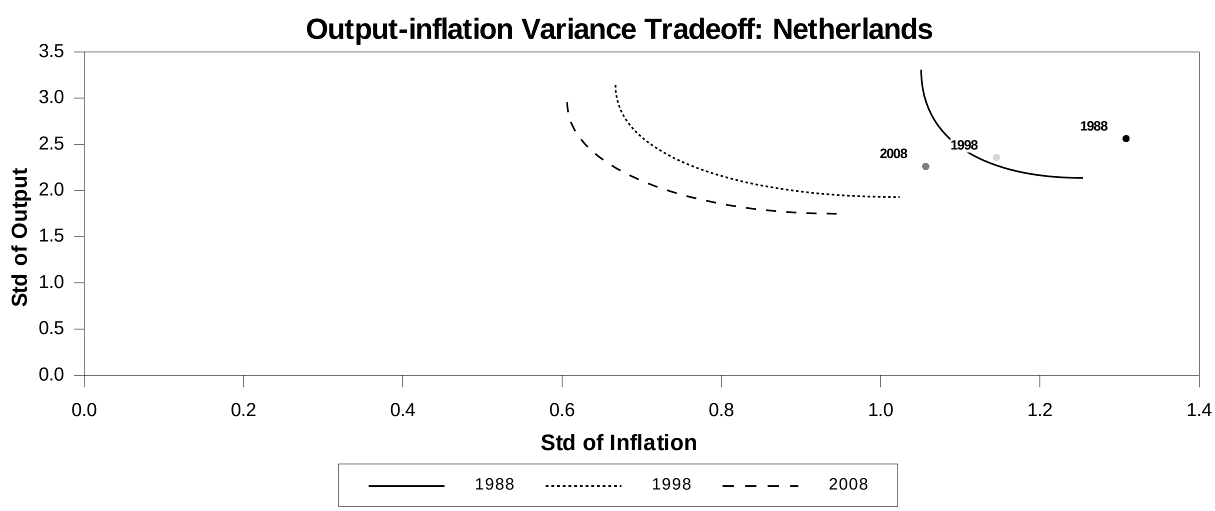


Figure 3.d. Output-Inflation Tradeoff: France

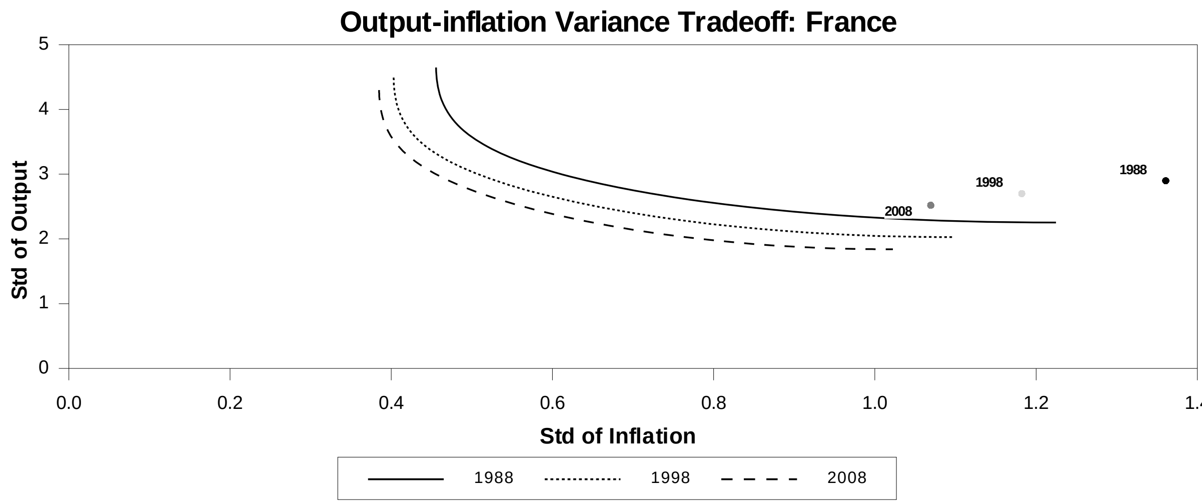


Figure 3.5e. Output-Inflation Tradeoff: Italy

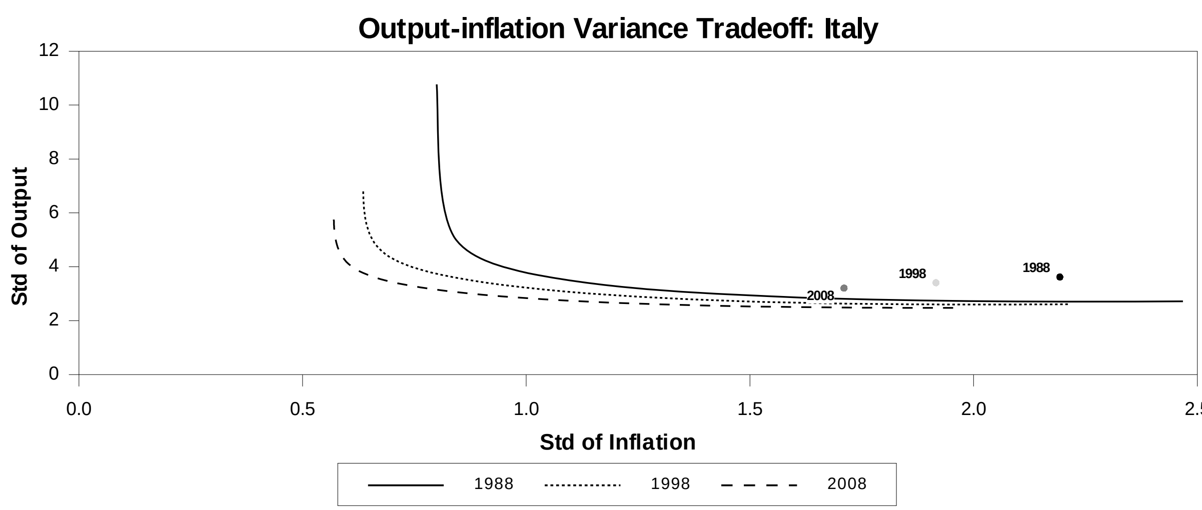
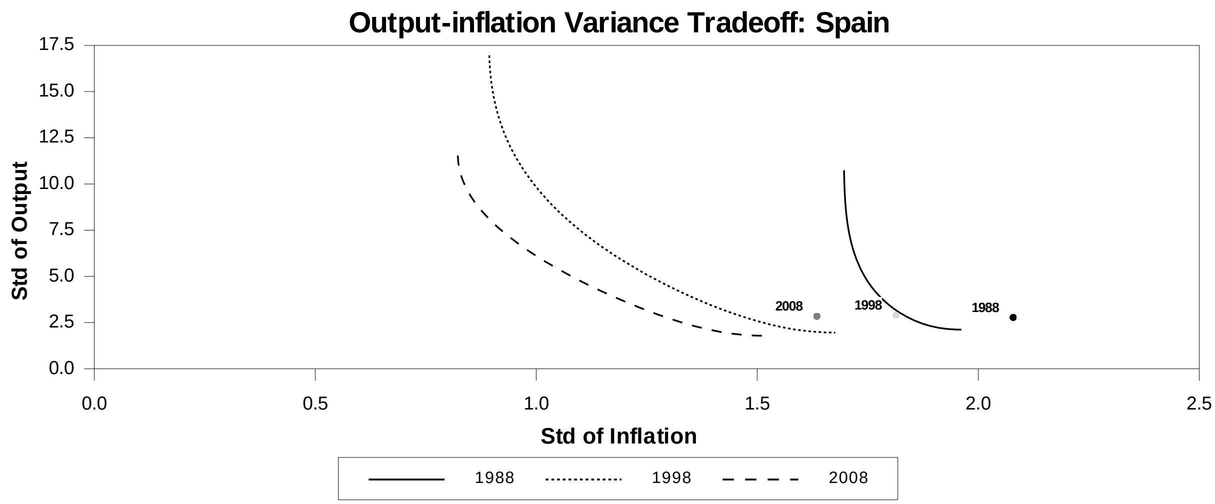


Figure 3.5f. Output-Inflation Tradeoff: Spain



3.5. Conclusion

By measuring the minimum orthogonal distance of the observed values of output and inflation volatilities from their optimal levels, I have historically evaluated macroeconomic performance of EU member states from the beginning of the EMS to the present. Results suggest the convergence criteria in Stage II of the Maastricht Treaty effected macroeconomic stability more than the beginning of active monetary policy of the ECB. The moderation in volatilities which occurred in many industrialized countries beginning in the mid 1980s is observed through inward shifts of EMU country Taylor curves. The compositional change of the European economies from a manufacturing to service sector economy has contributed to the decline in the relative price of inflation stability as measured by the slope of the Taylor curve. The significant variation in the location and concavity of European country Taylor curves' suggests that policy makers should be particularly cautious in using the Taylor curve as a policy menu.

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CHAPTER 4

CONCLUSION

The overall conclusions of this dissertation are the following. First, macroeconomic performance is substantially better when the Taylor curve relationship holds. Second, monetary policy history suggests that the stability of the economy is better during time periods in which interest rates are predictable. Third, ECB monetary policy is likely equally optimal for each member country. The currency crises in the EMS during the 1980s and early 1990s suggest are destabilizing for all EU countries. Central banks should be cautious in using the Taylor curve as a policy menu. Results suggests that the efficiency frontier frequently shifts.