Essays on Time Inconsistent Policy

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Essays on Time Inconsistent Policy

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Abstract

This research is mainly focused on the time-inconsistency during policy making process. It contains three chapters as follows:

Chapter One is to research into the time-inconsistency problem in policy making with extensive form games. The paper divides the game into four scenarios: one-stage independent game, one-stage forecasting game, finite stage forecasting game and infinite period game. The first two games show that neither government nor public want to be type 1 and government always has an incentive to deviate from announced policy. The last two games are mainly focused on the possibilities that both players want to randomize their strategies. The games are able to conclude that players only randomize under certain conditions.

Chapter Two is to prove the existence of time-inconsistent monetary policy in the U.S. empirically by applying both non-parametric method and rolling estimation for time varying analyses along with the asymmetric policy preference model, this paper proposes that with almost every recession since 1960, the rolling method reaches a break point shortly before or right at the recession date and that the non-parametric method reaches a peak for every recession that is not caused by supply shock. In addition, this paper uses the chain-weighted PCE index to conclude that there exists time-inconsistent policy preference over different recession periods, and also to compare results with the chain-weighted GDP index. The study discovers that the PCE index in general will result higher targeted inflation rate than the GDP index, and policy preferences are different during pre- and post-recessions with both indexes.

Chapter Three is extending the empirical analysis to different countries by studying the policy preferences of pre- and post-recession periods. Most countries depict their policy preferences as time-inconsistent. Moreover, by adjusting the non-stationarity problem in the data during the first-stage regression, the paper is able to capture the differences between both analyses. The study concludes that only Italy, Netherlands and Canada are not affected by non-stationarity problem that much and both analyses can reach a general consistent results; whereas the rest countries are greatly affected by the non-stationarity problem, especially the US and UK.

Contents

1 Chapter One

Applied Dynamic Games on the Time-inconsistency Problem

Abstract

This paper contributes to the literature by research into the time-inconsistency problem in policy making with extensive form games. The paper divides the game into four scenarios: one-stage independent game, one-stage forecasting game, finite stage forecasting game and infinite period game. The first two games show that neither government nor public want to be type 1 and government always has an incentive to deviate from announced policy. The last two games are mainly focused on the possibilities that both players want to randomize their strategies. The games are able to conclude that players only randomize under certain conditions.

1. Introduction

The debate over rules or discretion on monetary policy has continued since Kydland and Prescott (1977), from which the optimal policy is not time consistent. In the work of Calvo (1978), it stated that in any economy there exists a potential problem of time-inconsistency if public is sensitive to policy announcement. Hence, whether the time-inconsistency problem will be raised or not depends on public's belief and government's credibility on conducting monetary policy. In the subsequent work of Barro and Gordon (1983), Barro (1986), Backus and Driffill (1985a,b) and some others, they all include different types of government by conducting policies and allow the learning and reputation building process. In Barro's papers, they are able to compare the costs under commitment and discretion and conclude that time-inconsistent policy can result short-term benefit. However, in the long run, public has raised their expectations; hence, the costs will be lower than the short run. In Backus and Driffill's papers, they adopted game theoretical analysis by assuming public and government are having the expectations and policy conducted simultaneously. They conclude that whether government should stay committed or play discretionary is depending on its reputation by comparing the expected payoff. Moreover, in the later Backus and Drifill (1985b) paper, it includes different types of public as well, which is applied in this paper.

In more recent researches, time inconsistent problem is mainly focused on finding equilibriums without different types of government and publics. In Lambertini and Rovelli(2003), they examined the interactions between monetary and fiscal authorities in a game theoretical approach in finding Nash and Stackelberg equilibriums. It concludes that both authorities prefer Stackelberg equilibrium than Nash equilibrium and there exists a first mover disadvantage in the game. Moreover, it is better to have fiscal authorities to be the Stackelberg leader due to the institution process, such as fiscal policy always set before monetary policy in reality and revised less often. In Klein et al.(2008) paper, it studies how a benevolent government trade-off costs and benefits of public expenditures with a dynamic game theoretical approach between successive governments and solve for Markov-equilibrium under the assumption that government is time-inconsistent. The paper concludes that under time-inconsistent assumption, government may not be benevolent and there exists conflicts of goals between different parts of the governments. In Cargill and Guerrero(2007) paper, the time-inconsistent analysis in Japan's deflation is more related to the real problem. The paper applies the Barro and Gordon (1983) framework with one-stage game between central bank and private sector subject to the amount of debt that can be varied with deflation and inflation, and analyze the Nash equilibrium in the game. It concludes that the solution to time-inconsistent problem in both inflation and deflation is to provide central bank a current inflation target.

Despite all the researches have been done in this field, the thing that is absent from previous literatures is that most researches only considers simultaneous game with finite period. This paper proposes to analyze this problem with extensive form game and extend to infinite period. By applying Backus and Drifill's game theoretical analysis of two types of government and public together with Barro (1986)'s idea on analyzing the players willingness to randomize their strategies, this paper is able to discover that under different types of games, players willingness to randomize their strategy differs.

The rest of the paper is organized as follows. Part 2 includes the model and assumptions that are needed in the analysis; Part 3 is the one-stage extensive game under the assumption that both players are treating each stage independently; Part 4 is the two-stage game for the one-period forward forecasting on opponent's strategy; Part 5 is the finite period forecasting game; and Part 6 is the infinite period game with the assumption that neither player will choose to be type 1 and not change their strategies forever.

2. Model

This paper uses the model from Backus and Driffill (1985a) to extend the analysis on time-inconsistency problem. The payoff function for the government is the following

$$u_g = -\frac{1}{2}ax_t^2 + b(x_t - x_t^e) \tag{1}$$

where x_t is the actual inflation that is implemented by government at t and x_t^e is the expected inflation rate from public at time t. a, b are positive constants and they are common knowledge. From the utility function, it is obvious that government can gain benefits from surprise inflation while the public dislikes it with utility function as

$$u_p = -(x_t - x_t^e)^2 \tag{2}$$

where the maximum value can be reached when $x_t^e = x_t$. The government's objective is to maximize its expected payoff

$$G = \sum_{t=0}^{\infty} \beta^t u_g \tag{3}$$

where $\beta \in (0, 1)$ is the discount rate; similarly, public also wants to maximize its expected payoff

$$V = \sum_{t=0}^{\infty} \rho^t u_p \tag{4}$$

where $\rho \in (0, 1)$ is the discount rate. Dynamic inconsistency arises here due to government and public have different optimization problem (Fischer, 1980).

The game starts with government makes announcement that $x_t = 0$ for this period, then public makes his expectations and government makes move in the end. Public's expectation toward inflation rate can be captured by government from consumer expenditures. If public expects surprise inflation, they will spend more for the current period; vice versa. Government knows that play $x_t = \frac{b}{a}$ can give him higher utility than play$x_t = 0$ under both circumstances that $x_t^e = 0$ and $x_t^e = \frac{b}{a}$. It will reach maximum $U_g = \frac{b^2}{2a}$ if he successfully fools the public. Moreover, public knows that he can only reach the maximum payoff if his expectation on the inflation is the same as the actual rate. Hence, the questions arise here as if government will ever play committed case or if government wants to implement surprise inflation as soon as possible.

In this paper, there exists two types of government with the ability to build reputation, which is originated from Backus and Driffill (1985a). There are type 1 and type 2 government in the game. Type 1 government always follow the announced policy and never deviates while type 2 can randomize his choices on inflation rate but prefer to have surprise inflation. Type 2 government can choose to either behave as type 1 that follows the announced policy or reveal his true identity by conducting surprise inflation. In the paper, it assumes that public's view on type 1 government is with probability $p_t \in (0,1)$ and type 2 government behaves as type 1 with probability $\widetilde{\alpha_t} \in (0,1)$ whereas reveal his identity with probability $1 - \widetilde{\alpha_t}$. Government, on the other hand, knows his own type and the probability to fool the public is α_t, which α_t may or may not equal $\widetilde{\alpha_t}$. The process for reputation follows Baye's Law as

$$p_{t+1} = \begin{cases} 0 & \text{if } x_t \neq 0 \\ \frac{p_t}{p_t + (1-p_t)\widetilde{\alpha_t}} & \text{if } x_t = 0 \end{cases} \tag{5}$$

which $p_{t+1} > p_t$ if $x_t = 0$ and p_0 is common knowledge.

This paper also includes two types of public. Type 1 public always trust government's announcements and set the expectation $x_t^e = 0$. Type 2 public can either choose to believe government as type 1 or have doubts on the announcement and set the expectation as $x_t^e = \frac{b}{a}$. Government's view on type 1 public is with probability $q_t \in (0,1)$ and type 2 public that trusts government is with probability $\widetilde{\theta}_t \in (0,1)$ whereas have doubts in government's policy as $1-\widetilde{\theta}_t$. Similarly, public knows his own type and the probability of type 2 to trust government is θ_t, which θ_t may or may not equal $\widetilde{\theta}_t$. The reputation process here is

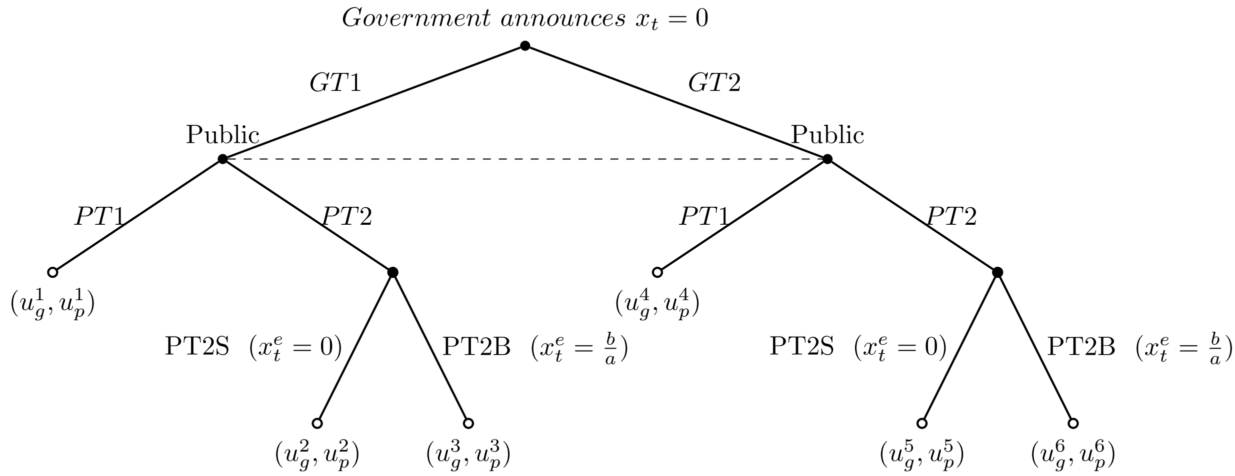
$$q_{t+1} = \begin{cases} 0 & \text{if } x_t^e \neq 0 \\ \frac{q_t}{q_t+(1-q_t)\widetilde{\theta}_t} & \text{if } x_t^e = 0 \end{cases} \tag{6}$$

where $q_{t+1} > q_t$ if public trusts government at last period and q_0 is common knowledge.

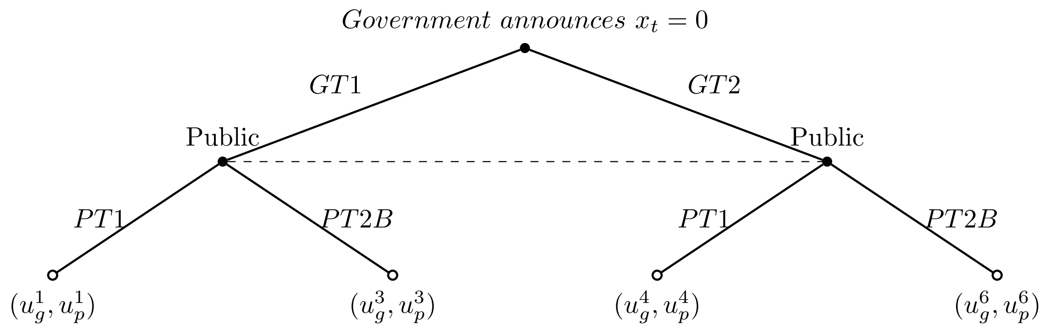
Both government's and public's nature are decided at the beginning and will not be changed since then. Furthermore, it assumes that government will reveal his identity at the last period and type 2 public will reveal his identity as soon as government reveals as type 2. Government will not try to play committed case after he reveals. The loss of reputation here exists as public will play $x^e = \frac{b}{a}$ for the rest of the game and not trust government anymore. It also assumes that α_t and θ_t follows the discrete time martingale, for which if $E[|\alpha_k|] < \infty$ then $E[\alpha_k|H_{k-1}] = \alpha_{k-1}$ where $k = 2, 3, \dots$ and $H_{k-1} = (\alpha_0, \alpha_1, \dots, \alpha_{k-1})$ (DasGupta, 2011); the same applies to θ_t. In other words, if type 2 government (public) masquerades as type 1 with probability α_t (θ_t)in time t, then the probability for government(public) to masquerade in the next period is also α_t (θ_t).

3. One-stage Extensive Game

In reality, if public and policy makers treat each stage as independent, then one-stage extensive form game is the natural method for this type of problem. In the game tree, the dashed line indicates incomplete information. $GT1$ represents the type 1 government while $GT2$ is type 2 government. $PT1$ is type 1 public, $PT2$ is type 2 public, $PT2S$ is the type 2 public that trusts government and $PT2B$ is the type 2 public that not believe government's announcement.



However, since this is a one-stage game, if type 2 public trusts government, then it will yield the same result as play type 1; therefore, the game tree can be reduced into the following



for which u_g and u_p represents the expected payoff to government and public respectively. When both players are playing type 1 in the game, $(u_g^1, u_p^1) = (0, 0)$. When government is playing type 1 but public does not trust government's announcement, the game results (u_g^3, u_p^3). Public being type 2 from government's point of view is with probability $(1 - q_t)(1 - \widetilde{\theta}_t)$, and the utility government can get is $-\frac{b^2}{a}$. The utility that public can get from not trust government in this case is $-\frac{b^2}{a^2}$, and the possibility this happens is p_t, which is the probability of government being type 1 from public's point of view. Moreover, with this one-stage game, if government plays in accordance with the announcement, then it is only because government is type 1 due to the assumption that type 2 government must reveal in the end. (u_g^4, u_p^4) represents the expected utility that government deviates from announcement but public trusts government. The possibility that public trusts government is $q_t+(1-q_t)\widetilde{\theta}_t$ and the possibility that government is type 2 is $1-p_t$. Therefore, $u_g^4 = (q_t + (1-q_t)\widetilde{\theta}_t)\frac{b^2}{2a}$ and $u_p^4 = -(1-p_t)\frac{b^2}{a^2}$. The last case is that both players are type 2 with the probability of $(1-q_t)(1-\widetilde{\theta}_t)$ on public and $1-p_t$ on government. So $(u_g^6, u_p^6) = (0, (1-q_t)(1-\widetilde{\theta}_t)(-\frac{b^2}{2a}))$. Due to existence of incomplete information, the game can be further written as a simultaneous game:

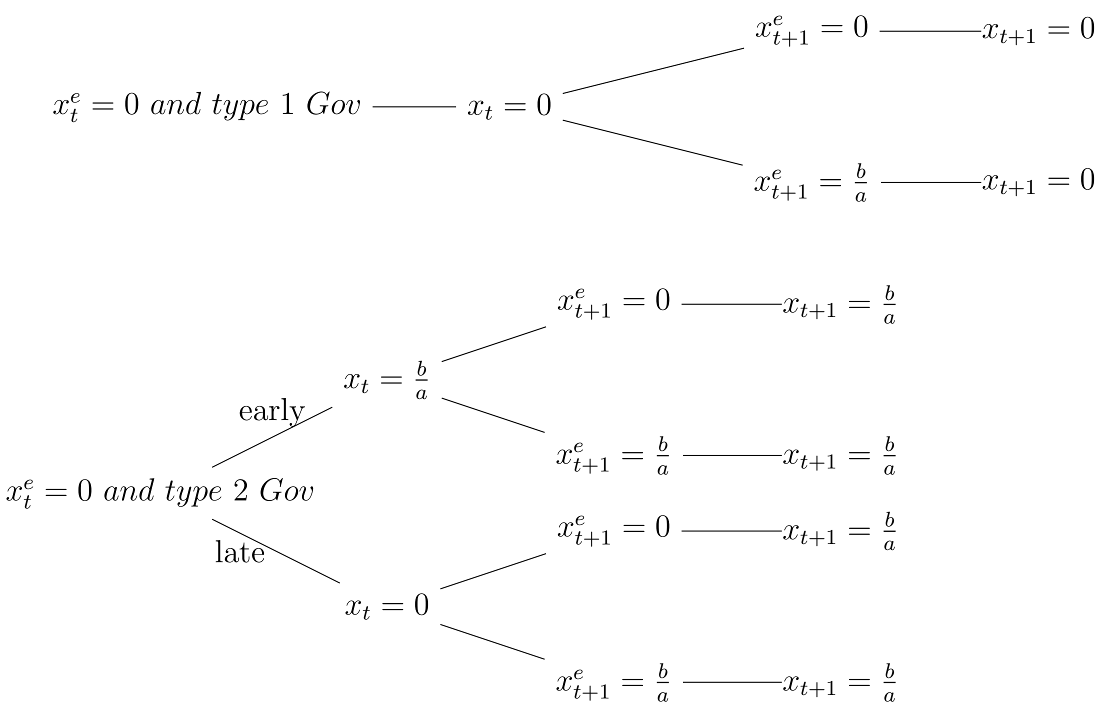
		Government	
		T1	T2
Public	T1	0,0	$(1-p_t)(-\frac{b^2}{a^2})$,$[q_t+(1-q_t)\widetilde{\theta}_t]\frac{b^2}{2a}$
	T2B	$p_t(-\frac{b^2}{a^2})$,$(1-q_t)(1-\widetilde{\theta}_t)(-\frac{b^2}{a})$	0,$(1-q_t)(1-\widetilde{\theta}_t)(-\frac{b^2}{2a})$ *

From the game matrix, it is not hard to see that government never play type 1 since playing type 2 can always bring government higher payoffs. When government behaves as type 2, the best response to public is to play type 2 as well. Therefore, both players are behaving as type 2 is the equilibrium point here. In this case, at every stage, government will choose to deviate from committed case and public will not trust government, which brings time-inconsistent problem and the loss of reputation continues. This equilibrium is Pareto inferior compared to the case when both players choose to be type 1. However, in a more realistic case, government may want to rebuild the credibility. In fact, in the US monetary history, 1980-86 is the time period that Federal Reserve builds its reputation and 1987-2007 is the period that Central Bank operates with credibility (Cooke and Gavin, 2014). Future researchers can consider this into the analysis as well.

4. Two-stage Extensive Game

In order to consider into the forward looking behaviors in this type of market, two-stage game is applied here as allow one period forward forecast. In the two-stage game, the paper looks into the questions if government ever play committed policy and if type 2 government always wants to reveal early. This part is not focusing on finding equilibrium; instead, it breaks into four cases and analyze each player's best response under each circumstance. Suppose only period t and period $t+1$ are considered here and assume from all periods prior to t, government played $x_k = 0$ for which $k = (1, 2, \ldots, t-1)$; therefore, there existed some reputations already.

4.1 If public plays $x_t^e = 0$, what is government's best response?



The above game trees show the possible government actions when he sees public does not expect surprise inflation. The expected utility for type 2 government with early reveal is:

$$EU^1 = \frac{b^2}{2a} + q_{t+1}\beta\frac{b^2}{2a} + (1 - q_{t+1})\beta(-\frac{b^2}{2a}) \tag{7}$$

which in this case there is no need to consider the possibility that type 2 public masquerade as type 1. According to previous assumption that public will reveal right after government; therefore, if public still plays zero inflation expectation after government reveals, it will result a type 1 case here. The expected utility of type 2 government with late reveal is:

$$EU^2 = [q_{t+1} + (1 - q_{t+1})\widetilde{\theta_{t+1}}]\beta\frac{b^2}{2a} + (1 - q_{t+1})(1 - \widetilde{\theta_{t+1}})\beta(-\frac{b^2}{2a}) \tag{8}$$

for which there exists possibility that type 2 public masquerades as type 1 and chooses to trust government. By comparing EU^1 with EU^2, it is able to find the best response for government in this case. One thing to notice from EU^2 is that it is an increasing function with $\widetilde{\theta_{t+1}}$; therefore, in order to maximize the expected payoff with late reveal, $\widetilde{\theta_{t+1}}$ has to be maximized.

First of all, if government believes that $q_{t+1} \geq \frac{1}{2}$, then $q_{t+2} = \frac{q_{t+1}}{q_{t+1}+(1-q_{t+1})\widetilde{\theta_{t+1}}} \geq \frac{1}{2}$. Therefore, $\widetilde{\theta_{t+1}} \leq \frac{q_{t+1}}{1-q_{t+1}} \leq 1$, which EU^2 is maximized at $\widetilde{\theta_{t+1}} = 1$, then the expected utility becomes

$$EU^2 = \beta\frac{b^2}{2a} \tag{9}$$

and the condition for $EU^1 > EU^2$ is

$$\beta < \frac{1}{2 - 2q_{t+1}} \tag{10}$$

which since $q_{t+1} \geq \frac{1}{2}$ and $\frac{1}{2-2q_{t+1}} \geq 1$, the condition holds for certain.

On the other hand, if government believes that $0 < q_{t+1} < \frac{1}{2}$, then $\widetilde{\theta_{t+1}}$ will be maximized at $\widetilde{\theta_{t+1}} = \frac{q_{t+1}}{1-q_{t+1}}$. Therefore,

$$EU^2 = q_{t+1}\beta\frac{b^2}{a} - (1-2q_{t+1})\beta\frac{b^2}{2a} \tag{11}$$

and the condition for $EU^1 > EU^2$ is

$$\beta < \frac{1}{2q_{t+1}} \tag{12}$$

which holds for sure since $\frac{1}{2q_{t+1}} > 1$. In other words, if public does not expect surprise inflation at the first stage, then the best response for type 2 government is to reveal early.

The next thing is to check if government is willing to be type 1. The expected utility of government behave as type 1 is EU^0, for which

$$EU^0 = (1-q_{t+1})(1-\widetilde{\theta_{t+1}})\beta(-\frac{b^2}{a}) \tag{13}$$

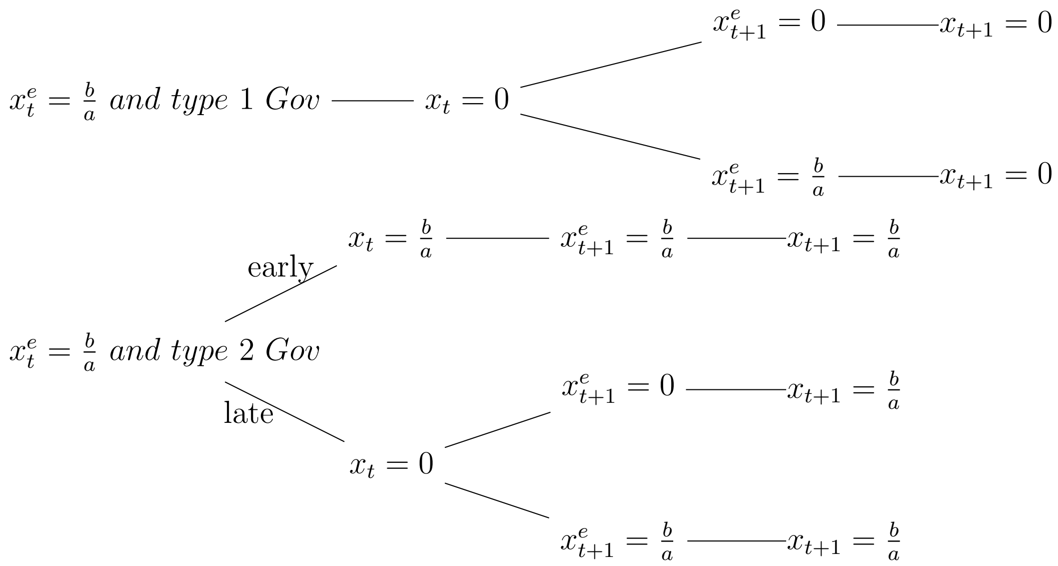
If Government decides not to be type 1, then the expected utility for being type 2 should be higher than type 1. Therefore, the following inequality holds

$$\begin{gathered}(1-\alpha_t)EU^1 + \alpha_t EU^2 - EU^0 > 0 \\ \iff \\ \frac{b^2}{2a}[1-\alpha_t + 2\beta(1-\widetilde{\theta_{t+1}})(1-q_{t+1}) + \beta(2q_{t+1}-1) + 2\beta\alpha_t(1-q_{t+1})\widetilde{\theta_{t+1}}] > 0\end{gathered} \tag{14}$$

for which this condition holds for certain regardless of the value on q_{t+1}[1]. Hence, government will not play type 1 and the discount rate does not matter in this case.

4.2 If public plays $x_t^e = \frac{b}{a}$, what is government's best response?

[1]Appendix A



Now, instead of trust government, the public here expects surprise inflation. If type 2 government decides to reveal early, then his expected utility is

$$EU^3 = -\frac{b^2}{2a} - \beta\frac{b^2}{2a} \tag{15}$$

whereas if he decides to reveal late, then

$$EU^4 = -\frac{b^2}{a} + \widetilde{\theta_{t+1}}\beta\frac{b^2}{2a} - (1-\widetilde{\theta_{t+1}})\beta\frac{b^2}{2a} \tag{16}$$

In this case, public plays zero inflation expectation is only with probability $\widetilde{\theta_{t+1}}$ since he has revealed as being type 2. It is not obvious on which one has the higher value and one way to do this is by analyzing the difference between EU^3 and EU^4:

$$EU^3 - EU^4 = \frac{b^2}{2a}(1 - 2\beta\widetilde{\theta_{t+1}}) \tag{17}$$

for which if (17) > 0, it means government prefers to reveal early; vice versa. Due the existence of $\widetilde{\theta_{t+1}}$, it needs to be separated into cases:

Case 1: If $\widetilde{\theta_{t+1}} < \frac{1}{2}$, then $\beta < \frac{1}{2\widetilde{\theta_{t+1}}}$ for certain. In this case, $EU^3 > EU^4$ for sure.

Case 2: If $\widetilde{\theta_{t+1}} > \frac{1}{2}$, then only at the condition that $\beta < \frac{1}{2\widetilde{\theta_{t+1}}}$, $EU^3 > EU^4$; otherwise, $EU^3 < EU^4$.

Case 3: If $\beta = \frac{1}{2\widetilde{\theta_{t+1}}}$, then it is possible that government has no preference on the time of reveal. However, since $\beta \in (0, 1)$, this is only possible at $\widetilde{\theta_{t+1}} > \frac{1}{2}$.

Moreover, there still exists the possibility that government prefers to be type 1. Then the expected utility for this case, which is denoted as EU^5, is as the following:

$$EU^5 = -\frac{b^2}{a} + \beta(1 - \widetilde{\theta_{t+1}})(-\frac{b^2}{a}) \tag{18}$$

By comparing the expected utility of government being type 2 with type 1, the following inequality has to be satisfied if government prefers not to be type 1:

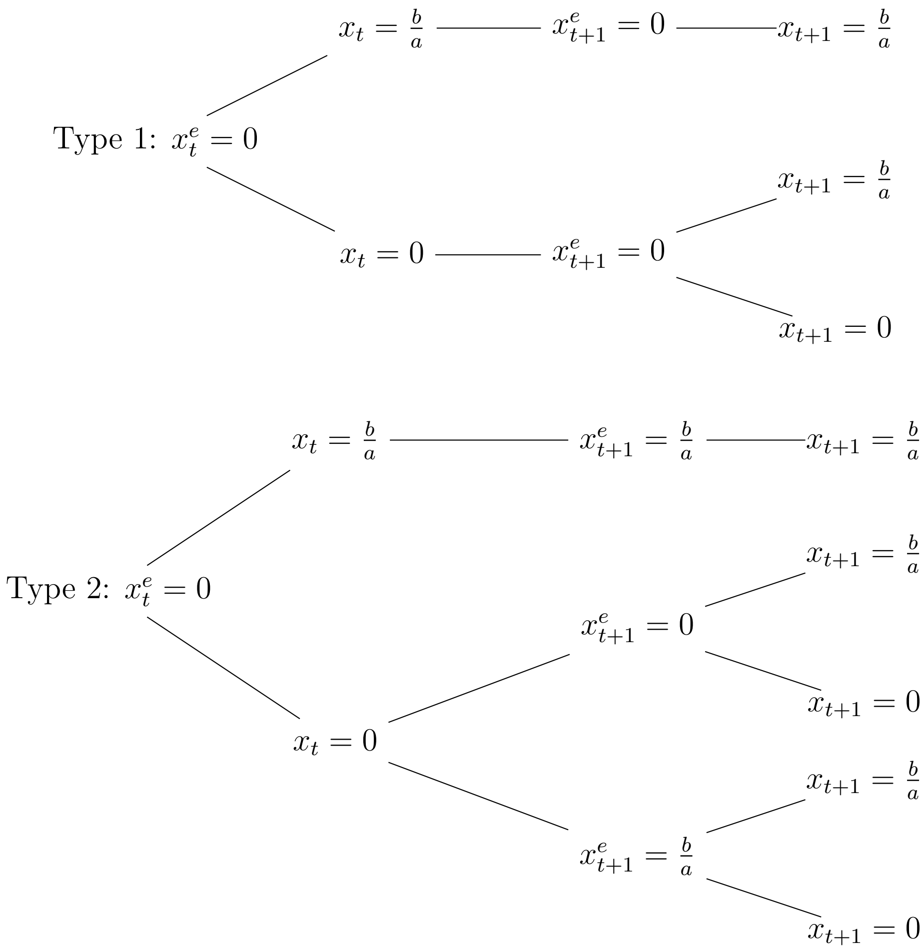
$$\begin{gathered} (1 - \alpha_t)EU^3 + \alpha_t EU^4 - EU^5 > 0 \\ \Longleftrightarrow \\ \frac{b^2}{2a}[1 + \beta - \alpha_t + 2\beta\widetilde{\theta_{t+1}}(\alpha_t - 1)] > 0 \end{gathered} \tag{19}$$

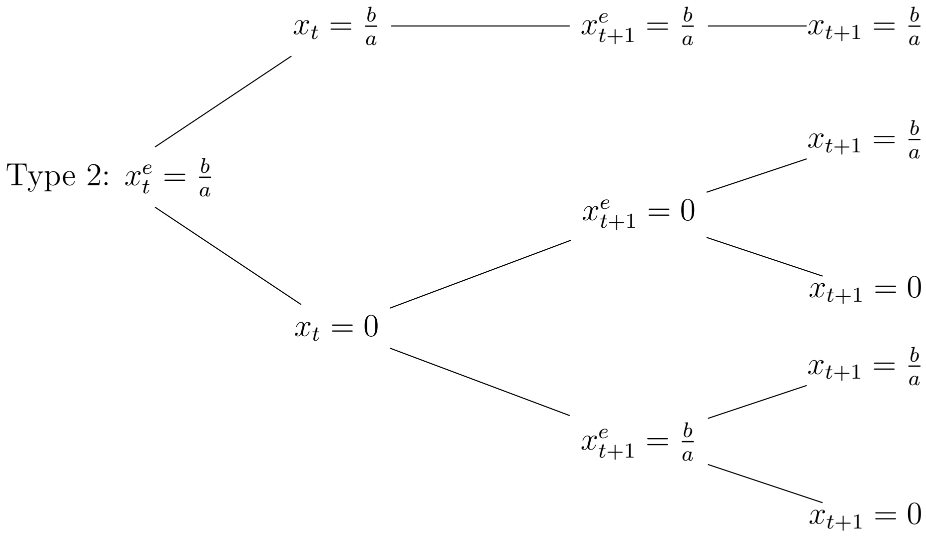
for which this condition holds for certain[2]. Therefore, in this case government will not choose to be type 1 either and it is possible that under certain condition between β and $\widetilde{\theta_{t+1}}$ government

[2] Appendix B

has no preference on the reveal time.

4.3 Since public moves first, what should be his best choice?





Now, instead of looking government's best response, this part is analyzing public's best response toward government's announcement. It has already proved that government will not choose to be type 1 on his own behalf; however, public does not know government's preference and it still has the possibility that public thinks government is type 1. Define the expected utility for type 1 public as EU_p^1, type 2 public that choose to trust government as EU_p^2 and expect surprise inflation as EU_p^3. Due to the fact that public is the first-mover in the game, he has to make a decision of his type before government's action.

Public sees surprise inflation from the first period with probability $(1 - p_t)(1 - \widetilde{\alpha}_t)$ and government stays committed with probability $p_t + (1 - p_t)\widetilde{\alpha}_t$. If government reveals at the first stage, the probability of surprise inflation, from public's point of view, will be 1. On the other hand, if government plays committed case at the first stage, then the possibility that government have surprise inflation at the last stage is $1 - p_{t+1}$. Therefore, the expected utility of type 1 public is

$$EU_p^1 = (1-p_t)(1-\widetilde{\alpha}_t)(1+\rho)(-\frac{b^2}{a^2}) + [p_t + (1-p_t)\widetilde{\alpha}_t](1-p_{t+1})\rho(-\frac{b^2}{a^2}) \tag{20}$$

Similarly, the expected utility for type 2 public is

$$EU_p^2 = (1-p_t)(1-\widetilde{\alpha}_t)(-\frac{b^2}{a^2}) + [(1-p_t)\widetilde{\alpha}_t + p_t]\rho(-\frac{b^2}{a^2})(p_{t+1} + \theta_{t+1} - 2p_{t+1}\theta_{t+1}) \tag{21}$$

$$EU_p^3 = [(1-p_t)\widetilde{\alpha}_t + p_t](-\frac{b^2}{a^2})\{1 + \rho\theta_{t+1}(1-p_{t+1}) + \rho p_{t+1}(1-\theta_{t+1})\} \tag{22}$$

for which equation (21) is the expected utility when public decides not to reveal at the first stage and equation (22) is the expected utility that public reveals early. The total expected utility for the type 2 public is

$$\begin{aligned} \theta_t EU_p^2 + (1-\theta_t)EU_p^3 =& (1-p_t)(1-\widetilde{\alpha}_t)\theta_t(-\frac{b^2}{a^2}) - \rho\frac{b^2}{a^2}[\theta_t\widetilde{\alpha}_t(1-p_t) + (1-\theta_t)p_t] \\ & - \frac{b^2}{a^2}(1-\theta_t)[(1-p_t)\widetilde{\alpha}_t + p_t] \end{aligned} \tag{23}$$

which θ_t is the probability that type 2 public trusts government and $1-\theta_t$ is the probability that public expects surprise inflation. Moreover, the martingale assumption is used here as the next period's probability to not trust government will be the same as this period. Therefore, the following condition has to be satisfied if public prefers to be type 1:

$$EU_p^1 > \theta_t EU_p^2 + (1-\theta_t)EU_p^3 \Leftrightarrow 1-\theta_t < \rho[(1-\theta_t)p_t - (1-p_t)(1-\theta_t\widetilde{\alpha}_t)] \tag{24}$$

There exists two possibilities. One is that if $(1-\theta_t)p_t - (1-p_t)(1-\widetilde{\alpha}_t\theta_t) < 0$, then $\rho < 0$ which cannot be true since ρ is the discount rate; the other one is that if $(1-\theta_t)p_t-(1-p_t)(1-\widetilde{\alpha}_t\theta_t) > 0$, then $\rho > \frac{1-\theta_t}{(1-\theta_t)p_t-(1-p_t)(1-\widetilde{\alpha}_t\theta_t)}$. However, $1-\theta_t > (1-\theta_t)p_t - (1-p_t)(1-\widetilde{\alpha}_t\theta_t)$; therefore, ρ in this case is greater than 1 and it is not possible for discount rate. Hence, public does not want to be type 1 either.

4.4 For type 2 public, when to stop trusting government?

Since public does not prefer to be type 1, so now the question becomes when to stop trusting government. Assume public choose to trusts government at the first stage and expects surprise inflation at the second stage, which needs to satisfy the condition

$$EU_p^2 > EU_p^3 \Leftrightarrow \widetilde{\alpha_t} > \frac{1-2p_t}{2-2p_t} \tag{25}$$

If public believes that $p_t \geq \frac{1}{2}$, then he will choose to trust government at the first stage, which also holds under the condition $0 < p_t < \frac{1}{2}$ and $\widetilde{\alpha_t} \in (\frac{1-2p_t}{2-2p_t}, 1)$. However, if $0 < p_t < \frac{1}{2}$ and $\widetilde{\alpha_t} \in (0, \frac{1-2p_t}{2-2p_t})$, then public will not trust government from the beginning. Public can also be indifferent between reveal early or late if $\widetilde{\alpha_t} = \frac{1-2p_t}{2-2p_t}$.

4.5 Summary

This part analyzes each player's best responses under different situations. There are four main points that can be concluded from this section:

1. Public under the framework here will never choose to be type 1, and government will always have an incentive to deviate

2. If public does not expect surprise inflation at the first stage, the best response for government is to reveal early

3. If public does not trust government's announcement at the first stage, then government

can choose to reveal either early or late or indifferent depends on the forecast of $\widetilde{\theta_{t+1}}$ and government's discount rate β

4. Public can choose to trust or not trust government at the first stage, which depends on p_t and $\widetilde{\alpha_t}$

5. Finite Forecasting Game

In a more general case, players may forecast more than one period ahead so that the two-stage game is not enough to explain the behaviors. In this part, assume players will have $N-1$ stage forecast, which $N \in (1, \infty)$; hence, the game goes from stage $n = 1$ to N and $n = 1$ is the current stage. From previous analysis, players are not willing to be type 1 for both finite period analysis; therefore, this game here will only consider the case with type 2 public and type 2 government. However, neither players knows the opponent's true type before some signals. The main problem that is analyzed here is whether players will randomize their strategies or to choose the strategy in accordance with the costs.

Type 2 Public: The expected utility for type 2 public in this game is:

$$\begin{aligned} EU_n^{p2} = &(1-\theta_n)\{[p_n + (1-p_n)\widetilde{\alpha_n}](-\frac{b^2}{a^2} + \rho EU_{n+1}^{p2})\} \\ &+ \theta_n\{[p_n + (1-p_n)\widetilde{\alpha_n}]\rho EU_{n+1}^{p2} + (1-p_n)(1-\widetilde{\alpha_n})(-\frac{b^2}{a^2})\} \end{aligned} \tag{26}$$

The first part of the equation is when public decides to reveal his identity at the first-stage by not trusting government's announcement. If government decides to stay committed, then public's payoff will be $-\frac{b^2}{a^2}$ and since the identity to government is uncertain, the game goes to the next stage. On the other hand, if government reveals at the first stage, then both players know each other's true type and the payoff to public is zero for the rest periods. The second part is type 2 public decides to trust government's announcement. If government does not reveal, this stage's payoff to public will be zero and the game goes to next stage. If government decides to reveal, for which by assumption public will reveal next period for certain, then the first-stage payoff to public will be $-\frac{b^2}{a^2}$ and the rest stages will result zero payoff. According to Barro(1986), if public wants to randomize his strategy between trust or not trust government, it has to be that EU_n^{p2} is independent of θ_n, which means $\frac{\partial EU_n^{p2}}{\partial \theta_n} = 0$; therefore, after simplification and re-arranging terms, the following condition has to be satisfied:

$$\widetilde{\alpha_n} = \frac{1 - 2p_n}{2 - 2p_n} \tag{27}$$

and this is only valid if $p_n < \frac{1}{2}$. In other words, if $p_n > \frac{1}{2}$, then $\widetilde{\alpha_n} < 0$, and this cannot be true; therefore, the randomization condition cannot be satisfied. Instead, if $p_n > \frac{1}{2}$, the expected utility is increasing with θ_n as $\frac{\partial EU_n^{p2}}{\partial \theta_n} > 0$; therefore, public in this case will play zero inflation expectation until the stage that $\frac{\partial EU_n^{p2}}{\partial \theta_n} < 0$.

Type 2 Government: The expected utility for type 2 government in this game is:

$$\begin{aligned} EU_n^{g2} &= [q_n + (1 - q_n)\widetilde{\theta_n}](1 - \alpha_n)\{\frac{b^2}{2a} + q_{n+1}\frac{b^2}{2a}(\beta + \cdots + \beta^{N-1}) \\ &+ (1 - q_{n+1})(-\frac{b^2}{2a})(\beta + \cdots + \beta^{N-1})\} \\ &+ (1 - \widetilde{\theta_n})(1 - \alpha_n)(-\frac{b^2}{2a})(1 + \beta + \cdots + \beta^{N-1}) \\ &+ \alpha_n\{[q_n + (1 - q_n)\widetilde{\theta_n}]\beta EU_{n+1}^{g2} + (1 - \widetilde{\theta_n})[-\frac{b^2}{a} + \beta EU_{n+1}^{g2'}]\} \end{aligned} \tag{28}$$

for which $EU_{n+1}^{g2'}$ is the expected utility that public reveals before government at stage $n+1$, such that

$$\begin{aligned} EU_{n+1}^{g2'} &= (1 - \widetilde{\theta_{n+1}})\{\alpha_{n+1}[(-\frac{b^2}{a}) + \beta EU_{n+2}^{g2}] + (1 - \alpha_{n+1})[(-\frac{b^2}{2a})(1 + \beta + \cdots + \beta^{N-2})]\} \\ &= (1 - \widetilde{\theta_{n+1}})\{\alpha_n[(-\frac{b^2}{a}) + \beta EU_{n+2}^{g2}] + (1 - \alpha_n)[(-\frac{b^2}{2a})(1 + \beta + \cdots + \beta^{N-2})]\} \end{aligned} \tag{29}$$

In equation (28), if government decides to reveal at the first stage and public does not expect surprise inflation, which means public is either type 1 or type 2 masquerades as type 1 from government's point of view, then the government's payoff for the first-stage is certain with $\frac{b^2}{2a}$. If public still plays committed at the second stage with probability q_{n+1}, which means public is type 1 and government's payoff will be $\frac{b^2}{2a}$ for the rest periods; instead, if public expects surprise inflation with probability $1 - q_{n+1}$, then the payoff to government will be $-\frac{b^2}{2a}$ from now on. If public also reveals at the first-stage, which means public is type 2 for certain and expects surprise inflation with probability $1 - \widetilde{\theta_n}$, then the payoff to government that decides to reveal will be $-\frac{b^2}{2a}$ forever. If both players choose to not reveal their identities at the first round, then the payoff to government will be zero and game moves on to the next stage. If public decides to reveal but government does not, then the first-stage payoff to government will be $-\frac{b^2}{a}$ and the expected payoff government can get is $EU_{n+1}^{g2'}$ by moving the game to the next stage. EU_{n+1}^{g2} is the process that public reveals before government. In equation (29), if public keeps expecting surprise inflation and government keeps playing the announced policy at stage $n+1$, the government's payoff will be $-\frac{b^2}{a}$ and game continues to the next stage with expected payoff EU_{n+2}^{g2}. If government reveals instead, then the payoff will be $-\frac{b^2}{2a}$ for the rest of the game. However, it is clear that the solution to $\frac{\partial EU_n^{g2}}{\partial \alpha_n} = 0$ is dependent on α_n and α_n depends on the knowledge of public; therefore, government will only randomize when $\alpha_n = sol(\frac{\partial EU_n^{g2}}{\partial \alpha_n} = 0)$ and $\alpha_n \in (0, 1)$. This condition arises here as government can purposely set the value α_n in accordance with the solution to randomize his strategies and makes his move unpredictable to the public, which may result false expectations from public. Otherwise, government will stay committed as long as $\frac{\partial EU_n^{g2}}{\partial \alpha_n} > 0$ and start to implement surprise inflation when $\frac{\partial EU_n^{g2}}{\partial \alpha_n} < 0$, which will continue to the rest of the periods. If $\frac{\partial EU_n^{g2}}{\partial \alpha} < 0$ from the first stage, then government will play discretionary policy till the end.

6. Infinite-periods Extensive Game

For a more general case, there will always be a next period for both public and government and nobody knows where it will end. Therefore, the infinite-period game is applied here as a natural agent for this problem. Type 1 case is dropped for the assumption that government cannot stay committed forever and public is not going to trust government forever. Suppose all players are playing $x = 0$ and $x^e = 0$ before they decide to randomize their strategies and nobody knows the opponent's true type before any signals. All other assumptions are consistent with previous analysis.

6.1 Public not reveal his type before government starts to randomize policy

If public plays $x^e_T = 0$ at period T, and government decides to randomize his strategy, then government can choose to reveal at T or not to reveal. If government decides to reveal at stage T, then his payoff at the first-stage is $\frac{b^2}{2a}$ for certain. At stage $T+1$, if public does not reveal, it means public is type 1 and government will have payoff $\frac{b^2}{2a}$ forever; however, if public expects surprise inflation, then the payoff to government will be $-\frac{b^2}{2a}$ for the rest of the game. If he chooses not to reveal, then the game will move on to the next stage with probability α_T. To reflect the expected utility of government EU^G_T in the equation:

$$\begin{aligned}EU^G_T &= (1-\alpha_T)[\frac{b^2}{2a} + q_{T+1}\frac{b^2}{2a}(\beta+\beta^2+\dots) + (1-q_{T+1})(-\frac{b^2}{2a})(\beta+\beta^2+\dots)] + \alpha_T\beta EU^G_{T+1} \\ &= (1-\alpha_T)\frac{b^2}{2a}[1 + q_{T+1}\frac{\beta}{1-\beta} - (1-q_{T+1})\frac{\beta}{1-\beta}] + \alpha_T\beta EU^G_{T+1}\end{aligned} \tag{30}$$

In order to randomize between $0 < \alpha_T < 1$, the government's expected utility has to be independent of α_T, which the following condition has to be hold:

$$\frac{\partial EU_T^G}{\partial \alpha_T} = 0$$
$$\Longleftrightarrow \tag{31}$$
$$EU_{T+1}^G \beta = \frac{b^2}{2a} + \frac{b^2}{2a} q_{T+1} \frac{\beta}{1-\beta} - \frac{b^2}{2a}(1-q_{T+1})\frac{\beta}{1-\beta} \qquad (*)$$

By plug-in equation (*) back to (26) and re-arrange terms, the original equation becomes

$$EU_{T+1}^G \beta = \beta[\frac{b^2}{2a} + \frac{b^2}{2a} q_{T+2} \frac{\beta}{1-\beta} - \frac{b^2}{2a}(1-q_{T+2})\frac{\beta}{1-\beta}] \qquad (**) \tag{32}$$

and by equating (*) and (**) with backward induction[3], a function of q_T can be written as

$$q_T = \frac{(2\beta-1)(1-\beta^{-T})}{2\beta} + \frac{1}{\beta^T} q_0 \tag{33}$$

Since public has not been expect surprise inflation before stage T, the original probability of public be type 1 should equation to the probability at stage T (Barro, 1986); therefore, $q_T = q_0 = \frac{2\beta-1}{2\beta}$ by equating equation (33) to q_0. Since $q_0, q_T \in (0,1)$, this condition can only hold when $\frac{1}{2} < \beta < 1$. In other words, government is willing to randomize if $\beta > \frac{1}{2}$ and not willing to if $\beta < \frac{1}{2}$. Therefore, under the circumstances of $\beta < \frac{1}{2}$, $\frac{\partial EU_T^G}{\partial \alpha_T}$ has to be examined, which depends on government's view on public been type 1 or type 2. If $\frac{\partial EU_T^G}{\partial \alpha_T} > 0$, government will stay committed until the stage that $\frac{\partial EU_T^G}{\partial \alpha_T} < 0$ for which will play discretionary policy by imposing surprise inflation till the end. If $\frac{\partial EU_T^G}{\partial \alpha_T} < 0$ from stage T, then government will play surprise inflation forever.

6.2 Government starts to randomize policy after public reveals at τ

[3] Appendix C

If public reveals before government randomizes, then government will know that public is type 2 for certain and government can choose to reveal immediately or not reveal. If he chooses to reveal, then the payoff to government will be $-\frac{b^2}{2a}$ forever. On the other hand, if government does not reveal, then the stage τ payoff will be $-\frac{b^2}{a}$. With probability $1-\widetilde{\theta_{\tau+1}}$, public will expect surprise inflation next period and it will result government payoff of $\widetilde{EU^G_{\tau+1}}$. With probability $\widetilde{\theta_{\tau+1}}$ public does not reveal next stage and expected payoff government can get is $E\hat{U}^G_{\tau+1}$, which is the process that public plays zero inflation expectation. Therefore, if government reveals, the $\tau+1$ stage payoff is $\frac{b^2}{2a}$ and the rest stages will only have $-\frac{b^2}{2a}$; if government does not reveal, then the expected utility for government becomes $E\hat{U}^G_{\tau+2}$ with probability $\widetilde{\theta_{\tau+2}}$ and $\widetilde{EU^G_{\tau+2}}$ with probability $1-\widetilde{\theta_{\tau+2}}$. To reflect these in the equation, it can be written as:

$$\widetilde{EU^G_\tau} = (1-\alpha_\tau)\frac{1}{1-\beta}(-\frac{b^2}{2a}) + \alpha_\tau[-\frac{b^2}{a} + (1-\widetilde{\theta_{\tau+1}})\widetilde{EU^G_{\tau+1}}\beta + \widetilde{\theta_{\tau+1}}E\hat{U}^G_{\tau+1}\beta] \tag{34}$$

which

$$\begin{aligned} E\hat{U}^G_{\tau+1} &= (1-\alpha_{\tau+1})\frac{b^2}{2a}(\frac{-\beta}{1-\beta}) + \alpha_{\tau+1}\beta[\widetilde{\theta_{\tau+2}}E\hat{U}^G_{\tau+2} + (1-\widetilde{\theta_{\tau+2}})\widetilde{EU^G_{\tau+2}}] \\ &= (1-\alpha_\tau)\frac{b^2}{2a}(\frac{-\beta}{1-\beta}) + \alpha_\tau\beta[\widetilde{\theta_{\tau+2}}E\hat{U}^G_{\tau+2} + (1-\widetilde{\theta_{\tau+2}})\widetilde{EU^G_{\tau+2}}] \end{aligned} \tag{35}$$

due to α_τ follows martingale process. It is not hard to see that the government's randomization decision depends on α_τ, for which can be set by government on purpose in order to randomize and misleading public's expectation; therefore, government will only randomize at a certain value of α_τ for which it is the solution to $\frac{\partial \widetilde{EU^G_\tau}}{\partial \alpha_\tau} = 0$. Otherwise, government will reveal immediately after public if $\frac{\partial \widetilde{EU^G_\tau}}{\partial \alpha_\tau} < 0$ and the expected utility will reach a solution of $\widetilde{EU^G_\tau} = \frac{1}{1-\beta}(-\frac{b^2}{2a})$. However, if $\frac{\partial \widetilde{EU^G_\tau}}{\partial \alpha_\tau} > 0$, then government will stay committed until the stage that $\frac{\partial \widetilde{EU_T^G}}{\partial \alpha_T} < 0$.

6.3 How about Public?

This section is examining public's expected utility upon the above two circumstances. The expected utility for public if he does not reveal before government randomizes strategy at stage T is the following:

$$\begin{aligned} EU_T^P &= (1-p_T)(1-\widetilde{\alpha_T})(-\frac{b^2}{a^2}) \\ &\quad + [p_T + (1-p_T)\widetilde{\alpha_T}][\rho(1-\theta_{T+1})\widetilde{EU_{T+1}^P} + \rho\theta_{T+1}EU_{T+1}^P] \end{aligned} \tag{36}$$

and $\widetilde{EU_{T+1}^P}$ is the expected utility to public at the next period if he reveals before government and it can be written as

$$\widetilde{EU_{T+1}^P} = [p_{T+1} + (1-p_{T+1})\widetilde{\alpha_{T+1}}][(-\frac{b^2}{a^2}) + \rho(1-\theta_{T+2})\widetilde{EU_{T+2}^P} + \rho\theta_{T+2}EU_{T+2}^P] \tag{37}$$

for which if government reveals at stage $T+1$, the payoff to public will be zero forever. If government still stay committed by playing zero inflation rate with probability $p_{T+1} + (1-p_{T+1})\widetilde{\alpha_{T+1}}$ and public expects zero inflation rate for stage $T+2$, then expected utility public can get is $\theta_{T+2}EU_{T+1}^P$; instead, if public expects surprise inflation, the expected utility will be $(1-\theta_{T+2})\widetilde{EU_{T+2}^P}$.

Since public does not reveal at stage T, which means $\theta_T = 1$, if government reveals himself by imposing surprise inflation with probability $(1-p_T)(1-\widetilde{\alpha_T})$, then the expected utility for public will be $-\frac{b^2}{a^2}$ at stage T and becomes zero for the rest stages. Instead, if government does not reveal at stage T, then public's payoff at this stage will be zero and the game goes to the next stage if public does not reveal himself at $T+1$ with probability θ_{T+1}. If public decides to reveal by expect surprise inflation, then the game will proceed with probability $(1-\theta_{T+1})$ of expected utility as $\widetilde{EU^P_{T+1}}$.

The expected utility for public to reveal before government randomize at stage τ is the following:

$$EU^P_\tau = [p_\tau + (1-p_\tau)\widetilde{\alpha_\tau}][-\frac{b^2}{a^2} + \rho\theta_{\tau+1}\hat{EU^P_{\tau+1}} + \rho(1-\theta_{\tau+1})EU^P_{\tau+1}] \tag{38}$$

and $\hat{EU^P_{\tau+1}}$ is the public's expected utility when he trusts government

$$\begin{aligned}\hat{EU^P_{\tau+1}} &= (1-p_{\tau+1})(1-\widetilde{\alpha_{\tau+1}})\rho(-\frac{b^2}{a^2}) \\ &\quad + [p_{\tau+1} + (1-p_{\tau+1})\widetilde{\alpha_{\tau+1}}][\rho(1-\theta_{\tau+2})EU^P_{\tau+2} + \rho\theta_{\tau+2}\hat{EU^P_{\tau+2}}]\end{aligned} \tag{39}$$

for which if government reveals, then the payoff to public is $-\frac{b^2}{a^2}$ at stage $\tau+1$ and zero for the rest stages. If government still stay committed, then the expected payoff to public will be $\hat{EU^P_{\tau+2}}$ if he still trusts government with probability $\theta_{\tau+2}$ and $EU^P_{\tau+2}$ if he decides to not trust government with probability $1-\theta_{\tau+2}$.

Since public reveals at stage τ, which means $1-\theta_\tau = 1$, if government reveals with probability $(1-p_\tau)(1-\widetilde{\alpha_\tau})$, the payoff to public will be zero forever. Otherwise, the payoff at current stage is $-\frac{b^2}{a^2}$ and the expected utility for next period will be $\hat{EU^P_{\tau+1}}$ if public decides to not reveal and $EU^P_{\tau+1}$ is he decides to reveal his identity as not trust government.

It is not hard to tell that under both cases, public will only randomize under a specific probability that he trusts government given the expected utility is dependent on θ_T or θ_τ and both of them can be set by public, for which with randomization public can force government to reveal his identity. Otherwise, public will play zero inflation expectation with the stages that $\frac{\partial EU^P_T}{\partial\theta_T} > 0$ ($\frac{\partial EU^P_\tau}{\partial\theta_\tau} > 0$) and switch the strategy at the stages as soon as $\frac{\partial EU^P_T}{\partial\theta_T} < 0$ ($\frac{\partial EU^P_\tau}{\partial\theta_\tau} < 0$); and vice versa.

7. Conclusion

By applying different forms of extensive game to different scenarios, this paper is able to show the following:

1. If both players treat each stage independent, then the equilibrium is at public expects surprise inflation and government deviates from committed policy;

2. If both players expect one-stage forward forecasting in the game, neither of them wants to be type 1 and government will always have an incentive to deviate. If public trusts government's announcement at the first stage, the best response for government is to reveal; on the other hand, if public does not trust government, then government's decision on whether to reveal depends on the knowledge of public to trust government the next stage and also government's discount rate;

3. In a more general case, if both players expect $N-1$ stage forward forecasting in the game, then public is willing to randomize only when his view on public been type 1 is less than $\frac{1}{2}$; otherwise, public's decision on whether to trust or not trust the announcement depends on his knowledge of government. Government, on the other hand, will only randomize in this finite forecasting game at a certain level of α and he can purposely set α equal to the value and mislead public's expectation;

4. In a more realistic case, nobody knows the value of N and it is likely this game will go on forever; therefore, in the infinite period game, two scenarios have been considered. First, public not reveal his type before government have an incentive to deviate. In this case, government is willing to randomize only when his discount rate is higher than $\frac{1}{2}$; otherwise,

he will choose the strategy in accordance with the related utility. The second case is government has the incentive to deviate after public reveals. In this case, government will only randomize at a certain level of α, for which government can purposely mislead public. The public, for both cases, will only randomize with certain level of θ and can purposely force government to reveal his identity.

Appendix A

For the two-period extensive form game, if public plays $x_t^e = 0$ and government is type 2, then it needs to satisfy the condition that

$$\frac{b^2}{2a}[1 - \alpha_t + 2\beta(1 - \widetilde{\theta_{t+1}})(1 - q_{t+1}) + \beta(2q_{t+1} - 1) + 2\beta\alpha_t(1 - q_{t+1})\widetilde{\theta_{t+1}}] > 0 \tag{40}$$

If $q_{t+1} \geq \frac{1}{2}$, then $\widetilde{\theta_{t+1}} = 1$ is the condition to maximize the expected payoff; therefore the equation becomes:

$$\frac{b^2}{2a}[1 - \alpha_t + \beta(2q_{t+1} - 1) + 2\beta\alpha_t(1 - q_{t+1})] > 0 \tag{41}$$

for which this holds for certain. If $0 < q_{t+1} < \frac{1}{2}$, then $\widetilde{\theta_{t+1}} = \frac{q_{t+1}}{1-q_{t+1}}$ to maximize expected payoff; therefore the equation turns into:

$$\alpha_t + 2\beta q_{t+1}(1 - \alpha_t) < 1 + \beta \tag{42}$$

and this holds for certain as well since $2\beta q_{t+1}(1 - \alpha_t) < 1$ here. Hence, it can be concluded that government will always play type 2.

Appendix B

For the two-period extensive game, if public plays $x_t^e = \frac{b}{a}$ and government prefers to be type 2, then the condition

$$\frac{b^2}{2a}[1 + \beta - \alpha_t + 2\beta\widetilde{\theta_{t+1}}(\alpha_t - 1)] > 0 \tag{43}$$

must be satisfied. However, since public has already revealed his identity as type 2, what really matters is the probability that he trusts government next period. Therefore, the following inequality on $\widetilde{\theta_{t+1}}$ has to be satisfied:

$$\widetilde{\theta_{t+1}} < \frac{1+\beta-\alpha_t}{2\beta(1-\alpha_t)} \tag{44}$$

and this condition holds for certain for both $\beta > \frac{1}{2}$ and $\beta \in (0, \frac{1}{2})$. Therefore, government will not be type 1.

Appendix C

By equate (*) and (**), we get:

$$(1-\beta)\frac{b^2}{2a} + \frac{\beta^2-\beta}{1-\beta}\frac{b^2}{2a} + \frac{b^2}{a}\frac{\beta}{1-\beta}q_{T+1} = \frac{\beta^2}{1-\beta}\frac{b^2}{a}q_{T+2} \tag{45}$$

After simplification we have

$$q_{T+2} = \frac{(2\beta-1)(\beta-1)}{2\beta^2} + \frac{1}{\beta}q_{T+1} \tag{46}$$

which is also the same as

$$q_T = \frac{(2\beta-1)(\beta-1)}{2\beta^2} + \frac{1}{\beta}q_{T-1} \tag{47}$$

By adopting back-ward induction:

$$
\begin{aligned}
q_T &= \frac{(2\beta-1)(\beta-1)}{2\beta^2} + \frac{1}{\beta}q_{T-1} \\
&= \frac{(2\beta-1)(\beta-1)}{2\beta^2} + \frac{1}{\beta}(\frac{(2\beta-1)(\beta-1)}{2\beta^2} + \frac{1}{\beta}q_{T-2}) \\
&= \frac{(2\beta-1)(\beta-1)}{2\beta^2}(1+\frac{1}{\beta}) + \frac{1}{\beta^2}q_{T-2} \\
&= \frac{(2\beta-1)(\beta-1)}{2\beta^2}(1+\frac{1}{\beta}) + \frac{1}{\beta^2}(\frac{(2\beta-1)(\beta-1)}{2\beta^2} + \frac{1}{\beta}q_{T-3}) \\
&= \frac{(2\beta-1)(\beta-1)}{2\beta^2}(1+\frac{1}{\beta}+\frac{1}{\beta^2}) + \frac{1}{\beta^3}q_{T-3} \\
&= \dots \\
&= \frac{(2\beta-1)(\beta-1)}{2\beta^2}(1+\frac{1}{\beta}+\frac{1}{\beta^2}+\cdots+\frac{1}{\beta^{T-1}}+\frac{1}{\beta^T}) + \frac{1}{\beta^T}q_0 \\
&= \frac{(2\beta-1)(1-\beta^{-T})}{2\beta} + \frac{1}{\beta^T}q_0
\end{aligned}
\tag{48}
$$

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2 Chapter Two

Time Varying and Time Inconsistent Analysis on U.S. Monetary Policy

Abstract

By applying both non-parametric method and rolling estimation for time varying analyses along with the asymmetric policy preference model, this paper proposes that with almost every recession since 1960, the rolling method reaches a break point shortly before or right at the recession date and that the non-parametric method reaches a peak for every recession that is not caused by supply shock. In addition, this paper uses the chain-weighted PCE index to conclude that there exists time-inconsistent policy preference over different recession periods, and also to compare results with the chain-weighted GDP index. The study discovers that the PCE index in general will result higher targeted inflation rate than the GDP index, and policy preferences are different during pre- and post-recessions with both indexes.

Introduction

Research regarding the time-inconsistent problem of asymmetric preference over policy making has recently grown popular. Typically, the approach used to study this type of question is applying the linex function that is introduced by Varian (1975), and the econometric method most often used is the generalized method of moments (GMM) estimation. By using this method, one is able to find the asymmetric preference from government policy makings by examining the coefficients on policy factors, such as the unemployment rate in the work of Ruge-Murcia (2003) and the inflation rate and output gap in the work of Surico(2007). The study of asymmetric preferences over policy and decision making first appeared in monetary economics as early as in Nobay and Peel's (1998) paper, which applied the linex loss function with asymmetric preference over the inflation gap. This study showed that preferences over inflation depend on the variance of inflation and inflationary bias cannot be erased even if the potential level of output is targeted. In the work of Ruge-Murcia(2003), a model similar to that of Nobay and Peel (1998) is used and indicates that the deviation from the targeted inflation can be positively or negatively related to the unemployment rate in a non-linearly manner. The work of Surico (2007) includes non-quadratic preferences over both inflation and the output gap to prove that there exist asymmetric preferences over the output gap by the central bank but not on the inflation rate. Therefore, in Surico's (2008) paper, the model is simplified into a non-quadratic preference over output gap only and proves the model is efficient and robust to data selection, for which it is applied in this paper.

Despite the growing interests in this field, some questions remain unanswered and gaps remain that need to be addressed. The first gap that previous literature has not filled is applying a chain-weighted PCE index for inflation measurements. Most of the current research focuses on the core CPI and the chain-weighted GDP index to measure inflation, such as in the works of Ruge-Murcia (2003, 2004), Surico (2008), Clausen and Hayo (2006) and Dolado et al.(2004). Surico (2007) included a comparison of results of PCE index inflation and GDP deflator and concluded that both type of inflations obtained similar results. In fact, according to Mishkin(2007) and Cogley et al. (2010), the Federal Reserve encourages researchers to look into PCE inflation and focuses more on the PCE index for policy purposes since PCE index is subject to less substitution bias than the CPI. Therefore, the first contribution of this paper is to provide a GMM analysis with the PCE index and to compare the results by using chain-weighted GDP. This paper finds that although both indexes are consistent in their results of policy preferences, the level of preferences differs between these two indexes at different times. For instance, before 1979, the central bank's policy over the negative output gap is more aggressive under the GDP index than the PCE index. We also find that during some time periods, such as from 1960-1979, the GDP index shows a higher targeted inflation rate than the PCE index. However, the PCE index results in a higher targeted inflation rate than the chain-weighted GDP in general.

The second gap that this paper addresses is examining how coefficients change regards to the two most recent recessions, the recession of 1991 and the Great Recession. The 2001 recession is skipped here because of the exceptional event that may influence the economic behavior. Despite the study of policy coefficients regarding the change in the regime switches of U.S. monetary policy, such as presented by Surico(2007,2008), Sims and Zha(2006) and Boivin(2006), there are rarely any studies to examine the change in coefficients before and after recessions in this field with non-quadratic preferences. However, in related fields of monetary economics, there have been various studies that proved the coefficients change on policy factors before and during recessions. For instance, Rabanal (2004) showed that the Fed used different rules during recessions and expansions and indicated its tolerance to not follow the targeted inflation increases during recessions, which is consistent with the findings of Lo and Piger (2003). Therefore, the second contribution here is to study the behaviors of coefficients and government preference over policies before and after the two recessions. The findings in this paper indicate an inconsistency in signs for policy coefficients and contradicts the original assumption of Surico (2008) that coefficient signs do not vary. Moreover, this paper also shows that the coefficient for output gap is positive before each recession and becomes negative after each recession. Therefore, the suspicion arises here that the coefficients are actually time varying and driven by business cycles. This leads to the third contribution of this paper, that is the implementation of time-varying coefficients analysis.

In previous literatures regarding the study of asymmetric preference over policy making, analysis of time varying coefficients is rarely performed. Dolado et al. (2005) used a time-varying inflation target to study the asymmetric preference in monetary policy over inflation and output gaps, which only allows the constant term to be time dependent. Rabanal (2004) and Boivin(2006) estimated that the time-varying parameter Taylor rule model could indicate the coefficients change at different times. Some literature has used non-parametric methods in studies on monetary policy, such as the work of Duffy and Engle-Warnick (2006), who applied different non-parametric versions of the Taylor rule to study the U.S. monetary policy on the targeted interest rate and were able to locate the regime shifts that are determined by data.

However, the time varying analysis over asymmetric policy preference model has never been conducted before; therefore, this paper contributes to the current literature by implementing time-varying analysis with the rolling method and the non-parametric method that is used in Cai(2007). The rolling method indicates the break points in the coefficients, and the non-parametric method estimates the coefficient's values. Both methods suggest that coefficients are time-varying, and the coefficient on output gap may related to U.S. business cycles. By examining the problem more deeply, this paper is able to show that the rolling estimation is reaching a break point shortly before or at almost every recession date since 1960. One weakness is that rolling estimation results before the 1990s have too many disturbances, which means some break points may not represent recessions. However, the results become much clearer after the 1990s in the sense that no disturbances are present in the results and break points are able to show the recessions. The non-parametric method in this paper is able to show that shortly before or at the recession, the coefficient for output gap will reach a peak for every recession that is not caused by supply shock since 1960. In addition, the results have fewer disturbances than rolling estimations. Hence, it is recommended to use both methods together to examine possible recession related break points or slope change. In addition, we further examined the possible factors that may cause the property on the coefficient of output gap. We find out that the coefficient of output gap is able to capture the downtowns in multifactor productivity growth (MFP) and reflect them as pre-recession warning.

The rest of this paper is organized as follows. Part I provides a replication of Surico's analysis of the PCE index and comparison of the results with the GDP index for coefficients and policy preferences change. In addition, it also includes the analysis of coefficients behaviors and policy change before and after two recent U.S. recessions. Part II is to verify that the coefficients are time-varying and to find connections with U.S. recessions.

Part I: Replication of Surico's Analysis and Recession Analysis

Section 1: Model

The model that is applied here to investigate the time-inconsistency is

$$L_t = \frac{1}{2}(\pi_t - \pi^*)^2 + \lambda \frac{e^{\gamma y_t} - \gamma y_t - 1}{\gamma^2} \tag{49}$$

where $\lambda > 0$, π_t is the current inflation rate that is measured as the changes in the log of the chain-type price index, and π^* is the implicit inflation target. y_t is the output gap that is subject to the New-Keynesian Phillips Curve $y_t = \theta(\pi_t - \pi_t^e) + u_t$, where $\theta > 0$, u_t is the supply disturbance that follows AR(1) process, and π_t^e is the public's inflation expectation such that $\pi_t^e = E_{t-1}\pi_t$. y_t is measured as the log difference between the real GDP and potential GDP. γ is the asymmetric policy preference factor that when denoted by a negative number indicates that the Federal Reserve will act aggressively on negative output gap and vice versa. Insignificant γ indicates Fed is more focusing on achieving potential level of output. By applying the minimization condition $\frac{\partial L_t}{\partial \pi_t} = 0$ with first-order Taylor expansion, the equation is approximately equal to the following:

$$(\pi_t - \pi^*) + \lambda\theta E_{t-1}(y_t) + \frac{\lambda\theta\gamma}{2} E_{t-1}(y_t^2) + e_t = 0 \tag{50}$$

where e_t is the error term. After rearranging terms and incorporating the current output gap, the equation can be rewritten as:

$$\pi_t = \pi^* + \alpha_t y_t + \beta y_t^2 + v_t \tag{51}$$

where v_t is the error term and $v_t = -\{\alpha(y_t - E_{t-1}y_t) + \beta[y_t^2 - E_{t-1}(y_t^2)] + e_t\}$, which is orthogonal to the information set at $t-1$. By assuming rational expectations, GMM is the best method for this type of problem (Surico, 2008). Moreover, we define $\alpha = -\lambda\theta$ and $\beta = -\frac{\lambda\theta\gamma}{2}$.

Section 2: Results

In this section, we will analyze the chain-weighted PCE, which is another alternative method for inflation measuring, by using Surico's method and compare the results with the GDP index to see if any dramatic difference exists.

All of the data used in this section are seasonally adjusted quarterly data that range from 1960Q1 to 2005Q2 and have been obtained from the FRED database. The real potential GDP is seasonally adjusted after E-views. The base year for the real values is 2009. However, the Surico(2008) test uses 2005 as the base year; therefore, in order to better compare the results between the PCE and the GDP, this section re-analyzes the test with the chain-weighted GDP index as well. The instrument set (1) includes three lags of inflation, output gap and squared output gap, while set (2) includes five-lags of inflation, two-lags of output gap and squared output gap, which are in accordance with the selections in the work of Surico(2008). Hansen's J statistic for over-identifying restrictions is also reported in the table, and fail to reject indicates valid instruments. The number in the parentheses shows the robust standard errors with the four-lagged Newey-West covariance matrix.

After running the GMM test with the chain-weighted GDP index data we obtained, we compare the results in Table 1 with those of Surico, and both are very similar except for minor differences in coefficients. The differences in π^* and coefficients may be because of the base year change. As shown in Figure 1(a), the data with different base year may cause change in results and an upward shift of estimated inflation target from Surico's analysis. Also contributing to this problem is the inconsistency of potential GDP data that was published by CBO, and according to Kliesen (2010), the potential GDP has often been revised. As in Figure 1(b) and 1(c), it is clear that the potential GDP data has changed with different publication dates and that the changes have no patterns. In other words, the data on potential GDP that are obtained at different dates are inconsistent, which may contribute to the regression differences.

Table 1: GDP Index Result

Instruments	π^*	α	β	p-values
(1)	2.84**	-.13	.05**	F-statistic: 0/0
	(.33)	(.102)	(.02)	J(7): .059
(2)	2.81**	-.12	.05**	F-statistic: 0/0
	(.316)	(.105)	(.019)	J(7): .07

The same method used for the GDP index was used here, and the PCE index results are shown in Table 2. In the table, the PCE index reports a higher implicit inflation target than the GDP index but a lower weight on the squared output gap. However, these two indexes have inconsistent significance results. For instance, with instrument set (2), α is insignificant from GDP index, but it is significant at the 10% level with the PCE index. Moreover, β with the GDP index is significant at the 5% level, but it is significant only at the 10% level with the PCE index. In addition, the results with the PCE index for IV(1) and IV(2) are inconsistent; in other words, the model with the PCE index is not robust to instrument selection.

Table 2: PCE Index Result

Instruments	π^*	α	β	p-values
(1)	2.91**	-.143	.039**	F-statistic: 0/0
	(.335)	(.098)	(.0193)	J(7): .1
(2)	2.98**	-.154*	.032*	F-statistic: 0/0
	(.327)	(.094)	(.0177)	J(7): .11

Tables 3 and 4 report the estimates for pre- and post-Volcker regimes with the GDP and the PCE index. Both indexes have consistent significance results from the regression analysis. As seen by comparing Tables 3 and 4, during the first time frame, targeted inflation rates with the GDP index are higher than the PCE, and both show similar results during the second period. For the coefficients, α with the GDP is smaller than the PCE but β is higher than the PCE during the first time period. For the second time period, the only significant coefficient β are very similar in both indexes. Moreover, both indexes have consistent policy preference over the output gap by the negativity of γ.

Table 3: GDP Index Result

Instruments	π^*	α	β	p-values	γ
1960(I)-1979(III)					
(1)	4.3**	-.62**	.1**	F-statistic: 0/0	-.32**
	(.42)	(.0772)	(.027)	J(7): .33	
(2)	4.41**	-.62**	.088**	F-statistic: 0/0	-.28**
	(.327)	(.066)	(.0252)	J(7): .28	
1982(IV)-2005(II)					
(1)	2.2**	-.069	.03**	F-statistic: 0/0	-.87**
	(.1563)	(.07)	(.008)	J(7)=.17	
(2)	2.2**	-.07	.03**	F-statistic: 0/0	-.86**
	(.12)	(.05)	(.0065)	J(7)=.17	

Table 4: PCE Index Result

Instruments	π^*	α	β	p-values	γ
1960(I)-1979(III)					
(1)	4.06**	-.586**	.08**	F-statistic: 0/0	-.27**
	(.48)	(.09)	(.034)	J(7): .42	
(2)	4.25**	-.584**	.07**	F-statistic: 0/0	-.24**
	(.43)	(.08)	(.033)	J(7): .47	
1982(IV)-2005(II)					
(1)	2.28**	-.06	.03**	F-statistic: 0/0	-1**
	(.21)	(.07)	(.007)	J(7)=.18	
(2)	2.25**	-.09	.028**	F-statistic: 0/0	-.62**
	(.13)	(.06)	(.008)	J(7)=.13	

In comparing Tables 3 and 4 together, the first thing to notice is that the implicit inflation target is much higher during the first time period than the second period for both indexes. The main reason is that for both the Volcker and Greenspan regimes, dis-inflationary policy was conducted. Volcker intended to reduce inflation rate in an effort to restore public credibility on low inflation, while Greenspan wanted to restore price stability by achieving low enough inflation (Goodfriend, 2003). Furthermore, the negative α and positive β indicates a negative asymmetric preference factor γ, which means that Federal Reserve regimes dislike negative output gap. The more negative γ in the second era of the analysis reflects a more aggressive Federal Reserve policy on negative output gap.

What we have noticed from the original Surico (2008) analysis is that γ is insignificant during the period of 1982Q4:2005Q2, which the results show that the Federal Reserve is aiming at stabilizing the output gap by playing inflation targeting (Goodfriend, 2003). However, this is inconsistent with our results here, as γ is a significant negative number. In fact, by examining the output gap in Figure (2), one is able to notice that for most of the time during this period, the U.S. is experiencing negative output gap. Therefore, it is very likely that during this period, the central bank was stabilizing the output gap by focusing more on the negative gaps, which can result in the negativity of γ. The other inconsistency in the results comes from the α. The original analysis shows α is significant at 10% level during the post-Volcker era; however, it becomes insignificant with the result of both indexes here.

Section 3: Recession Analysis

In this section, we analyze the change in coefficients before and after the two most recent recessions occurring in 1990 and 2007. We separated the time interval into four parts: 1987Q3-1990Q2, 1991Q1-2001Q1, 2002Q1-2007Q3 and 2009Q2-2014Q4. The first two periods are before and after the early 1990 recession, while the last two periods are before and after the Great Recession. We remove the 2001 recession due to the possible exogenous effects that the 9/11 attack may have had on the economy. We will still be using the GMM with instruments set (1) and removing set (2) due to the limitation of sample size, except for the period 1987Q3-1990Q2, we use the two-lagged inflation gap, output gap and the squared output gap. Moreover, by using the optimal lag selection method in accordance with Newey and West (1994), we will be using the two-lagged Newey-West covariance matrix for standard errors. The first-stage F-statistic test that was proposed by Staiger and Stock (1997) and Stock and Yogo (2005) together with Hansen's over-identification test indicate the instruments are both non-weak and valid.

In general, the PCE and GDP indexes produced similar results; however, differences exist in both the significance levels of coefficients with these two indexes and values on coefficients. For instance, from 2009Q2 to 2014Q4, where the PCE index is only valid at the 10% significance level but the GDP index is valid at the 5% level. The targeted inflation rate with the PCE index shows a higher rate than the GDP index before the 1990s recession and the opposite is true for the Great Recession. In addition, the value of α before the 1990s recession with the GDP index is much higher than the PCE index. The policy preference factor with the GDP index shows more aggressive action toward the positive output gap than the PCE index during the post Great Recession period, while less aggressive toward negative output gap during the post 1990s recession.

Table 5: GDP Index Result

Time	π^*	α	β	p-values	γ
1987Q3-1990Q2	3.08**	.93**	-.095	F-statistic: 0.01 /0.04	-.2
	(.074)	(.24)	(.3)	J(4): .46	
1991Q1-2001Q1	1.5**	-.15**	.09**	F-statistic: 0/0	-1.2**
	(.09)	(.032)	(.02)	J(7): .2	
2002Q1-2007Q3	3.2**	1.3**	.032**	F-statistic: 0/0	.05**
	(.146)	(.23)	(.076)	J(7): .54	
2009Q2-2014Q4	-.6	-1.16**	-.144**	F-statistic: 0/0	.248**
	(.48)	(.217)	(.022)	J(7): .56	

In comparing both results, both indexes show no significance on the policy preference factor before the 1990s recession and show a strong policy reaction on the negative output gap after the recession. The insignificant preference is in the sense of bring output gap to the potential level. As mentioned above, during this period, the Federal Reserve was trying to reduce the inflation rate by regaining credibility from the public after the inflation scare. By the end

Table 6: PCE Index Result

Time	π^*	α	β	p-values	γ
1987Q3-1990Q2	3.6**	.40**	.223	F-statistic: 0/0.015	1.12
	(.06)	(.06)	(.18)	J(4): .73	
1991Q1-2001Q1	1.5**	-.13**	.12**	F-statistic: 0/0	-1.85**
	(.15)	(.042)	(.03)	J(7): .35	
2002Q1-2007Q3	2.76**	1.3**	.04**	F-statistic: 0/0	.06**
	(.09)	(.18)	(.072)	J(7): .585	
2009Q2-2014Q4	-1.3	-1.37*	-.15*	F-statistic: 0/0	.008*
	(1.6)	(.74)	(.078)	J(7): .46	

of 1986 through early 1990, public confidence was increased by the lowered expectations of the Fed, and more importantly, the real GDP growth rate started to increase by moving the negative output gap toward the potential level again(Goodfriend 1993).

Between 2002Q1 and 2007Q3, the Central Bank's asymmetric preference factor was positive, which means the Fed sees the positive output gap as more severe than the negative output gap. As we know, this is the time frame of the housing bubble period; however, the Federal Reserve during this period did not consider the housing price increase to be a problem; instead, they believed that the housing market was in good shape (Yellen,2005), and their goals are to bring the output to the long-run potential level, as the economy is experiencing an expansionary output gap as estimated by both Laubach-Williams (LW) (solid) and the CBO (dashed) in Figure 2 (Weidner and Williams, 2015), which indicates the Central Bank's preference as positive γ.

After the Great Recession, the implicit inflation target is not statistically significant from zero. The targeted rate decreased dramatically after the early 1990 recession, and during this period, the Fed was able to maintain low inflation reputation without stalling economic growth (Goodfriend, 2003). Furthermore, the Central Bank's preference toward the output gap after the 1990 recession was dislike the negative gap, and after the Great Recession is to prevent the increase of inflation rate until it reaches fully employment level of output (Cooke and Gavin, 2014).

Another important aspect of the results is that for the periods before each recession, α was a positive number and then became negative after each recession. Although α should remain positive according to theory, various studies, such as those of Ball (1991,1994), Fuhrer and Moore(1995) and Mankiw and Reis(2002), have examined this problem with New-Keynesian Phillips Curve. These studies indicate that the problem has been caused by factors that cannot be explained by the model, such as sticky prices and staggered wage adjustment. For simplicity, the study here will ignore the reasons that may cause the opposite sign.

Due to the regular change in the signs of α with recessions, we are concerned with whether the coefficients are time varying and whether α may relate to business cycles. Therefore, Part II analyzes the time varying coefficients with two different methods: the rolling estimation and the non-parametric local linear estimator.

Part II: Time-Varying Analysis

Although in the work of Surico(2008), the model is treated as having time-invariant coefficients, we cannot rule out the case that π^*, α and β vary with time. To account for this problem, we re-write Surico's model using time-dependent coefficients:

$$\pi_t = \pi_t^* + \alpha_t y_t + \beta_t y_t^2 + v_t \tag{52}$$

subject to

$$v_t = -\{\alpha_t y_t - E_{t-1}\alpha_t y_t + \beta_t y_t^2 - E_{t-1} y_t^2 \beta_t + e_t\} \tag{53}$$

where π_t^*, α_t and β_t are the estimated coefficients that are time-dependent and v_t is still orthogonal to the information set at t-1. Figure 3 and Figure 4 are both time varying analyses but with different methods. Figure 3 uses the rolling forecast method together with GMM regression that is from the previous section but with a 3-lagged Newey-West Covariance matrix. Rolling estimation is able to capture the change in coefficients in the sample at a certain period of time (Zivot and Wang, 2006). Figure 4 applies the non-parametric method of Cai(2005) that uses local linear estimator together with the optimal bandwidth selection and a consistent estimate of standard errors. Moreover, the residual plot in Figure 4 is close to normal, which means our local linear estimates are efficient (Cai, 2005). Finally, by supporting the result that α_t, β_t and π_t^* are time varying, we use the wild bootstrap to test the null hypothesis that $H_o : \alpha_t = \alpha, \beta_t = \beta, \pi_t^* = \pi^*$. Because the P-value is less than 0.05, we reject the null hypothesis; hence, the coefficients are truly time dependent.

The coefficient on output gap, α_t, has shown consistent slope changes throughout the period, and we suspect that the changes are related to U.S. business cycles. According to the National Bureau of Economic Research (NBER), there have been seven recessions since 1960. The dates are 1969Q4, 1973Q4, 1980Q1, 1981Q3, 1990Q3, 2001Q1 and 2007Q4.[4] Among these dates, the 1973Q4 and 1981Q3 recessions are primarily caused by supply shock (Miller, 1983). Although the Great Recession was influenced by the oil price shock as well, the primary cause was the burst of the housing bubble and credit crisis (Holt,2009). Similarly, the early 1990s recession was primarily caused by loss of consumer confidence together with tightened monetary policy, and was influenced by oil prices as well (Walsh,1993). For this study, we ignore the 1960Q1 recession due to lack of data before 1960.

When examining both figures, the first thing to notice is that the coefficient on squared output gap with the non-parametric estimation is too stable to be connected with business cycles, and β_t fluctuates between -.2 and .2. The result for β_t using the rolling method, however, may be able to connect with business cycles by depicting similar patterns with α_t but with more disturbances. The targeted inflation rate is relatively stable and predictable from the 1980s

[4] http://www.nber.org/cycles.html

to around 2009 with the non-parametric method. With the exceptin of the 1960s recession, the targeted inflation rate with the rolling forecast has several break points, which are mostly consistent with the slope change with the non-parametric method.

By comparing both the rolling estimation and the non-parametric method in forecasting recession dates, we can conclude the following:

1. The non-parametric method has smoother results than rolling estimation. The α_t with the non-parametric method will reach a peak shortly before or right at the recession dates that are not caused by supply-shock. In other words, the 1973Q4 and 1981Q3 recessions were caused by supply shock; therefore, both dates failed to relate any break points on the graph. For the rest of the recessions, they are able to depict on the graph as a peak shortly before or right at the recession date. For instance, the 1960Q4 recession is the 40th quarter in the dataset and the graph reaches a peak at approximately quarter 36. The peak at around the 80th quarter represents the 1980Q1 recession, and the peak at about the 120th quarter on the graph is shortly before the 1990Q3 recession. The 2001Q1 recession is the 164th quarter in the dataset, and the result shows a peak at about 160th quarter on the graph, which is similar to the 2007Q4 recession. The remaining parameters are rather stable and not closely related to the business cycles.

2. The rolling method has break points in α_t that are irrelevant to any recessions during the 1960-1980 period, such as the two break points at the beginning of 1960s, and it fails to forecast the recession in 1981Q3. However, the result becomes much clearer after the 1990s, when the rolling estimation is able to show structural breaks before every recession and does not depict disturbances. Therefore, it can still be recommended for forecasting or examining future recessions. In addition, β_t with the rolling method is able to depict similar results as α_t and β_t has more disturbances than α_t; therefore, it

is not recommended. π_t^* also has similar patterns as α_t but is more stable. In general, from the graph, π_t^* is only able to show three structural break points, which is fewer than the number of recessions during this time frame. In addition, the 2001 recession is not depicted on the graph as a structural break point; therefore, this parameter is not recommended in forecasting or indicating recession either.

One reason may contribute to this coefficient pattern is the change is the multifactor productivity growth (MFP). Figure 5 is the estimated growth rate by Roberts(2001) using time-varying parameter techniques with time frame 1960 to 1999, and Figure 6 is the estimated rate by Fernald(2012) from 1973 to 2012. By examining α_t from non-parametric estimation with both estimated MFP results, we are able to discover that every peak in α_t is associated with a trough in MFP with Figure 5 or a turning point for MFP to start decreasing in Figure 6 before recessions. The rolling estimation result of α_t, in addition, has similar connections as the non-parametric result; however, rolling estimation result before 1990 is more related to the patterns in Figure 5 with the upper bound of 90% confidence interval. In fact, recent studies by Fabina and Wright(2013) and Fernald(2014) prove that before the Great Recession since 2004, the MFP has been declining at about 0.5% per year. In other words, α_t may be able to capture the effect of decreasing in multifactor productivity and to reflect this as a pre-recession warning. There maybe other factors that can influence α_t, which can be examined with future researchers' interests.

In general, both local linear estimation and rolling estimation can be used for forecasting or indicating recession dates because almost all of their results show break points shortly before or right at the recessions. However, the local linear estimator is better at forecasting recessions not caused by supply shock with very smooth results, while rolling estimation can also forecast recessions caused by supply shock and functions well after the 1990s but may have disturbances that are unrelated to any recessions. Nonetheless, rolling estimation may fail to forecast recessions that may or may not be caused by supply shock. Therefore, in order to produce better results, here we suggest that researchers use both methods in examining recessions and focus on each possible recession related break point.

Part V: Conclusion

In this paper, we performed a GMM analysis on monetary policy with the PCE index by applying Surico's model. To compare the difference between the GDP and PCE indexes, we analyzed the GDP index again and were able to discover that in general, the PCE index will result in a higher targeted inflation rate than the GDP index, and the policy preferences resulting from these two indexes also differ. In comparing the coefficients before and after the two recent recessions, we noticed that the sign of the coefficients change, which raised our concern as to whether the coefficients are time-varying. To test this theory, we applied both rolling estimation and a non-parametric model in time-varying coefficients analysis and surprisingly found that not only ae the coefficients time-dependent, but also the policy coefficient on output gap can be used to predict future recessions. Local linear estimation yields smoother results than rolling estimation but can only show recessions not caused by supply shock. Rolling estimation has more disturbances than the non-parametric method and cannot depict recessions that are either caused or not caused by supply shock, but the result becomes smoother and is able to depict every recession after the 1990s.

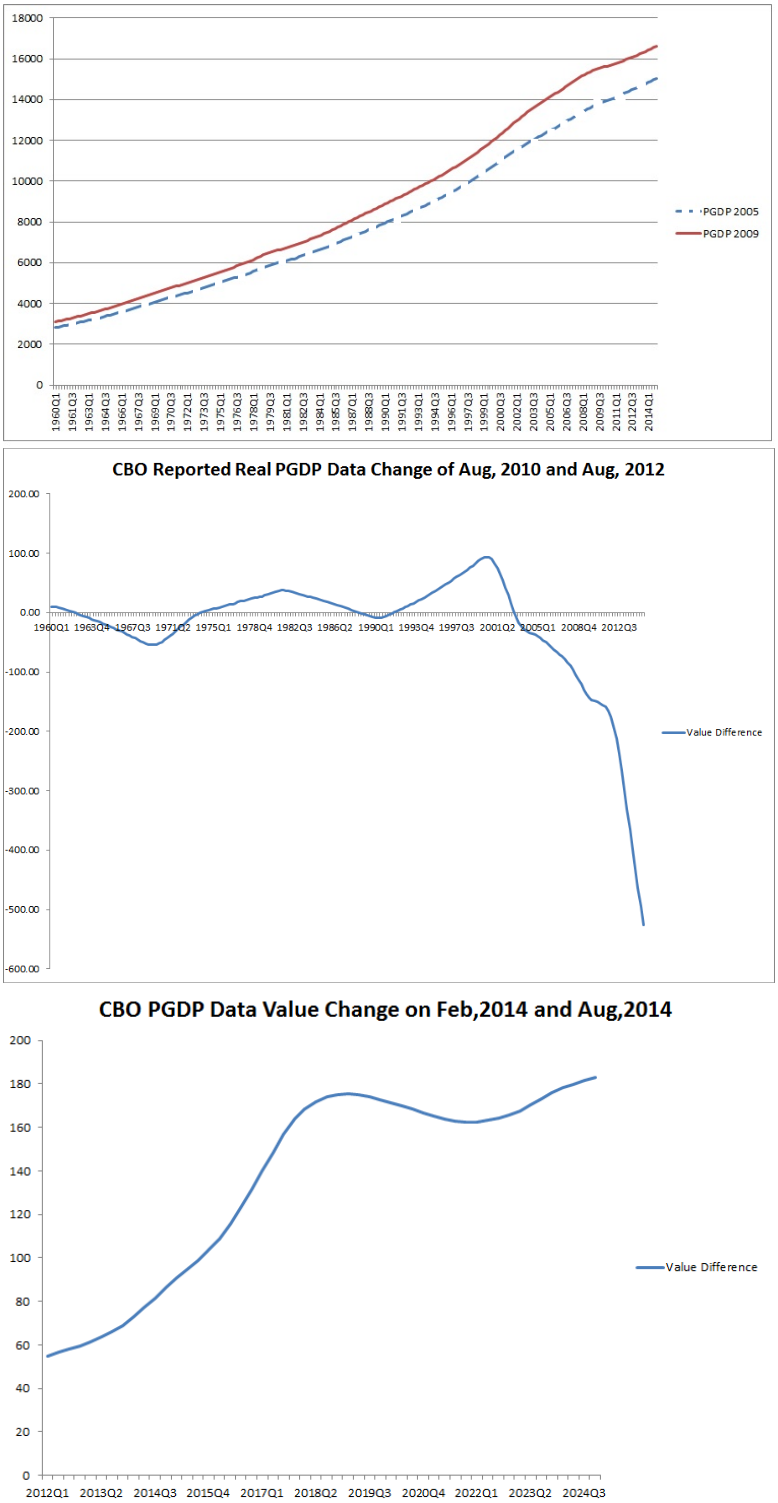


Figure 1: (a) Real GDP 2005 base year (dash) and 2009 base year (solid); (b) change in reported potential GDP that was resulted from inconsistency of CBO report between Aug 2010 and Aug 2012 from 1960Q1 to 2014Q4; (c) change in reported potential GDP that was resulted from inconsistency of CBO report between Feb 2014 and Aug 2014 from 2012Q1 to 2024Q4

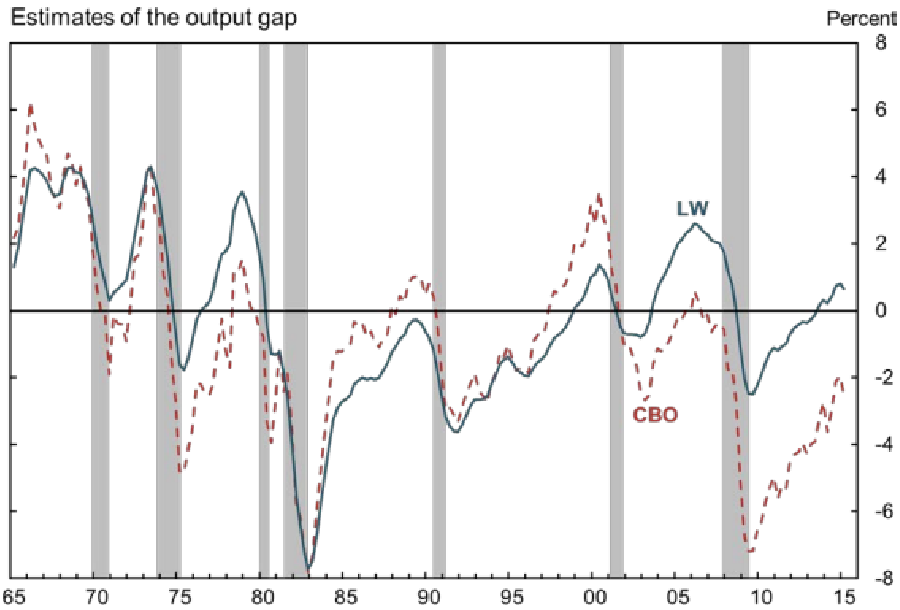
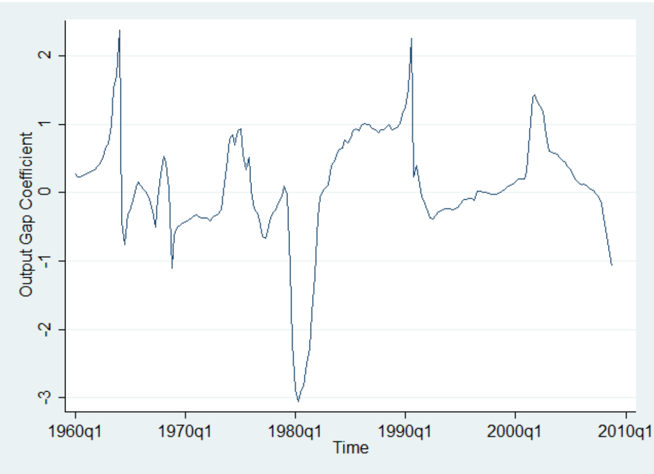
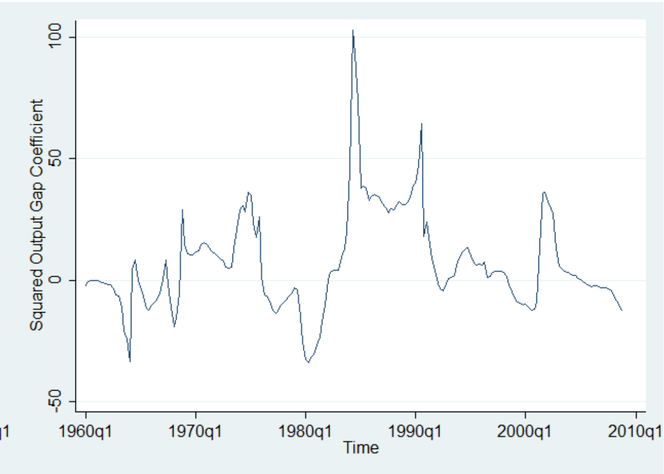


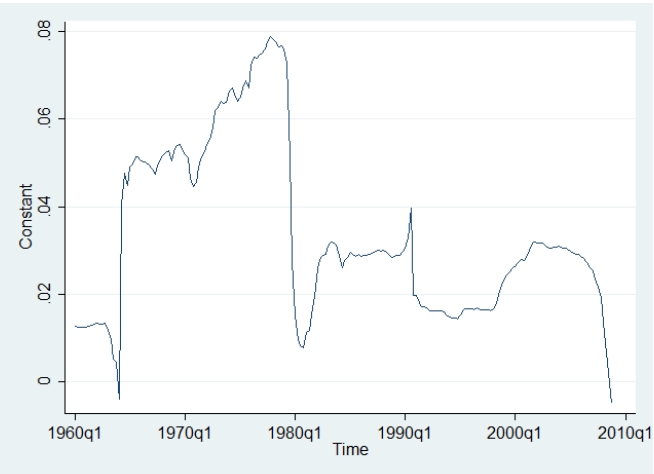
Figure 2: Laubach-Williams and CBO Estimated Output Gap



(a) α_t

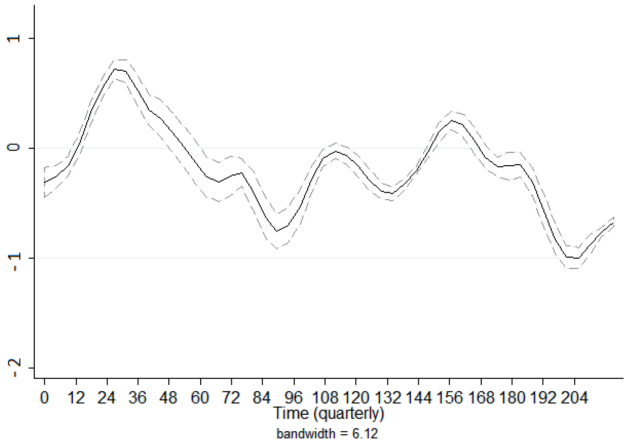


(b) β_t

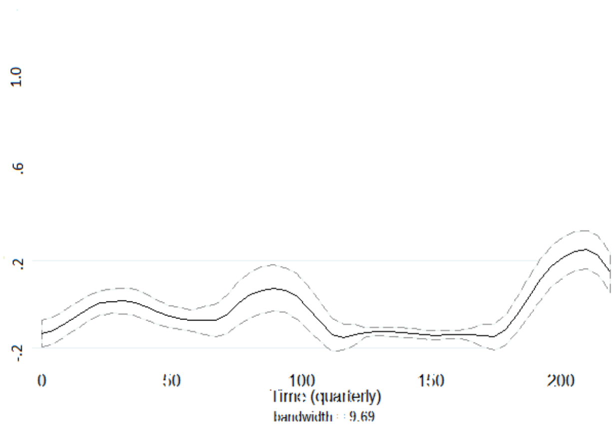


(c) π_t^*

Figure 3: Rolling Estimate using GDP 1960-2013



(a)



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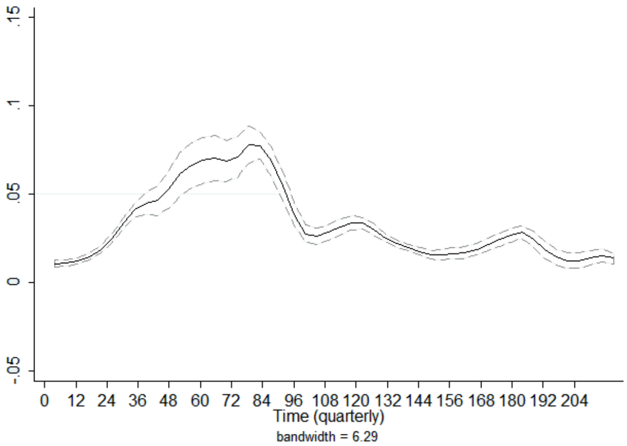
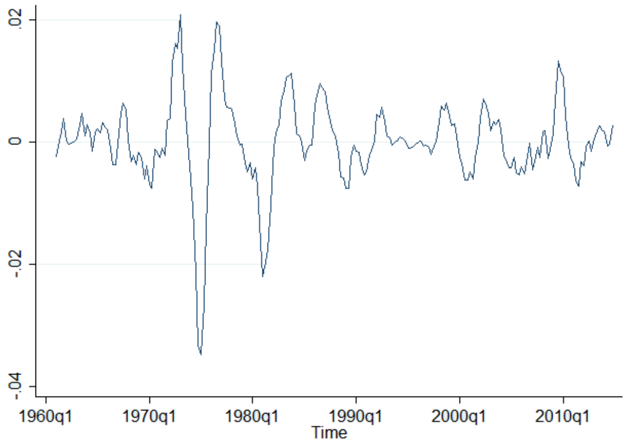


(c)



(d)

Figure 4: Local Linear Smoothing Estimator: (a) the local linear estimator (solid line) of α_t with optimal bandwidth with 95% confidence intervals (dashed line) with no bias correction; (b) the local linear estimator (solid line) of β_t with optimal bandwidth with 95% confidence intervals (dashed line) with no bias correction; (c) the local linear estimator (solid line) of π_t^* with optimal bandwidth with 95% confidence intervals (dashed line) with no bias correction (Note: not in percentage);(d) residual plot against time

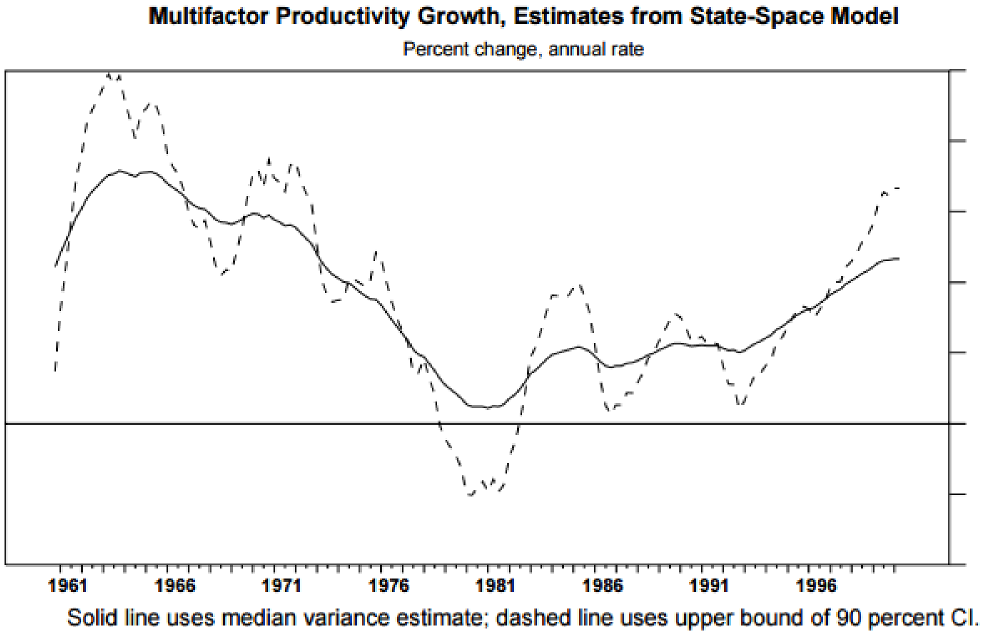


Figure 5: Roberts (2001)

Figure 6: Fernald(2012) and Fabina and Wright(2013)

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3 Chapter Three

Time Inconsistency in Monetary Policy Among OECD Countries With the Great Recession

Abstract

This paper analyzes asymmetric preferences over both output gap and unemployment gap among seven OECD countries. By studying the preferences of pre- and post-recession periods, most countries depict their policy preferences as time-inconsistent. The Netherlands, however, exhibits consistency before and after the recession. By separating countries into core and peripheral groups, the analysis shows a lower targeted inflation rate and stricter preference over the unemployment gap in core countries. In addition, with comparison over inflation targeting and non-inflation-targeting countries, one is able to notice that countries that adopted inflation targeting tend to have no preference on unemployment gap for the post-recession period. Moreover, by applying a non-parametric model to adjust the non-stationarity problem in the data during the first-stage regression, the paper is able to capture the differences between both analyses. The study concludes that only Italy, Netherlands and Canada are not affected by non-stationarity problem that much and both analyses can reach a general consistent results; whereas the rest countries are greatly affected by the non-stationarity problem, especially the US and UK.

Introduction

Previous studies on time-inconsistent monetary policy have primarily focused on the U.S. and apply the linex loss function to study changes in policy preferences during different periods. The linex function was introduced by Varian(1975) and it has been used in the recent literature for studying asymmetric preferences in government. The study of asymmetric preferences over policy and decisions making showed up in the literature as early as in Nobay and Peel (1998) paper, for which is the first paper in monetary policy to apply linex loss function with asymmetric preference over inflation gap and shows that preferences over inflation depend on the variance of inflation and inflationary bias cannot be erased even if target the potential level of output. Ruge-Murcia(2003) studied the policy preference changes in the unemployment gap and prove that the deviation from targeted inflation can be positively or negatively related to the unemployment rate non-linearly. In addition the paper also highlighted the advantages of using quadratic loss functions. First, the model allows for both positive and negative unemployment gaps. By examining different policy preference factors, the model can tell us policymakers' preferences on expansion and recession. Second, the effects of unemployment rates that deviate from the natural rate can be predicted from the model with both size and sign. Finally, the model is able to connect with the traditional quadratic loss function by setting the policy preference factor toward zero. Surico(2007a) studied the asymmetric policy preferences over inflation gaps and output gaps and showed that output gaps are more important to the Federal Reserve in policy preferences than is the inflation gap. Therefore, Surico(2008) reduced the model into asymmetric preferences over the output gap and was able to demonstrate that the model was robust to instrument selection. Moreover, the study concluded that policy preferences change at different periods, such as before and after the Volker regime. This paper combines the models in Ruge-Murcia(2003) and Surico(2008) to study time-inconsistent policy preferences over both unemployment and output gaps with inflation rates, respectively.

Despite the growing interests in time-inconsistent monetary policy in the U.S., few studies have studied the OECD or EU countries. Surico(2003) used a similar model to that used in Surico(2007a) to analyze the asymmetric preference by the European Central Bank (ECB), but did not particularly research the time-inconsistent problem. The 2003 study concludes that from 1997 to 2002, the ECB equally weighted the risk of inflation as well as deflation but weighted output recession more heavily than output contraction. Surico(2007b) used a linex loss function with the ECB's asymmetric preferences over the inflation gap, output gap and interest rate deviations. The model concludes that deviations from the inflation rate are associated with similar responses from the interest rate gap. Moreover, the ECB weighted output contractions more than expansions. Chari and Kehoe(2008) studied the time-inconsistent and free-riding problem in the monetary union, showing that free-rider problem existed under time-inconsistent monetary policy.

This paper is different from previous studies in three ways. First, despite all of the studies on the ECB's monetary policy, few have examined individual countries in Europe and the OECD. This paper contributes to the literature in analyzing time-inconsistent policy preferences in individual OECD countries and relates the results to real economic phenomena. Second, this paper selects countries in accordance with the core versus peripheral separation in Artis and Zhang(2001) and is able to find possible policy differences between core and peripheral countries in Europe. The core countries are Germany and the Netherlands; and the peripheral countries are the United Kingdom and Italy. North American countries are the U.S. and Canada, whereas Australia represents the Southern Hemisphere. In addition, this paper is able to compare the difference in policy preferences between inflation targeting and non-inflation targeting countries. Finally, this paper contributes to the literature in analyzing policy changes before and after the Great Recession. Using different instrument variables, the paper demonstrates that the model here is also robust to instrument selection.

By applying the traditional GMM analysis that was used in previous related studies such as those by Ruge-Murcia(2003), Surico(2008) and others, the results show that core countries tended to have lower targeted inflation rates than did the peripheral countries and that the peripheral countries had insignificant preferences regarding both gaps in the post-recession period. The time-inconsistent problem existed for most of the countries selected except the Netherlands, which showed consistent preferences during the pre- and post-crisis periods.

In addition, this paper also looks into the problem on the failure of expectation augmented Phillips Curve, which mainly focuses on the cause that may result an opposite sign on the unemployment gap coefficient. Some studies, such as Coibion and Gorodnichenko(2015) and Towbin and Weber(2015), has researched into this problem with U.S. data and find out that the increase in oil price and housing price may contribute to this issue. The paper is able to discover that for the countries that experienced opposite sign on unemployment gap coefficient during certain time periods are also exposed to the risk of housing bubble during that time frame.

Moreover, very few studies consider the differences that non-stationary data may bring to results. For instance, Surico (2007a,b,2008) did not consider the time-series property in the dataset, for which the output gap was non-stationary in the sample. Nobay and Peel(1998) were very likely to involve a non-stationary output and inflation in the data as well.

The current paper will adjust the non-stationary problem during the first-stage regression with the non-parametric model used by Cai and Wang(2014). In fact, Ruge-Murcia(2003) discussed a stationary innovation in the non-stationary unemployment rate but did not investigate further. Here, with similar techniques, innovations from AR(1) regressions will be added into the instrumental variables, and any differences between two tests may come from the non-stationarity problem.

Most of the selected countries had consistent results with both tests when the 5% significance level was chosen from the original test and 10% was chosen for the non-stationarity adjusted test. However, the United Kingdom was most affected by the non-stationary problem, and there was no method for finding consistent results in both tests; therefore, it was difficult to decide whether specific variables in the UK were significantly related to the model during certain time periods.

The rest of the paper is organized as follows. Part I is the analysis of policy preference changes in seven OCED countries during the pre- and post-crisis periods with connections to real economic phenomena. Part II is the non-stationarity-adjusted non-parametric analysis in the first-stage regression.

Part I: Analysis on Asymmetric Monetary Policies for the Great Recession

Section 1: Model

Surico(2008) studied the asymmetric monetary policy with preferences over the output gap; Ruge-Murcia (2003) used the model with asymmetric preference over the unemployment gap, which was the log difference between the unemployment rate and the natural rate of unemployment. Here, in order to study the policy preferences over these two factors, this paper combines both models, and the Central Bank's loss function becomes:

$$L = \frac{1}{2}(\pi_t - \pi_t^*)^2 + \lambda_1 \frac{e^{\gamma_1 y_t} - \gamma_1 y_t - 1}{\gamma_1^2} + \lambda_2 \frac{e^{\gamma_2 u_t} - \gamma_2 u_t - 1}{\gamma_2^2} \tag{54}$$

subject to the constraints

$$y_t = \alpha_1(\pi_t - \pi_t^e) + e_t \tag{55}$$

$$u_t = \alpha_2(\pi_t - \pi_t^e) + \epsilon_t \tag{56}$$

for which $\lambda_1, \lambda_2 > 0$, π_t is the inflation rate, π_t^* is the targeted inflation rate, y_t is the output gap that is measured as the log difference between real GDP and the potential output, u_t is the unemployment gap. γ_1 and γ_2 are the asymmetric preference factors on output and unemployment stabilization respectively. Negative γ implies that government dislikes negative gaps and positive γ indicates that positive gaps are weighted more severely than negative ones. Insignificant γ can be explained as a government's focus on bringing gaps to the potential or natural level regardless of the sign on the gaps. When γ is close to zero, the lost function can be written as the following by applying L'Hospital's rule with respect to γ

$$L = \frac{1}{2}[(\pi_t - \pi_t^*)^2 + \lambda_1 y_t^2 + \lambda_2 u_t^2] \tag{57}$$

for which the loss increases as long as output or unemployment rate deviates from the potential level or the natural rate.

Other factors, such as π_t^e is the public expectation at t-1 of the next period's inflation rate such that $\pi_t^e = E_{t-1}\pi_t$. The first constraint is the augmented New Keynesian Phillips Curve with $\alpha_1 > 0$, and the second constraint is the expectation-augmented Phillips Curve with $\alpha_2 < 0$. The Central Bank's objective is to minimize the loss with respect to the inflation rate at t

$$min\ E_{t-1}\Sigma_{j=0}^{\infty}\eta^j L_{t+j} \tag{58}$$

where η is the discount rate.

In order to better analyze the asymmetric preference factors regarding the output gap and unemployment gap, this paper follows the method in Ruge-Murcia (2003) and Surico (2008) to linearize around the exponential terms using first-order Taylor expansion. The reduced form is the following

$$\frac{\partial L_t}{\partial \pi_t} = \pi_t - \pi_t^* + \lambda_1\alpha_1 E_{t-1}y_t + \frac{\lambda_1\alpha_1\gamma_1}{2}E_{t-1}y_t^2 + \lambda_2\alpha_2 E_{t-1}u_t + \frac{\lambda_2\alpha_2\gamma_2}{2}E_{t-1}u_t^2 + e_t = 0 \quad (59)$$

for which e_t is the approximation error. The equation can be re-written as a function to π_t

$$\pi_t = \pi_t^* + \delta_1 y_t + \beta_1 y_t^2 + \delta_2 u_t + \delta_2 u_t^2 + v_t \quad (60)$$

where v_t is the new error term and

$$v_t = -\{\delta_1[y_t - E_{t-1}y_t] + \beta_1[y_t^2 - E_{t-1}y_t^2] + \delta_2[u_t - E_{t-1}u_t] + \beta_2[u_t^2 - E_{t-1}u_t^2] + e_t\} \quad (61)$$

where y_t^2 is the squared output gap and u_t^2 is the squared unemployment gap. $\delta_1 = -\lambda_1\alpha_1 < 0$, $\delta_2 = -\lambda_2\alpha_2 > 0$, $\beta_1 = -\frac{\lambda_1\alpha_1\gamma_1}{2}$ and $\beta_2 = -\frac{\lambda_2\alpha_2\gamma_2}{2}$. Therefore, the policy preference parameters $\gamma_1 = \frac{2\beta_1}{\delta_1}$ and $\gamma_2 = \frac{2\beta_2}{\delta_2}$. The signs of δ and β will both determine the policy preferences toward gaps, and the significance level on β will determine the significance on policy parameters.

One thing to notice from the sign restrictions on δ_1 and α_1 is that they may sometimes fail with an opposite sign, which will result in disinflationary boom, and this is caused by factors that cannot be explained by the model, such as sticky prices and staggered wage adjustment. Ball (1991) demonstrated that under monetary targeting with the Taylor-Blanchard model such that if a monetary growth decline was credibly announced and individual price was fixed for a certain period, then disinflationary boom could occur. Ball (1994) further demonstrated this point under the condition of full credibility. Fuhrer and Moore(1995) also found evidence that the curve is not always consistent with the interactions between inflation and output. Mankiw and Reis(2002) further deny the New Keynesian Phillips Curve and develop a model to replace it because the new model would not cause disinflationary boom. For the analysis in this paper, the different relationships between output gap and inflation are ignored for simplicity purposes.

Moreover, the sign restrictions on δ_2 and α_2, which should be positive and negative respectively, may also fail. According to Coibion and Gorodnichenko(2015), who used U.S. data, one reason is increasing inflation expectations due to high oil prices. Moreover, negative signs can also be triggered by increased housing prices or housing bubble according to Towbin and Weber(2015). Therefore, in order to study this problem with other countries, any sign conflicts on δ_2 and α_2 will be analyzed with changes in inflation expectations from housing and oil prices (Figure 14).

Section 2: Data

The data needed in the analysis are inflation rate, output gap, and unemployment gap. The output gap requires real and potential output, and the unemployment gap requires the unemployment rate and the natural rate. This paper examines quarterly data from 1991Q1 to 2015Q2. The OECD countries that were selected for the analysis were the U.S., the United Kingdom, Germany, Italy, Canada, Australia and the Netherlands. The U.S. and Canada represent North America economies among the OECD countries, Germany and the Netherlands represent core EMU countries, the United Kingdom and Italy are part of the peripheral countries, and Australia represents the Southern Hemisphere.

The quarterly data for the U.S. are all obtained from the FRED database, whereas the remaining countries are from the OECD database, which contains quarterly real GDP, unemployment rate, inflation rate and natural unemployment rate. All of the inflation rates are obtained from OECD database with CPI index, all of the real values in the dataset have 2010 set as the base year, and all data are seasonally adjusted. Due to the limited resources for obtaining the potential output for the countries except the U.S., the paper here applies the traditional HP-filter on real GDP to find the trend value, which is the potential GDP, for the rest of the countries.

Two sets of instrumental variables will be used in the analysis. An IV set (1) always includes three lags of each variable in the analysis, and the lags in the IV set (2) are chosen in accordance with the selection by the Akaike Information Criterion (AIC). The AIC here overrides the other methods in such a way that HQC works better with a sample size greater than 120 (Liew, 2004), and the BIC's prior was demonstrated to be insensible (Burnham and Anderson, 2002). Moreover, by comparing the predictive mean square error (PMSE) between the AIC and the BIC, the AIC has a smaller value than the BIC, and hence performs better (Burnham and Anderson, 2002,2004).

The standard errors reported in the tables are robust and use the appropriate lagged Newey-West covariance matrix. The lags are selected in accordance with Newey and West's (1994) results that the most accurately sized lag was $L = 3\frac{N}{100}^{\frac{2}{9}}$ where N is the sample size. The lags used for the full sample are always 3. In addition, the standard errors are considered for heteroskedasticity and auto-correlation problems in the error terms. The F-statistics in the table are used to test for weak instruments. Probability less than 5% indicates that the selected instruments are non-weak. Hansen's J-statistics in the table with probability greater than 5% mean that the instruments are valid. The results that are significant at the 5% level are indicated with **, and 10% levels are indicated with *.

Section 3: Results

1. The United States

The instrumental set (2) is chosen in accordance with the AIC value, which includes six lags of inflation, three lags of output gap and unemployment gap, one lag of squared output gap and two lags of squared unemployment gap. Table 7 shows the results for the full sample. The coefficients on output gap and squared unemployment gap are significantly different from zero, whereas those for squared output gap and unemployment gap are not. The targeted inflation rate is about 2.7%, which is above the targeted rate 2%.

Table 7: US Full Sample

Instruments	π^*	δ_1	β_1	δ_2	β_2	p-values
(1)	2.69**	1.3**	-.048	3.3	-31.3**	F-statistic: 0/0/0/0
	(.12)	(.37)	(.45)	(2.8)	(14.5)	J(11): .21
(2)	2.66**	1.2**	-.14	1.42	-22.9**	F-statistic: 0/0/0/0
	(.14)	(.41)	(.61)	(2.9)	(14.2)	J(11): .20

Table 8 reports the coefficients' behaviors before and after the Great Recession to examine the possible policy preference changes. According to the National Bureau of Economic Research (NBER), the Great Recession in the U.S. lasted from 2007Q4 to 2009Q2 and the early 2000s recession ended in 2001Q4. Therefore, this paper uses 2002Q1 to 2007Q3 as the period before the Great Recession so that it will not include any other recession effects. The first thing to notice from Table 8 is the targeted inflation rate, which was approximately 3.1% before the recession and not significantly different from zero afterward. Moreover, policy makers' actions regarding the negative unemployment gap were more aggressive than those for the positive gap before the recession. In other words, policy makers were more afraid of the positive inflation gap due to the inverse relationships between the unemployment gap and the inflation gap (Doh, 2011) given that the Federal Reserve was operating with the credibility of low-inflation during this period (Cooke and Gavin, 2014). However, the Fed's asymmetric policy toward the output gap was not as significant as the unemployment gap. Both IV sets reflect more aggressive policy action on the positive output gap only at the 10% significant level. This indicates that the government during this period acted toward the output gap by returning it to its potential level to stabilize inflation, but this action may not have been sufficiently strong. In fact, given the housing bubble in this period, policy makers believed the housing market was in good shape (Yellen, 2005); therefore, they did not want to correct the bubble, and their goal was to achieve potential GDP levels (Weidner and Williams, 2015).

Table 8: The US Recessions

Instruments	π^*	δ_1	β_1	δ_2	β_2	γ_1	γ_2	p-values
2002Q1-2007Q3:								
(1)	3.1**	.185	.54*	-3.26**	263.4**	5.84*	-161.6**	F-statistic: 0
	(.36)	(.64)	(.41)	(6.6)	(112.5)			J(11): .76
(2)	3.07**	.13	.68*	-3.36**	282.9**	10.5*	-168.4**	F-statistic: 0
	(.26)	(.49)	(.37)	(5.4)	(84.9)			J(11): .75
2009Q3-2015Q2:								
(1)	-.62	.62	-2.02*	27.4**	-55.5	-6.52*	-4.05	F-statistic: 0
	(.75)	(.96)	(1.21)	(12.5)	(50.0)			J(11): .82
(2)	-.67	.85	-2.14*	26.64**	-46.4	-5.04*	-3.48	F-statistic: 0
	(.78)	(1.1)	(1.13)	(12.04)	(49.2)			J(11): .84

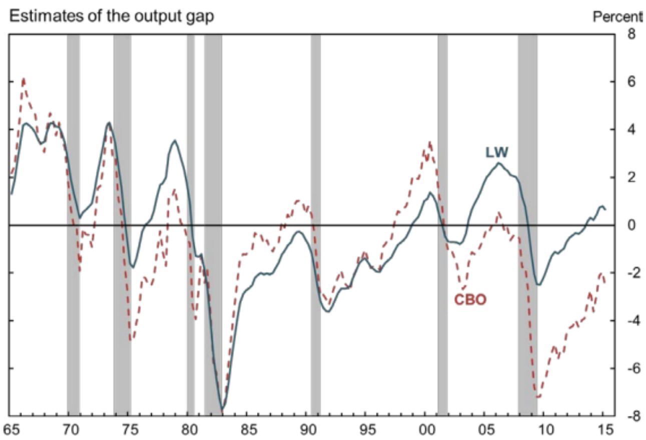


Figure 7: Laubach-Williams and CBO Estimated Output Gap

For the periods after the Great Recession, none of the policy preference factors are significant at the 5% level. The policy parameter over output gap is negative under the 10% significance level, and the government perceived negative output as more severe given that most of the time, the economy experienced a negative output gap (Figure 7). However, the action may not have been sufficiently strong given that the government lost credibility during the Great Recession; the priority issue was then to re-establish credibility and keep the inflation rate low and stable (Cooke and Gavin, 2014). This, somehow, resulted in an insignificant γ_2 because the government focused on returning the unemployment rate to the NAIRU level whether the gaps were positive or negative.

Other factors, such as the squared unemployment gap coefficient, show significant positive relationships with the inflation rate, although this effect disappears during the second time period. The output gap remains insignificantly related to the inflation rate for both periods. The parameter on unemployment gap shows a significant positive impact on inflation during the second period but is negative for the pre-recession period. The negativity may be trigged by the housing bubble during the pre-recession period according to Towbin and Weber(2015).

2. The United Kingdom

The IV(2) is selected according to the AIC, including two lags of inflation and output gap, three lags of squared output gap and seven lags of unemployment and squared unemployment gap. Table 9 presents the full sample. From the results, the average inflation target was approximately 2.4%, which is above the goal of 2%. Moreover, the only coefficients in the table is significant at 5% level is the squared output gap whereas other coefficients are insignificant.

Table 9: The UK Full Sample

Instruments	π^*	δ_1	β_1	δ_2	β_2	p-values
(1)	2.4**	.24	.57**	1.1	-4.66	F-statistic: 0/0/0/0
	(.21)	(.29)	(.26)	(3.18)	(8.98)	J(11): .48
(2)	2.4**	.34	.58**	.55	-7.2	F-statistic: 0/0/0/0
	(.15)	(.29)	(.21)	(1.9)	(6.7)	J(17): .76

In May 1997, the Bank of England shifted its original control of interest rates to a new bank division, the Monetary Policy Committee (MPC)(Martign and Samiei, 1999). Table 10 separates the data into three periods: 1991Q4-1997Q2, 1997Q3-2008Q1 and 2009Q3-2015Q2 to study the effects of policy changes before and after 1997 and the Great Recession. For the first period, due to a limited sample size, IV(2) will not be analyzed here for large lags; moreover, the first period starts from 1991Q4 to avoid the effects of the early 1990s recession, which lasted from 1990Q3-1991Q3 (Sentence, 2009).

Table 10: The UK 1997 and Recession

Instruments	π^*	δ_1	β_1	δ_2	β_2	γ_1	γ_2	p-values
1991Q4-1997Q2:								
(1)	3.0**	2.1**	-1.28	11.7**	-157.7**	-1.22	-27.0**	F-statistic: 0
	(.32)	(.59)	(2.8)	(3.07)	(35.1)			J(11): .93
1997Q3-2008Q1:								
(1)	2.6**	.82**	-1.35**	46.2**	99.5**	-3.29**	4.3**	F-statistic: 0
	(.21)	(.3)	(.48)	(19.2)	(39.8)			J(11): .65
(2)	2.5**	.87**	-1.2**	37.6**	82.4**	-2.8**	4.38**	F-statistic: 0
	(.26)	(.31)	(.58)	(19.1)	(40.2)			J(17): .93
2009Q3-2015Q2:								
(1)	4.3**	2.6**	.08	18.0**	-3.7	.06	-.41	F-statistic: 0
	(1.3)	(1.04)	(.9)	(12.4)	(27.9)			J(11): .78
(2)	4.5**	2.1**	-.3	21.5**	6.1	-.29	.57	F-statistic: 0
	(1.0)	(.93)	(.77)	(9.57)	(22.6)			J(17): .92

From the result, it is clear that establishing the MPC was able to bring down the targeted inflation rate from 3.0% to 2.5% for the first ten years; however, for the years after the great recession, the MPC did not seem to be effective at keeping the targeted inflation low. In fact, according to a speech by Cunliffe (2014), the MPC intentionally allowed inflation to deviate from targeted inflation to avoid financial instability risk after the crisis, and the recession shocks brought more volatile asset prices to the United Kingdom and affected trade channels, some financial channels and other factors (Chowla, 2014). Moreover, before the crisis, the Central Bank's preferences over the unemployment gap and output gap were significant by more heavily weighting the positive and negative gaps, respectively; however, either of the preferences becomes significant after the crisis. Before the recession, the negative output gap was treated as a more severe problem than was the positive gap by the central bank. Due to this, the UK's economy grew steadily and did not contract for even one quarter during these ten years (Cunliffe, 2014). The positive parameter on unemployment gap indicates that the Central Bank of England aimed to reduce the unemployment rate to promote economic growth. For the periods after the recession, it is clear that the government's major goal was to stabilize its economy (Sentence, 2011) by returning it to the potential level regardless of whether the unemployment rate or output level was below or above their equilibrium levels. The squared unemployment gap during the after-crisis period was significantly positively related to inflation rate for both IV sets.

For the period before the establishment of MPC, the government acted more aggressively on the negative unemployment gap and had no significant preferences for output gap. The 3% targeted inflation is within its initial objective range of 1% to 4%. Other factors are significantly related in determining inflation rate except the squared output gap.

Although the United Kingdom is experiencing increasing housing prices since 1995, studies such as Cameron et al.(2006) and Chandler and Disney(2014) did not find evidence for housing bubble; therefore, the sign of δ_2 is still consistent with the theory.

3.Germany

The IV(2) includes five lags of inflation, four lags of output gap, one lag of squared output gap, three lags of unemployment gap and squared unemployment gap that are chosen from the AIC method. Table 11 reports the results from the full sample. From the table, the targeted inflation rate for Germany was very low, less than 2%, and this is consistent with other studies, such as Beyer et al. (2009). The output gap shows a positive effect on inflation, and the unemployment gap has the same effect in both IV sets. All the rest coefficients are insignificant.

Table 11: German Full Sample

Instruments	π^*	δ_1	β_1	δ_2	β_2	p-values
(1)	1.6**	.83**	.017	2.3**	-2.3	F-statistic: 0/0/0/0
	(.27)	(.15)	(.16)	(1.1)	(25.9)	J(11): .70
(2)	1.3**	.82**	.14	1.7**	20.0	F-statistic: 0/0/0/0
	(.26)	(.14)	(.13)	(1.2)	(27.8)	J(12): .75

In order to analyze the policy changes before and after the Great Recession, the time frame has been divided into two parts in Table 12: 2002Q1-2008Q1 as before the crisis to avoid the early 2000s recession effects, and 2009Q4-2015Q2 as the post-crisis period because most studies, such as Burda and Hunt (2011), take 2008Q1-2009Q4 as the recession period.

Table 12: German Recessions

Instruments	π^*	δ_1	β_1	δ_2	β_2	γ_1	γ_2	p-values
2002Q1-2008Q1:								
(1)	2.2**	.14	.58**	-22.2**	117.5**	8.29**	-10.6**	F-statistic: 0
	(.55)	(.16)	(.17)	(11.0)	(56.0)			J(11): .74
(2)	2.6**	.08	.57**	-29.4**	146.3**	14.25**	-9.95**	F-statistic: 0
	(.57)	(.20)	(.21)	(11.0)	(55.0)			J(12): .82
2009Q4-2015Q2:								
(1)	1.3**	.42**	.37**	-26.1**	-275.1**	1.76**	21.1**	F-statistic: 0
	(.22)	(.21)	(.20)	(9.6)	(92.7)			J(11): .75
(2)	1.26**	.33**	.4**	-29.6**	-308.5**	2.4**	20.8**	F-statistic: 0
	(.25)	(.27)	(.18)	(7.5)	(71.4)			J(12): .8

The first thing to notice from Table 12 is the targeted inflation rate. The post-crisis targeted rate is much lower than the pre-crisis rate. Moreover, the central bank during the second time frame disliked the positive unemployment gap; that is the Central Bank was aiming for a high rate of employment. In fact, according to the research by Raukau and Schneider (2013), private consumption was likely to increase due to high employment and low inflation since the Great Recession, and this was consistent with the results here. In contrast, the pre-crisis result indicates that the governments disliked negative unemployment gap, which resulted in high rates of unemployment but could reduce inflation rate. According to Bornhorst and Mody (2012), despite high economic growth, the unemployment rate remained high in the 2000s, which caused a low level of private consumption growth and this continued into the Great Recession. For the asymmetric preference over output gap, both periods reflected dislike for positive output gaps, mainly due to the Central Bank's aim to keep inflation low (Thornton, 2012). Additionally, the Central Bank weighted a positive output gap more heavily during the pre-crisis period than post-crisis mainly due to the higher inflation rate from the first period.

One more thing to notice from the result is the negative coefficient for unemployment gap in both periods, which according to the model should have been positive. One reason that may contribute to this is the increase in public expectations on inflation rates. For the pre-recession period, according to a recent study from D'Acunto et al. (2015), household expectations on inflation began to increase from the end of 2005, mainly due to the announcement of a VAT increase, and this effect continued into 2008. At the same time, oil prices, as shown in Figure 14, started to increase in the early 2000s. The two effects together likely contributed to the negative δ_2. For the post-recession period, the oil price was stable and began to decrease in late 2014; the reverse was found for housing prices. According to a study conducted by the OECD, German housing prices began to increase after the recession and similar findings can be found in a very recent study by Kholodilin et al.(2014), which showed a sign for the speculative housing bubble in Urban Germany with data ranges from 1996 to 2013. Therefore, the negative δ_2 for the post-recession period is mainly caused by the increasing housing prices, or more precisely the risk of housing bubble.

Other factors are consistent with both IV sets. Squared output gap is shown as placing upward pressure on the inflation rate for both periods, and the negative unemployment gap does the same thing. The squared unemployment gap shows a positive relationship to the inflation rate for the pre-crisis period, but it was negatively related to inflation during the post-crisis period.

4.Italy

The IV(2) includes five lags of inflation and output gap, three lags of squared output gap and one lag of unemployment gap and squared unemployment gap that are chosen from the

AIC method. Table 13 reports the results from the full sample. From the table, all coefficients are significantly different from zero in both IV sets except for squared output gap. The targeted inflation rate is 2.7%, which is above the targeted level 2%.

Table 13: Italy Full Sample

Instruments	π^*	δ_1	β_1	δ_2	β_2	p-values
(1)	2.7**	1.0**	.1	10.7**	-175.7**	F-statistic: 0/0/0/0
	(.20)	(.30)	(.27)	(3.9)	(51.3)	J(11): .2
(2)	2.7**	.68**	-.087	5.4**	-136**	F-statistic: 0/0/0/0
	(.23)	(.29)	(.28)	(3.5)	(44.5)	J(11): .33

Table 14 separates the full sample into two periods: 2002Q1-2008Q1 as before the recession and 2009Q3-2015Q2 as afterward. From the table, both IV sets have consistent results under both time periods. Targeted inflation rate before recession is 2.3%, which is higher than in the post-crisis period, which indicates a higher rate of inflation before the crisis. The governments' asymmetric preferences over the unemployment gap were insignificant under both periods, indicating the aim at bring unemployment rate back to the natural level. The output gap preference factor is positive under the first period, given that between 1998-2008 Italy was experiencing a positive output gap (Deutsche Bundesbank Report, 2014)(Figure 8); however, the factor insignificant for the second period because it contains both output expansion and contraction.

Table 14: Italy Recessions

Instruments	π^*	δ_1	β_1	δ_2	β_2	γ_1	γ_2	p-values
2002Q1-2008Q1:								
(1)	2.3**	.43	.57**	12.2**	-38.9	2.65**	-6.4	F-statistic: 0
	(.08)	(.29)	(.2)	(4.3)	(31.7)			J(11): .81
(2)	2.2**	.13	.8**	10.9**	-31.7	12.3**	-5.8	F-statistic: 0
	(.05)	(.20)	(.14)	(2.4)	(19.6)			J(11): .75
2009Q3-2015Q2:								
(1)	1.9**	.8*	-.5	14.4	-168.6	-1.25	-23.4	F-statistic: 0
	(.8)	(.4)	(..5)	(29.0)	(199.2)			J(11): .76
(2)	1.4**	1.1*	-.25	32.1	-288.4	-.45	-17.97	F-statistic: 0
	(1.3)	(.57)	(.7)	(41.7)	(247.9)			J(11): .82

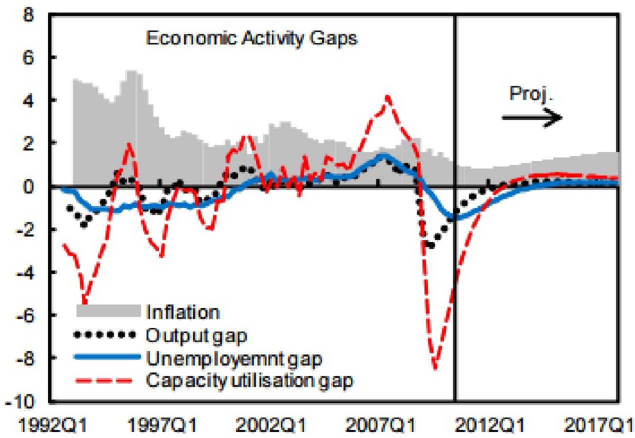


Figure 8: Morsy and Sgherri (2010): IMF Calculated Gaps

Other coefficients in the second period are not significantly related to inflation rate at the 5% level and output gap is positively related to the rate only under 10% significance level, which may not significantly increase inflation with the positive output gap. In the first period, squared output gap and unemployment gap are significantly positively related to inflation, but other coefficients are insignificant.

5. Canada

The instrument variables that are selected for analyzing Canada are IV(1) and IV(2). IV(1) contains three lags of inflation, output gap, squared output gap, unemployment gap and squared unemployment gap. IV(2) includes five lags of inflation, four lags of squared output gap, three lags of unemployment gap, two lags of output gap and one lag of squared unemployment gap that are chosen in accordance with the AIC. In the result, for both IV sets, only squared output gap is significantly negative related to the inflation rate while others are not statistically different from zero. The targeted inflation rate is around 1.9% and it is below the targeted rate 2% and within the range of 1 to 3 percent according to Bank of Canada.

Table 15: Canada Full Sample

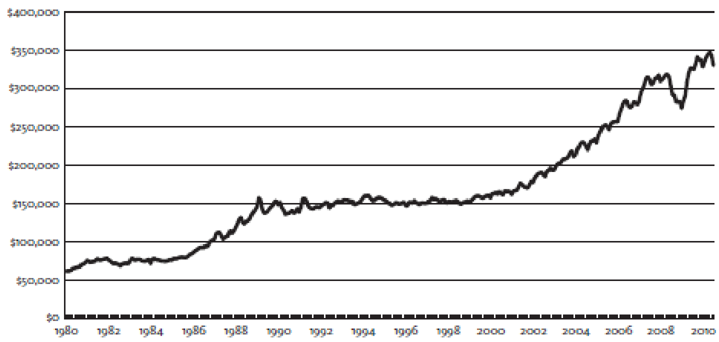
Instruments	π^*	δ_1	β_1	δ_2	β_2	p-values
(1)	1.9**	-.22	-.9**	-5.4	-69	F-statistic: 0/0/0/0
	(.15)	(.57)	(.45)	(5.4)	(57.4)	J(11): .16
(2)	1.8**	-.16	-.98**	-8.4	76.6	F-statistic: 0/0/0/0
	(.14)	(.50)	(.42)	(4.7)	(56.2)	J(11): .12

Table 16 separates the full sample into two periods for pre- and post-recession analysis. Canada was not affected by the early 2000s recession, and its last recession ended in 1992Q2. The Great Recession lasted from 2008Q3 to 2009Q2 (Cross and Bergevin, 2012). Therefore, the time frame is divided into 1992Q3-2008Q2 as pre-recession and 2009Q3-2015Q2 as post-recession.

Table 16: Canada Recessions

Instruments	π^*	δ_1	β_1	δ_2	β_2	γ_1	γ_2	p-values
1992Q3-2008Q2:								
(1)	1.7**	-.7	.047	-12.8**	73.7	-.13	-11.5	F-statistic: 0
	(.22)	(.5)	(.92)	(4.8)	(56.4)			J(11): .37
(2)	1.7**	-.45	-.5	-10.9**	58.3	2.2	-10.7	F-statistic: 0
	(.05)	(.20)	(.9)	(5.3)	(68.6)			J(11): .35
2009Q3-2015Q2:								
(1)	1.6**	3.0**	-.9**	32.6**	199.9	-.6**	12.3	F-statistic: 0
	(.22)	(.67)	(.19)	(4.3)	(247.2)			J(11): .77
(2)	1.7**	2.7**	-.76**	32.3**	53.8	-.56**	3.3	F-statistic: 0
	(.24)	(.69)	(.24)	(4.27)	(288.4)			J(11): .78

From the results in Table 16, the first item of note is the targeted inflation rate, which remained low and stable at approximately 1.7% for both periods. The Central bank's preference for output gap is reflected as aiming for stable output before recession and at disliking a negative output gap after the recession given that Canada had been experiencing negative output gap since 2009 (IMF Report, 2015). The preference toward unemployment gap is consistent for both periods as focusing on the natural level. Moreover, during the pre-crisis period, only unemployment gap is significantly related to the inflation rate, whereas only squared unemployment gap is insignificant during the post-recession time period.



(a)

Figure 9: Macdonald(2010)

An additional item to note from the table is that the unemployment gap during the first period has a negative relationship to the inflation rate, but it should have been positive. This may mainly come from the higher public inflation expectation during this period. According to Macdonald(2010), Canada in the post-2000 era experienced increased in housing prices, which is shown in Figure 3. In addition, it is very likely that there existed a housing bubble before the recession, which this might have led to a negative δ_2.

6. Australia

The IV(2) includes in the analysis are six lags of inflation, one lag of output gap, squared output gap and squared unemployment gap and three lags of unemployment gap that are chosen according to AIC results.

Table 17: Australia Full Sample

Instruments	π^*	δ_1	β_1	δ_2	β_2	p-values
(1)	2.2**	-3.15**	7.5**	-11**	-14.5	F-statistic: 0/0/0/0
	(.3)	(.84)	(3.6)	(3.6)	(45.8)	J(11): .18
(2)	2.1**	-3.3**	8.1**	-13.4**	.14	F-statistic: 0/0/0/0
	(.30)	(.96)	(3.5)	(3.7)	(48.5)	J(8): .09

In the table, the targeted inflation rate for Australia is approximately 2.2%, which is within the range of 2-3 percent. Other coefficients in the table show significant relationships with the inflation rate except for squared unemployment gap. One thing to notice from the result is the negativity of the unemployment gap coefficient, and one contributor to this is the consistent high inflation expectations in Australia, which is related to its housing bubble. According to Kennard and Hanne(2015), Australia's real estate prices began increasing since approximately 1998 and have been warned with housing bubble by the middle of 2000s (Yates, 2011).

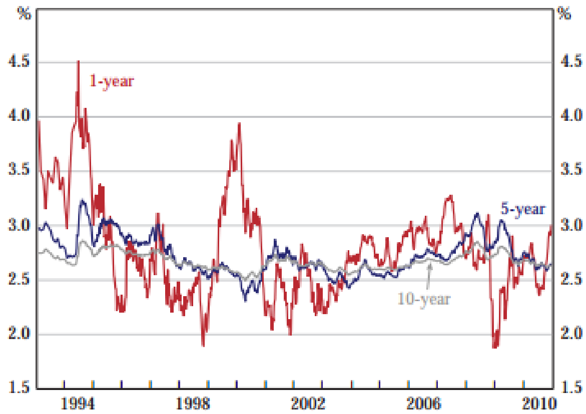


Figure 10: Source: Finlay and Wende (2012) Inflation Expectations

Australia did not suffer from the Great Recession, and its early 1990s recession ended in approximately 1993Q4. In order to better sees Australia's policies before and after the recession, Table 17 divides the full sample into three parts: 1994Q1-2015Q2 as Australia not suffering from any recessions; 1994Q1-2008Q1 as the policies before the recession and 2009Q3-2015Q2 as the policies after the recession.

The government preferences over unemployment gap are insignificant for all three time segments. The asymmetric preference over output gap is negatively significant for the first two segments but insignificant for 2009Q3-2015Q2, when the Central Bank focused on bringing the output gap to the potential level. In Figure 11, during the period between 1994 and 2008, Australia had a negative output gap until 2001 or so, and during this period, the Australian Reserve Bank might have aimed at bringing output level back to the potential GDP and attempting to stabilize growth; these goals would have contributed to the negative policy preference parameter on output gap. For the period from 2009 to 2014, the output gap fluctuates around the potential level and does not dramatically differ from it, which contributes to the insignificant policy parameter on output gap.

Table 18: Australia Analysis

Instruments	π^*	δ_1	β_1	δ_2	β_2	γ_1	γ_2	p-values
1994Q1-2015Q2:								
(1)	1.9**	-3.7**	9.9**	-6.1**	112.1	-5.4**	-36.8	F-statistic: 0
	(.35)	(1.04)	(3.4)	(4.2)	(72.3)			J(11): .34
(2)	2.0**	-3.6**	9.1**	-11.1**	85.7	-5.1**	-15.4	F-statistic: 0
	(.35)	(1.1)	(3.9)	(4.2)	(59.0)			J(8): .1
1994Q1-2008Q1:								
(1)	2.0**	-4.6**	9.0**	-11.6**	48.9	-3.9**	-8.4	F-statistic: 0
	(.39)	(1.1)	(3.6)	(5.5)	(78.9)			J(11): .6
(2)	2.0**	-4.7**	9.2**	-13.2**	10.9	-3.9**	-1.65	F-statistic: 0
	(.4)	(1.1)	(3.7)	(5.3)	(87.1)			J(8): .27
2009Q3-2015Q2:								
(1)	2.6**	-2.0**	-2.7	-13.0*	40.6	2.7	-6.2	F-statistic: 0
	(.12)	(.54)	(2.3)	(7.2)	(95.5)			J(11): .8
(2)	2.6**	-2.0**	-2.6	-12.8*	44.8	2.6	-7	F-statistic: 0
	(.15)	(.57)	(3.4)	(7.6)	(99.0)			J(8): .66

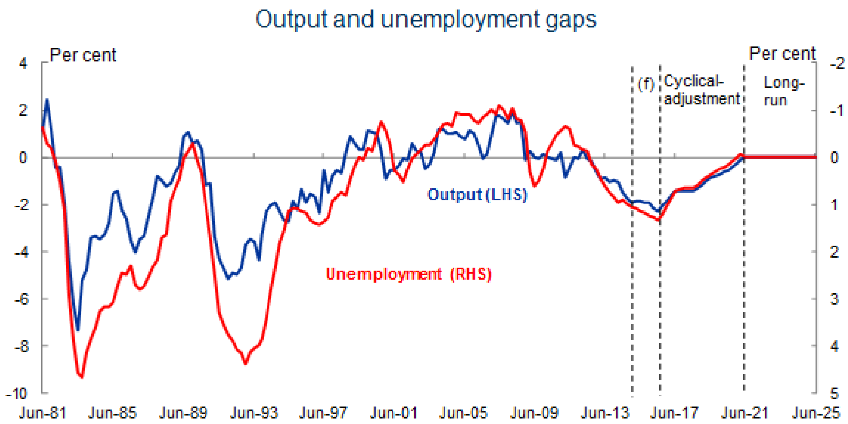


Figure 11: Source: Bullen et al. (2014)

The coefficient on unemployment gap is shown to be negatively related to the inflation rate in all time segments, the reason was explained above. One thing to notice from the result is the change in significance level. During the last time segment, this coefficient is only significant at 10%, indicating that the effect on inflation is not as strong as it was in the previous periods.

From Figure 10, the inflation expectation has a tendency to decrease and remain stable after 2009. In fact, according to the monthly survey from the Melbourne Institute for Consumer Inflationary Expectations[5], between January 2012 and December 2014 (Figure 12), consumers' expectations on inflation are rather stable and within the targeted range at approximately 2.5% during most of the periods except the second half of 2014. Therefore, together with the negative output gap since approximately 2011 in Figure 11, it is possible that the effect of high expectations on inflation rate is weakened.

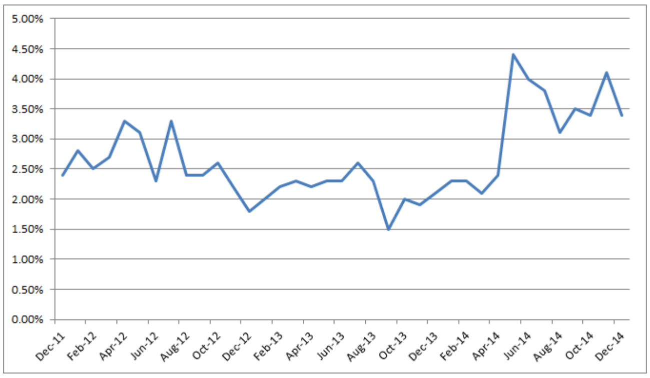


Figure 12: Source: Melbourne Institute for Consumer Inflationary Expectations

Other factors' results are consistent in all three periods, except the squared output gap in the last period, which is insignificant. Both IV sets have consistent results in all time frames.

7. The Netherlands

The last country that is selected for the analysis is the Netherlands, which is one of the core countries in the EMU. The instrumental variables that are used in this section are IV(1) and IV(2), which IV(2) includes five lags of inflation, three lags of output and unemployment gap, and two lags of squared output and unemployment gap, which are selected according to the AIC. Table 19 is the results for the full sample size.

[5]https://www.melbourneinstitute.com/miaesr/news/media_releases/recent_media_release.html

Table 19: The Netherlands Full Sample

Instruments	π^*	δ_1	β_1	δ_2	β_2	p-values
(1)	2.3**	.085	-.7**	-5.3**	12.4**	F-statistic: 0/0/0/0
	(.14)	(.31)	(.26)	(.9)	(4.6)	J(11): .17
(2)	2.2**	.03	-.7**	-5.4**	15.3**	F-statistic: 0/0/0/0
	(.15)	(.28)	(.30)	(.7)	(4.9)	J(11): .20

From the table, the targeted inflation rate is in the area of 2.3% in both IV sets, which is close to the objective of European monetary policy with its 2% inflation target. The coefficients on squared output gap and unemployment gap are significantly negatively related to inflation rate, and the squared unemployment gap shows a positive relationship in both IV sets. Output gap, in contrast, is insignificant. However, according to theory, the coefficient of unemployment gap should be positive, which depicts the possibility of the existence of housing bubble. In fact, according to Igan(2010), housing prices in the Netherlands are shown as increasing beginning in 1995 and housing market may experiencing a bubble, which the negative δ_2 may be caused by this reason during the full period.

For the analysis related to the recession, Table 20 divides the sample into two periods: 2002Q1-2008Q2 as before the recession and 2009Q3-2015Q2 as after the recession. From the results, both IV sets show consistent results.

The estimated targeted inflation rate before the recession is 1.3%, which meets the objective that was set by EMU. The targeted inflation for the post-recession period is not significantly different from zero given that the central bank wanted to reduce inflation by aiming low. The coefficients on unemployment gap are negative for the pre-recession period but becomes positive after the recession. The negativity on δ_2 for the pre-recession period mainly comes from the public's increasing inflation expectations, which has been mentioned above as Dutch housing market is experiencing increasing housing prices and risk of housing bubbles during this period. The post-recession period, however, suffers from negative output gap and stable and decreasing trends in both housing prices, as seen in Figure 13 and proved by Igan(2010), and oil prices; therefore might not have experienced high public inflation expectations such that δ_2 would be positive.

Table 20: Netherlands Recessions

Instruments	π^*	δ_1	β_1	δ_2	β_2	γ_1	γ_2	p-values
2002Q1-2008Q2:								
(1)	1.3**	-.8**	.1	-9.4**	40.6**	-.25	-8.64**	F-statistic: 0
	(.09)	(.12)	(.1)	(1.0)	(7.3)			J(11): .77
(2)	1.3**	-.9**	.1	-9.7**	42**	-.22	-8.66**	F-statistic: 0
	(.08)	(.11)	(.09)	(1.1)	(8.9)			J(11): .82
2009Q3-2015Q2:								
(1)	.22	-.98**	1.2	25.1**	-73.1**	-2.4	-5.8**	F-statistic: 0
	(1.16)	(.5)	(1.7)	(12.1)	(32.7)			J(11): .74
(2)	.25	-1.1**	-1.5	25.2**	-74.9**	2.7	-5.9**	F-statistic: 0
	(.87)	(.57)	(.9)	(10.8)	(33.5)			J(11): .77

Figure 13: Source: Statistics Netherlands

The government policy preference parameters during these two periods are consistent. Preference over the output gap is insignificant in terms of bringing output to the potential level. The preference over unemployment gap is negative, with the aim of reducing the inflation rate.

Section 4: Comparison and Conclusion

From above tables, the U.S. and the Netherlands had insignificant targeted inflation rates in the post-recession period. The United Kingdom and Australia showed an increase in targeted inflation rate after the recession, whereas Germany and Italy showed a decreasing trend. The UK among all countries had the highest targeted inflation rate after the recession, above 4%. Canada, in contrast, was stable in consistently keeping the implicit inflation target low at approximately 1.7%. For policy preferences, the Netherlands was able to keep its preferences toward both gaps consistent for pre- and post-recessions. The remaining countries experienced inconsistencies in policy preferences over time. For core and peripheral countries, there are no dramatic differences in policy preferences except that the peripheral countries tend to have insignificant policy preferences in post-recession periods. Additionally, core countries tend to have stricter policies on unemployment gaps than peripheral countries; specifically, core countries have significant preferences over unemployment gap for both pre- and post-recession periods, but peripheral countries are not. In other words, peripheral countries tend to have insignificant preference toward unemployment gap on either or both of the periods. Moreover, the core countries show lower targeted inflation rates than do the peripheral countries.

In addition, by separating countries into inflation targeting (Australia, Canada and the UK) and non-inflation-targeting groups (the U.S., Germany, Italy and the Netherlands), and compare their policy preferences, one is able to notice that all inflation targeting countries are having no preference on unemployment gap for the post-recession period but this does not apply on all non-inflation-targeting countries. Moreover, by look into the targeted inflation rate for the post-recession period, all non-inflation-targeting countries are showing low targeted rate by having either insignificant rate or below the central bank's target, which does not apply to most inflation targeting countries.

Moreover, by examining the coefficients of unemployment gap δ_2, the analyses above discover that with countries that are experiencing negative values on the coefficient during certain period, they also at the same time expose to the risk of housing bubbles at that time frame.

Part II: Correction of Non-stationarity

Section 1: Model

This section applies non-parametric method to adjust for non-stationarity in the dataset with the instrument variables.The idea is to minimize the loss of information that is caused by conventional first integration process and also to reduce the non-stationarity effect on the results from the first-stage regression. The method applied here is that of Cai and Wang (2014) and uses the original model from Part I:

$$\pi_t = \pi_t^* + \delta_1 y_t + \beta_1 y_t^2 + \delta_2 u_t + \beta_2 u_t^2 + v_t \tag{62}$$

where $v_t = -\{\delta_1[y_t - E_{t-1}y_t] + \beta_1[y_t^2 - E_{t-1}y_t^2] + \delta_2[u_t - E_{t-1}u_t] + \beta_2[u_t^2 - E_{t-1}u_t^2] + e_t\}$ is the error term. The GMM analysis in this section will considers IV(1), which includes three lags of inflation, output gap, squared output gap, unemployment gap and squared unemployment gap. Therefore, the five sets of instrumental variables can be written in the equation form for the first-regression as:

$$\begin{aligned} X_t = [y_t, y_t^2, u_t, u_t^2]' = \omega + \tau_{\pi_1}\pi_{t-1} + \tau_{\pi_2}\pi_{t-2} + \tau_{\pi_3}\pi_{t-3} \\ +\tau_{y_1}y_{t-1} + \tau_{y_2}y_{t-2} + \tau_{y_3}y_{t-3} + \tau_{y_1^2}y_{t-1}^2 + \tau_{y_2^2}y_{t-2}^2 \\ +\tau_{y_3^2}y_{t-3}^2 + \tau_{u_1}u_{t-1} + \tau_{u_2}u_{t-2} + \tau_{u_3}u_{t-3} + \tau_{u_1^2}u_{t-1}^2 \\ +\tau_{u_2^2}u_{t-2}^2 + \tau_{u_3^2}u_{t-3}^2 + \kappa_t \end{aligned} \tag{63}$$

where ω indicates constant terms, τ are the coefficients and κ_t is the error term. Assume that x_t

is the non-stationary variable(s) among $[\pi, y, y^2, u, u^2]$ and $X_t = \Omega + T_1 x_{t-1} + T_2 x_{t-2} + T_3 x_{t-3} + T[m_t] + K_t$ indicate first-stage regression. Ω, T and K_t represent constant term, coefficients and error term respectively. $[m_t]$ are the rest instrument variables. Moreover, x_t, x_{t-1},x_{t-2} and x_{t-3} satisfy the AR(1) model

$$\begin{aligned} x_t &= \rho_1 x_{t-1} + \psi_{t1} \\ x_{t-1} &= \rho_2 x_{t-2} + \psi_{t2} \\ x_{t-2} &= \rho_3 x_{t-3} + \psi_{t3} \\ x_{t-3} &= \rho_4 x_{t-4} + \psi_{t4} \end{aligned} \tag{64}$$

for which all the ρ in the analysis are within the interval of $\rho \in (.98, 1)$ and each instance of error term ψ_t is linearly projected onto the error term K_t in the instrument regression

$$K_t = \zeta_1 \psi_{t1} + \zeta_2 \psi_{t2} + \zeta_3 \psi_{t3} + \zeta_4 \psi_{t4} + z_t \tag{65}$$

for which ζ are the coefficients. Therefore, the equation after non-stationarity adjustment becomes

$$X_t = \Omega + T_1 x_{t-1} + T_2 x_{t-2} + T_3 x_{t-3} + T[m_t] + \zeta_1 \psi_{t1} + \zeta_2 \psi_{t2} + \zeta_3 \psi_{t3} + \zeta_4 \psi_{t4} + z_t \tag{66}$$

for which z_t is uncorrelated with ψ and the lagged values.[6]

According to the Part I analysis, the original model is robust to instrument selection for all seven countries that were examined. Therefore, any inconsistent results in the variables' significance levels between these two tests can be considered as caused by non-stationary data.

[6]The first stage regression will only use endogenous variables to regress on instrument variables

Section 2: Results

1.The United States

Unit-root tests on U.S. data indicate that the following variables are non-stationary from the previous analysis: output gap, unemployment gap and squared unemployment gap. The results in Table 21 reflects the non-stationarity problem in the data with instrument variables. By comparing these with previous results, the first difference comes from the full sample; the previous result showed significance in the squared unemployment gap at 5%, but significance was only 10% here. The other change comes from the pre-recession period, for which previous analysis indicates a significant positive relationship between squared output gap and inflation at 10% significance level. However, after the non-stationarity adjustment, squared output gap becomes insignificant, as does the policy parameter on output gap. In addition, the insignificant unemployment gap coefficient here contradicts with the significant negative value from previous test. The last difference comes from the post-recession period; the previous results show a positive relationship between unemployment gap and inflation at 5%; but significance was only 10% here.

Table 21: The U.S. Analysis

Instruments	π^*	δ_1	β_1	δ_2	β_2	γ_1	γ_2	p-values
Full Sample:								
(1)	2.7**	1.18**	-.03	2.0	-26.1*			F-statistic: 0
	(.13)	(.37)	(.57)	(2.7)	(14.8)			J(14): .33
2002Q1-2007Q4:								
(1)	3.0**	.34	.55	4.4	-252.6**	3.2	-114.8**	F-statistic: 0
	(.31)	(.56)	(.35)	(5.8)	(106.3)			J(14): .91
2009Q3-2015Q2:								
(1)	-.54	.56	-2.3*	26.0*	-48.5	-2.58*	-3.7	F-statistic: 0
	(.88)	(.99)	(1.3)	(14.5)	(53.5)			J(14): .93

All of the rest of the factors are similar to the results in the previous analysis despite the differences in values, which might have been caused by the amount of IV in the test. The possible non-stationarity effects in the U.S. analysis are reflected as decreasing significant levels of the variable, and both tests show consistent results if the original analysis uses 5% significance; however, the test here uses 10%.

2. The United Kingdom

Unit-root tests on UK data indicate that the following variables are non-stationary: output gap, unemployment gap and squared unemployment gap. Table 22 is the result after non-stationarity adjustment in the instrumental variables. From the table, the full sample and pre-recession analyses are consistent with previous analyses. However, the pre-reform and post-recession period show dramatic differences in these two results. The pre-reform era from the previous analysis shows significance in coefficients on every variable except the squared output gap; however, with the non-parametric analysis here, the squared output gap is also statistically significant from zero at 5%, and this change applies to the asymmetric preference factor here on output gap, which becomes significant. In addition, the coefficient value on output gap was positive from previous result, but becomes negative here, which also applies to the coefficients on unemployment gap and squared unemployment gap.

Table 22: The UK Analysis

Instruments	π^*	δ_1	β_1	δ_2	β_2	γ_1	γ_2	p-values
Full Sample:								
(1)	2.4**	.22	.57**	.75	-5.5			F-statistic: 0
	(.13)	(.26)	(.25)	(2.5)	(7.5)			J(14): .69
1991Q4-1997Q2:								
(1)	3.1**	-2.8**	-3.3**	-9.2**	-213.5**	2.4**	46.4**	F-statistic: 0
	(.22)	(.44)	(1.6)	(1.7)	(56.1)			J(14): .91
1997Q3-2008Q1:								
(1)	2.1**	.74**	-1.3**	49.8**	106.7**	-3.5**	4.3**	F-statistic: 0
	(1.8)	(.32)	(.54)	(15.2)	(31.5)			J(14): .81
2009Q3-2015Q2:								
(1)	4.0**	2.3	-.09	16.7	-3.9	-.08	-.47	F-statistic: 0
	(.88)	(1.6)	(1.4)	(16.4)	(39.2)			J(14): .92

For the post-recession period, although the policy preferences on output gap and unemployment gap are consistent in both analyses, the coefficient significance levels on both gaps are inconsistent. The previous analysis shows a positive significant relationship between the two gaps and inflation, but the effect disappears with the analysis here.

3. Germany

The unit-root test on the German data shows that the non-stationarity problem exists in the inflation, output gap, unemployment gap and squared unemployment gap. In comparing both analyses, the results indicate that the non-stationarity problem did not unduly affect the German results in the post-recession analysis. Most differences come from the coefficients on variables. The unemployment gap for both the full sample and the pre-recession period are significant at 5% in the previous analysis but only 10% here. Moreover, the coefficient on output gap before the recession is insignificantly related to the inflation from Table 12 but becomes significantly positive at 5% here.

Table 23: German Analysis

Instruments	π^*	δ_1	β_1	δ_2	β_2	γ_1	γ_2	p-values
Full Sample:								
(1)	1.6**	.81**	.03	2.1*	.76			F-statistic: 0
	(.22)	(.15)	(.1)	(1.2)	(22.5)			J(15): .85
2002Q1-2008Q1:								
(1)	2.1**	.18**	.4**	-16.2*	85.5**	4.4**	-10.6**	F-statistic: 0
	(.48)	(.07)	(.1)	(8.8)	(43.7)			J(15): .91
2009Q4-2015Q2:								
(1)	1.3**	.49**	.35**	-24.3**	-259.4**	.34**	21.3**	F-statistic: 0
	(.21)	(.14)	(.17)	(8.6)	(86.7)			J(15): .90

Despite the differences in coefficients, the policy preference parameters are not influenced by the non-stationarity; therefore, they are consistent in both tests.

4.Italy

The Italian data are non-stationary in the variables of inflation, output gap, unemployment gap and squared unemployment gap according to unit-root tests. Table 24 shows the test results with non-stationarity adjustments. The only difference from the non-stationarity problem is the output gap coefficient during the post-crisis era. The previous analysis in Table 14 shows a significant relationship between inflation and the output gap at 10% level, whereas the result here is insignificant. The remaining factors, especially the policy preference parameters, are consistent in both analyses.

Table 24: Italy Analysis

Instruments	π^*	δ_1	β_1	δ_2	β_2	γ_1	γ_2	p-values
Full Sample:								
(1)	2.8**	.86**	.03	8.8**	-171.1**			F-statistic: 0
	(.19)	(.36)	(.27)	(3.8)	(45.5)			J(15): .46
2002Q1-2008Q1:								
(1)	2.3**	.24	.64**	9.6**	-45.1	5.3**	-9.4	F-statistic: 0
	(.06)	(.24)	(3.2)	(8.7)	(29.2)			J(15): .95
2009Q3-2015Q2:								
(1)	1.9**	.74	-.5	10.3	-138.6	-1.35	-26.9	F-statistic: 0
	(.61)	(.47)	(.4)	(25.3)	(163)			J(15): .93

5. Canada

The unit-root test for Canada indicates non-stationarity exists in output gap, unemployment gap and squared unemployment gap. Table 25 shows the results after non-stationarity adjustment. The only difference in these two tests is the significance level for unemployment gap in the full sample, which is significantly different from zero at 10% here but was insignificant in the previous analysis. All other factors are consistent in both analyses.

Table 25: Canada Analysis

Instruments	π^*	δ_1	β_1	δ_2	β_2	γ_1	γ_2	p-values
Full Sample:								
(1)	1.9**	-.15	-1.1**	-8.9*	87.2			F-statistic: 0
	(.14)	(.51)	(.43)	(4.7)	(57.7)			J(14): .31
1992Q3-2008Q2:								
(1)	1.8**	-.69	-.3	-13.3**	78.3	.87	-11.8	F-statistic: 0
	(.2)	(.53)	(.93)	(5.3)	(64.4)			J(14): .50
2009Q3-2015Q2:								
(1)	1.7**	2.5**	-.77**	31.5**	39.2	-6.2**	2.5	F-statistic: 0
	(.26)	(.81)	(.3)	(5.1)	(346.2)			J(14): .89

6. Australia

The Australian data on unemployment gap and squared unemployment gap are non-stationary. Table 26 shows the result with non-stationarity adjustment in the IV set. Compared with the previous analysis, there exists change in the coefficients' significance levels for all periods except the pre-recession era. The squared output gap for the full sample changed from 5% significance to 10%. The 1994-2015 era has an inconsistent result in the squared unemployment gap, which becomes statistically significantly different from zero at 10% level. The policy preference parameter on unemployment gap also had a similar change. The post-recession period shows an inconsistent result for unemployment gap, which has significant negative relationship with inflation rate at 10% (Table 18) but becomes insignificant here. However, this does not bring changes in the policy preference parameter on unemployment gap.

Table 26: Australia Analysis

Instruments	π^*	δ_1	β_1	δ_2	β_2	γ_1	γ_2	p-values
Full Sample:								
(1)	2.3**	-2.7**	5.9*	-11.2**	-15.4			F-statistic: 0
	(.26)	(.75)	(3.3)	(3.4)	(44.7)			J(13): .33
1994Q1-2015Q2:								
(1)	1.9**	-3.6**	9.8**	-5.6**	116.2*	-5.4**	41.5*	F-statistic: 0
	(.32)	(1.1)	(3.4)	(4.2)	(69.8)			J(13): .49
1994Q1-2008Q1:								
(1)	2.0**	-4.2**	9.1**	-11.8**	11.4	-4.3**	-1.9	F-statistic: 0
	(.4)	(1.2)	(3.8)	(5.5)	(93.3)			J(13): .64
2009Q3-2015Q2:								
(1)	2.6**	-2.1**	-2.9	-11.1	35.2	1.4	-6.3	F-statistic: 0
	(.1)	(.50)	(2.0)	(7.0)	(100.6)			J(13): .87

7. The Netherlands

The unit-root tests on the Netherlands indicate non-stationarity problem in lagged inflation rate, output gap, unemployment gap and squared unemployment gap. Table 27 reports the results after non-stationarity adjustments. The only difference comes from the post-recession period, for which the output gap is only significant at 10% rather than the 5% from the previous analysis. However, this difference does not affect the significance of the policy preference parameters, and all remaining variables are consistent with the previous analysis.

Table 27: The Netherlands Analysis

Instruments	π^*	δ_1	β_1	δ_2	β_2	γ_1	γ_2	p-values
Full Sample:								
(1)	2.3**	.08	-.8**	-5.4**	13.6**			F-statistic: 0
	(.15)	(.26)	(.26)	(.82)	(4.4)			J(15): .37
2002Q1-2008Q2:								
(1)	1.3**	-.83**	.1	-9.4**	41.9**	-.24	-8.9**	F-statistic: 0
	(.08)	(.14)	(.1)	(1.3)	(6.2)			J(15): .91
2009Q3-2015Q2:								
(1)	.23	-.88*	-1.0	24.6**	-71.8**	2.3	-5.8**	F-statistic: 0
	(.76)	(.48)	(1.1)	(9.2)	(27.0)			J(15): .93

Section 3: Comparison and Conclusion

The countries selected here are all affected by the non-stationarity problem. The countries that are affected the least are Italy, Canada and the Netherlands. Italy and Netherlands results can reach a general conclusion if the previous test is using 95% confidence interval and 90% here; while Canada here can have consistent results if both analyses are using 95% confidence interval. The rest countries, especially the US and the UK, are greatly affected by the existence of non-stationarity in the dataset; therefore it is hard to find a common solution with both analyses.

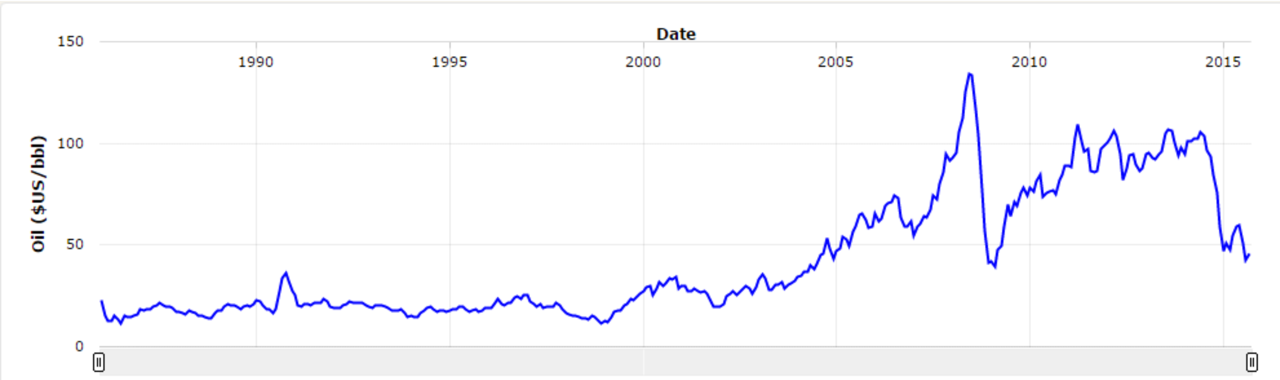
The analysis here only addresses the non-stationarity problem during the first-stage regression, but not during the second-stage. Therefore, it is for future researcher to study the non-stationarity problem and its effects on the results in more depth.

Conclusion

This paper analyzes the existence of time-inconsistent policy preferences for the pre- and post-recession periods. Among all seven OECD countries that were examined, only the Netherlands presented consistent policy preferences; all other countries had inconsistent preferences. Moreover, the core countries tended to have lower targeted inflation rates and stricter policies toward unemployment gaps than did peripheral countries. In addition, peripheral countries tended to have insignificant policy preferences in the post-recession periods. Also, with comparison over inflation targeting and non-inflation-targeting countries, one is able to notice that countries that adopted inflation targeting tend to have no preference on unemployment rate during the post-recession periods. In addition, non-inflation-targeting countries are able to reach the central bank's goal on targeted inflation rate better than inflation-targeting countries. Lastly, countries experiencing negative coefficients on unemployment gap also at the same time expose to the risk of housing bubbles at that time period.

Part II reanalyzes the results after non-stationarity adjustment in the dataset during the first-stage regression. There were minor differences in significance across the variables in only three countries and are able to reach a consistent conclusion with both analyses. The rest countries, especially the US and United Kingdom, are affected greatly by non-stationarity problem and cannot find a common solution.

However, the non-stationarity problem during the second-stage regression still exists, so that there may still exist some differences after the non-stationarity adjustment. This is also for future researchers to explore.



(a)

Figure 14: Source: WTI Price of Oil

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