HETEROGENEITY IN INFLATION PERSISTENCE AND OPTIMAL MONETARY POLICY

A Master's Thesis

by
SEVİM KÖSEM ALP

Department of
Economics
Bilkent University
Ankara
January 2009

To My Precious Harun

HETEROGENEITY IN INFLATION PERSISTENCE AND OPTIMAL MONETARY POLICY

The Institute of Economics and Social Sciences
of
Bilkent University

by

SEVİM KÖSEM ALP

In Partial Fulfillment of the Requirements For the Degree of
MASTER OF ARTS

in

THE DEPARTMENT OF
ECONOMICS
BİLKENT UNIVERSITY
ANKARA

January 2009

I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Arts in Economics.

Assist. Prof. Refet Gürkaynak
Supervisor

I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Arts in Economics.

Assist. Prof. H. Çağrı Sağlam
Examining Committee Member

I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Arts in Economics.

Assoc. Prof. Levent Akdeniz
Examining Committee Member

Approval of the Institute of Economics and Social Sciences

Prof. Dr. Erdal Erel
Director

ABSTRACT

HETEROGENEITY IN INFLATION PERSISTENCE AND OPTIMAL MONETARY POLICY

KÖSEM ALP, Sevim
M.A., Department of Economics
Supervisor: Assist. Prof. Refet Gürkaynak
January 2009

Inflation persistence differs substantially across sectors. This paper analyzes the relevance of sectoral inflation persistence differentials for optimal monetary policy using a two-sector sticky price model, which generalizes the models existing in the literature by introducing inflation persistence to both sectors. Heterogeneity in inflation persistence results from introduction of different price setting mechanisms across sectors. The literature suggests that in purely forward looking models, when the degree of nominal rigidity is uniform across sectors, it is optimal to target the CPI inflation. In this paper, the degree of nominal rigidity, which is computed according to the approximate measure proposed by Benigno and Lopez-Salido (2006), is uniform across sectors but the same rigidity is produced by different combinations of price change frequency and backward looking behavior. Based on a second order approximation to the utility function, first the fully optimal monetary policy is computed. Then, using the fully optimal policy as a benchmark, the performance of the CPI inflation targeting rule proposed by Benigno and Lopez-Salido and the optimal inflation targeting policy are compared under different parameter combinations culminating to the same degree of nominal rigidity but generating different degrees of inflation persistence across sectors. Welfare analysis shows that adopting CPI inflation targeting instead of optimal inflation targeting implies a significant increase in deadweight loss. This loss is highest when one of the sectors has inflation persistence close to zero.

Keywords: Relative prices; Optimal monetary policy; Welfare analysis; Inflation Persistence

ÖZET

ENFLASYON ATALETİNDEKİ HETEROJENLİK VE OPTİMAL PARA POLİTİKASI

KÖSEM ALP, Sevim
Yüksek Lisans, Ekonomi Bölümü
Tez Yöneticisi: Yrd. Doç. Dr.Refet Gürkaynak
Ocak 2009

Sektörel enflasyon ataletleri birbirinden epey farklıdır. Bu makalede, sektörel enflasyon ataleti farklılığının optimal para politikası ile ilişkisi, fiyat katılığına sahip iki sektörden oluşan ve her iki sektöre de geriye dönük fiyatlama davranışını getirerek literatürdeki modelleri genelleyen bir model kullanılarak analiz edilmektedir. Sektörel enflasyon ataleti farklılığı, sektörlerin farklı fiyatlama davranışları göstermelerinden kaynaklanmaktadır. Literatür, sektörlerin sadece ileriye dönük fiyatlama yaptığı ve birbirine eşit nominal katılığa sahip olduğu modellerde, optimal enflasyon hedeflemesi kuralı olarak tüketici enflasyonunun hedeflenmesini önermektedir. Bu makalede, sektörler Benigno ve Lopez-Salido (2006) tarafından önerilen bir nominal fiyat katılığı ölçütüne göre aynı nominal katılığa sahip olacak; ancak bu katılık farklı fiyat değiştirme olasılıkları ve geriye dönük fiyatlama davranışı oranı kombinasyonlarınca üretilecek şekilde modellenmiştir. İlk olarak, fayda fonksiyonuna ikinci derece yaklaşım kullanılarak optimal para politikası hesaplanmıştır. Optimal para politikası gösterge olarak kullanılarak, Benigno ve Lopez-Salido ölçütüne göre aynı fiyat katılığı ve farklı enflasyon ataleti üreten değişik parametre kombinasyonları altında, optimal enflasyon hedeflemesi ve tüketici enflasyonu hedeflemesi kurallarının performansları karşılaştırılmıştır. Refah analizi, optimal enflasyon kuralı yerine tüketici enflasyonunun hedeflenmesinin önemli bir refah kaybına sebep olduğunu göstermektedir. En yüksek refah kaybı sektörlerden birinin sıfıra yakın enflasyon ataleti sergilediği durumlarda gerçekleşmektedir.

Anahtar Kelimeler: Göreli fiyatlar; Optimal para politikası; Refah analizi; Enflasyon ataleti

ACKNOWLEDGMENTS

This thesis could not have been written without Dr. Refet Gürkaynak who not only served as my supervisor but also encouraged and challenged me throughout my academic program. The quality of this thesis is greatly enhanced by his never accepting less than my best attempts.

Thanks to Bilkent University and TÜBITAK for their financial support during my graduate study. Special thanks to Bilkent University Department of Economics for providing financial support to me to attend an international workshop.

Special thanks to all my friends for easing the stress of this graduate study and for sharing unforgettable moments with me during these years and, hopefully, for many years to come.

I owe my special thanks to my family for encouraging me to attend this graduate study without questioning my alternatives.

Last, but not the least, I would like to thank to my best friend, fine colleague and beloved husband Harun Alp for encouraging me to apply for this academic program and for helping me survive it. Among everything I am grateful to him, our discussions, which helped me develop some of the ideas put forward in this thesis, worth particular mentioning here.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Many macroeconomic studies show that the degree of persistence differs substantially across sectors.[1] The heterogeneity in inflation persistence arises from different price setting mechanisms in different sectors. The existence of this type of heterogeneity across sectors has implications for monetary policy for two main reasons. First, understanding sectoral responses to monetary policy shocks can be helpful in explaining the mechanism through which monetary policy affects the real economy.[2] Second, the heterogeneity across sectors determines the way monetary policy should be designed.

The relevance of the heterogeneity in price setting mechanism for the design of optimal monetary policy was studied before by assuming different price change frequencies, $1-\alpha$, for different sectors. Aoki (2001) employs a model with one flexible and one sticky price sector and shows that optimal policy is to stabilize the inflation of the sticky price sector. Benigno (2004) introduces sluggish price adjustment àla Calvo into both regions of a currency union and argues that optimal inflation targeting policy is to pay higher attention to the inflation of the sector that is constraint by lower frequency of price change.[3]

[1]See, among many others, Leith and Malley (2005), Aucramanne and Collin (2005), Altissimo, Mojon and Zaffaroni(2007), Bilke(2004), Lünnemann and Mathä (2004).

[2]See Carvalho (2005).

[3]Note that the analysis of the optimal monetary policy under a currency union with heterogeneous regions and in a single country with heterogeneous sectors is analogous. The only difference is that what is called terms of trade in the two region model corresponds

Note that the models mentioned above share the following common characteristics. First, the degree of nominal rigidity for each sector, which is measured by average duration of prices being fixed, is given by the expression $NR = 1/(1-\alpha)$. Therefore, the degree of nominal rigidity increases as α increases. Second, the only determinant of the degree of inflation persistence, which is the rate that inflation converges back to the steady state, is α. The higher α, the slower the adjustment of the aggregate price level and the more persistent the inflation. Third, as far as the optimal policy design is concerned, they argue that the optimal inflation targeting policy is to target the inflation of the sector that has higher α, at the same time, has higher degree of nominal rigidity and inflation persistence. Therefore, in these models inability to change the price governs all dynamics of the inflation and is a summary statistic to design the optimal policy.

Last, these models imply purely forward looking New Keynesian Philips curves (NKPC), in which inflation of the previous period is not part of price setting mechanism, and produce front-loaded impulse responses. These studies imply purely forward looking Philips curves and front loaded impulse responses. Thus, they do not incorporate the persistence of sectoral inflations observed in the data. An exception to this is Benigno and Lopez-Salido (2006) [BL-S] who develop a two-region sticky-price model of a currency union with a single region displaying inflation persistence. That is, only one of the sectors has NKPC with lagged inflation and inflation of that sector display hump shaped impulse responses, which is consistent with the results of the empirical studies. The persistence in that region is modeled by introducing a type of producers who set their prices according to a rule-of-thumb consistent with similar single sector model of Gali and Gertler (1999). BL-S proposes

to a relative price in the two sector model.

an approximate nominal rigidity measure for the hybrid price setting sector, which is explained in detail in section 3. BL-S suggests that when this measure implies the same degree of nominal rigidity across sectors, optimal inflation targeting policy is targeting the CPI inflation.

Having estimated the structural parameters for the euro area, BL-S concludes that it is optimal to target the inflation of the region that has higher degree of nominal rigidity and has inflation persistence. Here the measure for degree of inflation persistence is the coefficient of the lagged inflation in the NKPC. [4]

In this paper, I build on the insights of this approach, but extend the analysis to take account of sectoral differences in inflation persistence by assuming backward looking price setters for both sectors. Although evidence suggests that all sectors are characterized by hybrid price setting with different mechanisms, currently there exists no study allowing for inflation persistence for both sectors.[5] Thus, one of the goals of this paper is to fill this hole in the literature.

In this paper, the degree of nominal rigidity calculated using the measure proposed by BL-S, is uniform across sectors but the same rigidity is produced by different price setting mechanisms in different sectors. The sectors are assumed to be of equal economic size.[6] First, the optimal inflation targeting rule is calculated for different calibrations of the structural parameters of the price setting. The first main finding of this paper is that in contrast to proposition of BL-S, CPI inflation targeting is not the optimal inflation

[4] Note that the persistence in the forward looking region is zero. Thus, result of BL-S can be interpreted as targeting the inflation of the sector that has *higher* degree of inflation persistence as done by Levin and Moessner (2005).

[5] Leith and Malley (2005) shows that all sectors in US manufacturing industry display hybrid price setting mechanism, which is heterogeneous across sectors.

[6] Alternative calibrations of the economic sizes are possible and do not change the results of the paper.

targeting rule, even if the degree of nominal rigidity proposed by BL-S is the same across sectors. Moreover, the policy of targeting the inflation of the sector with higher degree of inflation persistence is not robust to different parameter calibrations.

The second main concern of this paper is the welfare cost of using the nominal rigidity measure proposed by BL-S as a summary statistic for inflation targeting policy design. The fully optimal policy is computed to conduct welfare analysis. The welfare measure is the percentage reduction in deadweight loss that can be realized by employing the optimal inflation targeting rule instead of CPI inflation targeting. Welfare analysis suggests that adopting the optimal inflation targeting rule instead of the CPI inflation targeting increases welfare by about 6% of the optimal welfare for standard calibrations. Thus, BL-S measure is not a sufficient summary statistic in a general model since the policy of targeting the CPI inflation, which is based on the equivalence of the rigidity across sectors using this measure, does not approximate the welfare obtained by adopting the optimal inflation targeting regime. Another finding is that the percentage reduction in welfare loss is highest when one of the sectors has inflation persistence that is close to zero.

The rest of the paper is structured as follows. Section 2 presents the model and the utility based welfare function that policymakers seek to maximize. The emphasis will be on how the existence of backward looking price-setters affects this welfare function. Section 3 shows the optimal inflation targeting rule and the welfare comparison of adopting the optimal inflation targeting regime versus the CPI inflation targeting regime, in the case that the degree of nominal rigidity proposed by BL-S is uniform but inflation persistence is heterogeneous across sectors. Section 4 concludes.

CHAPTER 2

THE MODEL

The model studied in this paper is a stochastic general equilibrium representative household model with two monopolistically competitive sectors. Both sectors are characterized by sluggish price adjustment and a fraction of producers in each sector are unsophisticated price setters, who adjust their prices to according to a rule of thumb. In this paper, I generalize the standard two sector models in the literature by introducing backward indexing producers into both sectors. [1]

2.1 Utility of a Representative Household

Each household consumes all of the differentiated goods in both sectors, and produces a single good. The objective of household j is to maximize

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[u(\xi_t^d C_t^j) - v(\xi_{i,t}^s y_{i,t}^j) \right] \tag{2.1}$$

where $u(\cdot)$ represents the utility of consumption and $v(\cdot)$ represents the disutility of production. I make the usual assumptions that $u(\cdot)$ is increasing and concave, and that $v(\cdot)$ is increasing and convex. The constant $\beta \in (0,1)$ is the discount factor and the argument C_t^j, which represents a CES index of representative household purchases of the differentiated goods of both sectors, is

[1] The model simulation procedure is implemented using the free-available and open source DYNARE software.

defined as

$$C_t^j = \frac{1}{2}\left(C_{1,t}^j\right)^{1/2}\left(C_{2,t}^j\right)^{1/2} \tag{2.2}$$

where C_t^j itself is a CES aggregate of sectoral goods

$$C_{i,t}^j = \left[\int_0^1 c_{i,t}^j(z)^{\frac{\theta-1}{\theta}} dz\right]^{\frac{\theta}{\theta-1}} \tag{2.3}$$

Here $i \in \{1,2\}$indexes sectors. The elasticity of substitution between any two differentiated goods in each sector, θ, is assumed to be greater than unity and uniform across sectors. The argument $y_{i,t}^j$ is the output of the good that representative household j in sector i produces. The household indexed by j produces one of the differentiated goods in sector i. Following Aoki (2001), I assume that the preference shock ξ_t^d is identical across all households. I also assume that $\xi_{i,t}^s = \xi_{1,t}^s$ for all households producing one of the differentiated goods of the first sector and $\xi_{i,t}^s = \xi_{2,t}^s$ for all households producing one of the differentiated goods of the second sector, where ξ_t^d and $\xi_{i,t}^s$ are stationary random shocks. These assumptions imply that all of the households in the same sector face the same supply shocks and that there is no sector specific demand shock in this economy.

2.2 The Consumption Decision

The model assumes complete financial markets with no obstacles to borrowing against future income, so that each household faces a single intertemporal budget constraint. The model further assumes that households can insure one another against idiosyncratic income risk. These assumptions imply that, if all households have identical initial wealth, they will choose identical consumption plans. The optimal allocation for a given level of nominal spending across all of the differentiated goods of both sectors at time t leads to the

Dixit-Stiglitz demand relations as functions of relative prices. For the following, the index j is suppressed, since the consumption decision is identical across all households. The total expenditure required to obtain a given level of consumption index C_t is given by P_tC_t, where P_t is defined as

$$P_t = (P_{1,t})^{1/2}(P_{2,t})^{1/2} \tag{2.4}$$

Here $P_{i,t}$ is the price index of the sector i defined below. Demand for the sectoral composite differentiated goods of sector i are the usual Dixit-Stiglitz demand relations as functions of relative prices, which are given by

$$C_{i,t} = \frac{1}{2}\left(\frac{P_{i,t}}{P_T}\right)^{-1} C_t \tag{2.5}$$

where $P_{i,t}$ is the Dixit-Stiglitz price index defined as

$$P_{i,t} = \left[\int_0^1 p_{i,t}(z)^{1-\theta} dz\right]^{\frac{1}{1-\theta}} \tag{2.6}$$

where $p_{i,t}(z)$ is the price of differentiated good in sector $i$indexed as z at time t.

Demand for each differentiated good z, $c_{i,t}(z)$, is given by

$$c_{i,t}(z) = \frac{1}{2}\left(\frac{P_{i,t}}{P_t}\right)^{-1}\left(\frac{p_{i,t}(z)}{P_{i,t}}\right)^{-\theta} C_t \tag{2.7}$$

The optimal consumption plan of the household must satisfy

$$\frac{\xi_t^d u'(\xi_t^d C_t)}{P_t} = \Lambda_t \tag{2.8}$$

where Λt is marginal utility of nominal income, which follows the rule of motion

$$\Lambda_t(1 + \mathrm{R_t}) = \beta\Lambda_{t+1} \tag{2.9}$$

where R_t is the risk-free nominal interest rate at time t.

2.3 The Production Decision

It is assumed, as is standard in this literature, that prices in both sticky-price sectors are changed at exogenous random intervals in the fashion of Calvo (1983). The producers in each sector can change their prices with a constant probability $1-\alpha$. A fraction $1-\psi_i$ of the households who can change their prices behave optimally when making their pricing decisions. I refer to these households as the forward-looking households. The remaining households, a fraction ψ_i, instead use a simple backward-looking rule-of-thumb when setting their prices. I refer to these households as the backward-looking households.

Given the complete markets and symmetric initial steady state assumptions, all forward-looking households that are able to adjust their price at date t , will choose the same price. Let $p^f_{i,t}$ denote this price. I assume that all backward-looking households who change their price at date T also set the same price. Let $p^b_{i,t}$ denote this price.

The forward looking producer who is able to choose his price in period t chooses $p^f_{i,t}$ to maximize the discounted future profits

$$E_t\left\{\sum_{k=0}^{\infty}\{(\alpha_i\beta)^k[\Lambda_{t+k}p_{i,t}y_{i,t+k}-v(\xi^s_{t+k}y_{i,t+k}\}\right\} \tag{2.10}$$

First term is the expected revenue in utility terms. Since the cost of production is in terms of utility, the revenue is multiplied by the marginal utility of income. Maximizing the objective function with respect to $p^f_{i,t}$ gives the following first order condition:

$$E_t\left\{\sum_{k=0}^{\infty}\left\{(\alpha_i\beta)^k\Omega_{i,t+k}(p^f_{i,t}-\frac{\theta}{\theta-1}S_{i,t+k}\right\}\right\}=0 \tag{2.11}$$

where

$$\Omega_{i,t+k} \equiv \frac{\xi^d_{t+k} u'(\xi^d_{t+k} C_{t+k})}{\xi^d_t u'(\xi^d_t C_t)} c_{i,t+k}(z) \qquad (2.12)$$

and

$$S_{i,t+k} = \frac{\xi^s_{i,t+k} v'(\xi^s_{i,t+k} y_{i,t+k})}{\xi^d_{t+k} u'(\xi^d_{t+k} C_{t+k})} P_{i,t+k} \qquad (2.13)$$

is interpreted as the nominal marginal cost of sector i. Since the household is both worker and the owner of the firm in sector i, the cost of production is the disutility resulting from working.

As in Gali and Gertler (1999), I assume that the backward-looking firms set their prices according to the following rule:

$$p^b_{i,t} = p^*_{i,t-1} \pi_{i,t-1} \qquad (2.14)$$

where $\pi_{i,t-1}$=$p_{i,t-1}/p_{i,t-2}$ and $p^*_{i,t-1}$is an index of prices set at *t-1*,given by

$$p^*_{i,t-1} = (p^f_{i,t-1})^{1-\psi_i} (p^b_{i,t-1})^{\psi_i} \qquad (2.15)$$

According to equation (2.15) the backward looking firms adjust their prices to equal the geometric mean of the prices that they saw chosen in the previous period, $p^*_{i,t-1}$, adjusted for the sectoral inflation rate they last observed in the previous period, $\pi_{i,t-1}$. That is, these firms use the inflation observed in the previous period a proxy for that of the current period. This way of price setting, while not optimal, keeps their relative prices same across periods when inflation is constant, for example at steady state.

The aggregate price level will then evolve according to

$$p_{i,t} = \left(\alpha_i p^{1-\theta}_{i,t-1} + (1-\alpha_i)(1-\psi_i)(p^f_{i,t})^{1-\theta} + (1-\alpha_i)\psi_i (p^b_{i,t})^{1-\theta} \right)^{\frac{1}{1-\theta}} \qquad (2.16)$$

Each period, a fraction α_i of the producers keeps charging the price of the previous period. The remaining $1-\alpha_i$ of the firms change their prices but only $1-\psi_i$ of them choose the optimal price and the remaining producers set their prices according to the rule of thumb.

Unsophisticated price setters are introduced into both sectors because standard New Keynesian models with purely forward looking price setting mechanisms fail to explain the hump shaped responses of sectoral inflations to demand and supply shocks. Introducing this type of backward looking behavior helps alleviate this problem.

2.4 Log-linearization of the Model

In this paper, the equations of the model, which is a general form of the model used by BL-S, are a quite complicated system of stochastic non-linear difference equations. I log-linearize the model around its steady state with zero inflation and study the dynamics of this approximate model.

The relative price charged at time t by firms with new prices of differentiated goods in sector i is denoted by $x_{i,t}^k = p_{i,t}^k/P_{i,t}$, k=f for price set by forward looking behavior and k=b for price set according to rule of thumb. $x_{i,t} = P_{i,t}/P_t$ denotes the relative price of each sector.

The aggregate demand equation is the log-linearized Euler conditions (2.9) and (2.11), imply the following IS curve [2]

$$\hat{y}_t = E_t\hat{y}_{t+1} - \sigma(r_t - E_t\hat{\pi}_{t+1} - \hat{\xi}_t^d + E_t\hat{\xi}_{t+1}^d) \tag{2.17}$$

[2] Variables with hats denote the percentage deviations from the steady state.

The NKPC of the sector i is given by

$$\hat{\pi}_{i,t} = \kappa_{i1}(\hat{y}_t - \hat{y}^n_{i,t}) + \kappa_{i2}\hat{\pi}_{i,t-1} + \kappa_{i3}\hat{\pi}_{i,t+1} + \kappa_{i4}\hat{x}_{i,t} \tag{2.18}$$

where

$$\kappa_{i1} = \frac{(1-\alpha_i\beta)(\omega^{-1}+\sigma^{-1})(1-\alpha_i)(1-\psi_i)}{(1+\frac{\theta}{\omega})(\alpha_i+\psi_i(1-\alpha_i+\alpha_i\beta))}$$

$$\kappa_{i2} = \frac{\psi_i}{\alpha_i+\psi_i(1-\alpha_i+\alpha_i\beta)}$$

$$\kappa_{i3} = \frac{\alpha_i\beta}{\alpha_i+\psi_i(1-\alpha_i+\alpha_i\beta)}$$

$$\kappa_{i4} = -\frac{(1-\alpha_i\beta)(1+\omega)(1-\psi_i)(1-\alpha_i)}{(\omega+\theta)(\alpha_i+\psi_i(1-\alpha_i+\alpha_i\beta))}$$

$$\hat{y}^n_{i,t} \equiv -\frac{1+\omega^{-1}}{\sigma^{-1}+\omega^{-1}}\hat{\xi}^s_{i,t} - \frac{\sigma^{-1}-1}{\sigma^{-1}+\omega^{-1}}\hat{\xi}^d_t$$

The parameter ω is the elasticity with respect to output of the disutility of supplying production, and σ is the elasticity the intertemporal elasticity of substitution.[3] $\hat{y}^n_{i,t}$ represents a change in the natural rate of output in sector i, which is the level of supply that keeps the real marginal cost in sector i constant at the flexible price level.

The measure of inflation persistence is the coefficient of the lagged inflations in the NKPC of the sectors, i.e. κ_{12} and κ_{22}. Note that when κ_{12} is zero, the first sector does not display inflation persistence and the model boils down to that of BL-S.

Table 1 shows the values of the degree of persistence when the degree of nom-

[3]Here $\sigma = -u''\xi^d C/u'$ and $\omega = -v''\xi^s_i Y_i/v'$ for $i = 1, 2$, evaluated in steady state. Following Aoki (2001), ω is assumed to be uniform across sectors.

inal rigidity is the same across sectors but they differ in underlying price setting mechanism. As α increases, to keep nominal rigidity constant φ decreases and thus the degree of persistence decreases. This implies that although each period the probability that the optimal price is set, $(1-\alpha)(1-\psi)$, is same across sector, the resulting degree of inflation persistence is not the same across sectors for different calibrations of (α, ψ) across sectors.

2.5 The Central Bank's Loss Function

The central bank is concerned with maximizing the welfare of the households. Following Rotemberg and Woodford (1998, 1999) and Woodford (2003, ch. 6), the welfare measure is the expected utility of the households given by

$$W = E\left\{\sum_{t=0}^{\infty} \beta^t U_t\right\} \tag{2.19}$$

where

$$U_t = 2u_t(\xi_t^d Y_t/2) - \int_0^1 v(\xi_{1,t}^s y_{1,t}(z))dz - \int_0^1 v(\xi_{2,t}^s y_{2,t}(z))dz \tag{2.20}$$

Following Aoki (2001), I assume that mass of one households produce for each sector. Therefore, in equilibrium the consumption of each good is the half of the production of that good. I assume that this steady state involves a tax rate, which is set such that the steady state levels of output in both sectors are efficient. Thus, monetary policy is not responsible for the welfare loss that arises from the distortion caused by monopoly power.

A second order Taylor series approximation of equation (2.20) around the zero inflation steady state is

$$U_t = -\frac{1}{2}u'\bar{Y}\{\lambda_1\hat{\pi}_{1,t}^2 + \lambda_2\hat{\pi}_{2,t}^2 + \lambda_3(\hat{y}_t - \hat{y}_t^n) + \lambda_4((\hat{y}_{1,t} - \hat{y}_{2,t}) - \kappa(\hat{y}_{1,t}^n - \hat{y}_{2,t}^n))^2\}$$
$$-\frac{1}{2}u'\bar{Y}\{\lambda_5(\Delta\hat{\pi}_{1,t})^2 + \lambda_6(\Delta\hat{\pi}_{2,t})^2\} \tag{2.21}$$

where

$$\lambda_1 = \frac{1}{2}(\theta^{-1} + \omega^{-1})\theta^2\frac{\alpha_1}{(1-\alpha_1)(1-\alpha_1\beta)}$$
$$\lambda_2 = \frac{1}{2}(\theta^{-1} + \omega^{-1})\theta^2\frac{\alpha_2}{(1-\alpha_2)(1-\alpha_2\beta)}$$
$$\lambda_3 = \sigma^{-1} + \omega^{-1}$$
$$\lambda_4 = \frac{1}{4}(1 + \omega^{-1})$$
$$\lambda_5 = \frac{1}{2}(\theta^{-1} + \omega^{-1})\theta^2\frac{\psi_1}{(1-\alpha_1)(1-\psi_1)(1-\alpha_1\beta)}$$
$$\lambda_6 = \frac{1}{2}(\theta^{-1} + \omega^{-1})\theta^2\frac{\psi_2}{(1-\alpha_2)(1-\psi_2)(1-\alpha_2\beta)}$$

Notice that, when $\psi_1 = 0$, the loss function simplifies to that of BL-S, where central bank takes into account inflations of both sectors and change in the inflation of the second sector only. The introduction of backward looking price setters makes the deviation of the current inflation from inflation of the previous period a concern of optimal policy, since the relative price of the backward looking price setters are distorted as much as this deviation. Note that, as ψ increases the weight of the deviation of this period's inflation from that of the previous period, λ_5 or λ_6, increases. Therefore, for a constant level of price change frequency, as the fraction of backward indexing producers increases, the weights attributed to inflation growth increases.

Note also that when $\psi_1 = \psi_2 = 0$ the loss function obtained is that of Aoki (2001) and Benigno (2004). Since there exists no backward indexing producers in the economy, deviation in inflation is not a concern of the central bank. Moreover, since the only parameter governing the nominal rigidity in a sector is α, once it is equal across sectors, the weights of the sectoral inflations is equal in the loss function. This clearly implies attaching equal weights to sectoral inflations in the optimal inflation targeting rule. Moreover, the equal weights can only be generated by equal frequency of price change across sectors, which is the sole source of heterogeneity in price setting in the model. Therefore, for purely forward looking models, the weights in the optimal inflation targeting rule is 0.5 *if and only if* α is the same across sectors. This implies uniform degree of nominal rigidity and inflation persistence across sectors.

2.6 Optimal Inflation Targeting Rule

Following BL-S, the model is closed by introducing a strict inflation targeting rule, which has the following form

$$\zeta\pi_{1,t} + (1-\zeta)\pi_{2,t} = 0 \tag{2.22}$$

where ζ is the weight that is attributed to the inflation of the first sector. The weight is chosen to maximize the welfare criterion (2.19) subject to the structural equations of the model ((2.17) and (2.18)). Once sectoral asymmetries are introduced, under inflation targeting regime, the concern of the central bank becomes which inflation to target. Therefore, under strict inflation targeting rule, the central bank defines the optimal basket, which is determined by optimally choosing the weights that should be attached to each sector.

When ζ is one, optimal inflation targeting policy is stabilizing the inflation of the first sector. Higher weight to one sector implies that the central bank is targeting the inflation of that sector. Because, to attain zero weighted inflation, central bank allows the inflation of the sector with higher weight to vary in a smaller band when compared to inflation of the other sector. To clarify, when ζ=0.9, 1% inflation in the first sector is accompanied by 9% deflation in the second sector. Central bank tries to ensure stabilization of the price level of the first sector by sacrificing the stability of the price level of the second sector. Note that, central bank attaches equal importance to both sectors when ζ=0.5 and in that case optimal inflation targeting rule becomes CPI targeting rule since the sectors are assumed to be of equal economic size.

In what follows, I first compute the optimal inflation targeting rule when both sectors same degree of nominal rigidity. Then, I compare the performance of the optimal inflation targeting rule and the policy proposed by BL-S suggesting giving equal weights to sectors in the inflation targeting rule, namely targeting the CPI inflation.

CHAPTER 3

OPTIMAL INFLATION TARGETING

The question that how optimal inflation targeting rule should be designed under heterogeneity in price setting mechanism is addressed so far using models that are obtained introducing certain restrictions to the model presented in the previous section. As mentioned elsewhere, for models of Aoki (2001) and Benigno (2004) it is possible to use the degree of nominal rigidity, which is given by $NR = 1/(1-\alpha)$, as a summary statistic for the optimal inflation targeting policy design. They suggest that the higher the degree of nominal rigidity in one sector, the higher the weight attached to the inflation of that sector in the optimal inflation targeting rule. Remember that for these models, the only source of nominal rigidity is inability to change the price.

With the introduction of the backward indexing producers, two sources affecting the degree of nominal rigidity arise. The first is given by the fraction of agents that cannot adjust their prices, α_i. The second is given by the fraction of agents that behave according to the rule of thumb, ψ_i. Therefore, for the model with backward indexation, the degree of nominal rigidity is not as clear as it is for purely forward-looking models.

BL-S addresses this issue by introducing backward looking price setters in one of the regions. In order to find a measure for the degree of nominal rigidity for the region with hybrid price setting, they use the strict inflation targeting rule in (2.22) that attaches weights equal to the economic sizes of the regions. In this paper, these weights are equal to each other and take the value of 0.5. Therefore, they assume that the optimal inflation targeting rule is given by:

$$0.5\pi_{1,t} + 0.5\pi_{2,t} = 0 \tag{3.1}$$

The motivation behind this is the result of Benigno (2004) that once the regions have same degree of nominal rigidity, the weight that should be attributed to their inflations in the optimal inflation targeting rule should be equal to the economic size of the regions. Instead of calibrating the structural parameters of the model and searching for the optimal weights in the inflation targeting rule, they fix the rule as (3.1) and calibrate all parameters of the model except for fraction of backward indexing price setters, ψ, for the hybrid price setting region. For given values of α_1 and α_2, they search over the values of ψ that maximizes the welfare. That is to say, not ξ as is standard but ψ is set optimally. Having computed the optimal fractions of backward indexing producers that ensure that the CPI inflation targeting policy corresponds to the optimal inflation targeting policy for different combinations of α_1 and α_2, they find a correspondence as follows:

$$\frac{1}{1-\alpha_1} = \frac{1}{1-\alpha_2}\frac{1}{1-\psi_2} \tag{3.2}$$

Note that, the left hand side of (3.2) is the degree of nominal rigidity for the purely forward looking region. They propose that the right hand side of (3.2) is a good approximate measure for degree of nominal rigidity for the hybrid price setting region for values of duration slightly higher than 3 or 4 quarters.

Since this paper generalizes the model of BL-S by introducing backward indexing producers to both sectors, I will use the nominal rigidity measure proposed by BL-S as that of both sectors. Throughout the paper, this measure of nominal rigidity is assumed to be uniform across sectors.

3.1 Calibration

The discount rate β is calibrated as 0.99. I calibrate the parameter θ equal to 6, which corresponds to a steady-state mark-up of 1.2. Following BL-S, the elasticity of substitution in consumption, σ, is 6 and the elasticity of the disutility of producing the differentiated goods, ω, is 0.6. The sectors are assumed to be equal in economic size. The asymmetric supply shocks and the symmetric demand shock follow an AR(1) process of the kind:

$$\mathrm{X}_t = \rho \mathrm{X}_{t-1} + \varepsilon_t$$

where X_t is the vector of shock processes, X_t=($\hat{\xi}^s_{1,t}$, $\hat{\xi}^s_{2,t}$, $\hat{\xi}^d_t$), ρ is 0.9 and ε_t is the vector of independently identified disturbances. The shocks $\hat{\xi}^s_{1,t}$, $\hat{\xi}^s_{2,t}$ and $\hat{\xi}^d_t$ have standard deviations of unity.

3.2 Optimal Inflation Targeting under Uniform Degree of Nominal Rigidity across Sectors

In this section, I compute the optimal inflation targeting rule under the (α_i,ψ_i) combinations culminating in the same degree of nominal rigidity computed by using the measure proposed by BL-S as $NR = ((1-\alpha_i)(1-\psi_i))^{-1}$. The optimal inflation targeting rule is calculated by choosing ζ in equation (3.1) to maximize the welfare criterion (2.19) subject to the structural equations of the model.

Table 2, Table 3 and Table 4 display the weights that should be attributed to the first sector in the optimal inflation targeting rule for nominal rigidity of 3, 4 and 8 quarters, respectively. First row displays the frequency of price change for the first sector and the first column displays that of the second sector. The fraction of backward indexing producers, which together with inability to change the price produces the relevant degree of nominal rigidity, is pinned down by the equation (3.2) shown in Table 1. To illustrate, to produce 3 quarters of nominal rigidity, a sector should have $\alpha = 0.01$ and $\psi = 0.66$. Note that, in order to produce same degree of nominal rigidity, for higher values of frequency of price change, $1 - \alpha$, a lower value of fraction of backward indexing producers, ψ, should exist in the economy.

The results in Table 2 shows that the weight attributed to first sector ranges between 0.615, which is 23% higher than the economic size of 0.5 and 0.385, which is 23% less than the economic size, when degree of nominal rigidity is 3 quarters. As shown in Tables 4 and 5, the optimal weight takes value within a 15% interval of the economic size when the degree of nominal rigidity is 4 quarters and this range decreases to 13% when the degree of nominal rigidity is 8 quarters. Therefore, as the degree of nominal rigidity increases, the optimal weight converges to the economic size. This is inline with the BL-S suggestion that this measure of nominal rigidity is a good approximation when the degree of nominal rigidity is higher than about 4 quarters. Note that, the optimal weight attached to the inflation of the first sector takes highest value when the two sectors are most different than each other when degree of nominal rigidity is 3 and 4 quarters. That is, the same degree of nominal rigidity is generated by the highest value of α in one sector and the lowest value of α in the other. However, when degree of nominal rigidity is 8 quarters, this weight takes the highest value when $\alpha_1 = 0.85$ and $\alpha_2 = 0.2$.

As shown in Table 1, as inability to change the price, α,increases, to keep nominal rigidity constant, the fraction of backward indexing producers and thus the degree of inflation persistence decreases. The inflation persistence is highest when α equals 0.01 since the fraction of backward indexing producers takes the highest value. Keeping the value of α_1 constant and moving column wise in Tables 2 to 4, α_2 increases and thus the inflation persistence in the second sector decreases monotonically. The weight attributed to the inflation of the first sector does not alter monotonically and takes values less than that of the second sector for some parameter calibrations. This implies that although first sector displays higher inflation persistence than the second sector, for some parameter calibrations, it is optimal to attribute higher weight to the sector with lower degree of inflation persistence. Therefore, another finding of this paper is that targeting the sector with higher inflation persistence is not a robust policy under this generalized model.

Having shown that optimal inflation targeting in this generalized model attributes different weights to different sectors even when the sectors display same degree of nominal rigidity as measured by the suggested method of BL-S, next subsection looks at the welfare cost of targeting the CPI inflation rather than the optimal inflation.

CHAPTER 4

WELFARE ANALYSIS

The previous subsection presents the optimal weights attached to sectoral inflations when the nominal rigidity measure proposed by BL-S is the same across sectors but this rigidity is created by different combinations of price change frequency and fraction of backward indexing producers. In this part, the welfare comparisons of optimal inflation targeting policy and CPI inflation targeting policy will be conducted. Having calculated the fully optimal policy, the two policies will be compared using the fully optimal policy as a benchmark. The measure of welfare is the reduction in the deadweight loss resulting from adopting the optimal inflation targeting policy instead of CPI inflation targeting policy relative to welfare under fully optimal policy. This percentage reduction in deadweight loss is computed as

$$DR = \frac{E(W_1) - E(W_2)}{E(W_3)} \times 100 \tag{4.1}$$

where $E(W_1), E(W_2), E(W_3)$ are the welfare criteria associated respectively with the CPI inflation targeting policy, the optimal inflation targeting policy and the fully optimal policy. Figure 1, Figure 2 and Figure 3 display the reduction in deadweight loss when the uniform degree of nominal rigidity is 3, 4 and 8 quarters, respectively.

Figures 1 to 3 show the welfare gains from adopting optimal inflation targeting when degree of nominal rigidity is the same across sectors at 3,4 and 8 quarters, respectively, but this rigidity is produced by heterogeneous price setting mechanism across sectors. Remember from Table 1 that, having this kind of heterogeneity in price setting mechanism implies heterogeneity in inflation persistence across sectors. The sector with higher α has a smaller fraction of backward indexing producers and thus a lower degree of inflation persistence. When α is higher than 0.4 for degree of nominal rigidity of 3 quarters, the implied inflation persistence takes values lower than 0.5. I refer to those cases as low inflation persistence.

Figure 1 displays that as the frequency of price change decreases, i.e. α increases, welfare gains from optimal inflation targeting increases. Adopting the optimal inflation targeting implies about 6% welfare gain in terms of optimal welfare when $\alpha_1 = 0.65$ and $\alpha_2 = 0.01$, or vice versa. That is to say, 4 quarters of nominal rigidity is produced with purely backward indexing price setting in one sector and purely forward looking pricing with a very low probability of price change in the other sector. Therefore, although the sectors have same degree of nominal rigidity, when one of the sectors has high inflation persistence and the other has almost zero inflation persistence, CPI inflation targeting policy is clearly suboptimal. For a constant degree of inflation persistence in one sector, the lower the inflation persistence in one sector and the more significant the heterogeneity in inflation persistence, the higher the welfare cost of targeting CPI inflation instead of optimal inflation.

Figure 2 displays the welfare measure when the degree of nominal rigidity is 4 quarters. When α takes values larger than 0.5 sectors displays low inflation persistence. Similar to the case with 3 quarters of nominal rigidity, results show that the lower the inflation persistence in one sector and the higher the inflation persistence differential across sector, the worse is the performance of the CPI inflation targeting. The welfare gain from adopting optimal inflation targeting takes the highest value 3% when $\alpha_1 = 0.75$ and $\alpha_2 = 0.01$. This is the case when one of the sectors does not have inflation persistence at all as the case in BL-S and the other is characterized by persistence close to unity. Notice that, the maximum possible welfare gain for 4 quarters of nominal rigidity is lower than that for 3 quarters of nominal rigidity.

Figure 3 displays the percentage welfare gains from adopting optimal inflation targeting when the degree of nominal rigidity is 8 quarters in both sectors. When α takes values larger than 0.65, both sectors display low inflation persistence. In contrast to Figures 1 and 2, Figure 3 displays a nonmonotonic relationship between the welfare measure and the frequency of price change when α is higher than 0.65. For those values of α, the sectors are characterized by low inflation persistence. Similar to the results of the Figures 1 and 2, the highest welfare gain is obtained when one of the sectors display low inflation persistence. However, the highest gain is not obtained when the inflation persistence differential is highest. The welfare gain displays a peak at 2% when $\alpha_1 = 0.85$ and $\alpha_2 = 0.3$, or vice versa. The monotonic relationship, which is observed in Figures 1 and 2, prevails when one of the sectors is characterized by high inflation persistence as the persistence in the other sector decreases, the welfare cost of adopting CPI inflation targeting increases.

To understand the nonmonotonicity in Figure 3 better, Figure 4 disaggregates the welfare cost of targeting CPI inflation instead of optimal inflation into its sources when the degree of nominal rigidity is 8 quarters. The frequency of price change in the second sector, α_2, is kept constant at 0.85. That is, sector two is characterized by a very low degree of inflation persistence. The price setting parameters of the first sector changes in a way that always produces 8 quarters of nominal rigidity, as before. The blue curve shows the total welfare loss as a percent of optimal welfare. The red curve displays the welfare loss that is resulting from variance of the output gap and the green curve displays the contribution of the variances of all other variables of the loss function into the welfare loss. It is easy to see that, the main determinant of the welfare loss is the variation of the output gap and the nonmonotonic behavior here is transferred to the welfare comparison criterion displayed in Figure 3. Therefore, when the degree of nominal rigidity is 8 quarters, CPI inflation targeting performs worse in stabilizing the output gap when compared to optimal inflation targeting policy and, more importantly, the variance of the output gap itself becomes a major welfare concern. When nominal rigidity is lower, the welfare loss stems overwhelmingly from price dispersion which hides the nonmonotonicity stemming from the behavior of the variance of the output gap. The fact that under high degrees of nominal rigidity welfare loss may depend more on the behavior of the output gap than price dispersion is underappreciated in the literature .

Note that, as the degree of nominal rigidity increases the range and the maximum possible value of the percentage welfare gain from adopting optimal inflation targeting instead of CPI inflation targeting decreases. That is, the maximum welfare loss is lower and at the same time the relationship becomes nonmonotonic. This is because the weight in the optimal inflation targeting rule converges to the economic size of 0.5 as the degree of nominal rigidity increases and the output gap volatility becomes the major determinant of the welfare loss.

CHAPTER 5

CONCLUSION

In this paper, the model of Benigno and Lopez-Salido (2006) is generalized in order to introduce heterogeneity in inflation persistence across sectors. The heterogeneity is obtained by differently calibrating the structural parameters of the price setting mechanism across sectors.

In this paper, the degree of nominal rigidity based on the measure proposed by BL-S is uniform across sectors but the same rigidity is produced by different mechanisms in different sectors. The optimal inflation targeting rule is computed and it is shown that the optimal weights attached to inflation of each sector do change for different calibrations of the structural parameters of the price setting mechanism culminating in same degree of nominal rigidity but heterogeneous degree of inflation persistence. Main concern of this paper is the welfare cost of using the nominal rigidity measure proposed by BL-S as a summary statistic for inflation targeting policy design.

The welfare cost of targeting the CPI inflation is calculated by using the fully optimal policy as a benchmark. Results show that adopting optimal inflation targeting instead of the CPI inflation targeting policy reduces the welfare loss significantly. The welfare gain obtained from adopting optimal inflation targeting is highest when one of the sectors is characterized by a low degree of inflation persistence. Therefore, the measure of nominal rigidity proposed by BL-S is not a sufficient summary statistics in terms of welfare, since the welfare under CPI inflation targeting policy cannot approximate that of the optimal inflation targeting policy.

In this paper, the measure proposed by BL-S is shown to be insufficient for optimal inflation targeting rule design. Further line of research can be working on estimation of a better summary statistic under heterogeneity in inflation persistence across sectors. The analysis here is limited to the case that central bank can adopt only optimal inflation targeting rule and robustness of CPI inflation targeting is checked. The relevance of inflation persistence differential across sectors can be further studied for alternative simple policy rules and welfare comparisons of these simple rules can be conducted.

BIBLIOGRAPHY

Altissimo F., Mojon B. and P. Zaffaroni (2007), "Fast Micro and Slow Macro: Can Aggregation Explain the Persistence of Inflation? " Working Paper Series WP-07-02, Federal Reserve Bank of Chicago.

Aoki, K. (2001), "Optimal Monetary Policy Responses to Relative Price Changes, " *Journal of Monetary Economics* 48, 55-80.

Aucremanne, L. and M. Collin (2005), "Has Inflation Persistence Changed over Time? Evidence from Aggregate and Sectoral Belgian CPI Data," Mimeo, National Bank of Belgium.

Blanchard, O. and C. Kahn (1980), "The Solution of Linear Difference Models under Rational Expectations," *Econometrica,* 48, 1305-1311.

Calvo, G. (1983), "Staggered Prices in a Utility Maximizing Framework," *Journal of Monetary Economics* 12, 383-398.

Carvalho, C. (2005). "Heterogeneity in Price Setting and the Real Effects of Monetary Shocks," Macroeconomics 0509017, EconWPA.

Benigno, P. and J. D. Lopez-Salido (2006), "Inflation Persistence And Optimal Monetary Policy In The Euro Area," Journal of Money, Credit and Banking, Blackwell Publishing, vol. 38(3), pages 587-614.

Benigno, P. (2004), "Optimal Monetary Policy in a Currency Area," Journal of International Economics, Elsevier, vol. 63(2), pages 293-320.

Bilke, L. (2005), "Break in the Mean and Persistence of Inflation: A Sectoral Analysis of French CPI," ECB Working Paper No. 179.

Fuhrer, J.C. (1997). "The (Un)importance of Forward-Looking Behavior in Price Specifications," *Journal of Money, Credit and Banking*, 29, 338-350.

Fuhrer, J.C. and G.R. Moore (1995), "Inflation persistence," *Quarterly Journal of Economics,* 109,197-230.

Gali, J. and M. Gertler (1999), "Inflation Dynamics: A Structural Econometric Analysis," Journal of Monetary Economics, Elsevier, vol. 44(2), pages 195-222.

Juillard, M. (2001), "DYNARE: A Program for the Simulation of Rational Expectation Models," *Computing in Economics and Finance 2001,* 213, Society for Computational Economics.

Levin, A. and R. Moessner (2005), "Inflation Persistence and Monetary Policy Design: An Overview, " ECB Working Paper No. 539.

Lünnemann, P. and T. Y. Mathä (2004) "How Persistent is Disaggregate Inflation? An Analysis across EU15 Countries and HICP Sub-Indices," ECB Working Paper No. 415.

Rotemberg, J. and M. Woodford (1998), "An Optimization-Based Econometric Framework for the Evaluation of Monetary Policy: Expanded Version," NBER Technical Working Papers No. 0233.

Woodford, M. (2003), Interest and Prices: Foundations of a Theory of Monetary Policy, Princeton University Press, New Jersey.

APPENDICES

A. TABLES

Table 1: Fraction of Backward Indexing Producers and Implied Degree of Inflation Persistence

	NR=3		**NR=4**		**NR=8**	
α	ψ	κ_2	ψ	κ_2	ψ	κ_2
0.01	0.66	0.985	0.75	0.987	0.87	0.989
0.05	0.65	0.929	0.74	0.937	0.87	0.946
0.1	0.63	0.864	0.72	0.879	0.86	0.897
0.2	0.58	0.746	0.69	0.776	0.84	0.810
0.3	0.52	0.637	0.64	0.683	0.82	0.734
0.4	0.44	**0.527**	0.58	0.595	0.79	0.666
0.5	0.33	0.401	0.50	**0.501**	0.75	0.602
0.6	0.17	0.218	0.44	0.386	0.69	0.536
0.65	0.05	0.068	0.38	0.306	0.58	**0.499**
0.7			0.29	0.193	0.50	0.456
0.75			0.17	0.000	0.38	0.401
0.8					0.17	0.320
0.85					0.87	0.164

The index i for sectors is suppressed. First column is the probability that price remains fixed and NR is the degree of nominal rigidity. Each value of degree of nominal rigidity is produced together with inability to change the price,α, and fraction of backward indexing producers, ψ. To illustrate, when α equals 0.1, ψ takes values 0.63, 0.72 and 0.86 to produce nominal rigidity of 3, 4 and 8 quarters, respectively. Column wise as α increases, to keep NR constant, ψ decreases. κ_2 is the coefficient of lagged inflation in the NKPC, the measure for the degree of inflation persistence, is given by $\kappa_2 = \psi/\alpha + \psi(1 - \alpha + \alpha\beta)$. Note that as ψ increases, κ_2 increases. When κ_2 takes value higher than 0.5, the sector is considered to display high inflation persistence and otherwise the sector is considered to display low inflation persistence.

Table 2: Optimal Weights to First Sector under Inflation Targeting (ξ),(NR=3)

α_1 / α_2	**0.01**	**0.05**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.65**
0.01	0.500	0.501	0.502	0.505	0.503	0.487	0.442	0.401	0.385
0.05	0.499	0.500	0.501	0.504	0.503	0.490	0.451	0.412	0.395
0.1	0.498	0.499	0.500	0.503	0.503	0.493	0.462	0.426	0.408
0.2	0.495	0.496	0.497	0.500	0.502	0.497	0.481	0.454	0.435
0.3	0.497	0.497	0.497	0.498	0.500	0.500	0.494	0.479	0.462
0.4	0.513	0.510	0.507	0.503	0.500	0.500	0.501	0.497	0.486
0.5	0.558	0.549	0.538	0.519	0.506	0.499	0.500	0.504	0.502
0.6	0.599	0.588	0.574	0.546	0.521	0.503	0.496	0.500	0.504
0.65	0.615	0.605	0.592	0.565	0.538	0.514	0.498	0.496	0.500

First row displays the probability that producers in the first sector cannot change their prices and first column is that of the second sector. The fraction of backward indexing producer is changed to obtain nominal rigidity of 3 quarters.

Table 3: Optimal Weights to First Sector under Inflation Targeting (ξ),(NR=4)

α_1 / α_2	**0.01**	**0.05**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.75**
0.01	0.500	0.500	0.501	0.503	0.505	0.501	0.479	0.443	0.430	0.421
0.05	0.500	0.500	0.501	0.503	0.505	0.502	0.483	0.451	0.437	0.428
0.1	0.499	0.499	0.500	0.502	0.505	0.503	0.488	0.461	0.447	0.436
0.2	0.497	0.497	0.498	0.500	0.503	0.504	0.496	0.479	0.465	0.450
0.3	0.495	0.495	0.495	0.497	0.500	0.502	0.501	0.494	0.482	0.465
0.4	0.499	0.498	0.497	0.496	0.498	0.500	0.502	0.504	0.498	0.480
0.5	0.521	0.517	0.512	0.504	0.499	0.498	0.500	0.507	0.510	0.495
0.6	0.557	0.549	0.539	0.521	0.506	0.496	0.493	0.500	0.512	0.508
0.7	0.570	0.563	0.553	0.535	0.518	0.502	0.490	0.488	0.500	0.507
0.75	0.579	0.572	0.564	0.550	0.535	0.520	0.505	0.492	0.493	0.500

First row displays the probability that producers in the first sector cannot change their prices and first column is that of the second sector. The fraction of backward indexing producer is changed to obtain nominal rigidity of 4 quarters.

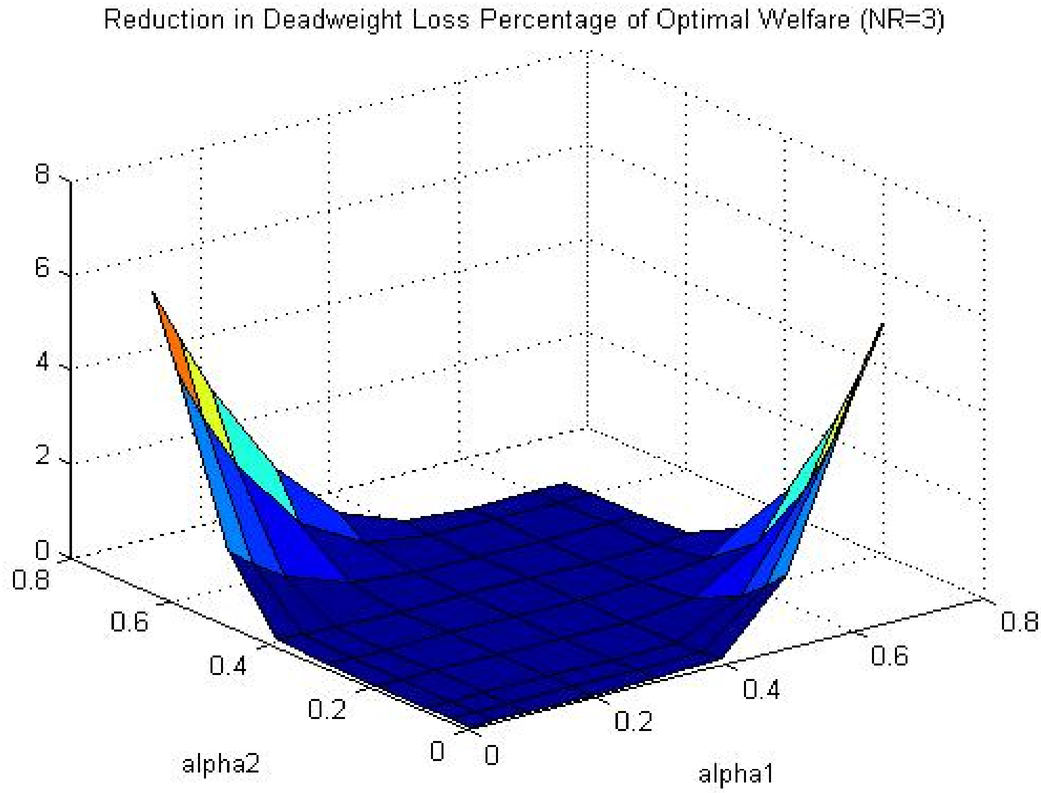
Table 4: Optimal Weights to First Sector under Inflation Targeting (ξ),(NR=8)

α_1 / α_2	**0.01**	**0.05**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.85**
0.01	0.500	0.499	0.499	0.499	0.501	0.504	0.508	0.508	0.506	0.539	0.559
0.05	0.501	0.500	0.499	0.499	0.501	0.505	0.510	0.510	0.509	0.541	0.561
0.1	0.501	0.501	0.500	0.500	0.502	0.506	0.511	0.512	0.513	0.544	0.563
0.2	0.501	0.501	0.500	0.500	0.502	0.507	0.512	0.516	0.520	0.549	0.565
0.3	0.499	0.499	0.498	0.498	0.500	0.505	0.511	0.517	0.525	0.552	0.564
0.4	0.496	0.495	0.494	0.493	0.495	0.500	0.507	0.516	0.527	0.553	0.561
0.5	0.492	0.490	0.489	0.488	0.489	0.493	0.500	0.510	0.526	0.550	0.555
0.6	0.492	0.490	0.488	0.484	0.483	0.484	0.490	0.500	0.518	0.543	0.545
0.7	0.494	0.491	0.487	0.480	0.475	0.473	0.474	0.482	0.500	0.528	0.533
0.8	0.461	0.459	0.456	0.451	0.448	0.447	0.450	0.457	0.472	0.500	0.514
0.85	0.441	0.439	0.437	0.435	0.436	0.439	0.445	0.455	0.467	0.486	0.500

First row displays the probability that producers in the first sector cannot change their prices and first column is that of the second sector. The fraction of backward indexing producer is changed to obtain nominal rigidity of 3 quarters.

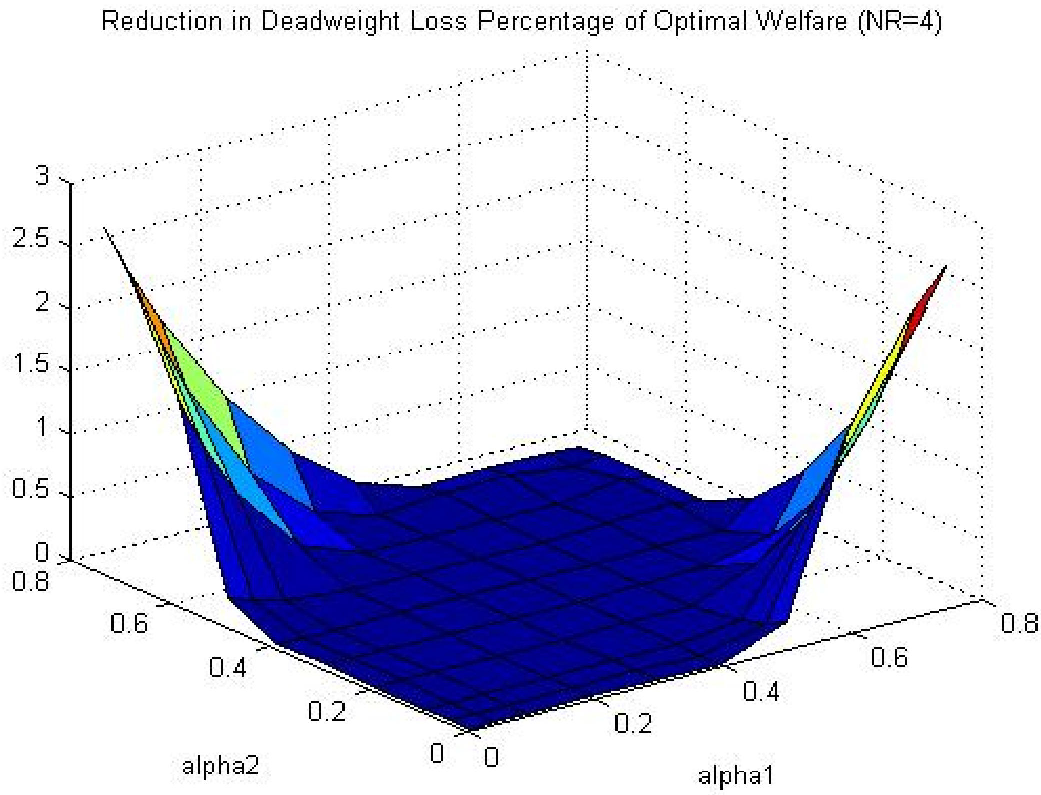
B. FIGURES

Figure 1



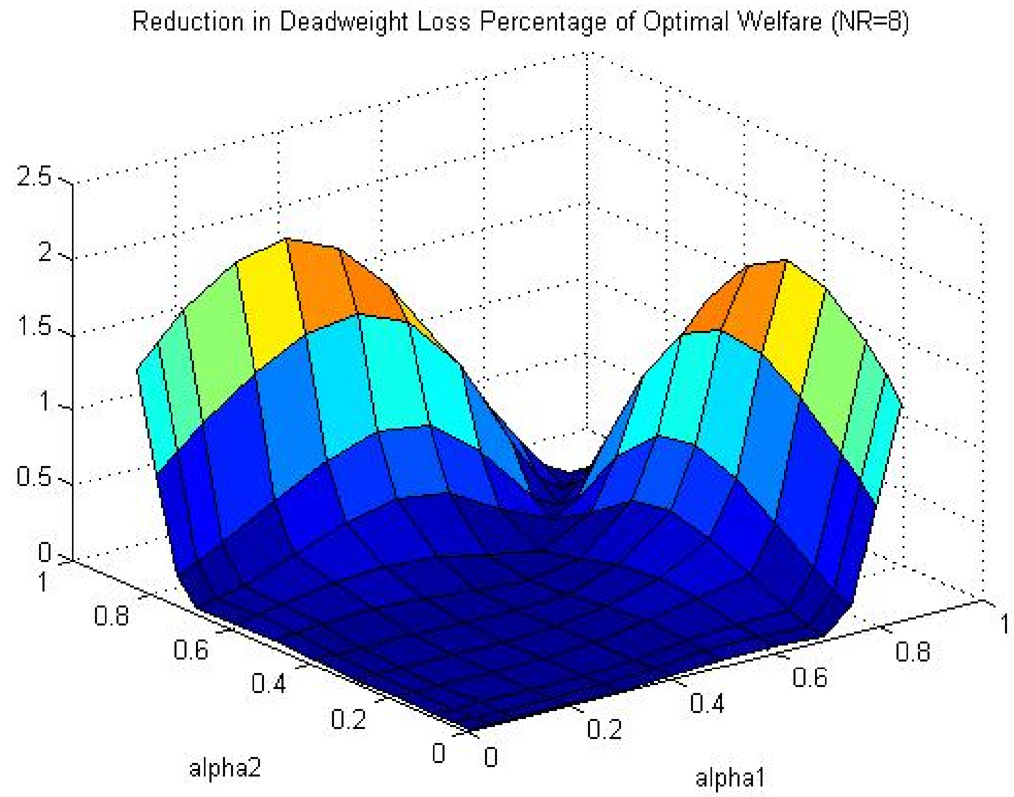
Welfare gain from adopting optimal inflation targeting instead of CPI inflation targeting as a percentage of the welfare under fully optimal policy when degree of nominal rigidity is 3 quarters.

Figure 2



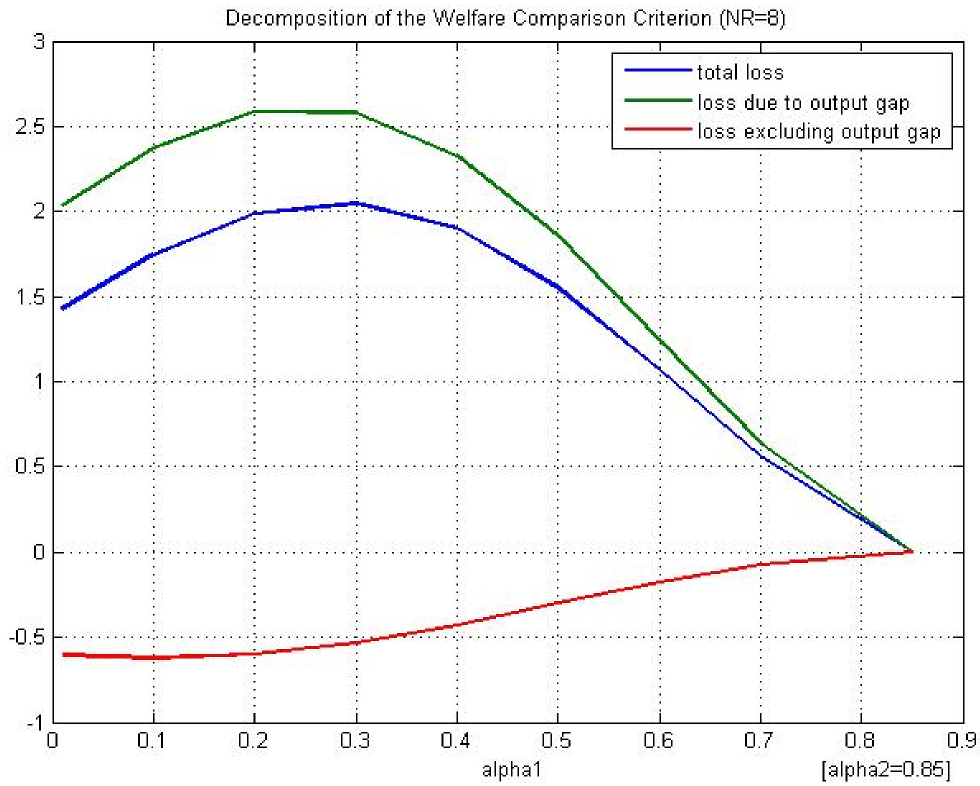
Welfare gain from adopting optimal inflation targeting instead of CPI inflation targeting as a percentage of the welfare under fully optimal policy when degree of nominal rigidity is 4 quarters.

Figure 3



Welfare gain from adopting optimal inflation targeting instead of CPI inflation targeting as a percentage of the welfare under fully optimal policy when degree of nominal rigidity is 8 quarters.

Figure 4



Welfare comparison criterion (4.1) is decomposed into its determinants and the dominant one is the variance of the output gap. The frequency of price change in the second sector is 0.85.