Essays in Credibility and the Source of Inflation Persistence

by

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to my family

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Declaration

From Chapter 1, we derived the paper "The Collapse of the "New EMS": an Explanation", published in Open Economies Review, 10, 203-19 (1999). The paper was originally prepared for the Conference of the Royal Economic Society in Swansea, 1-4 April 1996.

From Chapter 3, we derive a paper titled "An Investigation into the Source of Inflation Persistence ", prepared for the Conference "Expectations, Economic Theory and Economic Policy" organised by Banca de Italia, CEPR and European University Institute, and held in Perugia, 23-26 September 1999. As part of the joint project with my colleague Guido Ascari to investigate the implications of relative wage concern, we hopefully publish it as a joint paper.

From Chapter 4, we derive a paper titled "Relative Wage Concern: the Missing Piece in the Contract Multiplier", joint with my colleague Guido Ascari. This paper has been presented in the Southampton-Warwick-York PhD Macroeconomics Workshop, University of Southampton, May 1998, and XXXI Simposio de Analisis Economico, Universidad Autonoma de Barcelona, 15-17 December 1998.

SUMMARY

In the first chapter we investigate the strategy of exchange rate pegging as a solution to the lack of credibility of domestic monetary policy in the context of the European Monetary System (EMS). Existing theoretical models cannot explain the following features of the EMS and its crisis in 1992: its progressive hardening from 1987 onwards; the fact that credibility was 'shared'; the progressive deterioration of credibility after the first Danish referendum without changes in the economic fundamentals. We argue that the reason lies in the fact that the literature has not incorporated the changes in the perceived prospects of EMU. We show that an adjustable peg regime that incorporates those prospects can explain the three features listed above and provide an alternative interpretation of the EMS crisis.

We then focus our attention on the short-run dynamics of U.S. inflation. U.S. price inflation exhibits substantial inertia. The source of that inflation inertia is however controversial. In the second part of the thesis, we derive a wage contracting specification that implies inflation persistence to investigate the role of nominal rigidities to explain that degree of inertia. The contracting specification is derived from intertemporal optimisation under two basic assumptions: (i) wage staggering; (ii) relative wage concern by wage-setters. The novelty is the analysis of relative wage concern. In chapter 2 we review the existing evidence and theoretical support pointing at relative wage concern as a fundamental factor in the wage contracting process. In chapters 3 and 4, we build a dynamic general equilibrium macromodel to study its implications.

In chapter 3 we investigate two potential sources of inflation inertia: the contracting specification described above, and the lack of rationality of expectations. We then carry out a test for the source of inflation inertia. Our empirical results suggest that alternative sources of inertia beyond that imparted by the lack of full rationality of expectations are needed to characterise U.S. inflation dynamics.

In chapter 4 we focus our investigation on the persistence of the real effects of money shocks. In contrast to previous models of staggered wages/prices, output and inflation persistence are robust findings of the model. Moreover, persistence results hold for all the sensible parameterisations. Given the empirical evidence in favour of the existence of a strong relative wage concern, we conclude that relative wage concern may be the missing piece in the money shocks persistence puzzle raised by recent literature.

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Introduction

It is now widely acknowledged that the primary objective of central banks is - or should be - the maintenance of a low and stable rate of inflation. In fact, after more a decade of research, the literature on the optimal institutional design of the Central Bank and its objectives seems to have decisively influenced the politicians' view on the matter. The recent developments towards increased independence of many central banks from their corresponding governments and the explicit mandates in their statutes for controlling inflation as main objective are a clear reflection of that influence. In the United States, congressional resolutions setting inflation targets for the Federal Reserve have been proposed. The Bank of Canada, the Bank of New Zealand and the Bank of England have announced in recent years explicit near-term targets for inflation. In Europe, the overwhelming majority of the national central banks were given laws of independence from the political power in the last few years. Moreover, the statutes for the European Monetary Institute and the current European Central Bank agreed in Maastricht in December 1991, state that price stability is the primary objective. In this respect, these statutes just reproduce the primary responsibility of the Deustche Bundesbank, namely to safeguard the stability of the currency.

Economists have devoted substantial research effort to the analysis of the costs of inflation (see Fischer [1986], Chaps 1-4 for a review). As a result, a widespread agreement has been reached in the profession about the fact that such costs are of enough magnitude to bear the potential costs of eradicating them. The problem however arises from the fact that once inflation does rise, even for the moderate values experienced in western economies, it proves stubbornly persistent and, consequently, costly to reduce. Conventional estimates for the United States put the cost of a 1 percentage point reduction in inflation at about 2 percentage points of higher unemployment for a period of at least a year (Blinder [1987], pp. 38-39). The unemployment or output losses associated with reducing inflation appear to be widespread across countries and over time. Ball [1993] for instance has documented costly disinflation in 19 countries over a 30 year period.

Inflation may be persistent for a number of reasons. Despite the wide agreement on the fact that disinflations have been costly, the reason for the costs of disinflation is not agreed upon. At the core of the controversy is the nature of short-run inflation dynamics, which seems to be better characterised by substantial inflation inertia. However, that inertia has several potential explanations. Three main factors have been considered in the literature. Firstly, it may arise from the inertia that wage and price contracts impart to the inflation rate. Secondly, from the fact that inflation expectations may adjust slowly to changes in monetary policy stance. Thirdly, inertia may arise from imperfect credibility of monetary policy. Those three factors are considered along this thesis in the context of two specific macro-models.

The importance of the current effort to investigate inflation inertia stems from the fact that it is fundamental for related research in a number of areas. Firstly, it is crucial for the interpretation of past disinflationary episodes. Secondly, and even more importantly in our opinion, it is fundamental for the study of alternative monetary policy rules and for considering the potential costs of disinflationary experiments. This thesis is mainly motivated by the belief that to study such questions accurately a model that properly accounts for the persistence of inflation is required. The purpose is to analyse different sources of inflation persistence in an attempt to highlight their implications and relative importance for explaining some stylised facts.

Different sources of inflation persistence bear different implications for the conduct of monetary policy. If inflation persistence arises because the central bank lacks credibility, then the central bank should determine whether and how it can improve its credibility, and maintain it. On the other hand, if inflation persistence arises because economic agents slowly adjust their expectations to changes in the environment, or if inflation is inherently sticky as a result of the way in which prices and wages are negotiated, then monetary policy must take into account the associated costs of disinflation unless those practises change. A thorough investigation of the reason why such price-wage setting behaviour arises and how expectations are formed is then needed.

We will first consider the lack of credibility of central bank's announcements of disinflation as a common explanation for the output and unemployment costs associated with attempts to reduce the rate of inflation. A widely-used framework to highlight the problem of the potential lack of credibility of such policy announcements follows the seminal contributions of Kydland and Prescott [1979] and Barro and Gordon [1983]. In such a model, the government (or the central bank) optimises over a loss function subject to a Phillips curve constraint. The loss function is specified to capture the fact that the government dislikes deviations from inflation and output from some target levels. Whenever the output target is above the "natural rate", the crucial implication of such a model is that a disinflation announcement is "time inconsistent" in the sense that the government or the central bank *ex-post* has an incentive to renege from the announcement. Whenever the private sector is assumed to have rational expectations, it takes that incentive into account. The result is a persistent "inflation bias" afflicting the economy in the absence of a commitment technology that counteracts that incentive to renege.

Chapter 1 presents a model which is an extension of the framework of Barro and Gordon [1983] to an open economy context. The purpose is the analysis of the strategy of pegging the exchange rate as a commitment technology. The model follows the line of research that employs that framework to justify the policy decision by many European governments to enter the European Monetary System (EMS) as a strategy to "import" a credible monetary policy. This argument is well-known at least since Giavazzi and Pagano [1986]. The key feature of our model is that we incorporate a more specific definition of the reneging costs faced by policy-makers of the participating countries. This is the reason why the model may provide a better description of the EMS history.

The account for additional factors in the description of the EMS also allows the model to provide a better explanation for the collapse of the exchange rate system in the summer of 1992, which occurred after more than five years without any realignment. A substantial part of the chapter is devoted to the explanation of the 1992 events. The contribution stems from the fact that existing theoretical models cannot easily explain the following features of the EMS and its crisis in 1992: its progressive hardening from 1987 onwards; the fact that credibility was 'shared'; the progressive deterioration of credibility after the first Danish referendum without changes in the economic fundamentals. Our model argues that the reason lies in the fact that the literature has not accounted for the changes in the perceived prospects of EMU. We show that an adjustable peg regime that incorporates these prospects can explain the three features listed above.

In the second part of the thesis we consider two other alternative sources of inflation inertia, namely the lack of rationality of inflation expectations and the existence of inertia inherently introduced in the inflation dynamics by the price-wage contracting behaviour.

We motivate our investigation of wage contracting as source of the observed degree of inflation persistence in Chapter 2. Specifically, the contracting specification we advocate for is derived from intertemporal optimisation under two basic assumptions: (i) wage staggering; (ii) relative real wage concern on the part of the workers.

Chapter 2 explains the reasons why we propose the contracting specification described in the previous paragraph. More specifically, we show there that the famous Taylor model (Taylor 1979, 80) does not incorporate relative wage concern on the part of the workers, contrary to what was initially thought. We also show that without relative wage concern, the implied inflation dynamics does not exhibit the inertia that characterises actual inflation dynamics. The evidence on the existence of relative wage concern is also presented and our approach to account for it is then described. In the remaining chapters of the thesis we study the implications of such a contracting specification focusing on two stylised facts of aggregate U.S. data: inflation inertia and the persistence of the real effects of money shocks.

In Chapter 3, we first derive a contracting specification that displays inflation inertia by incorporating relative wage concern on the part of the workers, who solve an otherwise standard problem of intertemporal optimisation. However, we also consider the argument recently put forward in Roberts [1997]: if expectations are not formed under rational expectations, they may well incorporate the degree of inertia necessary to characterise actual inflation dynamics. The purpose of the empirical analysis carried out in Chapter 3 is therefore to investigate whether relative wage concern in wage contracting is a preferred explanation to characterise inflation inertia. Our approach is based on relaxing the assumption of rational expectations by employing direct observations of inflation expectations from two well-known surveys: the so-called Livingston survey of professional economists and the Michigan survey of consumers. We present some evidence supporting the idea that alternative sources of inertia beyond the lack of rationality of inflation expectations should be considered.

Chapter 4 further analyses the model introduced in the previous chapter. The focus of our analysis will be whether an explicit account of relative wage concern on the part of the workers may contribute to explain another puzzle raised by recent literature. Specifically, the standard contracting specification derived from imposing staggered price/wage setting in an optimising framework cannot generate the observed persistence of the real effects following money shocks. The intuition behind that result is the lack of *endogenous stickiness* embodied in the contracting specification, that is, the lack of an incentive for price/wage setters not to change their prices/wages by much when they re-set them. The existence of relative wage concern can potentially generate that endogenous stickiness. We thus look for plausible values for the parameters governing relative wage concern in our model, and investigate whether it can generate both output and inflation persistence. The approach is based on assessing the dynamic adjustment of output and inflation following shocks to the rate of growth of the money supply in our dynamic general equilibrium macromodel. Our results show that relative wage concern may be the source of endogenous stickiness that staggered wage models need to generate output and inflation persistence.

Chapter 1

Gaining Credibility through Exchange Rate Pegging: the EMS

1.1 Introduction

The European Monetary System (EMS) was launched in 1979 as a system of fixed but adjustable parities, and indeed realignments took place fairly frequently in its early years. However, from 1987 onwards, when the project of a Single European Currency emerged on the political agenda, the system progressively hardened. In fact, between 1987 and 1992 the central parities were not changed, although realignments were still possible. As a result, the system in this period became known as the "New EMS". After more than five years of stable parities, the confidence of markets and politicians in a smooth transition towards the Single Currency seemed to be complete. Yet, in the summer of 1992, the system collapsed under unprecedented speculative pressures.

The results of the empirical work on the credibility of the parities prior to and during the EMS crisis (see e.g. Rose and Svensson [1994] or Ozkan [1996] for two different approaches) can be summerised by five main findings: (i) credibility was steadily increasing during the New EMS period; (ii) movements in the credibility of the parities were usually common to all EMS currencies; (iii) there was little correlation between credibility and macroeconomic fundamentals; (iv) credibility started to decrease when a majority voted "No" in the first Danish referendum on the Maastricht Treaty; (v) there were nevertheless very few indicators of strong pressures on the parities until shortly before the collapse.

Theoretical models of the EMS crisis typically assume an optimising policymaker who maximises an objective function subject to a Phillips curve constraint. The collapse of the system is then viewed as the result of the policymaker's rational decision to devalue when the benefit of a devaluation exceeded the cost of abandoning the parity. As fundamental determinants of the benefits of devaluing, the literature has highlighted negative output shocks (Obstfeld [1994]), high interest rates (Ozkan and Sutherland [1993,1995]), high and persistent rates of unemployment (Drazen and Masson [1994] and Masson [1995]), and the lack of co-ordination among member countries concerning a realignment (Buiter *et al.* [1996]). Existing literature has nevertheless difficulties explaining several of the stylized facts found by the empirical works. In particular, it remains puzzling why the system was progressively hardening from 1987 onwards and why credibility was typically shared. Furthermore, there is no explanation for the striking contrast between the increase in the credibility of the parities in the first months of 1992 and its progressive deterioration after the first Danish referendum, since it occurred without substantial changes in the economic fundamentals.

We here argue that the reason for the shortcomings of the existing theoretical models is that they fail to account for changes in the perceived prospects of EMU. Although early informal discussions stressed the role of these prospects in understanding the crisis (see Eichengreen and Wyplosz [1993] and Group of Ten [1993]), the literature on the EMS crisis has neglected them. The reason appears to lie in the standard assumption of a fixed cost of devaluing, which is taken to be state and time invariant. In the context of the EMS, arguing that the realignment costs were state-independent and constant through the crisis is hardly justifiable on any grounds. Instead, these costs should be related to the risk of foregoing participation in the

Monetary Union and to the likelihood of the Monetary Union itself.

In this chapter, we model the EMS as an adjustable peg regime with an optimising policymaker. The benefits of a devaluation are kept in line with those in previous work (i.e. accommodation of adverse output shocks). Our framework however incorporates endogenous costs of realigning, which are state dependent and non constant over time. The crucial feature of the model is however that our cost of realignment accounts for the prospects of EMU. In our model, the possibility of a Monetary Union in the future increases the cost of resorting to realignments. The key idea is that, once the project of a Single Currency was launched, devaluations might lower credibility of monetary policy and jeopardise the countries' participation in the Single Currency. This allows our model to provide a better description of the New EMS. Specifically, we may explain the growing credibility of the parities prior to the crisis and the fact that credibility was shared.

Our interpretation of the crisis in September 1992 rests on the concurrence of two factors that had not been simultaneously present in the system prior to the summer of 1992, namely uncertainty about EMU and a deepening recession. With our endogenous cost of realignment, it is possible to show how the uncertainty about EMU modified governments' incentives to resort to realignments and made the system more fragile to adverse output shocks. Financial markets were aware of the fact that a realignment could take place as soon as the economies were afflicted by sufficiently large negative shocks. The "credibility shock" arising from the Danish "No" and the uncertainty surrounding the French referendum, in the middle of the recession, set the basis for the massive attacks on the currencies. The changing prospect of a Single Currency is shown to be an essential factor to understand: (i) the timing of the attacks, just four days before the French referendum; (ii) the reason why countries with weaker fundamentals, which were thus less likely to satisfy the convergence criteria (e.g. Italy, Spain), and countries with governments less committed to EMU (e.g. the UK), were the first suffering those explosive attacks. In addition, our model sheds new light on the reasons why reaching an agreement on a general realignment was so difficult, and helps to understand conditions under which the presence of multiple equilibria is a possible justification for the speculative attacks.

The chapter is organised as follows. The model is presented in Section 2. In Section 3, the implications of floating and pegged exchange rates are analysed, and a credible adjustable peg regime that better describes the EMS is derived. Section 4 explains the hardening of the system from 1987 onwards, giving rise to the so-called New EMS and Section 5 presents an interpretation of its collapse in September 1992. Finally, section 6 concludes. The codes used in the simulation of the model are presented in an appendix at the end of the chapter.

1.2 The Model

Our analytical framework is an extension of existing models of optimal monetary policy in small open economies (see e.g. De Kock and Grilli [1993] or Obstfeld [1994,97][1]). Variables are expressed in logs and we take domestic and foreign goods as perfect substitutes. Besides, Purchasing Power Parity (PPP) is assumed to hold. The (log of the) foreign price level is taken as constant and is normalised to zero, so that exchange rate depreciation, $\hat{e}_t$, and inflation, π_t, are the same: $\hat{e}_t = e_t - e_{t-1} = \pi_t$. Domestic output in period t is given by a Phillips curve relationship,

$$y_t = \alpha(\pi_t - \pi_t^e) - u_t \ , \tag{1.1}$$

where the (log of the) natural rate of output has been normalised to zero for simplicity. Furthermore, u_t is a serially uncorrelated shock to output, which has zero mean and a variance σ_u^2. Its density function is assumed to be continuous on the compact support $[\underline{u}, \bar{u}]$. The nominal rigidity in this economy arises from the fact that the one-period nominal wage contracts

[1] The starting point from which the policy implications of the different exchange rate regimes are derived is very similar as that of Obstfeld[1994]. However, there are substantial differences between his approach and ours: in his model the cost of realignment is exogenously given; and market expectations of governments' decisions are history-independent. Hence, he argues that the ERM crisis was the result of a switch from one of multiple equilibria to another. The present model shows that this is not the only possible explanation and establishes conditions under which multiple equilibria may be a valid explanation.

are signed before the output shocks are realised. We assume that those contracts cannot be state-contingent, so wages are not indexed to the value of the shock. The contracts are signed so as to maintain a constant real wage and, thus, incorporate the expected rate of inflation based on rational expectations. To give stabilisation policy a role, the government observes the realisation of the output shock before implementing the exchange rate policy. The government's objective is to minimise the following loss function:

$$L_t = E_t \sum_{j=t}^{\infty} \beta^{j-t} l_j = E_t \sum_{j=t}^{\infty} \beta^{j-t} (\theta \, {\pi_j}^2 + (y_j - y^*)^2). \tag{1.2}$$

In the government's loss for period t, l_t, the first term reflects the policy-maker's desire for low inflation, or equivalently, her concern with exchange rate stability. The second term incorporates an output target, y^*, that is larger than the natural rate ($y^* > 0$). The parameter θ reflects the weight of inflation relative to output stabilisation and $\beta \in (0, 1)$ denotes the discount factor.

1.3 The Choice of Exchange Rate Regime

In this section we analyse the implications of floating and pegging the exchange rate to highlight the key factors in the choice of the optimal exchange rate regime. Then, we build an adjustable peg regime which captures better some key features of the EMS.

1.3.1 Floating Exchange Rate

We assume that there are no reputational effects or commitment possibilities when the exchange rate floats (see Herrendorf [1997,98] for a justification). Hence, current policy actions do not affect the policy problem to be faced in future periods. Consequently, in any period t the government solves the optimisation problem of the stage game, minimising the one-period loss function l_t subject to (1.1). The Nash equilibrium outcome can be shown to be

$$\pi_t^F = \frac{\alpha}{\theta}\, y^* + \frac{\alpha}{\theta+\alpha^2}\, u_t, \qquad y_t^F = -\frac{\theta}{\theta+\alpha^2}\, u_t, \tag{1.3}$$

where the superscript "F" indicates floating. Equation (1.3) implies that the shock u_t is partially stabilised by the monetary authority and that the economy suffers from a systematic inflation bias, equal to $(\alpha/\theta)\, y^*$. A government deciding which exchange rate regime to choose evaluates the losses conditional on information available in the planning period $t-1$. The expected present value of the losses under floating is therefore given by[2]

$$L^F = E_{t-1} \sum_{j=t}^{\infty} \beta^{j-t}\, l_j^F = \frac{1}{1-\beta} \left[\frac{\theta+\alpha^2}{\theta}\, y^{*2} + \frac{\theta}{\theta+\alpha^2}\, \sigma_u^2 \right]. \tag{1.4}$$

1.3.2 Fixed Exchange Rate

In the context of the process towards EMU, it has been argued that inflation-prone periphery countries entered a fixed exchange rate agreement with the

[2] Note that the right hand side of (1.4) is independent of the time index, so a time subscript is not necessary.

centre countries (mainly Germany) to import credibility and the low inflation of the latter (see Giavazzi and Pagano [1988]). The rationale behind this argument is that if the commitment to a fixed exchange rate is credible, then it is possible to eliminate the inflation bias that afflicts the domestic economy under a float. On the other hand, a peg also implies the loss of a policy instrument, the exchange rate, which can be used to stabilise output shocks in the presence of short-run nominal rigidities. Consequently, there is only a case for fixing the exchange rate if the benefits of avoiding high average inflation exceed the costs caused by the lack of policy response to output fluctuations[3]. A credible peg implies that $\pi_t^{peg} = \pi_t^e = 0$, and $y_t^{peg} = u_t$. The expected present value of the losses under a peg is

$$L^{peg} = E_{t-1} \sum_{j=t}^{\infty} \beta^{\,j-t} \; l_j^{peg} = \frac{1}{1-\beta} \left[y^{*2} + \sigma_u^2 \right]. \tag{1.5}$$

Comparing (1.4) and (1.5), a peg is the preferred regime if and only if

$$\frac{\sigma_u^2}{y^{*2}} < K \equiv \frac{\theta + \alpha^2}{\theta}. \tag{1.6}$$

However, it is well-known that the policymaker has an incentive to renege ex-post on her commitment to a fixed parity and resort to a devaluation. For this reason, two questions are of primary interest to choose the optimal ex-

[3]Since the foreign monetary authority stabilises only foreign shocks, it is the difference between domestic and foreign shocks which is not stabilised by exchange rate pegging and leads to costly fluctuations from the domestic point of view. We can simplify this by normalising foreign supply shocks to zero.

change rate regime: first, whether there are forces that may prevent reneging from the announced parity; second, whether there are "intermediate" regimes which may be preferable to either a peg or a float. We now analyse these questions in greater detail, and relate them to the features of the European Monetary System.

1.3.3 The EMS as an adjustable peg regime

In the EMS years, realignments did take place, yet currencies remained in the system. To be consistent with that fact, we model an EMS-like system of pegged but adjustable parities in which the government's dilemma is whether to devalue or to maintain the parity. Such a system can be interpreted as a regime in which the commitment to the announced parity is state-contingent, i.e. a peg with an escape clause. More specifically, when the size of the shock hitting the economy exceeds a threshold value u^*, the 'trigger' point, the government breaks its commitment to the fixed parity to stabilise the adverse output shock, and in the following period returns to a new parity, which is in turn adjustable in extreme circumstances.

We formalise the adjustable peg as a trigger-strategy equilibrium of the monetary policy game presented in the first section [4]. The private sector

[4] In what follows we apply the analysis developed by De Kock and Grilli[1993] in an optimal tax model to the Barro-Gordon framework.

is aware of the government's incentives to implement surprise devaluations, but it is assumed to lose confidence in the adjustable peg regime only if the government resorts to a discretionary use of the exchange rate policy when $u_t < u^*$. In this case, the private sector punishes the government by playing Nash forever after the devaluation occurs[5], and the exchange rate reverts to floating.

Determination of the equilibrium trigger

The equilibrium trigger point that characterises the adjustable peg regime can be derived as follows. Let $\Psi(u_t, u^*)$ denote the net benefit of a devaluation,

$$\Psi(u_t, u^*) \equiv B^r(u_t, u^*) - C^r(u_t, u^*), \tag{1.7}$$

where $B^r(u_t, u^*)$ and $C^r(u_t, u^*)$ are respectively the benefit and the cost (defined below) of a realignment of the parity when it is not justified, that is, when the size of the shock is not sufficiently large ($u_t < u^*$). The equilibrium trigger point must then satisfy:

$$\Psi(u^*, u^*) = 0, \;\; \Psi(u_t, u^*) < 0 \;\; for \; u_t < u^* \;\; and \;\; \Psi(u_t, u^*) > 0 \;\; for \; u_t > u^*. \tag{1.8}$$

[5]This assumption follows De Kock and Grilli [1993] and is made in order to keep the model as simple as possible (shorter 'punishment' periods can be easily accommodated by assuming lower values of the government's discount factor).

Condition (1.8) defines an interior trigger point, that is, a threshold value u^* in the interior of the interval of support of the shock, $u^* \in (\underline{u}, \bar{u})$, such that the policymaker devalues if and only if $u_t \geq u^*$. Consequently, u^* describes an adjustable peg regime, in which the credibility loss, captured by the term $C^r(.)$ in (1.7), can deter the government from devaluing. The key feature of this exchange rate regime is that the closer u^* is to $\underline{u}$ the more frequent realignments are, and thus the closer is the adjustable peg to floating. On the other hand, the adjustable peg gets closer to a peg the closer is u^* to the upper bound $\bar{u}$.[6]

To obtain the equilibrium trigger we have to compute the benefit and cost of realigning in this adjustable peg regime. Consider first the benefits. They are assumed to arise in the period in which the realignment takes place, and are given by

$$B^r(u_t, u^*) = l_t^p(u_t, u^*) - l_t^r(u_t, u^*), \tag{1.9}$$

where $l_t^p(u_t, u^*)$ is the one-period loss if the peg is maintained and $l_t^r(u_t, u^*)$ is the loss if the parity is realigned. It is important to note that these one-period losses incorporate the expected rate of inflation under this mixed

[6]Note that a permanent peg is incentive-compatible only if the cost of an unjustified realignment of the peg exceeds the benefits for all possible realisations of the shock, that is if $\Psi(u_t, u^*) < 0$ for all u_t. Equivalently, floating is an equilibrium regime if the government has no incentive to peg the exchange rate provided that the public expects the exchange rate to float forever, i.e. if $\Psi(u_t, u^*) > 0$ for all u_t.

regime. Positive inflation expectations arise in this adjustable peg regime because agents take into account the possibility of a justified devaluation in the following period. Inflation expectations incorporate the inflation rate expected to prevail after a realignment, weighted by the probability that a realignment takes place. This probability is determined by the value of the equilibrium trigger point and the distribution of the shocks. Formally, we have:

$$\begin{aligned} \pi_t^e(u^*) &= F(u^*)\ E_{t-1}(\pi_t|\ peg\ in\ t) + [1-F(u^*)]\ E_{t-1}(\pi_t|\ realignment\ in\ t) = \\ &= \frac{\alpha\ [1-F(u^*)]}{\theta+\alpha^2 F(u^*)}\ y^* + \frac{\alpha}{\theta+\alpha^2 F(u^*)} \int_{u^*}^{\bar{u}} u_t f(u_t)\, du_t. \end{aligned} \tag{1.10}$$

where $f(.)$ is the density of u_t and $F(.)$ denotes the probability that $u_t < u^*$.

Given the knowledge of the realisation of the shock, the benefits of realigning can be shown to equal

$$B^r(u_t, u^*) = l_t^p(u_t, u^*) - l_t^r(u_t, u^*) = \frac{\alpha^2}{\theta+\alpha^2}\ [\alpha\pi_t^e(u^*) + y^* + u_t]^2. \tag{1.11}$$

Consider now the cost of realigning, $C^r(u_t, u^*)$. The cost is assumed to accrue in future periods, arising because the private sector loses faith in the government's commitment to the adjustable peg. It is therefore formalised as the discounted value of being under floating rather than under our adjustable peg from the period after the unjustified realignment onwards, i.e.

$$C^r(u^*) = \beta\,[L^F - L^M(u^*)]. \tag{1.12}$$

where L^F denotes the present discounted value of the losses under floating as derived before. The loss under our mixed regime is given by

$$L^M(u^*) = E_{t-1} \sum_{j=t}^{\infty} \beta^{\,j-t}\, l_j^M(u_j, u^*), \tag{1.13}$$

where the expected one-period loss is

$$E_{t-1} l_t^M(u_t, u^*) = F(u^*) E_{t-1} l_t^p(u_t, u^*) + [1 - F(u^*)]\; E_{t-1} l_t^r(u_t, u^*). \tag{1.14}$$

Since u_t is i.i.d., the losses under the adjustable peg regime can be written as

$$\begin{aligned} L^M(u^*) = \frac{1}{1-\beta} \Bigg\{ & 2\alpha y^* \pi^e(u^*) + \alpha^2 \pi^e(u^*)^2 - \frac{\alpha^2}{\theta+\alpha^2} \int_{u^*}^{\bar{u}} u_t^2 f(u)\, du - \frac{2\alpha^3 [1-F(u^*)] y \pi^e(u^*)}{\theta + \alpha^2} \\ & + y^{*2} + \sigma_u^2 - \frac{\alpha^2 [1-F(u^*)][y^{*2} + \alpha^2 \pi^e(u^*)^2]}{\theta + \alpha^2} - \frac{2\alpha^2 [y^* + \pi^e(u^*)]}{\theta + \alpha^2} \int_{u^*}^{\bar{u}} u_t f(u)\, du \Bigg\} \end{aligned}$$

$$. \tag{1.15}$$

The cost of reneging can be expressed as

$$C^r(u^*) = E_t \sum_{j=t+1}^{\infty} \beta^{j-t} \left[l_j^F - l_j^p(u_j, u^*) + \; [1 - F(u^*)] B^r(u_j, u^*) | u_j > u^*) \right], \tag{1.16}$$

Using the previous results, one obtains

$$\begin{aligned} C^r(u^*) \;=\; \Omega \Bigg\{ & \frac{\alpha^2 + 2\theta - \theta F(u^*)}{\theta}\, y^{*2} - \sigma_u^2 - [\theta + \alpha^2 F(u^*)]\, \pi_t^e(u^*)^2 + \int_{u^*}^{\bar{u}} u_t^2 f(u)\, du \\ & - 2\, \frac{\theta + \alpha^2 F(u^*)}{\alpha} \pi_t^e(u^*)\, y^* + 2[\alpha\, \pi_t^e(u^*) + y^*] \int_{u^*}^{\bar{u}} u_t f(u)\, du \Bigg\}, \end{aligned} \tag{1.17}$$

where $\Omega \;\equiv\; \alpha^2 \beta / (\theta \;+\; \alpha^2)(1 \;-\; \beta)$.

1.4 The "New EMS"

The EMS experienced a *de facto* forswearing of realignments from January 1987 onwards, which gave rise to a different exchange rate regime, the so-called "New EMS". The striking feature of this regime was the sound credibility of the parities. In fact, empirical analyses show that credibility was steadily increasing until the summer of 1992. There was however little correlation between credibility and macroeconomic fundamentals: even in the first months of 1992, despite the deepening recession, the credibility of the parities was surprisingly sound[7]. Moreover, movements in credibility were typically common to all EMS currencies. These empirical findings are a serious problem for many existing currency crisis models, which cannot easily provide an explanation for them. The institutional changes in the EMS do not offer a sound explanation either. It is true that the Basle-Nyborg Agreement of 1987 contributed to the stability of the system by extending the Very Short Term Financing Facility among central banks [8]. Yet, the existence of additional financial resources to cope with speculative attacks is not by itself a satisfactory explanation for the growing credibility of the parities.

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[7] For detailed analyses of the credibility of the parities the reader is referred for example to Rose and Svensson [1994].

[8] The Basle-Nyborg Agreement extended exchange market intervention at even intra-marginal level if agreed between the Central Banks involved.

In our opinion, the hardening of the EMS was fundamentally linked to the project of a Single European Currency. We argue here that this project increased the costs of resorting to realignments, since unjustified devaluations could jeopardize participation in the future Monetary Union. As a result, it is not surprising that the system hardened and credibility steadily increased since the project of a Monetary Union emerged in the political agenda and started being developed.

The New EMS can be described by our adjustable peg regime if the cost of realigning accounts for the possibility of a Monetary Union in the near future. This is done by assuming that EMU may take place in some future period "T". To enrich the analysis, the probability that EMU is implemented is introduced as "p", and "q" denotes the probability that the country under consideration actually qualifies. We also assume that if EMU is not implemented (a probability $(1-p)$ event), an EMS-like arrangement would be maintained among the member countries, whereas if a country does not qualify, but EMU is implemented (which occurs with probability $p(1-q)$), the country's currency will float [9]. The cost of realigning is then

[9]This assumption is taken to simplify the analysis. It could be argued that if a country was left out at period "T", a sort of New EMS arrangement could be also maintained between currencies left out and the Euro. However, as Persson and Tabellini [1996] argues, it seems rather difficult for "outsiders" to keep a peg with the Euro. Hence it is most likely that a float is the only option for outsiders.

modified as follows:

$$\begin{aligned}
C_t^r(u^*,p,q,T) &= E_t \sum_{j=t+1}^{T-1} \beta^{j-t}\left[l_j^F - l_j^{EMS}\right] + \\
&\quad + E_t \sum_{k=T}^{\infty} \beta^{k-t}\left\{pq\left[l_k^F - l_k^{EMU}\right] + (1-p)\left[l_k^F - l_k^{EMS}\right]\right\} \\
&= E_t \sum_{j=t+1}^{\infty} \beta^{j-t}\left[l_j^F - l_j^{EMS}\right] + \\
&\quad + E_t \sum_{k=T}^{\infty} \beta^{k-t}\left\{pq\left[l_k^{EMS} - l_k^{EMU}\right] - p(1-q)\left[l_k^F - l_k^{EMS}\right]\right\}.
\end{aligned} \tag{1.18}$$

Equation (1.18) clearly indicates that accounting for a Monetary Union adds an extra cost to the option of devaluing: this equation is composed of the cost already derived in equation (1.17) plus the term in the last line of (1.18). This new term captures the additional gains from participating in EMU with respect to the EMS, adjusted by the possibility that the country is left out of the Monetary Union. These situations are weighted by the probabilities "p" and "q". Note that obviously if EMU is not possible at all ($p = 0$), the last line in (1.18) vanishes and we are left with the same endogenous cost as in the previous section. Besides, note that given "p" and "q", the additional term in (1.18) also depends on "T": *ceteris paribus*, it is larger the closer the starting date of the Monetary Union is. So, getting closer to EMU increases the cost of devaluing, which in turn raises the trigger point towards u. This feature of the model is consistent with the progressive hardening of the system and the increase in the credibility of the parities.

To compute the additional cost of realigning resulting from the prospect of EMU, we formulate the country's expected loss under EMU along the lines of recent literature [10]. The postulated advantage of a Single Currency over the EMS is that the European Central Bank (ECB in what follows) could credibly pre-commit due to a successful institutional design. The ECB thus implements an optimal policy of stabilisation at an "European level" by accommodating the output shock common to the EMU economies. Under this assumption, the ECB's monetary policy would result in

$$\pi_{EMU} = \lambda\, \epsilon, \qquad \lambda = \frac{\alpha_{EMU}}{\theta_{ECB} + \alpha^2_{EMU}}, \tag{1.19}$$

where (1.3) has been used to derive the expression for λ. A Single Currency implies that all countries share the above rate of inflation. Thus, output in each country would be

$$y_i \;=\; \alpha(\pi_{EMU} - \pi^e) \;-\; u_i \;=\; \alpha\lambda\epsilon - u_i, \tag{1.20}$$

where "ϵ" is the common European shock, and "u_i" is the shock affecting each country [11]. As a result, the expected one-period loss under EMU is given by

$$E_{t-1} l_t^{EMU} = \left\{ \left[(\theta + \alpha^2)\lambda^2 + 1 - 2\alpha\lambda\rho_{\epsilon u} \right]\, \sigma_u^2 + \, y^{*2} \right\}. \tag{1.21}$$

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[10]See Alesina and Grilli [1992].

[11]For simplicity we have made the additional assumption that the shocks ϵ and u_i have the same variance but are not perfectly correlated.

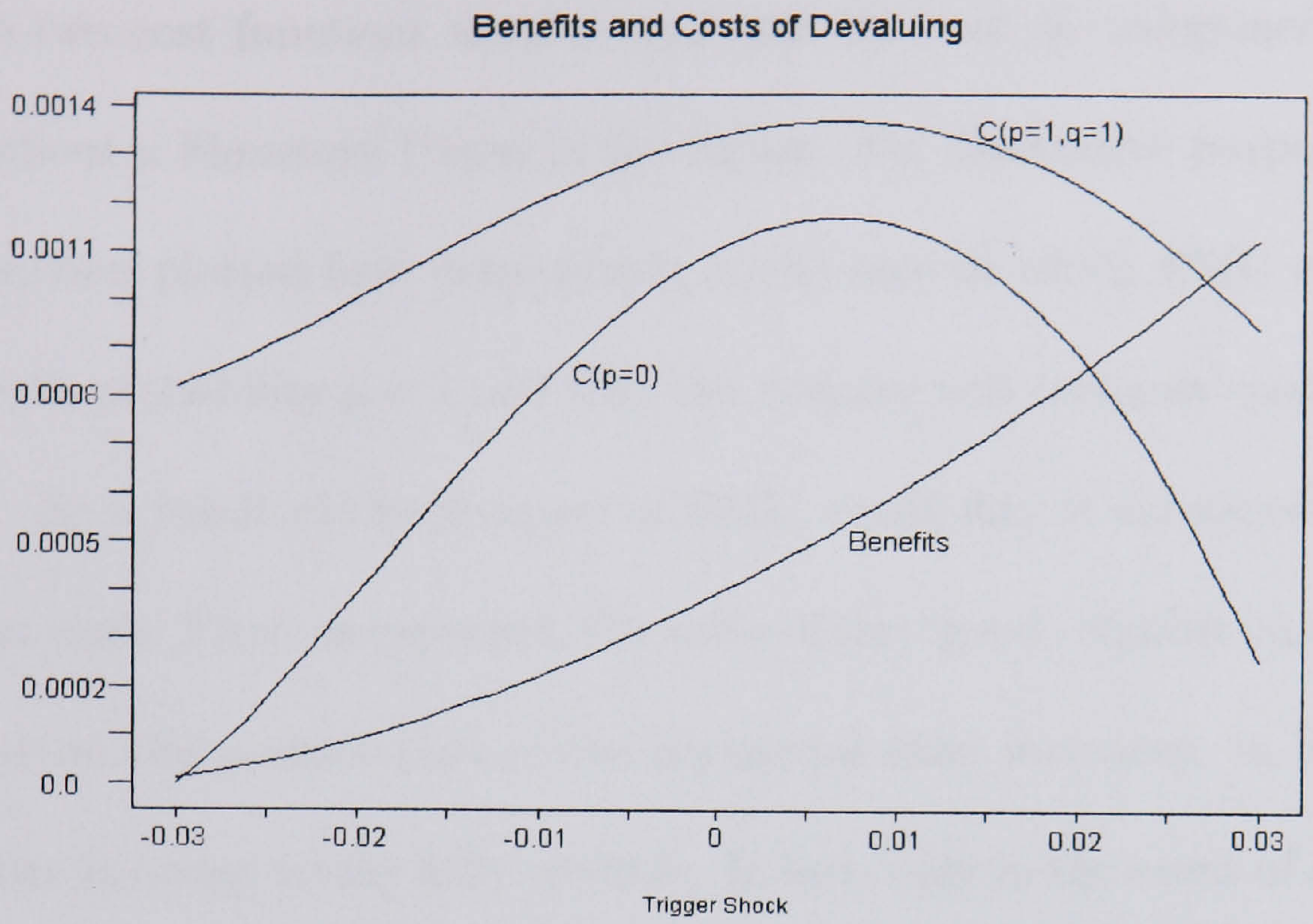

Figure 1.1: Benefits and costs of Devaluing

where $\rho_{\epsilon u}$ is the correlation between ϵ and u_i .

Figure 1.1 presents a numerical simulation of the benefits and cost of realignment in our model [12].

The two cost functions we plot represent the cost of realignments with

[12] The parameter values for the simulations are: $\beta = 0.9$, $\theta = 0.15$, $y^* = 0.01$, $\alpha = 0.6$, $u \sim U[-0.03, 0.03]$, $\lambda = 0.75$, $\rho_{\epsilon u} = 0.85$, $EMU\ in\ T = 1999$. The qualitative results are quite robust to changes in parameter values. Here we present the results for the uniform distribution used in Obstfeld [1994]. His work emphasises the presence of multiple equilibria when a lump-sum specification of the realignment cost is employed. In order to compare his results to ours, our choice of parameters also follows his.

The two cost functions we plot represent the cost of realignments with and without a Monetary Union in the future. For illustrative purposes, the cost function plotted here corresponds to the case in which EMU will take place with probability $p = 1$ and that the country will certainly qualify (i.e. $q = 1$). As a result of the prospect of EMU, credibility is enhanced by two forces at work. First, as expected, the value of the "good" equilibrium trigger (the one on the positive part of the horizontal axis) increases: in Figure 1 the parity becomes nearly fully credible. In fact, only in the event of a severe recession, that is, an adverse shock close to the upper limit of the support of the shock, $\overline{u}$, would a realignment take place. Second, and most noteworthy, although our model features an escape clause as in Obstfeld [1994,97], the trigger point becomes *unique* [13]. This is due to the explicit account of the likelihood of a Single Currency, which increases the cost of realignment for

[13] The New EMS can be represented as an adjustable peg with a trigger point close to the upper bound of the support for the output shock, very much resembling a permanent peg. No EMS government ever made any announcement of a level of interest rates, unemployment or threshold whatsoever that would trigger a departure from the system. In fact, governments repeatedly announced their intention not to leave the system at all. Such announcements obviously turned out not to be state-consistent. Furthermore, despite their progressive reduction, inflation and interest rate differentials remained at non-negligible levels during the New EMS period. This fact points to nonetheless imperfect credibility of the parities. The actual governments' commitment to the central parities is thus better characterised by a high trigger point, which would only be reached in a severe recession.

all the realisations of the output shock. Our model can then explain why the EMS had coped well with adverse circumstances before 1992. In the words of Rose and Svensson [1994, (p.1214)]:

> [.] the old parities had stood well, weathering a variety of events since 1987 which might have been expected to result in realignments including the removal of capital controls, German Reunification, the Gulf crisis [.]. The New EMS had weathered these situations well, with constant or enhanced credibility and did not appear to be very well described by traditional models.

This suggests that the credibility of the New EMS parities can only be understood in the presence of a *unique* trigger point. Under multiple equilibria, a sudden switch in market expectations from one equilibrium to another triggers a devaluation given the self-fulfilling property of expectations. It is then difficult to understand why any of the events enumerated by Rose and Svensson did not force a realignment.

Accounting for the prospects of EMU can explain the increasing credibility of the parities even during the first months of 1992, when the European economies were suffering a recession. We can offer two main reasons. First, with the agreement on the Maastricht Treaty, the project of EMU was continuing to take shape. In our model, we can capture it by an increase in "p", the likelihood of EMU taking place. Second, the perceived starting date of EMU,

"T". was definitely set and getting closer. As shown above, both these factors increase the expected present value of the cost of not qualifying , thereby enhancing credibility. A related point worth noting is that since these factors were common to most participants in the New EMS, our model also explains why credibility was *shared*, as found in the empirical analysis of Rose and Svensson [1994]. Provided EMU would take place as planned, only a very severe recession could then trigger realignments. Consequently, whenever market tensions emerged far from the unique state-consistent trigger during the period 1987-92, there was no disagreement among the participants that financial support to defend the parities should readily be available.

On 2nd June 1992, the scenario changed. The Danish voted "No" to the Maastricht Treaty, and a EMU, the additional source of credibility of the parities, was suddenly under threat. In addition, in the summer of 1992 all participants in the New EMS except Germany were experiencing a deepening recession. The next section provides an interpretation of the events of September 1992 in the light of these facts.

1.5 An explanation of the ERM crisis

Two main results arise from the empirical analyses on the ERM crisis: (i) there were very few indicators of strong pressures on the existing parities until shortly before the collapse: (ii) credibility nonetheless started to decrease when a majority voted "No" on June 2. Theoretical interpretations of the crisis based on multiple equilibria cannot convincingly explain these facts. While they do well with respect to the first finding, they have trouble with the timing of the attacks: neither the increase in expectations of realignment in the summer of 1992 nor the level of these expectations were without historical precedents. As argued in the previous section, an additional weakness of multiple equilibria models is that they are not consistent with the sound stability of the parities during the EMS years.

We argue that the explanation of the empirical findings mentioned above lies in the uncertainty about EMU. This factor has been clearly overlooked by existing literature. Uncertainty about EMU had not emerged before in the New-EMS period and, thus, may explain the otherwise puzzling instability of the system in the summer of 1992, as the economic conditions did not suffer substantial changes. The fact that the credibility of the parities started to decrease shortly after the negative outcome of the first Danish referendum is consistent with this view [14]. Moreover, the reason is straightforward in our model: EMU, the ultimate goal that had strengthened the system, became uncertain for the first time. While the message sent to the markets was that the project of EMU was still on track exactly as designed in the Maastricht Treaty (including the convergence criteria), the deepening

[14] See Rose and Svensson [1994].

recession had already made restrictive policies more harmful for a significant number of countries. As a result, governments' resolution to maintain the parities received renewed attention by the markets and the idea of a mini currency union started to gain momentum [15].

Our model explains the crisis by the concurrence in September 1992 of two factors, namely doubts about the future of EMU and a deepening recession. They are captured by reductions in the likelihood of EMU , "p", the probability of qualifying, "q", and a large adverse realisation of the output shock "u". Figure 1.2 below illustrates the effects of a reduction in the probabilities by starting at a point where the New EMS enjoys high credibility [16]. The reduction in "p" and "q" lowers the cost of devaluing, the value of the equilibrium trigger shock decreases and a realignment becomes more likely. As a result, the expected rate of devaluation increases (see equation (1.10)) and the credibility measures deteriorate. In this model, speculative attacks occur whenever the adverse output shock is believed to be large enough, that is $u_t \geq u^*$, since an optimising policy maker will then find it optimal to abandon the parity.

[15] See Financial Times, 20th June 1992 and the "Survey of Foreign Exchange Markets" in Eichengreen and Wyplosz [1993], in particular Tables 3 and 5.

[16] The first plot of the cost function, assuming $p = q = 1$, implies a trigger point $u^* = 0.0275$ and an expected devaluation of 0.19%.

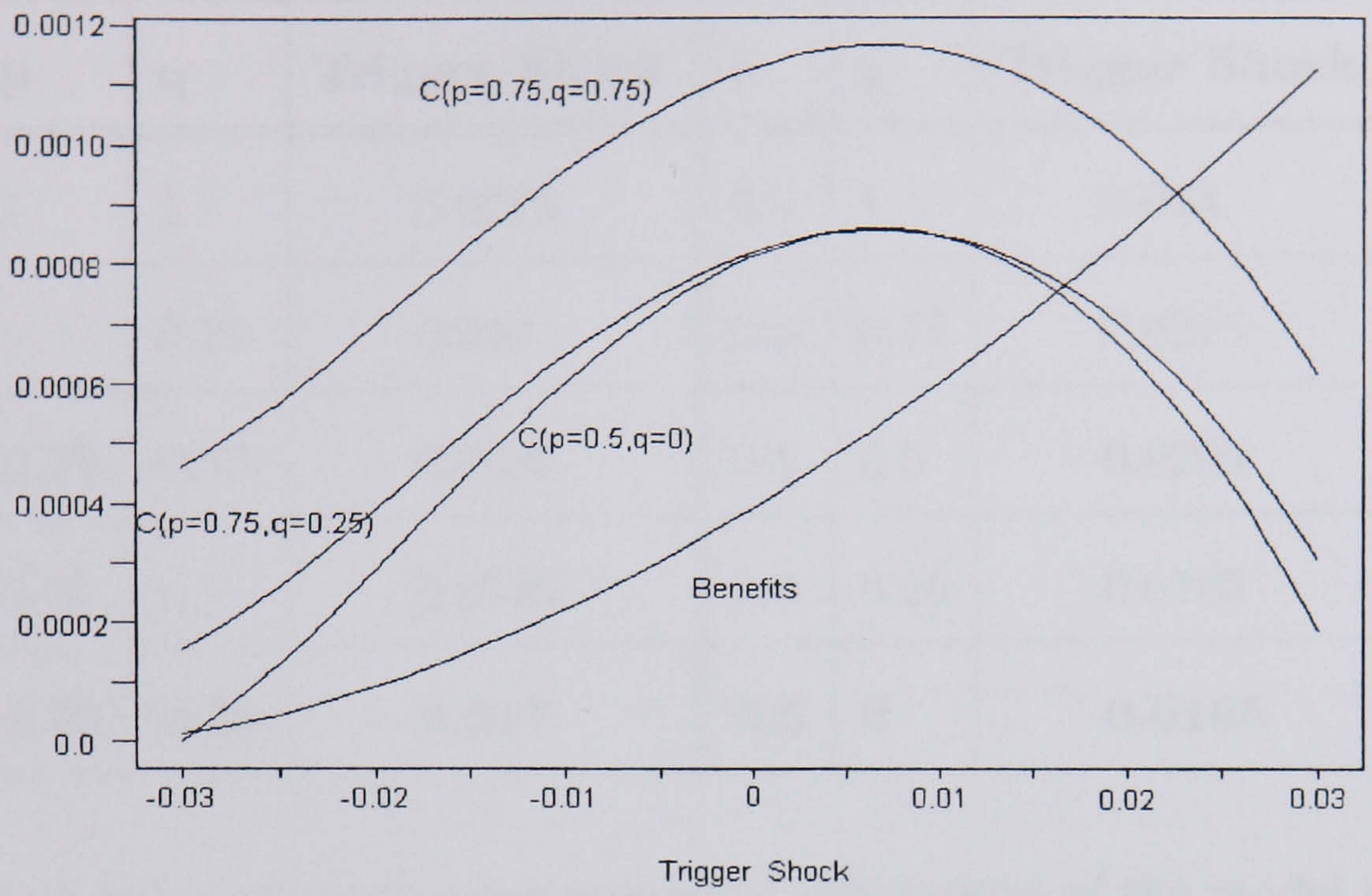

Figure 1.2: Benefits and Costs of Devaluing

The Referendum called by President Mitterrand fueled further the doubts about the stability of the parities in September 1992. The future of EMU was undoubtedly linked to its result, as explicitly acknowledged by the Commission President Jacques Delors [17] . This situation led financial markets to consider a set of alternative scenarios, accounting for both each country's probability of qualifying and the process towards a Single Currency itself [18].

Table 1 below presents some numerical simulations of the model to illustrate the effects of decreasing "p" and "q" on the trigger points.

[17]See Financial Times, 31st August 1992.

[18]See Financial Times, 20th June 1992.

Table 1.1: Equilibrium Trigger Points

p	q	Trigger Shock	p	q	Trigger Shock
1	1	0.0275	0.5	1	0.023
1	0.75	0.024	0.5	0.75	0.0215
0.75	**0.75**	**0.023**	0.5	0.5	0.0205
0.75	0.5	0.0195	0.5	0.25	0.0185
0.75	**0.25**	**0.017**	**0.5**	**0**	**0.0165**

Table 1 below presents some numerical simulations of the model to illustrate the effects of decreasing "p" and "q" on the trigger points.

These numerical results shed some light on particular aspects of the crisis that still remain puzzling. For the sake of concreteness, we assume $p = 0.5$ is the situation before the French referendum, and that a positive outcome causes $p = 0.75$. Consider first the timing of the attacks, just four days before the French referendum. The table shows a "perverse effect" of an expected French "Yes" on the triggers of countries that were believed *not to qualify* (given the increasing rumours that a mini-EMU was unavoidable). More specifically, for a probability of qualifying of q =0.75, we see that p=0.5 implies $u^* = 0.0215$ and p=0.75 $u^* = 0.023$; but for the lower probability of qualifying of q =0.25, an *increase* in the probability of EMU from p=0.5 to

p=0.75 implies a *decrease* in the trigger point from $u^* = 0.0185$ to $u^* = 0.017$. For the first time in the New EMS years, a successful attack on the currencies of countries believed unlikely to qualify became possible: these countries could no longer benefit from a positive outcome in the French Referendum to partially restore the credibility enjoyed after 1987. In fact, a narrow but positive outcome of the French referendum was probably anticipated. Of course, in the event of a French "No", the process of EMU would have been seriously damaged. The trigger point of the countries expected to qualify would have then decreased. The most likely result would have been speculative attacks on all the currencies in the system, since the co–ordinated defence of the parities would have been very unlikely [19].

The interior trigger points presented in Table 1 nevertheless remain unique, for countries with a positive probability of qualifying. The model implies that an interior trigger would cause a realignment, and not a reversion to float. This is consistent with the experience of several currencies in September 1992 (the Spanish peseta, or Portuguese escudo). Yet, some currencies floated af-

[19]The model has the implication that the triggers of the countries unlikely to qualify may increase in the event of a negative outcome in the French Referendum. The intuition behind that result is that such countries would benefit from exchange rate pegging rather than floating for longer if the project of EMU was delayed beyond "T". However, if the currencies of countries with stronger fundamentals come under attack, it is natural to assume that countries less likely to qualify would also suffer the attacks.

ter the attacks (Italian lira, sterling). Moreover, they seemed to be expected to float. Our endogenous cost may also explain why that was the case. In particular, our model predicts that countries believed very unlikely to qualify could face multiple equilibria. Figure 2 also illustrates this case. For $p = 0.5$, $q = 0$ multiple equilibria arises: the "second" equilibrium implies an almost necessary reversion to floating. The experiences of sterling and the Italian lira are consistent with this scenario, since those countries were believed to be the most unlikely to qualify for the Single Currency (the UK due to her opting-out clause). Our model shows that their low probability of qualifying may have been a fundamental factor in understanding the attacks.

There are several additional aspects on which our model can shed some light. First, it can explain the Bundesbank's selective defence of the currencies on 16th September [20]. The reduction in "p" and "q"creates a hedge between the triggers of countries likely to qualify and those unlikely to do so ($u^*_{(q=0.75)} = 0.023$ and $u^*_{(q=0.25)} = 0.017$, respectively), even when they were suffering a similar recession (captured here by size of the adverse shock u). Second, our model also provides a straightforward justification for the dif-

[20] In our interpretation we abstract from expectations of any delay in EMU beyond 1999. Any expectations of such a delay, for example to allow more countries to qualify, would damage here the credibility of the parities of those countries very likely to qualify. We do not follow that argument here, but it is clear that the case of the French franc in the aftermath of the narrow "Yes" would fit in that scenario.

ficulties in reaching an agreement on the co-ordinated general realignment. Such a realignment had been repeatedly proposed by the Bundesbank since as early as 1991. But a devaluation implies validating the trigger point at which it takes place for the formation of inflation expectations in our model. Thus, countries with higher state-consistent triggers as a consequence of their stronger fundamentals and higher probability of qualifying (France, Netherlands) were obviously reluctant to accept a realignment at other countries' lower triggers [21]. Third, in the present model it is possible that attacks take place without any previous remarkable decrease in the credibility of the parity, despite a substantial decrease in the trigger point [22], as found by Rose and Svensson [1994].

1.6 Concluding remarks

This paper has presented an EMS-like adjustable exchange rate regime comprising a peg with an escape clause allowing for realignments in unusual circumstances. The escape clause is formalised as a trigger value for an adverse output shock, where the equilibrium trigger is derived from an explicit

[21] These results in a unilateral peg framework support the case for a lack of co-ordination in the periphery, an explanation presented by Buiter *et al.*[1996].

[22] For the lowest of the unique triggers depicted in Figure 2, $\pi^e(0.017) = 0.97\%$, which cannot signal high expectations of realignment given the width of the ERM bands.

formulation of benefits and *endogenous* cost of realigning the parities. In contrast, existing work assumed the cost of realigning to be exogenously given and constant over time.

We argued that existing formal analyses have overlooked the fact that the cost of realigning had decreased prior to the EMS crisis in September 1992. The reason for such a decrease was that the likelihood EMU proceeding smoothly as planned decreased due to the "No" in the first Danish referendum and the increasing uncertainty that preceded the French referendum on the Maastricht Treaty. A decrease in the likelihood of EMU made it less costly to devalue and jeopardise qualifying for the Single Currency, given that EMU involves net benefits. The model shows that incorporating this effect allows for a more satisfactory explanation of the main stylized facts of the collapse of the New EMS in September 1992.

1.7 Appendix

In this appendix we include the codes used to simulate the model. The numerical simulations were carried out by S-Plus. The package required the construction of each function that were used later to generate the data and the figures presented in this Chapter.

```
"ejf"<-
function(u)
{a <- 1
b <- 1
(1/0.06) * dbeta((u + 0.03)/0.06, a, b)}
"ejcf"<-
function(u)
{integrate(ejf, -0.03, u)$integral}
"ejfu"<-
function(x)
{a <- 1
b <- 1
(1/0.06) * dbeta((x + 0.03)/0.06, a, b) * x}
"ejfu2"<-
function(x)
{a <- 1
b <- 1
(1/0.06) * dbeta((x + 0.03)/0.06, a, b) * (x^2)}
"ejint"<-
function(u)
{integrate(ejfu, u, 0.03)$integral}
"ejint2"<-
function(u)
{integrate(ejfu2, u, 0.03)$integral}
"ejeinf"<-
function(u)
{t <- 0.15
beta <- 0.9
y <- 0.01
al <- 0.6
((al * (1 - ejcf(u)))/(t + (al^2) * ejcf(u))) * y + (al/(t + (al^2) * ejcf(u))) *
ejint(u)}
"Lff"<-
function(u)
{t <- 0.15
y <- 0.01
beta <- 0.9
al <- 0.6
varu <- 0.000299999999999999996
(1/(1 - beta)) * ((((al^2) + t)/t) * (y^2) + (t/((al^2) + t)) * varu)}
"Lpeg"<-
function(u)
{beta <- 0.9
varu <- 0.0003
y <- 0.01
(1/(1 - beta)) * (varu + (y^2))}
"Lerm"<-
function(u)
{beta <- 0.9
t <- 0.15
y <- 0.015
al <- 0.6
varu <- (0.000299999999999999996)
k2 <- (1/(1 - beta))
primera <- k2 * (y^2 + (al^2) * ((ejeinf(u))^2) + varu + 2 * y * al * ejeinf(u))
segunda <- k2 * (-1) * (1 - ejcf(u)) * ((al^2)/((al^2) + t)) * (y^2 + (al^2) * ((
ejeinf(u))^2))
```

```
tercera <- k2 * (-2) * (1 - ejcf(u)) * ((al^3)/((al^2) + t)) * y * ejeinf(u)
cuarta <- k2 * (-1) * ((al^2)/((al^2) + t)) * ejint2(u)
quinta <- k2 * (-2) * ((al^2)/((al^2) + t)) * (y + al * ejeinf(u)) * ejint(u)
primera + segunda + tercera + cuarta + quinta
}
"costo1"<-
function(u)
{a <- 0.6
y <- 0.01
b <- 0.9
t <- 0.15
l <- 0.75
rho <- 0.85
varu <- 0.00029999999999999996
ejint <- integrate(ejfu, u, 0.03)$integral
ejint2 <- integrate(ejfu2, u, 0.03)$integral
ejeinf <- ((a * (1 - ejcf(u)))/(t + (a^2) * ejcf(u))) * y + (a/(t + (a^2) * ejcf(u))) *
ejint(u)
k1 <- ((a^2)/((a^2) + t))
primera <- k1 * (((a^2) + t * 2 - t * ejcf(u))/t) * (y^2)
segunda <- k1 * varu * (-1)
tercera <- k1 * (t + (a^2) * ejcf(u)) * ((ejeinf)^2) * (-1)
cuarta <- (k1 * (t + (a^2) * ejcf(u)) * y * (ejeinf) * (-2))/a
quinta <- k1 * ejint2(u)
sexta <- k1 * a * (ejeinf) * ejint(u) * 2
septima <- k1 * y * ejint(u) * 2
year <- 7
ye <- 0.01
pemu <- 1
qu <- 1
primeraems <- (y^2 + (a^2) * ((ejeinf)^2) + varu + 2 * y * a * (ejeinf))
segundaems <- (-1) * (1 - ejcf(u)) * ((a^2)/((a^2) + t)) * (y^2 + (a^2) * ((ejeinf)^2)
)
terceraems <- (-2) * (1 - ejcf(u)) * ((a^3)/((a^2) + t)) * y * (ejeinf)
cuartaems <- (-1) * ((a^2)/((a^2) + t)) * ejint2(u)
quintaems <- (-2) * ((a^2)/((a^2) + t)) * (y + a * (ejeinf)) * ejint(u)
primeraemu <- (t + a^2) * l^2 * varu
segundaemu <- varu
terceraemu <- y^2
cuartaemu <- (-2) * a * l * rho * varu
((primera + segunda + tercera + cuarta + quinta + sexta + septima) * ((b/(1 - b)))) + (
(b^year/(1 - b)) * pemu * qu * (primeraems + segundaems + terceraems +
cuartaems + quintaems - primeraemu - segundaemu - terceraemu - cuartaemu)) - ((
b^year/(1 - b)) * pemu * (1 - qu) * (primera + segunda + tercera + cuarta +
quinta + sexta + septima))
}

"costo"<-
function(u)
{
beta <- 0.9
t <- 0.15
y <- 0.01
al <- 0.6
varu <- 0.00029999999999999996
ejeinf <- ((al * (1 - ejcf(u)))/(t + (al^2) * ejcf(u))) * y + (al/(t + (al^2) * ejcf(u
))) * ejint(u)
k1 <- ((al^2)/((al^2) + t))
primera <- k1 * (((al^2) + t * 2 - t * ejcf(u))/t) * (y^2)
segunda <- k1 * varu * (-1)
tercera <- k1 * (t + (al^2) * ejcf(u)) * (ejeinf^2) * (-1)
cuarta <- (k1 * (t + (al^2) * ejcf(u)) * y * ejeinf * (-2))/al
quinta <- k1 * ejint2(u)
sexta <- k1 * al * ejeinf * ejint(u) * 2
septima <- k1 * y * ejint(u) * 2
year <- 7
lam <- 0.75
ye <- 0.01
pemu <- 0.75
qu <- 0
rho <- 0.75
primeraems <- (y^2 + (al^2) * (ejeinf^2) + varu + 2 * y * al * ejeinf)
segundaems <- (-1) * (1 - ejcf(u)) * ((al^2)/((al^2) + t)) * (y^2 + (al^2) * (ejeinf^2
```

```
))
terceraems <- (-2) * (1 - ejcf(u)) * ((al^3)/((al^2) + t)) * y * ejeinf
cuartaems <- (-1) * ((al^2)/((al^2) + t)) * ejint2(u)
quintaems <- (-2) * ((al^2)/((al^2) + t)) * (y + al * ejeinf) * ejint(u)
primeraemu <- (t + al^2) * lam^2 * varu
segundaemu <- varu
terceraemu <- y^2
cuartaemu <- (-2) * al * lam * rho * varu
((primera + segunda + tercera + cuarta + quinta + sexta + septima) * ((beta/(1 - beta)
)))
+ ((beta^year/(1 - beta)) * pemu * qu * (primeraems + segundaems + terceraems + cuartaems +
quintaems - primeraemu - segundaemu - terceraemu - cuartaemu))
- ((beta^year/(1 - beta)) * pemu * (1 - qu) * (primera + segunda + tercera + cuarta + quinta +
sexta + septima))
}

"bene"<-
function(u)
{
b <- 0.9
t <- 0.15
y <- 0.01
a <- 0.6
varu <- 0.000299999999999996
ejeinf <- ((a * (1 - ejcf(u)))/(t + (a^2) * ejcf(u))) * y + (a/(t + (a^2) * ejcf(u))) *
ejint(u)
k3 <- ((a^2)/((a^2) + t))
primera <- k3 * (ejeinf^2) * (a^2)
segunda <- k3 * (y^2)
tercera <- k3 * y * a * ejeinf * 2
cuarta <- k3 * (u^2)
quinta <- k3 * a * ejeinf * u * 2
sexta <- k3 * y * u * 2
primera + segunda + tercera + cuarta + quinta + sexta
}
```

Chapter 2

The Case for Relative Wage Concern

In this second part of the thesis we will investigate nominal rigidities arising from wage contracting as source of the observed degree of inflation persistence. The contracting specification we advocate for is derived from intertemporal optimisation under two basic assumptions: (i) wage staggering; (iii) relative wage concern on the part of the workers. In the remaining chapters we study the implications of such a contracting specification focusing on two stylised facts of aggregate U.S. data: inflation inertia and the persistence of the real effects of money shocks.

The purpose of this chapter is to explain the reasons why we propose the contracting specification described in the previous paragraph. To that end, a brief summery of the literature on the topic is in order here.

We will start this introduction by describing previous work on wage staggering. The seminal contribution by J. B. Taylor, Taylor [1979, 1980a], should be mentioned first as all the literature on staggered price/wage setting originates from it. Taylor's model had been a standard response of the literature to account for the two features of U.S. aggregate data mentioned before. We will highlight the properties of the model that justify its extensive use. We will also review the contributions that have tried to provide some micro-foundations that justify the assumption of staggered wage setting decisions embodied in the seminal contribution by Taylor.

Recent research has however seriously questioned the Taylor contracting equation as a sound explanation for the two features of actual data mentioned before. We will also present the criticisms recently raised to the contracting specification embodied in the standard Taylor model. In fact, such criticisms are to a large extent the motivation of the analysis we carry out in the remaining chapters. A brief description of them is therefore logical before presenting our own work on the subject.

We will then proceed to motivate the introduction of relative wage concern on the part of wage setters into a model with staggered wage setting. We present the case for such approach in two steps. Firstly, as a final remark on our brief description of the Taylor model, we show that, despite the explicit claims in Taylor's seminal articles, relative wage considerations had been left out of the analysis. In a second step to make our case, we start by reporting the numerous references in the literature to the introduction of relative wage considerations, and present the recent evidence from individual data that points at relative wage considerations as fundamental for workers' pay and job satisfaction.

2.1 The Taylor [1979, 1980a] Staggered Wage Model

In Taylor's [1979] model the economy is divided into two sectors, henceforth referred to as sectors A and B. In each sector the nominal wage is negotiated every two periods and it is kept fixed between the two periods. Moreover, wage contracting in those two sectors takes place in a staggered fashion. In other words, wage negotiations are not made at the same time in the two sectors. Specifically, sector A fixes the wages in periods t, $t+2$, $t+4$..., while sector B in period $t-1$, $t+1$, $t+3$... .[1] In his original article, Taylor justifies this timing structure on the basis of the observation of wage settlements in major U.S. sectors. However, as argued in his recent chapter

---

[1] "*To make things simple suppose that wage* contracts *last* one *year and that decision dates are evenly staggered:* half of *the contracts are set in January and* half *in* July." (Taylor [1979], p. 109)

for the Handbook of Macroeconomics, it seems to apply to the majority of industrialised countries as well.

Let us call x_t the 'new' nominal wage contract which is negotiated in period t.[2] Then, the fundamental equation of Taylor's model is the following wage setting rule

$$x_t = b\ x_{t-1} + d\ E_{t-1}x_{t+1} + \gamma\ (b\ E_{t-1}y_t + d\ E_{t-1}y_{t+1}) \qquad (2.1)$$

where p = price level, x = 'new' nominal wage; y = output and all the variables are expressed in terms of log-deviation from an initial trend. E_{t-1} is the expectation operator and in front of a variable represents its conditional expectation based on the information available at the end of period $t-1$. The wage contracts are assumed to be signed at the beginning of the period, that is, before the realisation of period t shock. Consequently they are based on period $t-1$ information set. As Taylor explains:

> *Equation [(2.1)] states the assumption that the contract wage set at the start of each semiannual period depends on three factors: the contract wage set in the previous period, the contract wage expected to be set in the next period, and a weighted average of excess demand expected during the next two periods. Since, by assumption, x_t will prevail for two periods, firms and/or unions contemplating a wage*

[2] Hence $x_t, x_{t+2}, x_{t+4}\dots$ are the wage contracts negotiated in sector A, while $x_{t-1}, x_{t+1}, x_{t+3}\dots$ are the ones negotiated in sector B.

> *adjustment in period t will be concerned with wage rates which will be in effect during periods t and t+1.* (Taylor [1979], p. 109)
>
> *...Most theories of wages adjustment suggest that labor market conditions will influence wages and, in particular, that wages will be bid up relative to the prevailing wage during periods when the unemployment rate is low, and conversely when the unemployment rate is high.* (Taylor [1983], p. 987-988)

A further assumption is introduced on the wage setting equation concerning the parameters "b" and "d". Taylor himself explains the reason for such an assumption:

> *Let us assume that b + d = 1 so that the current contract decision is homogenous of degree 1 in these lag and lead contracts. If b = d = 1/2 then the lag and lead distribution is symmetric. This has been the parametric assumption of my previous work and reflects the plausible assumption that current negotiations weight other contracts according to the number of periods that they overlap with the current contract. In this sense, when b and d are equal to 1/2, contract decisions are unbiased. Wage setters look forward to the same degree they look backward. However, I will allow for the possibility of biased weights in this paper by permitting b and d to differ from 1/2. This permit a spectrum of contract determination hypotheses between the extremes*

of pure backward looking (b = 1) and pure forward looking (d = 1). As will be demonstrated below the size of b vs. d is important for the dynamic behavior of contracts, and for the sensitivity of wage behavior to excess demand. (Taylor [1979], p. 109) *...more backward-looking wage determination increases the persistence or the inertia of the aggregate wages.[...] more forward-looking contract determination increases the impact of aggregate demand policy on wages.* (Taylor [1979], p. 110-111)

The model specification is completed with the following two equations

$$p_t = \frac{1}{2}(x_{t-1} + x_t) \tag{2.2}$$

$$y_t = m_t - p_t \tag{2.3}$$

Equation (2.2) is simply a mark-up equation, which states that the aggregate price level is given by an average of the existing nominal wage contracts. This equation implicitly assumes constant returns to labour, as we will show in this thesis. Equation (2.3) is just a static aggregate demand equation, where m is the log-deviation from trend of the money supply.

Taylor in his original articles [1979, 1980a] focused on real shocks and on the optimal monetary policy response to such shocks. However, the subsequent literature mainly focuses on monetary shocks (e.g., West [1988], Ambler and Phaneuf [1989], Phaneuf [1990]) in an attempt to exploit the properties of the contracting scheme assumed in the model as propagation mechanism. The money supply is usually assumed to follow an exogenously given stochastic process. For a given expected path of the money supply, the model exhibits the following saddle path solution

$$x_t = \lambda_s x_{t-1} + \sum_{i=0}^{\infty} \frac{(\varphi - 1)\lambda_s}{b} \left(\frac{1}{\lambda_u}\right)^i [bE_{t-1}(m_{t+i}) + dE_{t-1}(m_{t+1+i})] \quad (2.4)$$

where λ_s and λ_u are respectively the stable and the unstable root of the saddle equilibrium. They are given by

$$\lambda_s = \frac{\varphi - \sqrt{\varphi^2 - 4d(1-d)}}{2d}; \quad \lambda_u = \frac{\varphi + \sqrt{\varphi^2 - 4d(1-d)}}{2d}; \quad \varphi = \frac{1 + \frac{\gamma}{2}}{1 - \frac{\gamma}{2}} \,. \quad (2.5)$$

To further clarify the implications of the structural parameters in the wage contracting equation postulated in the model, suppose that m_t follows a random walk. Then, (2.4) becomes

$$x_t = \lambda_s x_{t-1} + (1 - \lambda_s)m_{t-1} \quad (2.6)$$

The dynamics of output are given by

$$y_t = \lambda_s y_{t-1} + (m_t - m_{t-1}) + \frac{1}{2}(1 - \lambda_s)(m_{t-1} - m_{t-2}) \,. \quad (2.7)$$

The equation above makes evident the fact that the model can potentially generate persistence in the real effects of money shocks. This feature has made of it one of the most important forms of introducing nominal rigidities in dynamic general equilibrium macromodels. It is however crucial to note the fundamental role played by the parameter γ in the model. It captures the sensitivity of real wages to the business cycle conditions. An immediate conclusion of equations (2.5) is that persistent real effects of money shocks only arise for low values of that sensitivity. A low sensitivity of wages to business cycle conditions implies a slower adjustment of the nominal variables which allows for the deviations of output from trend to persist over time.

A second crucial feature is that the Taylor model was originally developed as an *ad hoc* log-linear structural model in which the behavioral equations are exogenously specified from the very outset. It lacks microfoundations and intertemporal optimisation. This point is openly acknowledged in Taylor [1979].[3]

With respect to the rationale for staggered price/wage setting, some literature following Taylor's contributions has shown that it could be optimal to stagger price setting decisions. For example, Fethke and Policano [1984, 1986] demonstrate that staggering can arise as a stable equilibrium when there are sector specific shocks, while Ball and Romer [1989] do the same assuming asymmetric seasonal shocks. Ball and Cecchetti [1988] show that a staggering equilibrium can be supported as an equilibrium because it allows

[3] "*Unfortunately, the assumed contract formation behavior is not explictly derived from a utility maximization model. [...] the micro foundations of the staggered contract model presented here are far from complete.*" (Taylor (1979), p. 111) "*The microfoundations of such models need to be developed more rigourously*" (Taylor [1979], p. 112).

price-setter agents to obtain information about the prices of the others, before choosing their own prices. Maskin and Tirole [1988] and De Fraja [1993] show that staggering can arise endogenously in oligopoly models because of strategic considerations. In a more recent contribution, Bhaskar [1998] has proved that staggering can be an equilibrium in a model with many heterogeneous firms, which have a stronger within-industry strategic complementarity than across-industry. This latter result may be particularly important since it does not rest on strategic considerations between 'few large' price-setters. In contrast to the previous results, it arises in a model with 'many small' firms, as in the standard monopolistic competition set-up usually employed in macromodels.

More importantly for the approach we take here, a new strand of research in monetary dynamic general equilibrium macromodels has in recent years incorporated price/wage staggering *à la* Taylor into an explicit intertemporal optimisation problem . The aim was to open the 'black box' of the structural *ad hoc* parameters of Taylor's famous wage setting equation and show how these parameters depend upon the microeconomic fundamentals of the underlying economic structure. Besides, intertemporal optimisation adds new features to the model due to the intertemporal links missing in the simple Taylor model. This important research effort has highlighted some serious weaknesses of the contracting specification postulated by Taylor. In fact, recent research has seriously questioned that the Taylor contracting equation generates substantial output or inflation persistence following money shocks. We briefly analyse these problems next.

2.2 Implications of Taylor's model of wage staggering

2.2.1 The persistence of the real effects of money shocks

Modern business cycle research is almost entirely carried out within the context of quantitative dynamic stochastic general equilibrium (DSGE) macromodels. In recent years, monetary DGE macromodels have incorporated various forms of nominal rigidities to study the role of monetary shocks in generating the output fluctuations observed in actual data. In that approach, the overlapping contracts models of Calvo [1983] and Taylor [1979, 80a] have played a prominent role. The reason is that such contracting schemes bring in not only the nominal rigidity necessary for the impact effect of the monetary innovation, but also were believed to provide a nominal propagation mechanism for the monetary shocks. This is a fundamental property, since the fact that DSGE framework otherwise lacks endogenous propagation mechanisms is by now widely acknowledged.

The introduction of money and nominal rigidities into the powerful framework developed by the proponents of the so-called Real Business Cycle theory can considerably enhance our understanding of the effects of monetary policy in the real economy. Besides, it has also allowed researchers to open the "black box" of the directly-postulated structural parameters in the wage contracting equation proposed by Taylor. Two studies deserve an explicit mention in that research effort.

Chari, Kehoe and McGrattan [1996] (CKM henceforth) place a staggered contract mechanism into an optimising model in which price setting rules are derived assuming monopolistic competition. Ascari [1998] develops an optimising model of staggered wage setting. Both models find little persistence of the real effects of money shocks beyond the length of the longest contract. The existence of a powerful contract multiplier induced by staggering price/wage setting has since then been put under serious doubts.

To explain the intuition between such results, the fact that the price/wage setting rule derived in CKM and Ascari [1997], when log-linearised around the zero inflation steady-state, keeps the same structure of the Taylor equation is fundamental. An example of the analytical insights one can get from intertemporal optimisation is the fact that a clear link between the *ad hoc* structural parameters of Taylor contracting specification and the parameters of the underlying economic structure can be established. We have shown above the crucial role of a low value of the parameter γ for the existence of output persistence in analytical terms. Recall that γ captures the sensitivity of real wages to business cycle conditions, which is shown to explicitly depend, among other things, on the intertemporal elasticities of both labour supply and consumption. Once that sensitivity is precisely identified as a composite of the parameters of the underlying economy, it can be calibrated from well-established evidence from micro data. The main finding of the two studies mentioned above is that the resulting value is far too high to generate output persistence.[4]

Intuitively, the reason why the Taylor-type model of price/wage staggering cannot account for persistent real effects after money shocks can be summarised as follows. The model incorporates exogenous stickiness through the assumption of the price/wage setting structure. Generating monetary business cycles is then a trivial task in such a model. To do so we just need to assume that prices/wages are exogenously sticky for a period of say four years in the sense that firms/unions are prohibited from changing their prices/wages for that period at a time. Such an assumption is however implausible. To generate persistent output fluctuations following money shocks

[4] It should be noted that the actual expression of γ as function of the underlying parameters is, of course, model-specific, since it captures some features of the underlying economic structure assumed in the model. For a thorought analysis of different economics structures on the composition and calibrated value of γ, the reader is referred to Ascari and Garcia [1998].

what is however required is endogenous stickiness in the sense that price/wage setters choose not to change prices/wages very much when they can do so. The standard model of price/wage staggering fails to generate the required degree of endogenous stickiness. We will investigate this problem in greater depth in Chapter 4, when we analyse the implications of the contracting specification we derive here.

2.2.2 Inflation persistence under conventional wage contracting

In an influential contribution, Fuhrer and Moore [1995] (FM henceforth) have shown that the conventional Taylor model of overlapping contracts stands in stark contrast with important features of U.S. macro data. Of fundamental importance for the topic of this thesis is that it implies far too little inflation persistence. Though the Taylor model clearly imparts considerable inertia to the level of wages and to the price level, it bears less desirable implications for the inflation rate. Their argument can be briefly illustrated as follows. By combining equation (2.2) above with the Taylor contracting specification (equation (2.1)), one can obtain the inflation dynamics implied by the model

$$\Delta p_t - E_t \Delta p_{t+1} = \widetilde{\gamma}\ \widetilde{y}_t \tag{2.8}$$

Thus, a one-period shock to output will affect inflation for one period only; the contracting specification adds no inflation persistence of its own.

Similarly, a one-period shock to inflation that does not alter $\tilde{y}_t$ affects inflation for a single period, after which inflation returns to its expectation. Unless the shock itself persists, the effect on inflation will not persist.

Fuhrer and Moore present autocorrelation plots that nicely document some of the difficulties with the ability of the Taylor model to reproduce inflation persistence. They show that the cross autocorrelation functions based on actual inflation and output were not matched by the simulated data from the basic staggered contract model.

Drawing on Buiter and Jewitt [1981], FM propose an alternative contracting specification to tackle the problem. Buiter and Jewitt [1981] were the first to highlight that the contracting equation proposed by Taylor could at most account for relative wage concern in *nominal terms.* In fact, they refer to Taylor's contracting equation as the Relative Nominal Wage (RNW) model. Buiter and Jewitt [1981] argue that relative wage concern is more plausibly modelled on the basis of a comparison of the wages in *real terms.* We will show that it could be better defined as a contracting specification which reflects exclusively own real wage concern on the part of wage setters.

FM explore in greater detail the implications of the following contracting specification for inflation persistence

$$x_t - p_t = \left(\frac{1}{2}\right) \left[(x_{t-1} - p_{t-1}) + E_t(x_{t+1} - p_{t+1})\right] + \gamma\, y_t \tag{2.9}$$

The similarities to the Taylor equation are evident are first sight.[5] Crucially however, nominal wages now appear deflated by the price level. to capture relative wage concern in real terms. The model specification is completed with the same equations as those in Taylor's original work, that is

$$p_t = \frac{1}{2}(x_{t-1} + x_t)$$

$$y_t = m_t - p_t$$

The implications of the alternative contracting specification for the inflation dynamics are however radically different. Proceeding as before, after some algebra one obtains

$$\Delta p_t - \frac{1}{2}\left[\Delta p_{t-1} + E_t \Delta p_{t+1}\right] = \gamma \; (y_{t-1} + y_t). \tag{2.10}$$

As this equation shows, the inflation rate exhibits now inertia of its own. As a result, the contracting specification postulated by FM is better equipped to match the properties of U.S. inflation. In fact, FM also test their contracting specification against the Taylor model under rational expectations. While

[5]Note that in order to easy their empirical work on the paper, FM introduce some simplifications into the wage contracting equation. Specifically: (i) the moving average structure on the term capturing business cycle conditions is simplified by the current period value; (ii) the expectations are taken based on the available information at period t. Both simplifications are however not crucial for their argument.

they resoundingly reject the Taylor contracting model, they however cannot reject their contracting specification.

2.2.3 Taylor's contracting specification and relative wage concern

Equation (2.1) above simply states that the nominal wage set in t, for periods t and $t+1$, depends on the other sector's wages in those two periods; that is, on the wage negotiated last period by the other sector but still valid in t, i.e., x_{t-1}, and on the wage the other sector will fix next period. i.e., x_{t+1}. This feature is crucial since the model was thought of incorporating a "Keynesian" component of relative wage concern on the part of wage-setters based on the fact that wage settlements were staggered. Taylor explicitly describe his model as incorporating such a concern,

> "[] the behavioral equations reflect a relative wage concern on the part of the workers" (Taylor [1983], p. 987-988)

However, as already noted by Buiter and Jewitt [1981] and Blanchard [1990], the above statement is inaccurate. Substituting equation (2.2) into (2.1) yields

$$x_t = \frac{1}{2}\left(p_t + E_{t-1}p_{t+1}\right) + \gamma\,\frac{1}{2}\,y_t \qquad (2.11)$$

which shows that Taylor's wage contracting specification actually has a different interpretation. By setting the wage according to equation (2.1), workers only care about the level of their own real wage for the length of the contract. Workers care about the wages in the other sectors only through the effect these wages have on the aggregate price level and, in turn, on their own absolute real wage. Hence, there is no actual relative wage concern *per sé* in Taylor's model. [6] In Blanchard's [1990], p. 805] words: *"[] It is sometimes argued that the Taylor's model depends on the assumption that workers care directly about their wages in comparison to other wages [...] this is not the case."*

The omission of relative wage concern in Taylor's contracting specification in fundamental for our approach in this second part of the thesis. In the remaining chapters, following which was most likely to be the original aim of Taylor [1979], we will consider explicit relative wage concern on the part of the workers. Specifically, the argument we will develop is that the weaknesses of a Taylor-type contracting specification that have been briefly described above may have their origin in the omission of relative wage concern in wage setting. With respect to Buiter and Jewitt [1981] and FM, our analysis extends their approaches by deriving the wage contracting specification from an explicit

[6] This point is explictly demonstrated in CKM and Ascari [1997], which derive a Taylor-type wage setting equation imposing the staggering structure on a standard utility maximising framework.

intertemporal optimisation problem by wage setters. We next review some literature supporting our approach.

2.3 Relative wage concern in the literature

2.3.1 Theoretical justifications

The issue of relative comparisons has a long tradition in economics, starting from Adam Smith [1976]. Smith considered satisfaction as a relative concept. He argued that people judge the value or utility associated with any job by comparing it with the other jobs available and the utility associated with them.

However, beyond any doubt, the most influential account of relative wage concern and its potential implications came undoubtedly from John Maynard Keynes. Apart the quite radical view of Cambridge economists close to Keynes (e.g., Robinson [1937], Kalecki [1944]), many others celebrated economists have held the general view that central to the explanation of wage stickiness is the fact that workers, *individually and in groups*, are concerned with their relative wage. The most often quoted argument in favour of relative wage concern is the following extract from Keynes [1936] (p. 14):

Though the struggle over money-wages between individuals and groups is often believed to determine the general level of real wages, it is, in fact, concerned with *a different object. Since there is imperfect mobility of labour, and wages do not tend to an exact equality of net advantage in different occupations, any individual or group of individuals, who consent to a reduction of money-wages relatively to others, will suffer a* ***relative*** *reduction in real wages, which is sufficient justification for them to resist it. [...] In other words, the struggle about money-wages primarily affects the* ***distribution*** *of the aggregate real wage between different labour groups, and not its average amount per unit of employment, [...] . The effect of combination on the part of a group of workers is to protect their* ***relative*** *real wage.*[7]

This fragment of *The General Theory* has inspired several contributions, *including Taylor [1979, 1980a].* Keynes' words have however been interpreted as supporting a number of different reasons why relative wages may be arguments of the labour supply function.

Psychological or sociological considerations form the basis for the argument that relative wages are crucial for the morale and satisfaction of the worker on the job place. The pioneer work of Ruciman [1966] or very recently Bewley [1988] provide strong support for such approaches. Macroeconomists have already explored that argument with respect to the effects of relative wage considerations on effort. Part of the efficiency wage literature has introduced relative wages as fundamental for a fair wage determination and its

[7]The emphasis is as in the original.

impact on effort (e.g., Akerlof [1982], Frank [1984], Akerlof and Yellen [1986], Summers [1988], among many others). In fact, those efficiency wage models incorporate relative wages through an effort function that determines both the labour supply and demand functions.

However, given those psychological and sociological considerations that form the basis for the efficiency wage literature, it seems natural that relative wage concern also arises whenever workers, individually or as union members, enjoy market power in wage bargaining. This is our purpose here. The literature is full of supportive statements on this somehow more literal interpretation of Keynes's words. Before proposing the wage bill as unions' maximand, the founder of the modern economics of trade unions states

> *Wage changes may spread by the simple method of imitation and social transference. Wage increases originating in one sector may be diffused because wage earners are determined to fare just as well as their associates. The argument that "everyone is getting an increase" is not simply a superficial point advanced in all negotiations but a vital force in the labor market that deserves more detailed attention. [...] The community of housewives, with the inevitable "you are good as the next fellow", is not to be underestimated.* [J. T. Dunlop [1966], p. 126]

Appealing to direct observation J. Hicks [1974] is even more explicit with respect to the existence of relative wage concern

> Everyone, on some comparison or other, feels left behind. The electricians get a rise, so the gasmen must follow; but when the gasmen get their rise, it is the electricians who feel themselves to be treated unfairly. In terms of just two industries, the behaviour sounds exaggerated; but generalize it over many, and is it not what happens?

Relative wage concern may also arise from customary or institutional phenomena. In fact, the aim to obtain fair wage determined in relative terms was certainly behind the development of unionism in its early days. Theoretical foundations of union "rivalry" and inter-union "jealousy" in wage setting have been studied in Oswald [1979] and Gylfason and Lindbeck [1984]. Strong evidence of the existence of "fairness" can be found not only in episodes that can be reported from simple observation. Survey evidence such as Kahneman et al [1986] shows that people have strong views about fairness in economic exchange. Results from laboratory experiments on the so-called ultimatum games (Fehr and Schmitt [1998]) strongly suggest that individuals will throw away real income to obtain a fairer division of a certain pie.

Empirical evidence supports the presence of very strong wage interdependence. as found in Ashenfelter *et al.* [1972]), Risager [1992], de la Croix [1994] and many others. After reviewing the empirical evidence and presenting some potential explanations, Fallick and Elliot [1981] conclude their book

"*Incomes Policies, Inflation and Relative Pay*" by stating:

"[ ] *the argument is essentially that relative wages enter the labour supply function*" and that "*[ ] substantial evidence now exists of the considerable interdependencies that exist between the wage settlements of different bargaining groups throughout wide areas of the economy*", p. 251-252.

We briefly review an alternative source of evidence on relative wage concern next.

2.3.2 Empirical Evidence from Microeconomic Data

In recent years a new source of empirical evidence has received considerable attention by economists: surveys on self-reported levels of satisfaction of workers, which already form the fundamental material of study for a large empirical literature in social psychology. Such data has been used as proxy for utility data. Despite its potential shortcomings, the relevance of this new source of evidence should not be overlooked. As pointed out by Clark and Oswald [1996a]: "*It might be argued, in the extreme, that these are random numbers merely made up by survey respondents. Psychologists, who are at least as aware of this possibility as economists, have long since abandoned such a view.*"

In fact, the huge literature on job satisfaction in psychology journals - although often concerned with different issues of the ones investigated by the papers reported here-is a testament to the seriousness with which research psychologists treat such survey data. We here describe in certain detail the results of two contributions in the economic literature: Capelli and Sherer [1988] and Clark and Oswald [1996a].

Capelli and Sherer [1988] use data from a major, heavily unionised U.S. airline. Their sample is composed of 579 employees selected at random (approximately a one in 20 sample), and stratified to ensure a minimum of 50 respondents in each subgroup or cell considered in the analysis. Given the survey data on pay satisfaction, they investigate economic arguments that use the market context and opportunities elsewhere to explain the variance in pay satisfaction across individuals. Their aim is to provide a direct measure of the extent to which the outside market is an important factor in employee assessments of pay by asking respondents questions about the importance they attach to different pay comparisons. The prevailing wage for equivalent jobs and seniority in the outside market is calculated by unweighted means of the wages paid at carriers of comparable size. Regression results consistently found the outside market wage statistically significant.

Clark and Oswald [1996a] use data from the British Household Panel Survey, which includes detailed information on job satisfaction from approximately 10,000 individuals in approximately 5,500 households. The sample used excludes those who are self-employed, those who are retired, and those who are younger than 16.

They treat people's reported satisfaction levels as proxy for utility data. The aim is testing a simple form of the textbook utility function that assumes that well-being depends on the level of income and the number of hours worked on that data. With respect to hours of work, they enter in the theoretically expected negative way. However, counter to the spirit of the standard economics textbook, regression results suggest that satisfaction is more strongly correlated with relative income than absolute income. This main result is robust to some alternative specifications of the regression equation, including the use of an external source of income data for the relative comparison: the New Earnings Survey.

These findings from individual survey data provide quite strong support for utility functions that allow for relativities in wage setting. Besides, they justify the presence of the union rivalry mentioned above from the personal preferences of their potential members. This may provide an explanation for the fact that, even if employers are increasingly trying to establish bargaining norms that focus on attention on circumstances at the firm, they find it difficult to get away from union demands based on wages and settlements elsewere and from traditional "pattern" negotiations in collective bargaining. In fact, other studies have asked employers which are the determinants of wage negotiations with workers. Campbell and Kamlani [1997] (Table II) report a survey of them. Results from other studies based on survey data from employers/firms suggest that relative wage concern is very significant, especially in heavily unionized firms (see Agell and Lundborg [1995]).

2.4 Our approach

The purpose of this introduction to the remaining chapters of this thesis is to highlight the main motivations behind our analysis. As mentioned before, the analysis of the implications of relative wage concern on the part of wage-setters is the fundamental contribution of the research carried out here. A last effort to put our contribution in the context of the recent literature we have just reviewed seems to be appropriate before reporting our results in detail. More specifically, some basic comments on the structure of our choice of the analytical framework are made next. As mentioned at the beginning of the chapter, the contracting specification we advocate for is derived from intertemporal optimisation under two basic assumptions: (i) wage staggering; (ii) relative wage concern on the part of the workers.

2.4.1 Why wage staggering?

With respect to wage staggering, it is worth mentioning that an overwhelming part of the recent literature on staggering decisions focuses on price staggering rather than wage staggering. As reported before, the original contribution by John Taylor considered wage staggering. However, his work was soon extended to the analysis of price staggering by Blanchard [1983]. The subsequent literature has mainly followed this latter approach, both in directly postulated log-linear models and those incorporating nominal rigidities into DSGE.

We here focus on wage staggering. We can offer three main reasons for this choice. Firstly, we believe that persistent nominal rigidities are more likely to arise in the labour market rather than in the goods market. Secondly, we will argue that the wage setting process is better represented as the result of the combination of small nominal *and* real rigidities, in contrast to the simpler approach of the above previous studies. Our source of real rigidity in the labour market arises from an explicit account of relative real wage concern.

Finally, the purpose is to focus the analysis on wage rigidities. The need for wage rigidities to complement price rigidities has been recently acknowledged by two recent influential papers. When considering the ability of both the so-called "limited participation models" and the sticky price models to account for the salient facts about how the economy responds to an anticipated monetary shock, Christiano *et al.* [1997] conclude that both models suffer from important, and related shortcomings. Their results suggest that a model aimed at convincingly accounting for the key effects of a monetary policy shock, in addition to the frictions considered in their paper, will have to allow for labor market frictions. Specifically, the role for labour market frictions they have in mind is to inhibit strong cyclical movements in marginal costs (by mickmiking very high labour supply elasticities) so as to allow for endogenous stickiness.

Focusing exclusively on inflation dynamics, in particular on inflation persistence, Gali and Gertler [1999] derive and estimate an structural Phillips curve from an account of price staggering by monopolistic firms. They arrive to the same conclusion as Christiano *et al.* [1997]. Their analysis suggests that persistence in inflation and the costs of disinflation are likely to be related to the sluggish cyclical behaviour of marginal costs. Given the link between unit labor costs and marginal costs, a candidate source for the strong counterfactual contemporaneous positive correlation between output and real marginal costs in the standard sticky-price model is the absence of any type of labor market frictions.

A similar conclusion is found by Ellison and Scott [1998] in a standard dynamic general equilibrium macromodel with price staggering and a cash-in-advance constraint. Their paper extents Yun [1997], which reports that the introduction of nominal price rigidity in such models contributes to explain the impact effect of monetary shocks on output and the co-movement of inflation with the cyclical component of output. Ellison and Scott [1998] find that while simulations reveal a strong positive correlation between inflation and output there is no evidence of any cyclical movements along a Phillips curve- instead the economy oscillates counterfactually between periods of high and low output.

Our purpose here is far more modest than accounting for all the effects of a monetary policy shock. But we believe that by considering wage staggering alone, a better understanding of the implications of relative wage concern will be achieved. The task of combining it with price rigidities may be a promising avenue for further research on the topic.

2.4.2 The role of intertemporal optimisation

To incorporate intertemporal optimisation we consider relative wage concern in DSGE. The purpose is to follow recent literature that has extended the early work of Taylor [1979, 80] by casting relative wage concern into an explicit intertemporal optimisation problem. The power of general equilibrium framework is then incorporated into the analysis. Recent research has provided a large number of additional insights (see the discussion above for an example of them). We aim at a better understanding of the directly-postulated log-linear wage contracting equations employed by Buiter and Jewitt [1981] and more recently FM.

2.4.3 Modelling Relative wage concern

Taking support on the evidence presented in the previous section, we model relative wage concern by including an additional argument in the utility function of the representative household. This approach runs against the deeply-rooted resistance to modify the structure of preferences of agents. However, as Akerlof [1997, p. 1005] states: *"Traditional economics has been based on methodological individualism. Until quite recently, with some rare exceptions, it has not been appreciated that this method can be, or perhaps I should say,* ***should be****, extended in describing social decisions to include dependence of individuals' utility on the utility or the actions of others."*

Similar kind of preferences have been nevertheless proposed as an explanation for some puzzles in asset pricing (Abel [1990], Gali [1994], Campbell and Cochrane [1995]), consumption (Carrol and Weil [1994]), and growth (Carrol et al. [1997]).[8] More generally, in recent years a growing literature has emerged encompassing economic and social elements, and in particular status concern (see Frank [1984, 1985] and the references therein, Baxter [1988], Kandel and Lazear [1992], Clark and Oswald [1996a,b] and Akerlof [1997]). Nevertheless, despite the available empirical evidence on unions' be-

[8]Depending on the particular specification they are referred to as "interdependent preferences", "external habit formation", "Keeping up (or catching up) with the Joneses" or "relative income hypothesis".

haviour, and sociological and psychological considerations, our introduction of relativities in the utility function may be seen as an *ad hoc* unjustifiable short-cut. It should however be seen as a first step towards a complete understanding of its implications. In fact, further microfoundations are certainly desirable and even necessary given our results.

Chapter 3

An Investigation into the Source of Inflation Persistence

3.1 Introduction

U.S. price inflation data exhibits substantial persistence. An account of inflation persistence is therefore crucial for the study of monetary policy and business cycles. However, most of the existing dynamic general equilibrium macromodels with money, though fairly successful in reproducing other empirical regularities, fail to account for inflation persistence.[1] The explanation for that failure may well lie on the contracting specifications embodied in those dynamic macromodels.

[1] See Nelson [1998] for the inflation dynamics implied by some related literature.

Goodfriend and King [1997] among others have conjectured that a "New Neoclassical Synthesis" to study the role of money in dynamic macromodels has emerged in recent years. A vital component of that emerging synthesis is the combination of intertemporal optimising behaviour and nominal rigidities. With respect to the latter, the most popular models of sticky prices today are the overlapping contract models of Taylor [1980] and Calvo [1983]. While the Taylor-type contracting specifications imply *price stickiness*, they do not imply any *inflation stickiness*. Inflation behaves as a pure forward looking variable under those contracting specifications, so it exhibits a counterfactual flexibility.

Recent literature have addressed that weakness of the Taylor-type contracting specification. Two different potential sources of inflation inertia have been proposed. In a first contribution to the debate, Fuhrer and Moore [1995] (FM henceforth) have proposed a departure from a standard (Taylor-type) wage contracting equation. The alternative contracting equation considers nominal wage contracting as motivated by pure relative real wage considerations. FM show that such a contracting specification can reproduce the observed degree of inflation inertia. Furthermore, FM tested their equation against Taylor's contracting specification and found strong evidence in favour of a wage contracting equation based on pure relative real wage concern. The main reason is that such a contracting specification accounts for inflation persistence under rational expectations, while a Taylor-type wage contracting equation cannot. FM's result suggests that inflation persistence should be a must for any model aiming at replicating stylized facts of U.S. macro data. Yet, more importantly, their results can be interpreted as demanding a richer treatment of wage contracting decisions so as to account for inflation persistence. A weakness of their approach is however that the contracting specification is not derived from an explicit intertemporal optimisation problem, in contrast to the standard contracting specification.

We here cast relative real wage concern into an explicit intertemporal optimisation problem. Recent research has derived a Taylor-type contracting specification by assuming price/wage staggering in a dynamic general equilibrium framework (Chari *et al.* [1996] (section 4), Ascari [1997] among others). We extend here that line of research and cast relative real wage concern into that optimising framework. Specifically, we look for a richer treatment of the wage contracting specification arising from the existence of relative real wage concern on the part of workers, who optimise intertemporally under wage staggering.

The crucial novelty of the wage contracting specification derived here is the presence of a combination of both *own* real wage concern and *relative* real wage concern. Both arise naturally from intertemporal optimisation under wage staggering and relative wage concern. Our contracting specification thus nests the "standard" sticky-price models characterised by no relative wage concern, and FM's sticky-inflation model as two particular cases. The result is a richer contracting specification that implies inflation persistence.

In a very interesting contribution, Roberts [1997] has however presented an alternative explanation for the source of inflation inertia. The inflation dynamics implied by the contracting specification proposed by FM could be observationally equivalent to a standard sticky-price model *if* inflation expectations are not fully rational. Hence, FM's evidence on inflation inertia do not allow us to determine whether the contracting specification or the imperfect rationality of inflation expectations is the source of that inflation inertia.

Taking support on the evidence of lack of full rationality of surveys of inflation expectations, Roberts [1997] develops a direct test for those two competing sources of inflation inertia. The test is based on relaxing rational expectations by making use of survey data on inflation expectations. Roberts [1997] concludes that inflation inertia actually arises from the presence of non-fully-rational expectations.

Existing empirical results on the source of inflation inertia are therefore contradictory. Both approaches imply sticky dynamics for inflation. Crucially for further research, the results however point at opposite directions towards a deeper understanding of inflation dynamics: one points at persistent inflation arising from richer wage contracting specifications while the other points at sticky-prices complemented by non-fully-rational expectations.

In this chapter we investigate whether the contracting specification derived here can shed some new light in the debate. We first derive the conditions under which the implied sticky-inflation dynamics is observationally equivalent to an sticky-price model in presence of non-fully-rational expectations. We then proceed as Roberts [1997] and test the two competing hypothesis on inflation expectation survey data. In sharp contrast to Roberts [1997], our results suggest that alternative sources of inertia beyond that imparted by the lack of full rationality of expectations are needed to characterise U.S. inflation dynamics. The fact that intertemporal optimisation provides our contracting specification with a richer structure compared to that of FM is the reason behind our results.

The rest of the chapter is organised as follows. Section 2 presents our dynamic macromodel. We present a log-linearisation of the optimal nominal wage setting decision in section 3. Its implications for inflation persistence are the focus of the analysis. Section 4 shows that our contracting specification may become observationally equivalent to an sticky-price model if we relax the assumption of rational expectations. We then develop a test for the competing hypothesis of sticky-prices and sticky-inflation. Our empirical results are reported in Section 6, and we explore subsample stability in section 7. Finally, some concluding remarks are presented in Section 8.

3.2 The model

The aim of this section is to derive a wage contracting specification from intertemporal optimisation under two basic assumptions: (i) staggered wage setting (ii) relative real wage concern on the part of the workers. Our framework is a fairly standard monetary dynamic general equilibrium macromodel in which nominal wages are negotiated in staggered fashion. It should be stressed from the very outset that providing a detailed analysis of forces at work in business cycle fluctuations is beyond the scope of our analysis. The key assumption of the model is the presence of relative real wage concern on the part of the workers. The purpose of the analytical framework is simply that its effects in the wage-setting decision are readily identifiable. In fact, our model is deliberately stylised in many aspects. For example, capital accumulation is ignored for the sake of simplicity and the contracts are assumed to be signed for just two periods.

The model economy consists of a continuum of uniformly distributed industries (indexed by $i \in [0, 1]$) and a continuum of industry-specific "household-unions" (indexed by $j \in [0, 1]$).[2] Every industry produces a differentiated

[2] The 'household-union' should be thought of as an aggregate of all the households

perishable product and, in turn, comprises a continuum of firms. Household j consumes a composite good, defined by a CES index over the consumption good of each industry, i.e.

$$C_{jt} = \left[\int_0^1 C_{jit}^{\frac{\theta-1}{\theta}} di\right]^{\frac{\theta}{\theta-1}}$$

where $\theta > 1$ is the elasticity of substitution among the different goods. This specification gives rise to the standard demand function for good i by household j

$$C_{jit} = \left[\frac{P_{it}}{P_t}\right]^{-\theta} \frac{\chi_{jt}}{P_t} \tag{3.1}$$

where χ_{jt} is household's total nominal expenditure on goods. P_{it} is the price of good i and the aggregate price index is given by $P_t = \left[\int_0^1 P_{it}^{1-\theta} di\right]^{\frac{1}{1-\theta}}$.

3.2.1 Firms

All firms employ a production function given by $Y_{it} = \alpha L_{it}^{\sigma}$. The firm's capital stock is taken as fixed and labour is the only variable factor of production. Individual firms within each industry behave as price-takers both in the goods and the labour market. Consequently, firms maximise profits period by period taken as given the nominal wage W_{it}, which is set by the workers, and P_{it}, the price of their product. The profit maximising labour

which work in the industry, who collude in wage contracting.

demand and output of firm i are then given by

$$L_{it} = \left[\frac{1}{\alpha\sigma}\frac{W_{it}}{P_{it}}\right]^{\frac{1}{\sigma-1}} ; \qquad Y_{it} = \alpha\left[\frac{1}{\alpha\sigma}\frac{W_{it}}{P_{it}}\right]^{\frac{\sigma}{\sigma-1}} . \tag{3.2}$$

Imposing the equilibrium condition in the goods market for each good i,

$$C_{it} = \int_0^1 C_{jit}dj = Y_{it} \qquad \forall i \in [0.1], \tag{3.3}$$

yields the following relation between the labour demand and the nominal wage

$$L_{it} = K_t W_{it}^{-\varepsilon} ; \quad \text{where} \quad \varepsilon = \frac{\theta}{\sigma + (1-\sigma)\theta} \quad \text{and} \quad K_t = \sigma^{\varepsilon}\left[\frac{\chi_t}{(\alpha P_t)^{1-\theta}}\right]^{\frac{\varepsilon}{\theta}} . \tag{3.4}$$

The labour demand function faced by the monopolistic wage-setters in each industry thus exhibits a constant money-wage elasticity equal to ε, which depends on technology and preference parameters. Note that K_t is parametric to wage-setters, since they take aggregate variables as given ($\chi_t = \int_0^1 \chi_{jt}dj =$ aggregate nominal expenditure).

3.2.2 Households

We assume that industry-specific workers enjoy monopoly power in wage setting. Households have the same preferences (to be specified below) and supply identical labour input.

Wage Contracting

The structure of wage setting in the model is characterised by two features: (i) staggered wage setting; (ii) relative wage concern.

(i) *Staggered Wage Setting*

This setting is standard in the related literature. The economy is divided into 2 sectors, for simplicity of equal size. Industries indexed by $i \in [0, 1/2]$ and the industry-specific households indexed by $j \in [0, 1/2]$ compose sector A. Nominal wage contracts, denoted by X, are then fixed for 2 periods in staggered fashion. More specifically, sector A fixes the wages in even periods, while sector B does so in odd periods. We denote by X_t the 'new wage' in Sector A for periods t and $t+1$, so $W_{At} = W_{At+1} = X_t$. Meanwhile, in period t, sector B workers are locked into the wage contract they signed one period before, so $W_{Bt} = W_{Bt-1} = X_{t-1}$. Therefore $X_t, X_{t+2}, X_{t+4}, \ldots,$ are the wages fixed by sector A, and $X_{t+1}, X_{t+3}, X_{t+5}, \ldots,$ are the wages fixed by sector B.

Denote by P_{At} the common price charged by sector-A industries, and likewise P_{Bt} for sector B. The supplied output levels of a typical industry in each of the two sectors in period t can then be expressed as

$$Y_{At}^s = \alpha \left[\frac{1}{\alpha\sigma} \frac{X_t}{P_{At}} \right]^{\frac{\sigma}{\sigma-1}}; \qquad Y_{Bt}^s = \alpha \left[\frac{1}{\alpha\sigma} \frac{X_{t-1}}{P_{Bt}} \right]^{\frac{\sigma}{\sigma-1}} \tag{3.5}$$

and the demands for the outputs in each of the two sectors in period t are[3]

$$Y_{At}^{d} = \left[\frac{P_{At}}{P_t}\right]^{-\theta} \frac{\chi_t}{P_t}; \qquad Y_{Bt}^{d} = \left[\frac{P_{Bt}}{P_t}\right]^{-\theta} \frac{\chi_t}{P_t}; \tag{3.6}$$

where $P_t = \left[\frac{1}{2}P_{At}^{1-\theta} + \frac{1}{2}P_{Bt}^{1-\theta}\right]^{\frac{1}{1-\theta}}$ denotes the aggregate price level.

(ii) *Relative Wage Concern*

Here we incorporate relative wage concern to the wage staggering structure described above. Note that staggered wage setting breaks the complete symmetry among households in different sectors. However, the complete intra-sectorial symmetry implies that all households belonging to the same sector receive the same wage. That is, in any period t there are just 2 different contracts in effect. Our purpose is first to characterise relative wage concern based on the existence of those two different contracts each period. Then we proceed to highlight its implications for wage setting behaviour.

Taking support from the empirical evidence reviewed in the previous chapter, we model relative wage concern by an additional argument in the

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[3] In equilibrium, aggregate nominal output is equal to aggregate nominal expenditure on consumption

$$\frac{1}{2}P_{At}Y_{At} + \frac{1}{2}P_{Bt}Y_{Bt} = \chi_t = P_tC_t = \frac{1}{2}P_tC_{At} + \frac{1}{2}P_tC_{Bt} = \frac{1}{2}\chi_{At} + \frac{1}{2}\chi_{Bt}$$

where (for example) $\chi_{At} \equiv P_tC_{At}$ is expenditure by a typical sector-A household. Note that $P_{At}Y_{At} \neq P_{At}C_{At}$, in general. This is for two reasons: households which work in sector A receive profits also from sector B; and households in sector A can borrow from (or lend to) sector-B households.

utility function of the representative household. This term is defined as a ratio of the two different real wages existing in each sector. The lack of symmetry among (otherwise identical) households in different sectors arising from wage staggering is thereby naturally incorporated to wage contracting. We postpone a more explicit definition of the relative wage concern arguments to the next section.

The intertemporal optimisation problem

In period t the household maximises a utility function of the form[4]

$$U_j = E_t \sum_{k=0}^{\infty} \beta^k \left[u(C_{j,t+k}, m_{j,t+k}, L_{j,t+k}, RW_{j,t+k}) \right] \tag{3.7}$$

The arguments in the utility function $C_{j,t+k}$, $m_{j,t+k}$ and $L_{j,t+k}$ are, respectively, the consumption of the composite good, the end-of-period real money balances, and the labour supply of the households. Without loss of generality for our purpose here, the utility function is taken as additive separable in all its arguments. The standard conditions $u_c(\cdot)>0$, $u_m(\cdot)>0$, $u_L(\cdot)<0$, $u_{cc}(\cdot)<0$, $u_{mm}(\cdot)<0$, $u_{LL}(\cdot)<0$, where $u_r(t)$ denotes the first partial derivative of the instantaneous utility function and $u_{rr}(\cdot)$ the second derivative, with respect

[4]Our aim in this chapter is to highlight the implications of relative wage concern under staggering and intertemporal optimisation. A general utility function is sufficient for this purpose, so we do not present here a particular parametrisation. For an example of a fully calibrated specification, the reader is referred to the next chapter.

the argument r are assumed to be satisfied. Besides, the utility function satisfies $u_{RW}(\cdot)>0$, $u_{RWRW}(\cdot)<0$.

The household's budget constraint evolves according to

$$P_t C_{jt} + M_{jt} + \sum_{s^{t+1}} Q(s^{t+1} \mid s^t) B_j(s^{t+1}) \leq M_{jt-1} + B_{jt} + W_{jt} L_{jt} + \Pi_{jt} + T_{jt} \tag{3.8}$$

where $Q(s^{t+1} \mid s^t)$ is the stochastic discount factor equal to the money value of a contingent claim in state s^t to one dollar in state s^{t+1}.[5] M_{jt} denotes money holdings at the end of period t, B_{jt} the quantity of bonds, T_{jt} the nominal lump-sum transfer received by the household, Π_{jt} the profits distributed by firms and $W_{jt}L_{jt}$ the labour income.

Households maximise their expected lifetime utility subject to the sequence of budget constraints (3.8), the sequence of labour demand curves they face as wage-setters (3.4), and the additional constraint that the nominal wage is fixed for the next two periods. Their choices are the level of consumption, the quantities of money and bonds transferred to the next

[5] Let s_t be the state of the world in period t. Denote with $\Pr(s^{t+1} \mid s^t)$ the probability that in the next period the state of the world will be s^{t+1}, conditional to the state s^t in period t. To lighten notation and avoid indexing each variable with respect the state of the world, we use the expectation operator and the dating of the variables. Then, $\Theta_t = \Theta(s^t)$ and $E_t(\Theta_k) = \sum_{s^k} \Pr(s^k \mid s^t)\Theta(s^k)$, where Θ_t is whatever variable or function of variables, s^k is the state in period $k > t$ and the sum is calculated on all the possible future states s^k.

period and the level of the nominal wage for the next two periods. The first-order conditions for that problem can be expressed as follows (the index j is dropped to lighten notation),

$$\frac{u_m(t)}{u_C(t)} = \frac{R_t - 1}{R_t} \tag{3.9}$$

$$u_C(t) = \beta R_t E_t\left(\frac{u_C(t+1)P_t}{P_{t+1}}\right) \tag{3.10}$$

$$\sum_{s^{t+1}} Q(s^{t+1} \mid s^t) = \frac{\beta E_t(\lambda_{t+1})}{\lambda_t} = \beta E_t\left(\frac{u_C(t+1)P_t}{u_C(t)P_{t+1}}\right) = \frac{1}{R_t} \tag{3.11}$$

$$\begin{aligned} X_t = \left(\frac{\varepsilon}{\varepsilon-1}\right)\Bigg\{ & \frac{E_{t-1}\left[\sum_{r=o}^{N-1}\beta^r\left(-u_L(t+r)K_{t+r}\right)\right]}{E_{t-1}\left[\sum_{r=o}^{N-1}\beta^r\left(\frac{u_C(t+r)K_{t+r}}{P_{t+r}}\right)\right]} + \\ & + \frac{\frac{X^{\varepsilon+1}}{\varepsilon-1}E_{t-1}\left[\sum_{r=o}^{N-1}u_{RW}(t+r)\frac{\partial RW(t+r)}{\partial X_t}\right]}{E_{t-1}\left[\sum_{r=o}^{N-1}\beta^r\left(\frac{u_C(t+r)K_{t+r}}{P_{t+r}}\right)\right]}\Bigg\}, \end{aligned} \tag{3.12}$$

where λ_t is the multiplier attached to the budget constraint. The first three equations are standard: (3.9) represents the optimal choice between consumption and money; (3.10) is the Euler equation for consumption and (3.11) gives the gross nominal interest rate R_t.[6]

[6]Note that $\sum_{s^{t+1}} Q(s^{t+1} \mid s^t)$ is the current value of a nominal bond that gives one unit of money for sure in the next period. On the other hand, $Q(s^{t+1} \mid s^t) = \beta \Pr(s^{t+1} \mid s^t)\left(\frac{u_C(s^{t+1})P_t}{u_C(t)P(s^{t+1})}\right)$ is the current price of a claim of one unit of money contingent on the realisation of state s^{t+1} in the next period.

Equation (3.12) gives the optimal nominal wage set by the monopolistic household-union for the next 2 periods. That expression is composed of two terms. The optimal wage is given by a fixed mark-up $\varepsilon/(\varepsilon - 1)$ over the quantity in the curly brackets, which is the ratio between expected weighted averages of the marginal disutility from (hours of) labour supply and the marginal utility of consumption over the next 2 periods. In other words, the first component is a weighted average of the optimal flexible wages (without relative wage concern) of those periods. The second term is an expected weighted average of the concern for the relative wages resulting from the contracts in effect over the *next* 2 periods. The weights are defined by β, K_{t+i}, P_{t+i} and ε.

The role of the government is limited to provide lump-sum transfers, through which money is introduced in the economy. These transfers satisfy $T_t = M_t - M_{t-1}$ and the nominal money supply process is described by[7]

$$M_t = \mu_t M_{t-1} \tag{3.13}$$

3.3 Wage contracting and inflation dynamics

This section describes the implications of relative wage concern in wage contracting once intertemporal optimisation is taking into account. The basis

[7] The particular stochastic process followed by μ_t is of no particular relevance for our analysis.

of our analysis is the log-linearisation of the first-order condition for the choice of the money-wage (equation (3.12) above) around a deterministic zero-inflation steady-state. Ignoring discounting, the log-linearisation yields[8]

$$\Omega\ x_t = \Omega\left(\frac{1}{2}\right)[p_t + E_t p_{t+1}] - \Gamma\left(\frac{1}{2}\right)[rw_t + E_t rw_{t+1}] + \gamma\left(\frac{1}{2}\right)[y_t + E_t y_{t+1}] \tag{3.14}$$

Nominal wages are signed taking into account three factors: (i) the price levels expected to prevail in the two periods of the contract-life, since they affect the real wage; (ii) the relative wages resulting from the different contracts in force in those two periods; (iii) an additional adjustment for the business cycle conditions in the life of the contract.

The crucial novelty of the contracting specification derived above is the presence of a combination of both *own* real wage concern, weighted by Ω, and *relative* real wage concern, weighted by Γ.[9] Both arise naturally from intertemporal optimisation under staggered wages and relative wage concern on the part of the workers. To better understand this contracting specification, a comparison to two widely-used particular cases of it are useful benchmarks. First, the "standard" staggered-wage models, either directly

[8] Hereon lower case letters denote log-deviations from steady state values.

[9] Ω, Γ and γ are non-negative composites of the preference and technology parameters of our model economy. Their specific expressions play no crucial role for our argument in this chapter, so they are omitted here. The interested reader can find them in the Appendix at the end of the Chapter.

postulated as in Taylor [1980], or derived from intertemporal optimisation as the version in Chari *et al.*[1996] (section 4)[10] or Ascari [1997], impose $\Gamma = 0$. Wage contracting is then characterised exclusively by own real wage concern. Second, FM impose a pure relative real wage concern by implicitly setting $\Omega = 0$ in their directly-postulated contracting specification. The contracting specification derived here thus encompasses the two factors that have been highlighted in the literature so far. We will now define the rw terms in (3.14) above for further analysis.

Relative wage concern is captured by the RW_{t+i} terms in (3.7) and (3.12). We have introduced wage staggering as a fundamental feature of the model, and now exploit its implications for the definition of the RW_{t+i} terms. Recall that, given the asyncronised wage contracting by the two sectors and the fixed length of the contracts, at any period t there are two different wage contracts in effect. This breaks the complete symmetry among otherwise identical households. We take this fact as the basis for the definition of

[10]The model presented in Chari *et al.* [1996] is actually a model of price staggering rather than wage staggering. Obviously, some differences arise from the fact that different nominal variables are staggered. However, the structure of the price/wage setting equation is equivalent. In fact, Chari *et al.* [1996] in their Section 4 use it to highlight the additional insights obtained from intertemporal optimisation for that type of wage contracting equations. This is the sense in which we refer to their model. A thorough comparison of the implications of price or wage staggering under different economic structures is developed in Ascari and Garcia [1998b].

the alternative wage. The RW_{t+i} terms are then defined as a ratio of the wage contract signed by the households who are currently negotiating their nominal wage, to the contract signed by the *other* sector. We further assume that wage setters compare the real value of the wage contracts in the period in which the wages are signed in each sector. More specifically, they compare the real wage they receive in period t (in which they negotiate the nominal wage for the next two periods), to the real value of the wage contracts that overlap with it: those negotiated in $t-1$ and still in effect in t, and those expected to be negotiated in $t+1$. The real value is obtained by deflating the nominal contracts by the price level for the period in which the contract is signed.[11] Consequently

$$RW_t = \frac{X_t/P_t}{X_{t-1}/P_{t-1}} \; ; \qquad RW_{t+1} = \frac{X_t/P_t}{(X_{t+1}/P_{t+1})} \tag{3.15}$$

The log-linearised version of the rw terms then reduces to

$$rw_t = (x_t - p_t) - (x_{t-1} - p_{t-1}) \; ; \qquad E_t rw_{t+1} = (x_t - p_t) - E_t(x_{t+1} - p_{t+1}) \tag{3.16}$$

[11] It is worth noting that in this case, agents behave to a certain extent miopically, since the fact that the contracts last for two periods, the one in which they are negotiated and the following one, is somehow overlooked. We could also carry out our analysis for a "theoretically preferable" case in which agents however compare the real value of the contracts in the two periods they last. As a result, the dynamics of such a model would be richer. However, a direct comparison to Roberts [1997] would not be possible then.

Substituting the above terms into (3.14) and re-arranging, the wage contracting equation becomes

$$\begin{aligned}\Omega\left[x_t - \left(\frac{p_t + E_t p_{t+1}}{2}\right)\right] &= \left(\frac{1}{2}\right)\Gamma\ [(x_{t-1} - p_{t-1}) - (x_t - p_t)] \\ &+ \left(\frac{1}{2}\right)\Gamma\ [E_t(x_{t+1} - p_{t+1}) - (x_t - p_t)] \\ &+ \left(\frac{\gamma}{2}\right)\ [y_t + E_t y_{t+1}] \end{aligned} \tag{3.17}$$

We are now in a position to analyse the implications of the contracting specification in greater detail. To focus the discussion recall that: (i) by imposing $\Gamma = 0$, we are back to Taylor's wage contracting equation (pure *own* real wage concern); (ii) by imposing $\Omega = 0$ we obtain the equation presented in FM and employed in Roberts [1997] (pure *relative* real wage concern).

Under constant returns to labour[12], the log-linearised price level is simply given by

$$p_t = \frac{1}{2}(x_t + x_{t-1}) \tag{3.18}$$

[12] The general expression for the log-linearised price level is given by $p_t = \frac{1}{2}(x_t + x_{t-1}) + \left(\frac{1-\sigma}{\sigma}\right) y_t$. The aggregate price level is then characterised by both "cost push" and "demand pull" factors. Recall that labour is the only variable factor of production in our stylised economy. It is inmediate that constant returns to scale to labour ($\sigma = 1$) are implicitly assumed in the directly-postulated log-linear models of Taylor [1980] and Fuhrer and Moore [1995]. Such an assumption does not affect inflation dynamics in the contracting specification derived here, so we also incorporate it to allow for a straightforward comparison.

Inflation is defined as

$$\Delta p_t = p_t - p_{t-1} = \frac{1}{2}(\Delta x_t + \Delta x_{t-1}) \tag{3.19}$$

Simple algebra allows to characterise the wage contracting specification as implying

$$\Delta x_t - \left(\frac{1}{2}\right)[a\Delta p_t + bE_t\Delta p_{t+1}] = \widetilde{\gamma}\ \ [y_t + E_t y_{t+1}] \tag{3.20}$$

where

$$a = \frac{2\Gamma}{\Omega + 2\Gamma}, \quad b = \frac{2\Omega + 2\Gamma}{\Omega + 2\Gamma} \quad and\ \widetilde{\gamma} = \frac{\gamma}{\Omega + 2\Gamma}$$

It states that the change in nominal wages is related to the inflation rates in the periods in which the contract will be in force, adjusted by the (expected) level of economic activity.

The notation in equation (3.20) allows for a straightforward comparison to the Taylor-type and the FM contracting specifications. In the former, relative wage concern is absent (Γ=0), $a = 0$, so only future (expected) inflation matters for wage setting. In the latter, own real wage concern is absent (Ω=0), $a = b = 1$, so current and future inflation are equally weighted, and forward looking behaviour is somehow diminished.

We can now analyse the implications of our wage contracting equation for the dynamics of inflation. (3.19) and (3.20) can be used to obtain the following expression in terms of the inflation rates[13]

$$a\Delta^2 p_t - bE_t\Delta^2 p_{t+1} = 2\tilde{\gamma}\ \left[(\overline{y}_{t-1} + \overline{y}_t)\right] + b(E_{t-1}\Delta p_t - \Delta p_t) \qquad (3.21)$$

The key feature of this equation is that inflation exhibits the inertia that characterises actual inflation dynamics. The source of that inertia, as in the directly-postulated equation advocated by FM, is the presence of relative wage concern in wage setting. To illustrate this point, consider the traditional Taylor-type contracting equation in which agents are only concerned with the level of their own real wages (Γ=0). If $a = 0$, and we are only left with the second term in the left hand side, that is

$$\Delta p_t - E_t\Delta p_{t+1} = \tilde{\gamma}\ \left[(\overline{y}_{t-1} + \overline{y}_t)\right] + (E_{t-1}\Delta p_t - \Delta p_t) \qquad (3.22)$$

This equation captures the trade-off between output and inflation that characterises the so-called "New Keynesian Phillips curve". Its main virtue is the fact that the nominal rigidities, which underlie the dynamics of inflation, can be derived from intertemporal optimisation. However, the implied inflation dynamics is not that satisfactory. Current inflation just depends on future expected inflation, with no dependence on previous inflation levels whatsoever. This is a direct consequence of the underlying contracting behaviour: recall that without relative wage concern the change in nominal wages is related only to future inflation (consider $a = 0$ in (3.20) above). As a result,

[13] Note that we have defined $\overline{y}_{t-1} = y_{t-1} + E_{t-1}y_t$ and $\overline{y}_t = y_t + E_t y_{t+1}$ to economise some terms in the equations.

the period t inflation rate is free to "jump" in response to new information that becomes available in period t, in sharp contrast to empirical evidence on actual inflation dynamics. In short: prices are sticky. but the inflation rate is not. Thus, we will henceforth refer to it as a (standard) sticky-price model.

Consider now the more general contracting specification derived here. The counterfactual flexibility of inflation described above is not present in equation (3.21). Simply by re-arranging terms, a somehow more explicit expression for (3.21) is

$$\Delta p_t - \left[\frac{a\Delta p_{t-1} + bE_t\Delta p_{t+1}}{2}\right] = \widetilde{\gamma}\ \left[(\overline{y}_{t-1} + \overline{y}_t)\right] + \left(\frac{b}{2}\right)(E_{t-1}\Delta p_t - \Delta p_t) \tag{3.23}$$

In the last equation, new information about current or future monetary policy that becomes available at t can be reflected in $E_t\Delta p_{t+1}$ but not. by definition, on Δp_{t-1}. The presence of Δp_{t-1} in (3.23) limits the flexibility of current inflation. In fact, it rules out counterfactual jumps in response to new information, in contrast to the sticky-price model given by equation (3.22). This equation can therefore better replicate actual features of inflation dynamics. In what follows. we thus refer to this equation as the sticky inflation model.

With respect to the directly postulated equation in Fuhrer and Moore [1995]. we share the presence of relative wage concern in wage contracting and, consequently, of inflation inertia. Fuhrer and Moore [1995] implicitly impose $\Omega = 0$, i.e. pure relative wage concern in wage setting. As a result, $a = b = 1$, and equation (3.23) becomes

$$\Delta p_t - \frac{1}{2}\left[\Delta p_{t-1} + E_t \Delta p_{t+1}\right] = \widetilde{\gamma}\ \left[(\overline{y}_{t-1} + \overline{y}_t)\right] + \left(\frac{b}{2}\right)(E_{t-1}\Delta p_t - \Delta p_t). \tag{3.24}$$

FM test this sticky-inflation equation against the Taylor-type sticky-price model. Their results show that sticky-inflation models fit U.S. data better than sticky-price ones. The intuition behind their results is simply that Taylor-type wage contracting equations provide price stickiness but are not able to account for the degree of inflation stickiness observed in U.S. data *under rational expectations*. FM's result suggests that inflation persistence should be a must for any model aiming at replicating stylized facts of U.S. macro data. However, equation (3.23) allows us to identify the effect of the omission of own real wage in FM's contracting specification. The degree of inflation inertia is weighted by $a = 2\Gamma/(\Omega + 2\Gamma)$. By imposing $\Omega = 0$, FM contracting specification may assign an excessive weight to lagged inflation, and diminish the role of forward looking behaviour. This may play a crucial role when testing empirically competing hypotheses on the source of inflation inertia. In the remaining part of the chapter we investigate that conjecture. We describe the alternative source of inflation inertia next.

3.4 Non-fully-rational Expectations as Source of Inflation Inertia

In an interesting contribution, Roberts [1997] considers an alternative interpretation for the source of the observed inflation inertia. Surveys of inflation expectations often do not pass the usual tests of rationality.[14] If those surveys are to be considered a reliable proxy for actual inflation expectations, non-fully-rational expectations may be the source of the observed inflation inertia.

Consider (3.22) again and recall that we labelled that equation as the sticky-price model since it does not imply inflation inertia. In the previous section we have highlighted that feature as a major weakness. We have also showed that, by considering relative wage concern, equation (3.23) allows for inflation inertia and can therefore better replicate actual inflation dynamics. However, whether or not (3.22) exhibits inflation inertia depends on the inflation expectation process. This argument can be easily understood by considering again equation (3.22).

$$\Delta p_t - S_t \Delta p_{t+1} = \tilde{\gamma} \left[(\overline{y}_{t-1} + \overline{y}_t) \right] + (S_{t-1} \Delta p_t - \Delta p_t) \qquad (3.25)$$

Specifically, if inflation expectations are not fully rational, they may well depend on last period level and equation (3.25) can then exhibit some degree

[14]See Roberts [1997] and references therein.

of inflation inertia. Assume further that the inflation expectation for next period, $S_t\Delta p_{t+1}$, is given by a weighted average of the inflation rate in the last period, Δp_{t-1}, and of the mathematical expectation of next period inflation, $M_t\Delta p_{t+1}$, that is

$$S_t\Delta P_{t+1} = \frac{1}{2}\left[a\Delta p_{t-1} + bM_t\Delta p_{t+1}\right]$$

By relaxing rational expectations in this specific way, an sticky-price model becomes observationally equivalent to an sticky-inflation one. Both equations show the dynamics of inflation being "sticky", since it depends on previous period value. However, the key point is that their implications for the source of inflation inertia are radically different. In the case of the contracting specification derived in the previous section, inflation is sticky as a result of intertemporal optimisation by wage-setters concerned with relative wages. The source of inflation persistence is thus the wage contracting behaviour. The alternative interpretation of equation (3.23) instead considers inflation stickiness being the result of sticky prices in presence of *"sticky expectations"*. It is the lack of full rationality of inflation expectations which makes the current inflation rate depend on its lagged value, leading to sticky dynamics for inflation.

If we relax the assumption of rational expectations, whether price stickiness or inflation stickiness best characterises the actual inflation process is then an open empirical issue. It is important to stress that the imperfect rationality of inflation expectations is a necessary condition for the sticky-prices-plus-less-than-fully-rational expectations to hold. However, it is not sufficient. Inflation may well be sticky *even if* inflation expectations are imperfectly rational. The question has to be settled empirically, given the potential observational equivalence between (3.25) and FM's sticky-inflation equation (3.24). Roberts [1997] provides some evidence favouring the standard sticky-price models. The test is based on the lack of statistical significance of lagged inflation once survey data are used as proxy for actual inflation expectations. The conclusion is that the presence of less-than-fully-rational expectations is the preferred explanation for inflation stickiness.

Our contribution to the debate is to analyse the competing hypotheses of inflation inertia on the light of the contracting specification derived here. Recall that the crucial novelty of this wage setting equation is the presence of a combination of both *own* real wage concern, weighted by Ω, and *relative* real wage concern, weighted by Γ, in the wage setting rule. Both arise naturally from intertemporal optimisation under wage staggering and relative wage concern. The contracting specification thus generalises the directly postulated equation by FM, since intertemporal optimisation adds an additional own real wage concern under wage staggering. Equation (3.23) shows that the contracting specification derived here may also become observationally equivalent to a sticky-price model if inflation expectations were non-fully-rational. In the remaining sections of the chapter we investigate the source of inflation inertia when wage contracting is defined by the equation derived here.

3.5 Econometric specification

3.5.1 Deriving the estimation framework

Our wage contracting specification implies inflation persistence by a combination of both own real wage (weighted by Ω) and relative real wage concern (weighted by Γ). Our purpose here is to highlight the importance of the omission of own real wage concern in the empirical results presented in Roberts [1997] to discriminate between the sticky-inflation model and the competing hypothesis of sticky prices.

To allow for a straightforward comparison, we follow Roberts [1997] in making wages in (3.17) dependent only on the current period business cycle conditions. That is the term $(1/2)\ [y_t + E_t y_{t+1}]$ in (3.17) reduces to y_t.[15] We

[15] This is without any loss of generality since next period expected level of economic activity can be simply proxied by the current one.

obtain

$$
\begin{aligned}
\Omega\left[x_t-\frac{p_t+E_tp_{t+1}}{2}\right] = {} & \delta_0+\gamma\ y_t+ \\
& +\left(\frac{1}{2}\right)\Gamma\ [(x_{t-1}-p_{t-1})-(x_t-p_t)]+ \\
& +\left(\frac{1}{2}\right)\Gamma\ [E_t(x_{t+1}-p_{t+1})-(x_t-p_t)]
\end{aligned} \tag{3.26}
$$

The basis for the empirical analysis is given by the implications for inflation persistence of equation (3.26). Proceeding as in previous sections, making use of (3.19) and re-arranging to take full advantage of inflation expectations, simple algebra leads to

$$
\begin{aligned}
\Delta p_t-\left[\frac{S_{t-1}\Delta p_t+S_t\Delta p_{t+1}}{2}\right] = {} & \frac{\delta_0}{2}+\frac{\widetilde{\gamma}}{2}\ [y_{t-1}+y_t]\ +\epsilon_t- \\
& -\left(\frac{a}{4}\right)[(S_{t-1}\Delta p_t-\Delta p_{t-1})+(S_t\Delta p_{t+1}-\Delta p_t)]
\end{aligned} \tag{3.27}
$$

This expression provides by itself a nested version of both competing specifications. Recall that $a=2\Gamma/(\Omega+2\Gamma)$. It is then immediately obvious that a sticky price model, that is, one without relative wage concern ($\Gamma=0$, and therefore $a=0$) implies

$$
\Delta p_t-\left[\frac{S_{t-1}\Delta p_t+S_t\Delta p_{t+1}}{2}\right]=\frac{\delta_0}{2}+\frac{\widetilde{\gamma}}{2}[y_{t-1}+y_t]+\epsilon_t' \tag{3.28}
$$

Hence a simple way to discriminate between the two specifications is to estimate

$$\Delta p_t - \left[\frac{S_{t-1}\Delta p_t + S_t\Delta p_{t+1}}{2}\right] = \widehat{\delta_0} + \widehat{\delta_1}\left[\frac{y_{t-1} + y_t}{2}\right] + \epsilon_t$$
$$-\widehat{\delta^*}\left[(S_{t-1}\Delta p_t - \Delta p_{t-1}) + (S_t\Delta p_{t+1} - \Delta p_t)\right] \tag{3.29}$$

and test whether or not $\widehat{\delta^*}$ is statistically different from zero.

Alternatively, we can re-write equation (3.29) as follows

$$\Delta p_t - \left[\frac{S_{t-1}\Delta p_t + S_t\Delta p_{t+1}}{2}\right] = \widehat{\delta_0'} + \widehat{\delta_1'}\left[\frac{y_{t-1} + y_t}{2}\right] + \epsilon_t'' +$$
$$+\widehat{\delta^*}'\left[\Delta p_{t-1} - \frac{S_{t-1}\Delta p_t + S_t\Delta p_{t+1}}{2}\right] \tag{3.30}$$

and test whether the estimate $\widehat{\delta^*}'$ is statistically different from zero.

3.5.2 Data description

Our regression results are carried out for semiannual data. Semiannual data is useful in the present context for two reasons. Firstly, it seems logical to consider year-long contracts for the nominal wages. Therefore, since a key ingredient of the present framework is wage staggering and two-period contracts, this leads naturally to semiannual estimation in order to boost the explanatory power of the regressions. Secondly, semiannual frequency also allows us to perform our tests using data on inflation expectations as reported on the surveys.

As source of inflation expectations we employ both the Michigan Survey and the Livingston Survey of economists' forecast of inflation[16]. The so-called Michigan survey is conducted by University of Michigan as part of the programme to assess households' behaviour. It is a survey of households' inflation forecasts as measured by the expected change in the CPI twelve months ahead. The Livingston survey was launched by a journalist of that name in the 1940s and is currently conducted by the Federal Reserve Bank of Philadelphia. The data are obtained from a panel of more than forty economists. The Livingston survey reports expected levels of CPI for the upcoming 6 and 12 months. Lack of rationality of inflation expectations is often found for forecast horizons of a year or longer. In order to incorporate lack of rationality in our estimation, we use inflation expectations for the upcoming 12 months, implicitly assuming that agents expect the same rate of inflation for the two 6-month periods. The Livingston survey reports the expected CPI levels 12 months ahead from the date of publication. However, due to the presence of publication lags of the official CPI, the usual forecast is made for 14 months. To extract the implicit rates of inflation we follow the approach suggested by Carlsson [1977].[17] To conform with our measures

[16]The data are currently available from the web sites. An alternative source of inflation forecast is the Survey of Professional Forecasters (SPF). It however refers to the GDP deflator.

[17]Specifically, $\pi^e_{t+12} = 100 * \left(\left(\frac{cpi12}{cpio} \right)^{12/14} - 1 \right)$, where $cpi12$ is the average value of the

of inflation expectations we use the consumer price index as our measure of inflation.

We present regression results employing the three major measures of economic activity: the unemployment rate, GDP and capacity utilisation measures. For GDP and unemployment we present results from detrended data.[18] As usual in the business cycle literature, we employ Hodrick-Prescott filtered data. We make use of two values for the filter's smoothing parameter to estimate the trends: (κ =1,600) and (κ =100). The former is the value suggested by Hodrick and Prescott in their seminal contribution, and it is employed in Roberts [1997]. The results using that value therefore allow for a direct comparison to those in Roberts [1997]. The latter value is chosen by adjusting the recommended value for quarterly data with the fourth power of the observation frequency ratios, as suggested by Ravn and Uhlig [1997]. The purpose is then to filter the data so as to obtain cycles in our semiannual data of the same approximate length of those obtained with the value of κ =1,600 for quarterly data.[19]

---

reported price levels by survey participants and *cpio* is the last value of the actual price level published at the point in time in which the survey was conducted.

[18]All the data employed in our analysis have been obtained from the International Financial Statistics Database. Otherwise the explicit data source is mentioned in the main text.

[19]It should be mentioned here that when alternative adjustments for the filter parameter previously considered in the literature are employed (that is by multiplying the standard

It is hard to explain the history of inflation in the 1970s without accounting for the large changes in real oil prices. Such changes are a potentially important and readily identifiable source of shocks to inflation. We therefore incorporate an additional regressor in our regressions to account for them. Δrpo is defined as the percentage change in the real price of oil, where real oil prices are obtained by dividing nominal prices by the GDP deflator. As measure of nominal oil prices we employ those for the West Texas Intermediate. The estimated equations are

$$\begin{aligned}\Delta p_t - \left[\frac{S_{t-1}\Delta p_t + S_t\Delta p_{t+1}}{2}\right] &= \widehat{\delta_0} + \widehat{\delta_1}\left[\frac{y_{t-1}+y_t}{2}\right] + \widehat{\delta_2}\;\Delta rpo_t + \epsilon_t \\ &\quad -\widehat{\delta^*}\;\left[(S_{t-1}\Delta p_t - \Delta p_{t-1}) + (S_t\Delta p_{t+1} - \Delta p_t)\right]\end{aligned} \tag{3.31}$$

instead of (3.29), while in place of (3.30) we estimate

$$\begin{aligned}\Delta p_t - \left[\frac{S_{t-1}\Delta p_t + S_t\Delta p_{t+1}}{2}\right] &= \widehat{\delta'_0} + \widehat{\delta'_1}\left[\frac{y_{t-1}+y_t}{2}\right] + \widehat{\delta'_2}\;\Delta rpo_t + \epsilon''_t \\ &\quad + \widehat{\delta^*}'\left[\Delta p_{t-1} - \frac{S_{t-1}\Delta p_t + S_t\Delta p_{t+1}}{2}\right]\end{aligned} \tag{3.32}$$

Two additional comments should be made clear before presenting our empirical results. OLS estimates of the above equations may have two potential

smoothing parameter value 1,600 by the square of the alternative sampling frequency as in Backus and Kehoe [1992] or linearly with the frequency of the data as in Correia *et al.* [1992] or Cooley and Ohanian [1991]), the qualitative results are not altered. Our results also hold when GDP is filtered by applying a quadratic time trend.

sources of bias. Firstly, the economic activity measures may be correlated with the error term. In this respect, we follow Roberts [1997] and take support from the results in King and Watson [1994] to assume that they are not correlated with the error term, at least for the period length implied by the equations we estimate. The assumption of lack of correlation between regressors and the error term is however not justifiable for the terms involving lagged inflation in equations (3.31) and (3.32), since the errors are likely to be correlated. Therefore we employ the instrumental variable method in our regressions, with the instruments being three lags of the economic activity measures.[20] Secondly, as a consequence of the overlapping inflation expectations and wage contracting, the empirical model developed in the last section may suffer from the presence of residual correlation. In order to provide correct inference, the standard errors presented are those obtained after applying the Newey-West [1987] correction for up to eight lags.

3.6 Empirical Results

Table 3.1 below presents results for detrended output as measure of economic activity. We employ the HP filter making use of a value for the smoothing

[20] We have also employed more justifiable exogenous instruments. Results employing the change in the federal funds rate, M2 and real government expenditure as instruments point at the same qualitative result that those presented here.

Table 3.1: Economic Activity: detrended GDP, HP filter, κ =100.

Test for sticky inflation. Semiannual data.
Two-stage least squares. Newey-West correction, eight lags
Sample 1961:1-1996:2. Dependent variable $\Delta p_t - [S_{t-1}\Delta p_t + S_t\Delta p_{t+1}]/2$

	Livingston Survey		Michigan Survey	
Constant	0.24	0.35	-0.13	-0.18
	(0.15)	(0.21)	(0.15)	(0.21)
Real oil price	0.025	0.036	0.024	0.033
	(0.01)	(0.012)	(0.008)	(0.011)
Detrended GDP[1]	0.32	0.45	0.29	0.39
	(0.10)	(0.13)	(0.094)	(0.12)
$[S_{t-1}\Delta p_t - \Delta p_{t-1}+$	-0.28	-	-0.249	-
$+S_t\Delta p_{t+1} - \Delta p_t]$	(0.060)	-	(0.051)	-
$\Delta p_{t-1}-$	-	0.358	-	0.29
$-(S_{t-1}\Delta p_t + S_t\Delta p_{t+1})/2$	-	(0.121)	-	(0.09)
$\overline{R}^2$	0.46	0.45	0.39	0.38
SER	0.96	1.33	0.95	1.27
$\overline{R}^2$, first stage	0.45	0.36	0.33	0.27

Notes: Numbers in parenthesis are standard errors.
[1]Average of current and previous period.

parameter of $\kappa = 100$ to estimate the trend.

Overall, the point estimates are in line to their expected values. Detrended output has the correct sign and is statistically significant. So are real oil prices. With respect to the parameters of interest for our test, the results are conclusive. In the four cases, the parameter estimates are significantly different from zero, the value they should take under the sticky-price hypothesis. The corresponding p-values are lower than 0.01 in all cases.

These results therefore allows us to clearly reject the sticky price model in favour of an sticky-inflation contracting specification. The rest of the chapter tries to assess the robustness of those results.

We start by considering some sensitivity to detrending by an alternative value for the smoothing parameter in the HP filter.

Table 3.2: Economic Activity: detrended GDP, HP filter, κ =1,600.

Test for sticky inflation. Semiannual data.
Two-stage least squares. Newey-West correction, eight lags
Sample 1961:1-1996:2. Dependent variable $\Delta p_t - [S_{t-1}\Delta p_t + S_t\Delta p_{t+1}]/2$

	Livingston Survey		Michigan Survey	
Constant	0.22	0.32	-0.16	-0.22
	(0.15)	(0.21)	(0.15)	(0.21)
Real oil price	0.027	0.038	0.027	0.036
	(0.009)	(0.01)	(0.007)	(0.009)
Detrended GDP[1]	0.24	0.33	0.19	0.25
	(0.077)	(0.10)	(0.065)	(0.085)
$[S_{t-1}\Delta p_t - \Delta p_{t-1}+$	-0.268	-	-0.23	-
$+S_t\Delta p_{t+1} - \Delta p_t]$	(0.061)	-	(0.062)	-
$\Delta p_{t-1}-$	-	0.35	-	0.27
$-(S_{t-1}\Delta p_t + S_t\Delta p_{t+1})/2$	-	(0.11)	-	(0.10)
$\overline{R}^2$	0.47	0.46	0.36	0.36
SER	0.97	1.32	0.99	1.29
$\overline{R}^2$, first stage	0.45	0.38	0.32	0.26

Notes: Numbers in parenthesis are standard errors.

[1] Average of current and previous period.

Specifically, we consider $\kappa = 1,600$, as it is usual for quarterly data and employed for example in Roberts [1997]. The point estimates in Table 3.2 are very similar to those in Table 3.1. In fact, the results in Table 3.2 are also strongly supportive for the sticky-inflation contracting specification.

We now proceed to present some sensitivity analysis to the measure of economic activity. Table 3.3 presents the results obtained by employing capacity utilisation as the measure of economic activity.

The results are somewhat less conclusive. Specifically, the results for the Livingston Survey data are in line to those for detrended output. The estimated values are statistically different from zero for standard significance measures (p-values <0.01 in both cases). Instead, for the Michigan Survey data we cannot reject the hypothesis that the parameter $\widehat{\delta}^*$ is statistically not different from to zero. The point estimates become slightly lower. However, their standard errors are substantially higher. Consequently, the implied p-values for the sticky-price hypothesis are respectively 0.065 and 0.128.

Since our source of inflation persistence arises from relative wage concern in wage contracting, it seems logical to look at the results from the estimation of equations (3.31) and (3.32) using the rate of unemployment as measure of economic activity. In Table 3.4 we present results both for raw unemployment rates and in Table 3.5 below we report results for HP-detrended values.

Table 3.3: Economic Activity: Capacity Utilisation

Test for sticky inflation. Semiannual data.
Two-stage least squares. Newey-West correction, eight lags
Sample 1961:1-1996:2. Dependent variable $\Delta p_t - [S_{t-1}\Delta p_t + S_t\Delta p_{t+1}]/2$

	Livingston Survey		Michigan Survey	
Constant	-9.11	-12.5	-5.54	-6.66
	(2.54)	(3.35)	(2.96)	(3.65)
Real oil price	0.027	0.038	0.032	0.038
	(0.008)	(0.01)	(0.009)	(0.01)
Capacity Utilisation[1]	0.11	0.15	0.065	0.078
	(0.032)	(0.042)	(0.037)	(0.046)
$[S_{t-1}\Delta p_t - \Delta p_{t-1}+$	-0.267	-	-0.17	-
$+S_t\Delta p_{t+1} - \Delta p_t]$	(0.046)	-	(0.091)	-
$\Delta p_{t-1}-$	-	0.342	-	0.20
$-(S_{t-1}\Delta p_t + S_t\Delta p_{t+1})/2$	-	(0.088)	-	(0.13)
$\overline{R}^2$	0.49	0.48	0.37	0.30
SER	0.96	1.31	0.99	1.36
$\overline{R}^2$, first stage	0.49	0.38	0.26	0.26

Notes: Numbers in parenthesis are standard errors.
[1]Average of current and previous period.

The results for raw unemployment rates are similar to those for capacity utilisation. That is, for the Livingston Survey data they are strongly favourable to the sticky-inflation hypothesis. Instead, for the Michigan Survey data the point estimates are substantially lower, and for standard significance levels we cannot reject the hypothesis that the parameter of interest is statistically not different from zero. However, some caution should be taken when interpreting the latter results, since the point estimates from the economic activity are so low that they are not statistically significant either.

Table 3.4: Economic Activity: Unemployment Rate

Test for sticky inflation. Semiannual data.
Two-stage least squares. Newey-West correction, eight lags
Sample 1961:1-1996:2. Dependent variable $\Delta p_t - [S_{t-1}\Delta p_t + S_t\Delta p_{t+1}]/2$

	Livingston Survey		Michigan Survey	
Constant	2.25	2.84	0.55	0.67
	(0.06)	(0.62)	(0.48)	(0.57)
Real oil price	0.033	0.042	0.033	0.04
	(0.009)	(0.01)	(0.008)	(0.01)
Unemployment Rate[1]	-0.31	-0.39	-0.12	-0.14
	(0.078)	(0.08)	(0.07)	(0.08)
$[S_{t-1}\Delta p_t - \Delta p_{t-1} +$	-0.20	-	-0.177	
$+S_t\Delta p_{t+1} - \Delta p_t]$	(0.062)	-	(0.076)	
$\Delta p_{t-1} -$	-	0.26		0.21
$-(S_{t-1}\Delta p_t + S_t\Delta p_{t+1})/2$	-	(0.099)		(0.11)
$\overline{R}^2$	0.45	0.50	0.29	0.29
SER	1.07	1.35	1.13	1.38
$\overline{R}^2$, first stage	0.48	0.41	0.29	0.30

Notes: Numbers in parenthesis are standard errors.
[1]Average of current and previous period.

When detrended unemployment values are employed, economic activity becomes strongly significant. With respect to the parameters of interest, the estimation is now strongly favourable to the sticky-inflation hypothesis. The parameter estimates are significantly different from zero, the value consistent with an sticky-price model, with the corresponding p-values being lower than 0.025 in all four cases.

Table 3.5: Economic Activity: detrended Unemployment Rate

Test for sticky inflation. Semiannual data.
Two-stage least squares. Newey-West correction. eight lags
Sample 1961:1-1996:2. Dependent variable $\Delta p_t - [S_{t-1}\Delta p_t + S_t\Delta p_{t+1}]/2$

	HP Filter $\kappa = 100$		*HP Filter* $\kappa = 1,600$	
	Livingston	Michigan	Livingston	Michigan
Constant	0.27	-0.13	0.26	-0.15
	(0.17)	(0.16)	(0.17)	(0.17)
Real oil price	0.025	0.024	0.026	0.025
	(0.009)	(0.008)	(0.009)	(0.008)
Unemployment Rate[1]	-0.69	-0.59	-0.69	-0.59
	(0.21)	(0.19)	(0.21)	(0.19)
$[S_{t-1}\Delta p_t - \Delta p_{t-1} +$	-0.25	-0.23	-0.25	-0.21
$+S_t\Delta p_{t+1} - \Delta p_t]$	(0.044)	(0.085)	(0.044)	(0.094)
$\overline{R}^2$	0.47	0.39	0.47	0.38
SER	0.99	0.98	0.99	1.00
$\overline{R}^2$. first stage	0.46	0.48	0.47	0.48

Notes: Numbers in parenthesis are standard errors.
[1] Average of current and previous period.

3.7 Subsample Stability

In order two assess the robustness of the results presented so far we next consider the subsample stability of the results presented in the previous section. Specifically, three subsamples are considered: 1961:1-1978:2, 1970:1-1989:2 and 1980:1-1996:2.

Table 3.6: Subsample 1961:1-1978:2

Two-stage least squares. Newey-West Correction with eight lags. Semiannual data. Dependent variable $\Delta p_t - [S_{t-1}\Delta p_t + S_t \Delta p_{t+1}]/2$

	Det.Unem. Rate[2]		Detrended GDP[2]		Cap. utilisation	
	Liv.	Mich.	Liv.	Mich.	Liv.	Mich.
Constant	0.56	0.13	0.38	0.12	-6.76	-5.01
	(0.14)	(0.24)	(0.10)	(0.20)	(2.99)	(3.28)
Real oil price	0.005	0.01	0.005	0.009	0.01	0.01
	(0.002)	(0.005)	(0.003)	(0.006)	(0.004)	(0.007)
Economic activity[1]	-0.96	-0.81	0.41	0.37	0.085	0.061
	(0.24)	(0.36)	(0.071)	(0.11)	(0.037)	(0.04)
$[S_{t-1}\Delta p_t - \Delta p_{t-1} +$	-0.32	-0.21	-0.39	-0.27	-0.38	-0.36
$+S_t \Delta p_{t+1} - \Delta p_t]$	(0.046)	(0.14)	(0.042)	(0.10)	(0.062)	(0.12)
$\overline{R}^2$	0.52	0.24	0.51	0.23	0.30	0.12
SER	0.89	1.07	0.84	0.98	0.97	1.00

Notes: Numbers in parenthesis are standard errors.

[1] Average of current and previous period. [2] HP filter. $\kappa = 100$.

Despite the fact that the evidence from the first subsample is less conclusive, for the remaining two subsamples the broad picture remains largely unchanged. The parameter estimates do not indicate substantial problems of subsample instability of the results presented is the previous section.

Table 3.7: Subsample 1970:1-1989:2

Two-stage least squares. Newey-West Correction with eight lags.
Semiannual data. Dependent variable $\Delta p_t - [S_{t-1}\Delta p_t + S_t \Delta p_{t+1}]/2$

	Det.Unem. Rate[2]		Detrended GDP[2]		Cap. utilisation	
	Liv.	Mich.	Liv.	Mich.	Liv.	Mich.
Constant	0.24	0.024	0.21	0.012	-13.48	-11.22
	(0.26)	(0.22)	(0.23)	(0.20)	(3.23)	(3.40)
Real oil price	0.024	0.021	0.024	0.021	0.018	0.018
	(0.011)	(0.009)	(0.012)	(0.010)	(0.01)	(0.009)
Economic activity[1]	-0.71	-0.60	0.33	0.29	0.17	0.139
	(0.24)	(0.23)	(0.11)	(0.11)	(0.041)	(0.043)
$[S_{t-1}\Delta p_t - \Delta p_{t-1} +$	-0.26	-0.24	-0.28	-0.26	-0.31	-0.27
$+S_t \Delta p_{t+1} - \Delta p_t]$	(0.048)	(0.07)	(0.07)	(0.046)	(0.042)	(0.055)
$\overline{R}^2$	0.47	0.39	0.46	0.40	0.61	0.43
SER	1.17	1.13	1.14	1.09	1.02	1.07

Notes: Numbers in parenthesis are standard errors.

[1]Average of current and previous period. [2]HP filter, κ=100

Table 3.8: Subsample 1980:1-1996:2

Two-stage least squares. Newey-West Correction with eight lags.
Semiannual data. Dependent variable $\Delta p_t - [S_{t-1}\Delta p_t + S_t\Delta p_{t+1}]/2$

	Det.Unem. Rate[2]		Detrended GDP[2]		Cap. utilisation	
	Liv.	Mich.	Liv.	Mich.	Liv.	Mich.
Constant	-0.10	-0.23	-0.093	-0.27	-5.22	-3.32
	(0.077)	(0.10)	(0.09)	(0.13)	(2.46)	(2.21)
Real oil price	0.044	0.041	0.048	0.045	0.047	0.048
	(0.006)	(0.005)	(0.009)	(0.007)	(0.007)	(0.005)
Economic activity[1]	-0.18	-0.19	0.12	0.15	0.064	0.037
	(0.15)	(0.10)	(0.11)	(0.072)	(0.030)	(0.028)
$[S_{t-1}\Delta p_t - \Delta p_{t-1}+$	-0.32	-0.35	-0.27	-0.29	-0.26	-0.25
$+S_t\Delta p_{t+1} - \Delta p_t]$	(0.039)	(0.061)	(0.048)	(0.046)	(0.030)	(0.072)
$\overline{R}^2$	0.65	0.58	0.59	0.53	0.60	0.47
SER	0.72	0.72	0.74	0.74	0.74	0.80

Notes: Numbers in parenthesis are standard errors.
[1]Average of current and previous period. [2]HP filter, κ=100

3.8 Some additional tests

So far our empirical analysis has followed the approach carried out in Roberts [1997]. The purpose is to allow the reader for a direct comparison to the results presented there. However, such an approach is based on a restricted model. In this section, we present some additional empirical analysis. The purpose is twofold. Firstly, we provide a direct test of the restrictions imposed in the equations we have estimated in the previous sections. Though the restricted model may be justified as appropiate in the light of the limited availability of data on inflation expectations, it is also true that some additional information can be obtained from testing on a more unrestricted model. Therefore, we also aim at obtaining additional evidence on the significance of lagged inflation through the estimation of alternative equations.

To derive the estimated equations (3.31) and (3.32) in the thesis, we first impose[21] the restriction $a + b = 2$.

We can test that restriction as follows. Firstly. we rearrange equation (3.23) above as follows

$$\Delta p_t = \delta_1 + \delta_2 \left[\frac{y_{t-1} + y_t}{2} \right] + \delta_3 \Delta rpo_t + \delta_4 \left[S_{t-1} \Delta p_t + S_t \Delta p_{t+1} \right] + \delta_5 \left[\Delta p_{t-1} \right]$$

where $\delta_4 = b/(4-a)$ and $\delta_5 = a/(4-a)$. The restriction $a + b = 2$, therefore implies in linear form that $2\delta_4 + \delta_5 = 1$. This linear restriction can be tested from the estimation of the above equation.

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[21] Recall that $a = 2\Gamma/(\Omega + 2\Gamma)$ and $b = (2\Omega + 2\Gamma)/(\Omega + 2\Gamma)$

Table 3.9: Alternative test for lagged inflation

Two-stage least squares. Newey-West Correction with eight lags.
Sample 1961:1-1996:2. Semiannual data. Dependent variable Δp_t

	Det. Un. Rate[2]		Detrended GDP[2]		Cap. utilisation	
	Liv.	Mich.	Liv.	Mich.	Liv.	Mich.
Constant	0.38	-1.66	0.37	-1.76	-16.37	-10.9
	(0.32)	(0.65)	(0.32)	(0.62)	(4.07)	(3.24)
Real oil price	0.035	0.028	0.036	0.028	0.033	0.027
	(0.0012)	(0.010)	(0.013)	(0.010)	(0.011)	(0.008)
Ec. activity[1]	-0.93	-0.62	0.45	0.31	0.19	0.10
	(0.28)	(0.25)	(0.13)	(0.11)	(0.047)	(0.037)
$S_{t-1}\Delta p_t + S_t\Delta p_{t+1}$	0.33	0.57	0.32	0.59	0.44	0.76
	(0.063)	(0.16)	(0.091)	(0.13)	(0.093)	(0.21)
Δp_{t-1}	0.33	0.12	0.35	0.10	0.29	-0.052
	(0.083)	(0.21)	(0.13)	(0.16)	(0.12)	(0.26)
$\overline{R}^2$	0.80	0.85	0.80	0.85	0.84	0.85
P-value for Wald stat.						
$(2\delta_4 + \delta_5 = 1)$	0.981	0.009	0.961	0.009	0.058	0.005

Notes: Numbers in parenthesis are standard errors.
[1]Average of current and previous period. [2]HP filter, κ=100.

From the results reported in Table 3.9, note that when the Livingston survey data is employed both Δp_{t-1} and $[S_{t-1}\Delta p_t + S_t\Delta p_{t+1}]$ are statistically significant. That is however not the case when we employ the Michigan survey data. Specifically, the estimated coefficient for Δp_{t-1} is substantially lower than those for $[S_{t-1}\Delta p_t + S_t\Delta p_{t+1}]$ or the estimates for the Livingston survey. Consequently, lagged inflation is no longer statistically significant when we use the Michigan survey data.

With respect to the linear restriction $2\delta_4+\delta_5 = 1$, at standard significance levels we cannot reject the restriction for the Livingston Survey data for any of the alternative measures of economic activity considered. Instead, for the Michigan survey data, the restriction is rejected.

To test for equal coefficients for $[S_{t-1}\Delta p_t + S_t\Delta p_{t+1}/2]$ and Δp_{t-1} in the estimated equations in the previous sections, we impose $a+b = 2$ and factorise to obtain

$$\begin{aligned} \Delta p_t - \left[\frac{S_{t-1}\Delta p_t + S_t\Delta p_{t+1}}{2}\right] &= \delta_1 + \delta_2 \left[\frac{y_{t-1} + y_t}{2}\right] + \delta_3\Delta rpo_t \\ &+\delta_4 \left[\frac{S_{t-1}\Delta p_t + S_t\Delta p_{t+1}}{2}\right] + \delta_5\Delta p_{t-1} \end{aligned}$$

The additional restriction imposed in the equations estimated in the thesis is that of $-\delta_4 = \delta_5$, which we can directly test on the data by estimating the last equation above.

The results are summerised in Table 3.10 below. They are in line with those in the previous table. That is, we cannot reject the restriction for the Livingston Survey data for any of the alternative measures of economic activity considered. However, for the Michigan survey data, the restriction is rejected.

Table 3.10: Testing for equal coefficients

Two-stage least squares. Newey-West Correction with eight lags.
Sample 1961:1-1996:2. Semiannual data.
Dependent variable $\Delta p_t - [S_{t-1}\Delta p_t + S_t\Delta p_{t+1}]/2$

	Det. Un. Rate[2]		Detrended GDP[2]		Cap. utilisation	
	Liv.	Mich.	Liv.	Mich.	Liv.	Mich.
Constant	0.38	-1.66	0.37	-1.76	-15.65	-10.9
	(0.32)	(0.65)	(0.32)	(0.62)	(3.58)	(3.24)
Real oil price	0.035	0.028	0.036	0.028	0.032	0.027
	(0.012)	(0.01)	(0.013)	(0.01)	(0.011)	(0.008)
Economic activity[1]	-0.93	-0.62	0.45	0.31	0.18	0.10
	(0.28)	(0.25)	(0.13)	(0.11)	()0.041	(0.037)
$[S_{t-1}\Delta p_t + S_t\Delta p_{t+1}]/2$	-0.33	0.15	-0.35	0.19	-0.22	0.53
	(0.12)	(0.32)	(0.18)	(0.27)	(0.14)	(0.42)
Δp_{t-1}	0.33	0.12	0.35	0.10	0.39	-0.052
	(0.083)	(0.21)	(0.13)	(0.16)	(0.088)	(0.26)
$\overline{R}^2$	0.46	0.49	0.45	0.49	0.56	0.50
P-value for Wald stat						
($\delta_4 + \delta_5 = 0$)	0.981	0.018	0.961	0.009	0.058	0.005

Notes: Numbers in parenthesis are standard errors.
[1]Average of current and previous period. [2]HP filter, κ =100.

The results reported here are a consequence of a rather different behaviour for inflation expectations depending on whether they are formed by consumers or profesional economists. A preliminary analysis of the inflation expectation series points at the presence of more important role for actual lagged inflation in the expectation formation for the Michigan survey, together with a much stronger response to lagged expectational errors with respect to that of the Livingston survey data. This may explain the lack of significance of Δp_{t-1} for the Michigan survey in the results reported in Table 3.9. The additional evidence reported in this section suggests that a thorough analysis of the expectation formation processes is likely to be needed before searching for a more definite answer to the source of inflation persistence.

3.9 Concluding comments

U.S. inflation exhibits substantial inertia. Therefore, it should be a fundamental feature for any monetary dynamic macromodel to account for. Unfortunately, the current strand of research incorporating New Keynesian ingredients, in particular nominal rigidities, to the dynamic general equilibrium framework developed for the study of business cycles, has failed to account for it. Replicating that degree of inflation persistence is thus a fundamental area for future research. Two departures from the standard New Keynesian framework have been proposed. Fuhrer and Moore [1995] have advocated for richer contracting specifications, on the basis that their empirical results resoundingly reject the Taylor-type contracting specifications. Roberts [1997] proposes relaxing the rational expectations hypothesis on the basis of some evidence from direct observations of inflation expectations. Moreover, evidence presented in Roberts [1997] suggests that by incorporating lack of rationality into Taylor's contracting specification we can reject the hypothesis that inflation is inherently persistent as a consequence of contracting behaviour.

In this chapter, we have incorporated relative wage concern to a dynamic general equilibrium macromodel with wage staggering. Our purpose here was to obtain additional insights for the implications of relative wage considerations on wage contracting. Specifically, we have shown that the result of dynamic optimisation under wage staggering and relative wage concern is a wage contracting specification comprising *both* own real wage and relative real wage considerations. Previous studies have therefore consider simplified versions of the contracting specification derived here. The theoretical part of the chapter has stressed how relative wage concern under wage staggering allows for inflation persistence, in contrast to the sort of Taylor-type contracting equation commonly derived in recent literature on staggering. In this sense, we share our result with the directly-postulated log-linear equation employed in Fuhrer and Moore [1995] by incorporating exclusively relative wage considerations.

In the empirical part of the chapter we have build a test equation that allows us to discriminate between the two sources of inflation inertia previously considered in the related literature, namely relative wage concern in wage setting and the lack of rationality of inflation expectations. Following the approach in Roberts [1997], we employ direct observations of inflation expectations to relax the assumption of rational expectations. Our results have shown that alternative sources of inertia beyond that imparted by the lack of full rationality of expectations might be needed to characterise U.S. inflation dynamics. The intuition behind our results lies in the richer dynamic structure of the contracting specification derived here, which allows us to reverse the results in Roberts [1997].

3.10 Appendix

The expressions for the weights in the wage contracting specification (equation (3.14)) are as follows:

$$\Omega = \frac{-\varepsilon U_l(t)K_t[\varepsilon\eta_l + 1] - (\varepsilon - 1)U_{RW}X_t^{\varepsilon}}{U_{RW}(t)X_t^{\varepsilon} - \varepsilon U_l(t)K_t}$$

$$\Gamma = \frac{-[1 + \eta_{RW}]U_{RW}X_t^{\varepsilon}}{U_{RW}(t)X_t^{\varepsilon} - \varepsilon U_l(t)K_t}$$

$$\gamma = \frac{-\varepsilon U_l(t)K_t\{\frac{\varepsilon}{\theta}\eta_l - \eta_c\} - [\frac{\varepsilon}{\theta} + \eta_c]U_{RW}X_t^{\varepsilon}}{U_{RW}(t)X_t^{\varepsilon} - \varepsilon U_l(t)K_t}$$

Chapter 4

Relative Wage Concern: an Explanation for Output and Inflation Persistence?

4.1 Introduction

Modern business cycle research is almost entirely carried out within the context of quantitative dynamic general equilibrium (DGE) macromodels. In recent years, monetary DGE macromodels have incorporated various forms of nominal rigidities to study the role of monetary shocks in generating the output fluctuations observed in actual data. In that approach, the overlapping contracts models of Calvo [1983] and Taylor [1979, 80a] have played a prominent role. The reason is that such contracting schemes bring in not only the nominal rigidity necessary for the impact effect of the monetary innovation, but also provide a nominal propagation mechanism, the so-called contract multiplier, in a framework otherwise lacking endogenous propagation mechanisms.

Recent quantitative DGE macromodels, notably Chari. Kehoe and McGrattan [1996] (CKM henceforth) and Ascari [1997], have however cast serious doubts on the explanatory power of staggered price/wage setting in accounting for output persistence. They show that persistence does not exceed the length of the contracts. In other words, there is no contract multiplier. This results arises because persistence requires endogenous stickiness in the sense that price-setting agents choose not to change their prices/wages by a large amount when they reset them. CKM and Ascari [1997] have shown that, for sensible values of the intertemporal elasticity of substitution of consumption and/or the intertemporal elasticity of substitution of labour, the response of wages to the output gap is too high to generate output persistence.

This chapter reconsiders the existence of a contract multiplier. Our approach is based on incorporating an explicit relative real wage concern in the wage seting process, that otherwise takes place in a standard staggered fashion. We focus on wage staggering for two reasons. Firstly, we believe that persistent nominal rigidities are more likely to arise in the labour market rather than in the goods market. Secondly, we will argue that the wage setting process is better represented as the result of the combination of small nominal *and* real rigidities. Our source of real rigidity in the labour market arises from an explicit account of relative real wage concern. We have reviewed in Chapter 2 the empirical evidence pointing at relative wages as a fundamental factor in the wage setting process. We have also shown that the Taylor contracting specification does not incorporate a "Keynesian" component of relative wage concern on the part of the workers as was initially thought. Relative wage concern considerations have been therefore left out of the analysis so far. Such an omission seems to be a serious weakness of the contracting specification assumed in Taylor's model. In Chapter 3 we have employed the structure of the wage contracting specification and showed that relative wage concern could be the source of the observed inflation inertia. Here we aim at a further analysis of the dynamic general equilibrium features of our model.

We keep our analytical framework as close as possible to those of the previous studies which have highlighted the weaknesses of the Taylor contracting specification, namely CKM, FM and Ascari [1997]. By incorporating relative wage concern in that framework, we try to capture the spirit of the original work by Taylor since it was aimed at considering relative wage considerations. Our analysis should then be seen as a first step towards assessing how crucial the omission of relative wage concern is for the analytical and quantitative results of CKM. In particular, the aim of the chapter is the search for reasonable values of the relative wage concern parameters.

Contrary to previous studies, the quantitative version of the model provides strong support for the existence of a powerful contract multiplier. Two features of the model strengthen the importance of our result. Firstly, the wage contracting specification is the only mechanism through which the effects of nominal shocks are propagated in our model. We refrain from introducing capital accumulation, adjustment costs, input-output structure, endogenous mark-ups, or any other possible factor which may enhance the nominal propagation mechanism derived here. Secondly, as in previous analyses of staggered wage setting, our results also highlight the potential role of high intertemporal elasticities of substitution of consumption and labour supply in favoring persistence, but *by no means* rely on them to generate a substantial degree of persistence. This latter point is evident from our calibration exercise. Notwithstanding these features of the model, we find that output persistence is a likely outcome.

Some intuition for the sharp contrast between our results and those of CKM can be obtained by comparing a log-linearisation of our wage contracting equation to theirs. A key difference is the elasticity of wages with respect to business cycle conditions. Relative wage concern on the part of workers lowers that elasticity. The calibration of the parameters governing relative wage considerations generates a powerful contract multiplier and thus substantial persistence in both inflation and output.

The remainder of the chapter is organized as follows. In section 2 we present our model. We study the analytical implications of relative wage concern in section 3, and compare our findings to previous studies of staggered wage/price models. We then proceed to analyse the quantitative implications. Section 5 describes the calibration of the model and reports our simulation results. This analysis is extended in sections 6 and 7, that consider, respectively, sensitivity of the results to the calibration of the key parameters and the definition of the relative wage agents are concerned with. Finally, Section 8 summerises the main conclusions.

4.2 Relative Real Wage Concern and Staggered Wage Setting

The purpose of this chapter is to analyse the implications of the omission of relative wage concern for the recent research that has questioned the power of staggered wage setting to generate persistent real effects of money shocks. The model presented in this chapter is a straighforward extension to the model introduced in the previous chapter. The most important differences are the following: (i) our benchmark definition of the relative wage the agents are concerned with; (ii) the fact that we consider four period contracts and four sectors, instead of just two. We however describe it in detail again to allow the reader to proceed to this chapter without constant references to the material presented in previous one.

Wage setting in our model is defined by two features: (i) staggered wage setting; (ii) relative real wage concern.

(i) *Staggered Wage Setting*

This setting is standard in the related literature. The economy is divided into N sectors. Each sector is composed of the industries indexed by $i \in [0, 1/N]$ and their corresponding unions (indexed by j)[1]. Wage contracts, denoted by X, are negotiated in nominal terms, and are fixed for N periods. That is, for a union setting the nominal wage in period t, $X_{jt+k} = X_{jt}$ for $k = 0, ...N - 1$. Furthermore, unions indexed $j \in [0, 1/N]$ set their wages in periods 0, N, $2N$, unions indexed $j \in [1/N, 2/N]$ do so in periods 1, $N + 1$, $2N + 1$, etc. Note that staggered wage setting breaks the complete symmetry among households in different sectors. However, unions belonging

[1] A continuum of industries means that no imperfectly competitive agent is 'large' relative to the economy as a whole. The 'household-union' should be taken as an aggregate of all the households who work on the industry, who implicitly collude in the wage setting decision.

to the same sector will set the same wage[2]. Thus, in any period t there are N different contracts in effect.

(ii) *Relative Real Wage Concern*

Taylor's model was aimed at incorporating relative wage concern on the part of the workers. However, we have showed in chapter 2 that his contracting specification is analytically equivalent to a model in which workers are concerned only about the level of their *own* real wages. Chapter 2 also presents some evidence that suggests that relative wage considerations play a fundamental role in the wage setting process. Then, the two questions of interest for our purpose here are how to introduce relative wage concern in the model and how to define the reference wage index to model it analytically.

With respect to the first question, taking support on the evidence presented in chapter 2, we model relative wage concern by including an additional argument in the utility function of the representative household. Despite the available empirical evidence on unions' behaviour, and sociological and psychological considerations, our introduction of relativities in the

[2]Let us call the new wage set in period t in industries $i \in [0, 1/N]$, X_t. Then, unions indexed $j \in [1/N, 2/N]$ will set their new nominal wage in period $t+1$, unions indexed $j \in [2/N, 3/N]$ will set their new nominal wage in period $t+2$, and so on. Therefore X_t, X_{t+N}, X_{t+2N}...are the wages fixed by the sector which comprises industries $i \in [0, 1/N]$, $X_{t+1}, X_{t+1+N}, X_{t+1+2N}$...the wages fixed by the sector that comprises industries $i \in [1/N, 2/N]$ and so on.

utility function may be seen as an *ad hoc* unjustifiable short-cut. However, by introducing relative wage considerations explicitly we aim at: (i) identifying the analytical implications of relative wage concern in wage setting; (ii) establishing whether sensible values of the key parameters governing relative wage concern can explain output and inflation persistence. We can then assess how crucial the omission of relative wage concern is for the analytical and quantitative results of CKM.

We now turn to the definition of the reference wage. We denote the relative wage argument in the utility function of the representative household j, ${RW_t}^j$. Following FM[3], we define the *contract price in period s*, "CP_s^j", as the value of the contract signed by the union j in period s. To clarify the definitions note that in this subsection we use the index t to refer to the period in which the real wage comparison takes place. s instead refers to the period in which the contract is signed. Recall that for a union setting the nominal wage in period s, $X_{s+k} = X_s$ for $k = 0, ...N - 1$. Workers compare the value of the contract they sign in period s, that is CP_s, to the *index of contract prices* "V". Crucial to the modelling of the relative wage concern is

[3]In what follows we keep the notation as close as possible to that of FM. The definition of our benchmark case corresponds to their *Theoretically Preferable Case.* Section 4.7 introduces two alternative specifications as part of our sensitivity analysis for the main results of the chapter. We also present a brief comparison of our model with FM's one in Section 4.3.

the choice of the reference wage index for comparison purposes. We define V_t as the average of the contract prices of the workers in the *other* sectors in effect in period t, that is, the average of the contracts negotiated by the *other* unions. We believe this "*outward comparison*" specification to be the most relevant in the real world.[4] Thus, $RW_t{}^j$ is defined as the ratio between the value of the contract in force for union j in period t to the index of contract prices signed by the other sectors and still valid in period t.

At any period t there are N different contracts in effect, therefore N different CP_s and N different RW_t^j, one for each representative sectorial union. Consider the problem faced by a union that sets the nominal wage in period t and assume that the contract lasts for four periods ($N = 4$). The decision of the union then takes into account that by setting X_s, it also fixes CP_s for the next four periods (hence, we have indexed it by s). The optimal X_s is thus set by comparing the current price contract the union is negotiating (that is CP_s) to the indexes of real contract prices V in effect in periods t to $t + 3$. The RW the workers will face in period t and in the following three periods as a result of the wage they negotiate in t are then

[4]The term "outward comparison" follows a recent work by Carrol *et al.* [1997]. Its purpose is to highlight the absence of own variables in the definition of the reference stock for comparison purposes. Specifically, in our setting the "own contract price" does not enter the definition of the index of contract prices to which it is compared in the bargaining process.

$$RW_t^j = \left(\frac{CP_s}{V_t}\right) = \frac{CP_s}{(1/3)(CP_{s-3}+CP_{s-2}+CP_{s-1})}; \quad RW_{t+1}^j = \left(\frac{CP_s}{V_{t+1}}\right) = \frac{CP_s}{(1/3)\ (CP_{s-2}+CP_{s-1}+CP_{s+1})}$$

$$RW_{t+2}^j = \left(\frac{CPs}{V_{t+2}}\right) = \frac{CP_s}{(1/3)\ (CP_{s-1}+CP_{s+1}+CP_{s+2})}; RW_{t+3}^j = \left(\frac{CP_s}{V_{t+3}}\right) = \frac{CP_s}{(1/3)\ (CP_{s+1}+CP_{s+2}+CP_{s+3})}.$$

Note that, because of the "outward comparison" specification, the V_t terms are not just updated symmetrically in the four periods of duration of the contract.[5]

We suppose that the workers are concerned with their average real wage over the life of the contract. Accordingly CP is defined as the money wage deflated by a weighted average of the price level in the four periods in which the contract lasts. Hence: $CP_t = X_t/\overline{P}_t$, where

$$\overline{P}_t = \frac{P_t + \beta P_{t+1} + \beta^2 P_{t+2} + \beta^3 P_{t+3}}{1 + \beta + \beta^2 + \beta^3}$$

Agents therefore calculate the average $\overline{P}_t$ by discounting the future price levels by the preference discount factor β. They then compare the value of their contract, i.e. CP_t, with an average of the ones that overlap with it, that is

$$CP_t = \frac{X_t}{\overline{P}_t}\ ; \quad RW_t = \frac{X_t/\overline{P}_t}{(1/3)\left(\frac{X_{t-3}}{\overline{P}_{t-3}} + \frac{X_{t-2}}{\overline{P}_{t-2}} + \frac{X_{t-1}}{\overline{P}_{t-1}}\right)}.$$

[5]Future variables are replaced by their expected values. We drop the expectation operator for convenience. Note also that the RW terms are different for each household-union in different sectors, depending on the period in which they set their wage.

We present two alternative formulations for RW_t in section 4.7.

4.3 The Model

There are three types of agents in our model economy: firms, households and the government. The economy consists of a continuum of industries indexed by $i \in [0,1]$, and a continuum of industry-specific unions. Every industry produces a differentiated perishable product and comprises a continuum of firms. The goods market in every industry is hence competitive. All households have the same preferences. Household j consumes a composite good, defined by a CES index over consumption goods of each industry, i.e.

$$C_{jt} = \left[\int_0^1 C_{jit}^{\frac{\theta-1}{\theta}} di\right]^{\frac{\theta}{\theta-1}}$$

The elasticity of substitution among goods, θ, is assumed strictly greater than one. This specification gives rise to the standard demand function

$$C_{jit} = \left[\frac{P_{it}}{P_t}\right]^{-\theta} \frac{X_{jt}}{P_t} \tag{4.1}$$

where X_{jt} is household's total nominal expenditure on goods, and P_t is the aggregate price index defined as $P_t = \left[\int_0^1 P_{it}^{1-\theta} di\right]^{\frac{1}{1-\theta}}$.

4.3.1 Firms

All firms have the same technology, given by $Y_{it} = \alpha L_{it}^{\sigma}$, where labour is the only factor of production. Firms within each industry are price takers both in the goods and the labour market. Profits are maximised period by period given the nominal wage X_{it}, set by the sectorial union. The labour demand and output of firm i are given by

$$L_{it} = \left[\frac{1}{\alpha\sigma}\frac{X_{it}}{P_{it}}\right]^{\frac{1}{\sigma-1}}; \qquad Y_{it} = \alpha\left[\frac{1}{\alpha\sigma}\frac{X_{it}}{P_{it}}\right]^{\frac{\sigma}{\sigma-1}}. \tag{4.2}$$

Imposing the equilibrium condition in the goods market, given by

$$C_{it} = \int_0^1 C_{jit}dj = Y_{it} \qquad \forall i \in [0, 1], \tag{4.3}$$

yields the following relation between the labour demand and the nominal wage

$$L_{it} = K_t X_{it}^{-\varepsilon} \qquad \text{where} \qquad \varepsilon = \frac{\theta}{\sigma + (1-\sigma)\theta} \qquad \text{and} \qquad K_t = \sigma^{\varepsilon}\left[\frac{\chi_t}{(\alpha P_t)^{1-\theta}}\right]^{\frac{\varepsilon}{\theta}}. \tag{4.4}$$

The labor demand function faced by the monopolistic union in each industry exhibits a constant money-wage elasticity equal to ε, which depends on technology and preference parameters. K_t is parametric to the union, which takes aggregate variables as given ($\chi_t = \int_0^1 \chi_{jt}dj$ = aggregate nominal expenditure).

4.3.2 Households

The two fundamental features of the households' behaviour are their monopoly power in nominal wage setting and their concern with relative wages.

The industry-specific household-unions enjoy monopoly power because labour is not allowed to move across industries. In period t the household maximises a utility function of the form

$$U_j = E_t \sum_{k=0}^{\infty} \beta^k \left[u(C_{t+k}, m_{t+k}, L_{t+k}, RW_{t+k})\right] \tag{4.5}$$

The arguments in the utility function C_{t+k}, m_{t+k} and L_{t+k} are, respectively, the consumption of the composite good, the end-of-period real money balances and the labour supply of the households.[6] The specification of the relative wage argument RW_{t+k} is the novelty of the chapter and has been discussed in Section 4.2. The utility function satisfies $u_{RW}(\cdot)>0$, $u_{RWRW}(\cdot)<0$.

The household's budget constraint evolves according to

$$P_t C_{jt} + M_{jt} + \sum_{s_{t+1}} Q(s^{t+1} \mid s^t) B_j(s^{t+1}) \leq M_{jt-1} + B_{jt} + W_{jt} L_{jt} + \Pi_{jt} + T_{jt} \tag{4.6}$$

where $Q(s^{t+1} \mid s^t)$ is the stochastic discount factor equal to the money value of a contingent claim in state s^t to one dollar in state s^{t+1}.[7] M_{jt} denotes money holdings at the end of period t, B_{jt} the quantity of bonds in period t, T_{jt} the

[6]The utility function satisfies the standard conditions $u_c(\cdot)>0$, $u_m(\cdot)>0$, $u_L(\cdot)<0$, $u_{cc}(\cdot)<0$, $u_{mm}(\cdot)<0$, $u_{LL}(\cdot)<0$, where $u_r(t)$ denotes the first partial derivative of the instantaneous utility function and $u_{rr}(\cdot)$ the second, with respect the argument r.

[7]Following CKM, let s^t denote the state of the world in period t. Denote with $\Pr(s^{t+1} \mid s^t)$ the probability that in the next period the state of the world will be s^{t+1}, conditional to the state s^t in period t. To lighten notation and avoid indexing each variable with respect the state of the world, we use the expectation operator and the dating of the variables.

nominal lump-sum transfer received by the household from the government. Π_{jt} the profits distributed by firms and $L_{jt}W_{jt}$ the labour income.

Households maximise their expected lifetime utility subject to the sequence of budget constraints (4.6), the sequence of labour demand curves (4.4), and the additional constraint that the nominal wage will be fixed for N periods. Their choices are the level of consumption, the quantities of money and bonds transferred to the next period and the level of the nominal wage that must be fixed for N periods. The first-order conditions for that problem can be expressed as follows (the index j is dropped to lighten notation),

$$\frac{u_m(t)}{u_C(t)} = \frac{R_t - 1}{R_t} \tag{4.7}$$

$$u_C(t) = \beta R_t E_t \left(\frac{u_C(t+1)P_t}{P_{t+1}} \right) \tag{4.8}$$

$$\sum_{s^{t+1}} Q(s^{t+1} \mid s^t) = \frac{\beta E_t(\lambda_{t+1})}{\lambda_t} = \beta E_t \left(\frac{u_C(t+1)P_t}{u_C(t)P_{t+1}} \right) = \frac{1}{R_t} \tag{4.9}$$

Then, $\Theta_t = \Theta(s^t)$ and $E_t(\Theta_k) = \sum_{s^k} \Pr(s^k \mid s^t)\Theta(s^k)$, where Θ_t is whatever variable or function of variables, s^k is the state in period $k > t$ and the sum is calculated on all the possible future states s^k.

$$X_t = \left(\frac{\varepsilon}{\varepsilon-1}\right)\left\{\frac{E_{t-1}\left[\sum_{r=o}^{N-1}\beta^r\left(-u_L(t+r)K_{t+r}\right)\right]}{E_{t-1}\left[\sum_{r=o}^{N-1}\beta^r\left(\frac{u_C(t+r)K_{t+r}}{P_{t+r}}\right)\right]}+\right.$$

$$\left.+\frac{\frac{X^{\varepsilon+1}}{\varepsilon-1}E_{t-1}\left[\sum_{r=o}^{N-1}u_{RW}(t+r)\frac{\partial RW(t+r)}{\partial X_t}\right]}{E_{t-1}\left[\sum_{r=o}^{N-1}\beta^r\left(\frac{u_C(t+r)K_{t+r}}{P_{t+r}}\right)\right]}\right\}, \tag{4.10}$$

where λ_t is the multiplier attached to the budget constraint in period t. The first three equations are standard: (4.7) represents the optimal choice between consumption and money; (4.8) is the Euler equation for consumption and (4.9) gives the gross nominal interest rate R_t.[8]

Equation (4.10) gives the nominal wage set by the monopolistic household-union for N periods. Firstly, note that we assume the wage to be set before the realisation of period t shock, hence based on $t-1$ information set. That expression is composed of two terms. The optimal wage is given by a fixed mark-up $\varepsilon/(\varepsilon-1)$ over the quantity in the curly brackets, which is the ratio between expected weighted averages of the marginal disutility from (hours of) labour supply and the marginal utility of consumption over the next 4 periods. In other words, the first component is a weighted average of the optimal flexible wages (without relative wage concern) of those periods. The second term is an expected weighted average of the concern for the relative

[8]Note that $\sum_{s^{t+1}} Q(s^{t+1} \mid s^t)$ is the current value of a nominal bond that gives one unit of money for sure in the next period. On the other hand, $Q(s^{t+1} \mid s^t) = \beta \Pr(s^{t+1} \mid s^t)\left(\frac{u_{C}(s^{t+1})P_t}{u_{C}(t)P(s^{t+1})}\right)$is the current price of a claim of one unit of money contingent on the realisation of state s^{t+1} in the next period.

wages resulting from the contracts in effect over the next 4 periods. The weights are defined by β, K_{t+i}, P_{t+i} and ε.[9]

4.3.3 Government

The role of the government is limited to provide the lump-sum transfers through which money is introduced in the economy. These transfers satisfy

$$T_t = M_t - M_{t-1} \tag{4.11}$$

and the nominal money supply process is described by

$$M_t = \mu_t M_{t-1} \tag{4.12}$$

where μ_t follows a stochastic process (to be specified below).

The resource constraint for this economy is obtained by aggregating (4.6) over all households and imposing equilibrium conditions on the money and bond markets

$$\int_0^1 P_t C_{jt} dj \leq \int_0^1 (W_{jt} L_{jt} + \Pi_{jt}) dj \tag{4.13}$$

[9] Given (4.10), note that it is ex-post optimal for the unions to satisfy an unexpected increase in labour demand. Households are obviously ex-post willing to satisfy extra demand for labour until the real wage is equal to the competitive one. In what follows we assume that never to be the case. The fact that employment is always on the labour demand curve is hence consistent with optimisation in this case, in contrast to the old style Gray-Fischer-Taylor models in which the wage was set in accordance with a target level that cleared the labour market in expectation.

while the equilibrium condition on goods markets (4.3) implies

$$\int_0^1 P_t C_{it} di = \int_0^1 P_{it} Y_{it} di = P_t Y_t \tag{4.14}$$

where

$$Y_t = \frac{\int_0^1 P_{it} Y_{it} di}{P_t} = C_t$$

is real aggregate output, defined as in national income accounting.

An equilibrium for this economy is described by a vector of allocations $\{C_{jt}, M_{jt}, B_{jt}, X_{t-k}, L_{jt}, Y_{it}, P_{it}, P_t, Y_t, R_t, Q(s^{t+1} \mid s^t)\}$ for $k = 0, ..., N-1$ such that: (i) taking other sectors' variables and aggregate variables as given, consumer allocations solve the consumer's problem $\forall j$, that is, (4.7), (4.8), (4.9) and (4.10) hold $\forall j$; (ii) taking the nominal wage as given, firms' output and labour demand maximise profits according to (4.2) and (4.4); (iii) the transfers and the money supply process satisfy (4.11) and (4.12); (iv) the resource constraint (4.13) and the goods market equilibrium ((4.3) and (4.14)) are satisfied.

To solve for the model dynamics, we first calculate the deterministic steady state of the model. We then apply Blanchard-Khan [1980] methodology to the log-linearised model around that steady state.

4.4 Analytical Implications of Relative Wage Concern

In this section we provide some intuition on the how relative wage considerations may influence both the output and the inflation persistence properties of staggered wage setting.

4.4.1 The "γ-puzzle"

A crucial property of the wage setting equation postulated by Taylor is the dependence of wages on business cycle conditions. We have already highlighted this feature in Chapter 2. There we show that persistent real effects of money shocks require slow adjustment of nominal variables to output fluctuations. Since output levels feed back directly into the wage contracting equation, it immediately follows that fluctuations of output will have a small impact on prices *if and only if* the elasticity of wages with respect to output, Taylor's γ, is low. Early authors have estimated this parameter from macrodata. For the US, Taylor [1980b] estimates γ to be between 0.05 and 0.1, while Sachs [1980] estimates it to be between 0.01 and 0.07. In his numerical investigation of persistence properties of Taylor's [1980a] model, West [1988] uses two possible values for γ: 0.01 and 0.1. More recently, Phaneuf [1990] takes estimated values for γ for Canada, Germany, Italy, UK and US. He finds γ to lie between 0 and 0.32 and hence Ambler and Phaneuf [1992] calibrate $\gamma = 0.15$. Jeanne [1997] suggests that γ should lie between 0.05 and 0.2. These results suggest a value for γ around 0.1, which is consistent with the existence of a contract multiplier.

Recent research incorporating staggered wages/prices into a DGE framework, notably CKM and Ascari [1997], has opened the "black box" of the *ad hoc* parameters in the wage setting equation. Log-linearising the FOC for wage setting around a deterministic steady-state with constant money supply ($\overline{\mu} = 1$) and constant returns to scale to labour ($\sigma = 1$), the parameter γ is found to be determined by the elasticities of the marginal utilities of consumption with respect to consumption, i.e., η_C, and of labour with respect to labour, i.e., η_L, both evaluated at steady state. For example, a log-linearisation of the present model with an additively separable utility function in all its arguments and without relative wage concern gives[10]

$$\gamma = \left\{ \frac{\frac{\varepsilon}{\theta}\eta_L - \eta_C}{\varepsilon\eta_L + 1} \right\} \tag{4.15}$$

Given the existing evidence from microdata on the intertemporal elasticities of substitution of consumption $(-1/\eta_C)$ and of labour supply $(1/\eta_L)$, a sensible calibration of (4.15) gives a value of γ far too high to generate

[10]The present model without the relative wage concern term coincides exactly with Ascari's [1997] model. See Ascari [1997] for an exhaustive analysis of the persistence properties of such a model.

persistence.[11] As a conclusion, the calibration of γ based on well-established evidence from microdata is at odds with all the empirical estimates from macrodata. This is what we call the "γ-puzzle".

4.4.2 Effects of Relative Wage Concern

Can our model solve the "γ-puzzle"? We argue that this is the case. The intuition is as follows. A negative η_{RW} determines a "following" behaviour in wage setting.[12] Suppose a negative shock to the rate of growth of money. Agents want to keep their real wage in line with the existing ones. Under staggering, it generates a slower adjustment in nominal variables, that is, a degree of *endogenous stickiness*, which allows for persistence of the real effects of money shocks. In short, relative real wage concern lowers the sensitivity of nominal variables to the business cycle conditions.

The intuition can be formalised as follows. Let the utility function be separable in all its arguments and the RW_t term be linear in X_t. Then, log-linearising the resulting wage setting rule around the steady-state with

[11] A low intertemporal elasticity of substitution of labour supply means that a substantial increase in wages is required for workers to supply more labour. This makes the marginal cost to rise fast after a money shock, pushes up the nominal variables and dampens persistence.

[12] See Clark and Oswald [1996b]. η_{RW} represents the elasticity of the marginal utility of the relative wage term in the utility function with respect to the relative wage term.

$\overline{\mu} = 1$, the elasticity of wages with respect to output is

$$\gamma_{RW} = \left\{ \frac{\left\{ \frac{\frac{\varepsilon}{\theta}\eta_L - \eta_C}{\varepsilon\eta_L + 1} \right\} - \left\{ \left[\frac{\frac{\varepsilon}{\theta} + \eta_C}{\varepsilon\eta_L + 1} \right] \left[\frac{U_{RW}(.)}{-\varepsilon\, U_L(.)\, K_t\, X_t^{-\varepsilon}} \right] \right\}}{1 - \left\{ \left[\frac{\eta_{RW} + \varepsilon}{\varepsilon\eta_L + 1} \right] \left[\frac{U_{RW}(\cdot)}{-\varepsilon\, U_L(.)\, K_t\, X_t^{-\varepsilon}} \right] \right\}} \right\} \tag{4.16}$$

It is the immediately evident that γ_{RW} is decreasing in the absolute value of η_{RW}. The first term in curly brackets in the numerator corresponds to the γ arising from staggered wages, i.e., (4.15). In our model, it is complemented by additional terms incorporating the marginal utility of the relative wage term, $U_{RW}(\cdot)$, and its own elasticity η_{RW}. The inconsistency of the microfounded wage setting equations and the empirical estimates can then be solved. For this, the presence of $(-\eta_{RW})$ increasing the denominator of the expression is crucial, as it lowers the sensitivity of wages to the business cycle conditions, allows for endogenous stickiness and thus makes output persistence a likely outcome. Its quantitative implications are the focus of the remaining sections of the chapter.

4.4.3 A Comparison to FM Specification

This section completes the description of the analytics of the model by deriving the full log-linearisation of the money-wage setting rule. Our log-linearised model is somehow close to the FM contract equation. Hence, a brief comparison between the two specifications clarifies further the driving forces behind the model. Moreover, the log-linearised wage setting equation that we obtain here will play a fundamental role for the calibration of the relative wage parameters in Section 5.

We parameterise the instantaneous utility function by

$$u\left(C, \frac{M}{P}, L, RW\right) = \frac{1}{\nu}\ln\left[bC^{\nu} + (1-b)\left(\frac{M}{P}\right)^{\nu}\right] - \frac{1}{e}L^{e} + \frac{\phi}{1-\tau}\,(RW)^{1-\tau} \tag{4.17}$$

Note that the crucial $\eta_{_{RW}}$ is simply equal to $(-\tau)$ in our formulation.

A log-linearisation of (4.10) around the steady state with $\overline{\mu} = 1$ and $\beta = 1$ then yields

$$\Omega\, x_t - \frac{1}{4}\Omega\sum_{i=0}^{3} E_t p_{t+i} = \frac{1}{4}\,\Gamma\sum_{i=0}^{3} E_t(v_{t+i} - cp_t) + \gamma\frac{1}{4}\sum_{i=0}^{3} E_t y_{t+i} \tag{4.18}$$

where lower case letters denote log-deviations from steady state values and

$$\Omega \equiv \tfrac{\sigma(\varepsilon-1)[1+\varepsilon(e-1)]-\phi e\varepsilon}{\sigma(\varepsilon-1)}; \qquad \Gamma \equiv \tfrac{\phi(\tau-1)}{\sigma(\varepsilon-1)}; \qquad \gamma \equiv \tfrac{\sigma(\varepsilon-1)[\theta+\varepsilon(e-1)]-\phi e\varepsilon}{\theta\sigma(\varepsilon-1)}.$$

Ω represents the weight on the own real wage, Γ weights the relative wage concern and γ captures the sensitivity of the nominal wage with respect to the business cycle conditions, exactly as in Taylor's model.[13] The crucial novelty of the model is the presence of the relative wage concern weighted by Γ in the wage setting rule. Traditional staggered wage models, like Taylor [1980a], CKM and Ascari [1997], instead impose $\Gamma = 0$.

Our log-linearised wage setting rule could be thought as a microfounded version of that of FM. They present and estimate an *ad hoc* "*...contracting model, in which agents are concerned with relative real wages, that is data*

[13]For standard parameter values Ω, Λ and Γ are non-negative.

consistent" (FM, abstract). In FM, agents set nominal wages such that CP equals the average real contract price index expected to prevail over the life of the contract, adjusted for excess demand conditions, that is

$$cp_t = \sum_{i=0}^{3} f_i E_t(v_{t+i} + \gamma y_{t+i}) \tag{4.19}$$

Since, given the definition of the contract price in our model, $cp_t = x_t - \frac{1}{4}\sum_{i=0}^{3} E_t p_{t+i}$, we can rewrite equation (4.18) as

$$cp_t = \frac{1}{4}\frac{\Gamma}{\Omega+\Gamma}\sum_{i=0}^{3} E_t v_{t+i} + \frac{1}{4}\frac{\Gamma}{\Omega+\Gamma}\sum_{i=0}^{3} E_t y_{t+i} \tag{4.20}$$

which looks very much alike FM's formulation (4.19).

Note that there are two important differences between our microfounded wage setting equation and the one of FM.[14] First, FM define the v_{t+i} terms as the average of the existing real contract prices *including* the real contract price of the sector currently negotiating the wage. As explained in Section 4.2, we believe that our outward comparison better replicates actual relative wage concern. Second, the coefficient on the sum of v_{t+i} is not necessarily equal to unity in our model. Put differently, for equation (4.20) to match FM's formulation we need to impose $\Omega = 0$. This implies: (i) setting the

[14] A third minor difference highlights the additional insights obtained from microfoundations. FM impose the weights f_i to be decreasing linearly and estimate the slope parameter. Instead, without imposing $\beta = 1$, in our model the equivalent to the f_i terms are decreasing and have a very intuitive interpretation: they depend naturally on the discount factor β.

own real wage concern equal to zero; (ii) imposing a one-to-one following behaviour in wage setting, since a 1% change in v_{t+i} then leads to a 1% change in CP_t.

4.5 Quantitative Implications of Relative Wage Concern

4.5.1 Model Calibration

We set one period equal to one quarter and we assume that contracts last for one year ($N = 4$). The rate of growth of money is assumed to follow the stochastic process

$$\ln \mu_t = \rho \ \ln \ \mu_{t-1} + \ (1 - \rho) \ \ln \ \overline{\mu} \ + \ \xi_t \tag{4.21}$$

where ξ is a normally distributed i.i.d. mean zero shock with standard deviation $\widetilde{\sigma}_\xi$. Following CKM, we calibrate $\overline{\mu} = 1.06^{\frac{1}{4}}$ and $\rho = 0.57$.[15]

Since households can exchange contingent claims, they perfectly insure themselves against fluctuations in income by pooling resources. They will

[15]Since we are just interested in the persistence properties of the model, we actually focus only on impulse response functions to money shocks. Hence, the standard deviation of the rate of growth of money process does not play any role. In addition, in what follows, we calibrate the model as closely as possible to CKM to allow for a comparison with their results.

therefore attain the same marginal utility of consumption in every period. Given (4.17), they will enjoy the same level of consumption and real money balances in each period. Moreover, given (4.17), (4.7) implies the following money demand equation

$$\ln\left(\frac{M_t}{P_t}\right) = -\frac{1}{1-\nu}\ln\left(\frac{b}{1-b}\right) + \ln C_t - \frac{1}{1-\nu}\ln\left(\frac{R_t-1}{R_t}\right) \tag{4.22}$$

which is identical to equation (43) in CKM. Following CKM, we use Mankiw and Summers' [1986] money demand regressions, and obtain $\nu = -17.52$ and $b = 0.73$.

The parameter e determines the intertemporal elasticity of labour supply ($1/\eta_L = 1/(e-1)$). Macurdy [1981] suggests $e = 4.3$, while Pencavel's [1986] estimations place e between 3.2 and infinity. We calibrate $e = 6$ (which implies a small intertemporal elasticity of substitution of labour supply of 0.2).

For the discount factor we choose the standard value from business cycle literature, i.e. $\beta = 0.96^{\frac{1}{4}}$. We interpret our production function as a short-run production function where the level of capital is fixed. Hence, the labour share of output, i.e. σ, is set equal to 0.67. Following Hairault and Portier [1993], we calibrate $\theta = 6$.[16] Finally we calibrate α (which is just a scaling factor in this model) such that aggregate output is equal to one.

[16]There is no parameter corresponding to our θ in CKM. Since they use a CES function as technology for producing final goods from intermediate goods, it follows that their CES parameter is a technology parameter which gives the elasticity of substitution in input

4.5.2 Calibration of the Relative Wage Concern Parameters

Crucial for the analysis are the values of the parameters of the relative wage concern argument in the utility function, i.e. ϕ and τ. To our knowledge, there are no microestimates in the labour literature for these parameters. We thus proceed as follows.

Traditional staggered wage models (as Taylor [1980a], CKM or Ascari [1997]) impose $\Gamma = 0$. The empirical evidence reviewed in Chapter 2 instead suggests that wage setting behaviour is better characterized by strong following behaviour and almost pure relative wage considerations, with the level of own real wage playing a minor role, if any at all. We therefore impose $\Omega = 0$ and employ the estimates in FM to calibrate ϕ and τ. Specifically, from equation (4.20), we use the constraint $\Omega = 0$ to pin down ϕ; then use FM's estimate of γ =0.00109 to determine τ.[17] We obtain a value for ϕ of 0.76.[18] However the value of τ implied by the estimate of FM is sky-high,

---

demand.

[17]These values are extremely low and only marginally significant: the t-ratio for their Theoretically Preferable Specification (the equivalent to our benchmark case) is 1.54. For their Simplified Case (equivalent to our case B in the appendix) $\gamma = 0.00435$ and the t-ratio is 2.3.

[18]The steady state of the model imposes an upper bound on the value of ϕ equal to $\bar{\phi} = 0.84$, otherwise the nominal wage is negative.

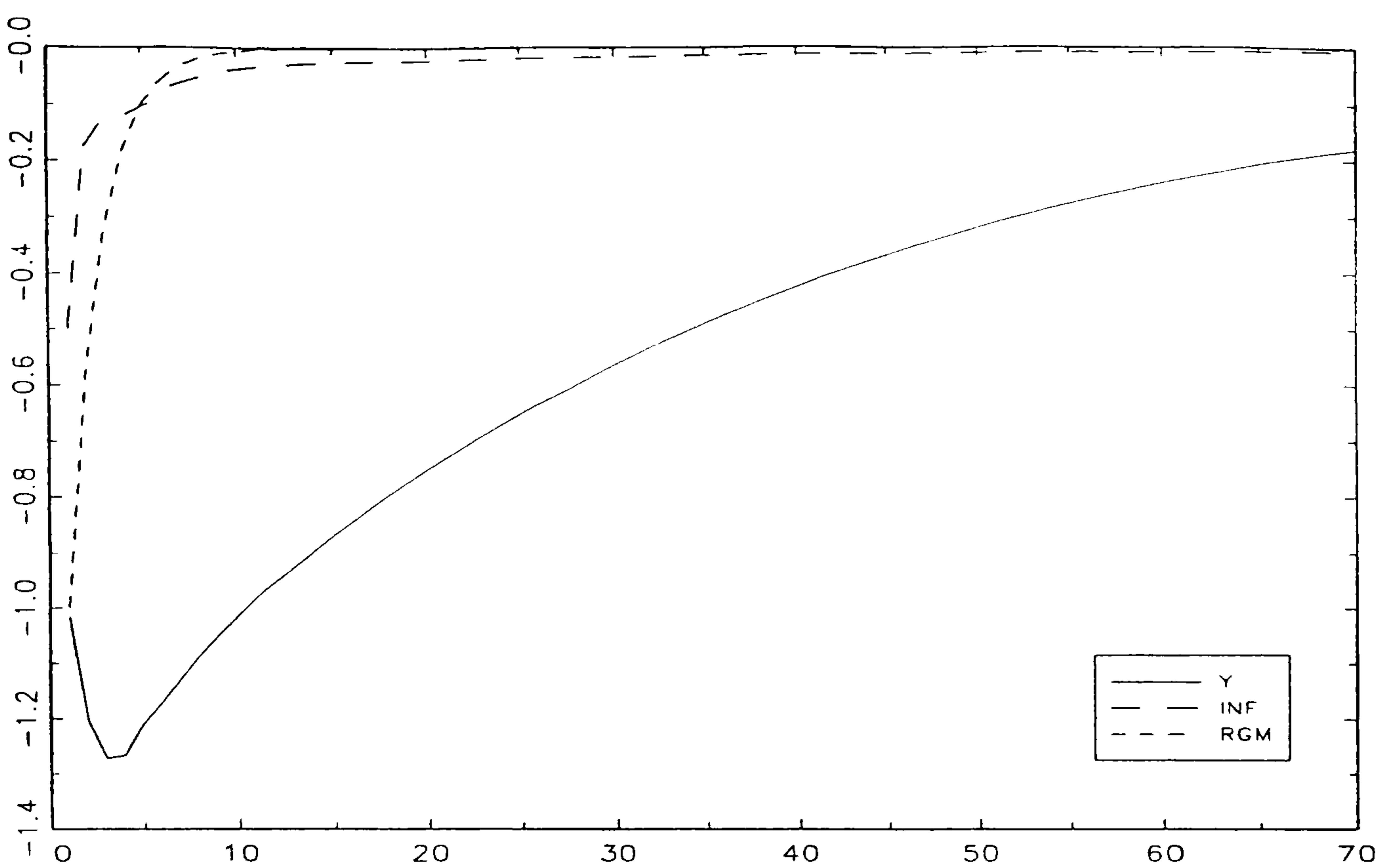

Figure 4.1 *Benchmark Case, 1% Money Shock: Output and inflation.*

$\tau = 843.9689$, $\phi = 0.7588$.

equal to 844!!.

With $\tau = 844$ the model generates a ridiculous degree of persistence, as Figure 4.1 shows. The level of output remains unrealistically below its steady state value for more than 60 periods. However, FM estimates of γ are substantially lower than the results from the empirical literature discussed in Section 4.4.1. Moreover, coming from macrodata, they are likely to pick up all the persistence in the output process. Recall that γ measures the sensitivity of wages to business cycle conditions. An alternative piece of evidence on that sensitivity, not directly linked with the persistence of output, is provided by Blanchflower and Oswald [1994]. They estimate the effects of unemployment on wages using microdata from household statatistics. Their estimates, for more than 10 industrialised countries, are consistently around "0.1" in absolute value. We have shown in Section 4.4.2 that such value is not incompatible with microfundations once relative wage concern is taken into account. So, we therefore consider as a benchmark case a value of γ equal to 0.1 and use it to pin down τ. The implied value of τ is 10.2. Table 4.1 summarizes the calibration of the model parameters.

Table 4.1: Calibrated Parameter Values

Preferences	$\beta = 0.96^{\frac{1}{4}}$; $\nu = -17.52$; $b = 0.73$; $\theta = 6$; $e = 6$
Technology	$\sigma = 0.67$
Money Growth Process	$\overline{\mu} = 1.06^{\frac{1}{4}}$; $\rho = 0.57$
Relative Wage Concern	$\phi = 0.76$; $\tau = 10.2$

Section 4.6 presents some sensitivity analysis with respect to the calibration of the relative wage concern parameters.

4.5.3 A brief review of the empirical evidence on the effects of money shocks

Before presenting our own simulation results, it might be useful to briefly report the results obtained in the already vast empirical literature trying to evaluate the dynamic effects of monetary shocks on some key economic variables. It should however be clear that reproducing all the effects that characterise the responses to money shocks is beyond the scope of our model. As mentioned before, our purpose is instead to assess whether the absence of relative wage concern in wage setting might be the reason why recent theoretical research, mainly CKM, has found that price/wage staggering is not enough to generate persistent effects in output and inflation following money shocks. Nonetheless, a brief look at the empirical evidence on the properties and magnitude of the degree of persistence that our model should aim at reproducing could be useful here.

It should also be mentioned that, despite the substantial effort and the large number of papers devoted to the analysis of the effects of money shocks, the literature has not yet converged on a particular set of assumptions for identifying the effects of an exogenous shock to monetary policy.[19] Nevertheless, there is considerable agreement about the qualitative effects of monetary policy in the sense that inference is robust across a large subset of the identification schemes that have been considered in the literature. We will report the nature of this agreement with respect to the effects on output as recently

[19]The main source of controversy concerns the identification of the shocks to monetary policy themselves. The literature has explored three main general strategies for isolating monetary shocks. The interested reader can find a through description of the different strategies in Christiano *et al.* [1998].

documented in Christiano *et al.* [1998].[20] The specific nature of this agreement can be summarised as follows: after a contractionary monetary policy shock, short-term interest rates rise; aggregate output, employment, profits, and various monetary aggregates fall; the aggregate price level responds very slowly, and various measures of wages fall, albeit by a very modest amounts. In addition, there is agreement that monetary policy shocks account for only a very modest percentage of the volatility of aggregate output. Given our purpose of analysis, we will document here in greater detail the qualitative characteristics of the identified responses of output and inflation to monetary shocks obtained from multivariate VARs, the aim being to provide some benchmark to which evaluate the degree of persistence shown in the impulse responses we are about to present.[21]

With respect to output, regardless of the monetary policy instrument chosen (the federal funds rate, non-borrowed reserves, or total reserves) with

[20]The purpose of that paper is to document the current state-of-art of the empirical literature on money shocks, so the reader is referred to such a paper for an excellent review of the different approaches and the main recent contributions to this topic.

[21]Given the large number of contributions on this literature, as can be seen from the multiple sets of impulse responses reported in Christiano *et al.* [1998] for the different identification schemes, we consider innapropiate to reproduce any responses based on a particular identifying scheme here. We refer the interested reader to that paper, and limit our comments to the qualitative features that we consider as robust in the sense that they hold regardless of the particular identifying strategy taken.

a short delay after the shock, there is a sustained decline in real GDP. Such a decline presents a severe "hump shape" as also found in earlier literature imposing different identifying schemes (see Blanchard and Quah [1989], Cochrane [1994] or Cogley and Nason [1995]). The maximal decline occurs roughly a year to a year and a half after the policy shock. Finally, output returns to values similar to the initial ones after roughly 12 to 16 quarters.

With respect to inflation, a more thorough analysis of the impulse responses of inflation has been presented in Yun [1996] and Nelson [1998]. The former paper uses a bivariate VAR with output and inflation, and identifies money shocks under the assumption that such shocks do not have long-run effects on output. The reported impulse response of inflation to such shocks exhibits an immediate jump in the impact period, followed by a gradual return to the initial value which losses statistical significance after roughly 10 quarters (see p. 349). Nelson [1998] highlights the inability of existing models of nominal rigidities and optimising behaviour to reproduce two empirical regularities involving solely nominal variables: (i) the long lag from monetary growth to inflation; (ii) the degree of inflation persistence. With respect to the latter, the author reports a first-order autocorrelation coefficient of 0.89, with higher-order autocorrelations remaining above 0.60 even at lag six (see Table 1 p. 305). That is, inflation exhibits considerable persistence. In fact, the impulse response of inflation to a 1% monetary innovation, calculated from a bivariate VAR system consisting of log M_t (St. Louis Adjusted Monetary Base (new definition)) and log P_t, reaches a peak after 13 quarters, without returning to its initial value for more than 25 quarters. This represents a degree of persistence impossible to match for the current generation of models of dynamic optimisation unless substantial restrictions are imposed on the ability of price/wage setters to reset their prices/wages.

4.5.4 Simulation Results

Figure 4.2 shows the impulse response functions for output and inflation, following a 1% negative shock to the rate of growth of money. Output jumps on impact below its steady state value and the dynamics of adjustment back to equilibrium then mimics the hump-shaped response of output mentioned in the previous section. Persistence both in output and inflation is substantial. Specifically, the effects on output last for roughly 12 quarters.[22] Our analysis hence suggests that staggered wage setting together with a relative real wage concern can be a powerful mechanism through which monetary shocks are propagated. Previous studies may have therefore failed to obtain output persistence after money shocks in a microfounded model with staggering because of their oversimplified modelling of the wage setting decisions.

[22] To measure the degree of persistence we take the quarter in which the log-deviation of output from steady state falls and remains thereafter below 0.05% in absolute value.

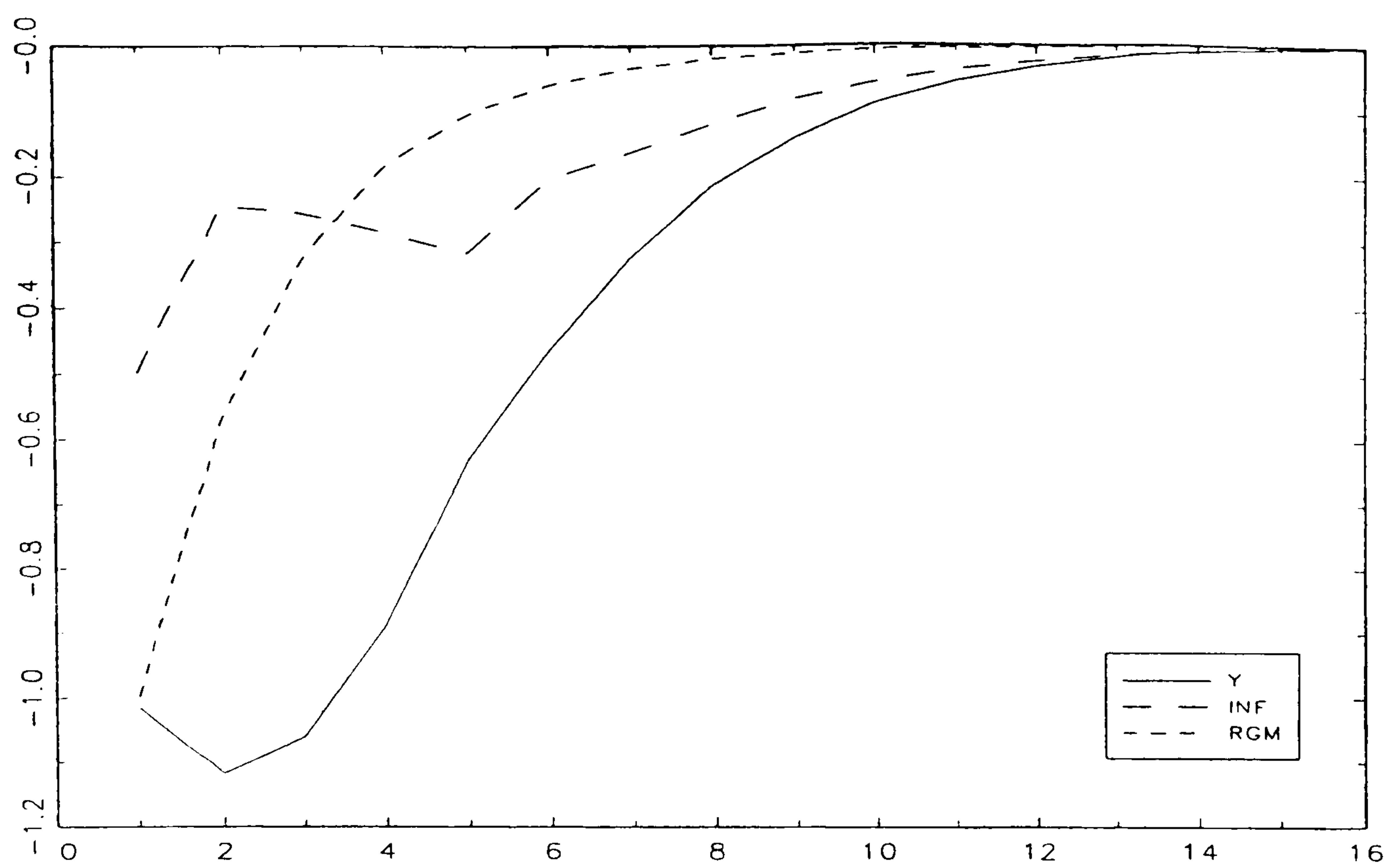

Figure 4.2 *Benchmark Case, 1% Money Shock: Output and Inflation.*

$\tau = 10.1884$, $\phi = 0.7588$.

These quantitative results show that both output and inflation persistence are a likely outcome in our framework. The aim of this chapter is to highlight the importance of the omission of relative wage considerations in wage setting for the findings of the recent literature that questions the existence of a contract multiplier. It is then important to stress the robustness of our quantitative results. The two crucial elements of our approach are the specification of the relative wage argument, RW, and the calibration of the parameters governing the relative wage concern. We present some sensitivity analysis in the next two sections.

4.6 Alternative Calibration of the Relative Wage Concern Parameters

We here provide some sensitivity analysis of the two key parameters ϕ and τ. Our aim is to show that the results do not critically depend on the specific calibration of these parameters, but are mainly due to the introduction of relative wage considerations in wage setting. This section also contributes to highlight the mechanisms at work in the model to generate persistence.

4.6.1 Sensitivity of Persistence with respect to τ.

Figures 4.3, 4.4 and 4.5 show the impulse response functions for values of τ of 31.63, 19.38 and 5.59, corresponding to values of γ of 0.03, 0.05 and 0.2 respectively. Unsurprisingly, the degree of output persistence consistently decreases with τ. With $\tau = 31.36$, the effects of money shocks on output die away after 21 quarters, if $\tau = 19.38$ after 4 years and if $\tau = 5.59$ after 9 quarters.

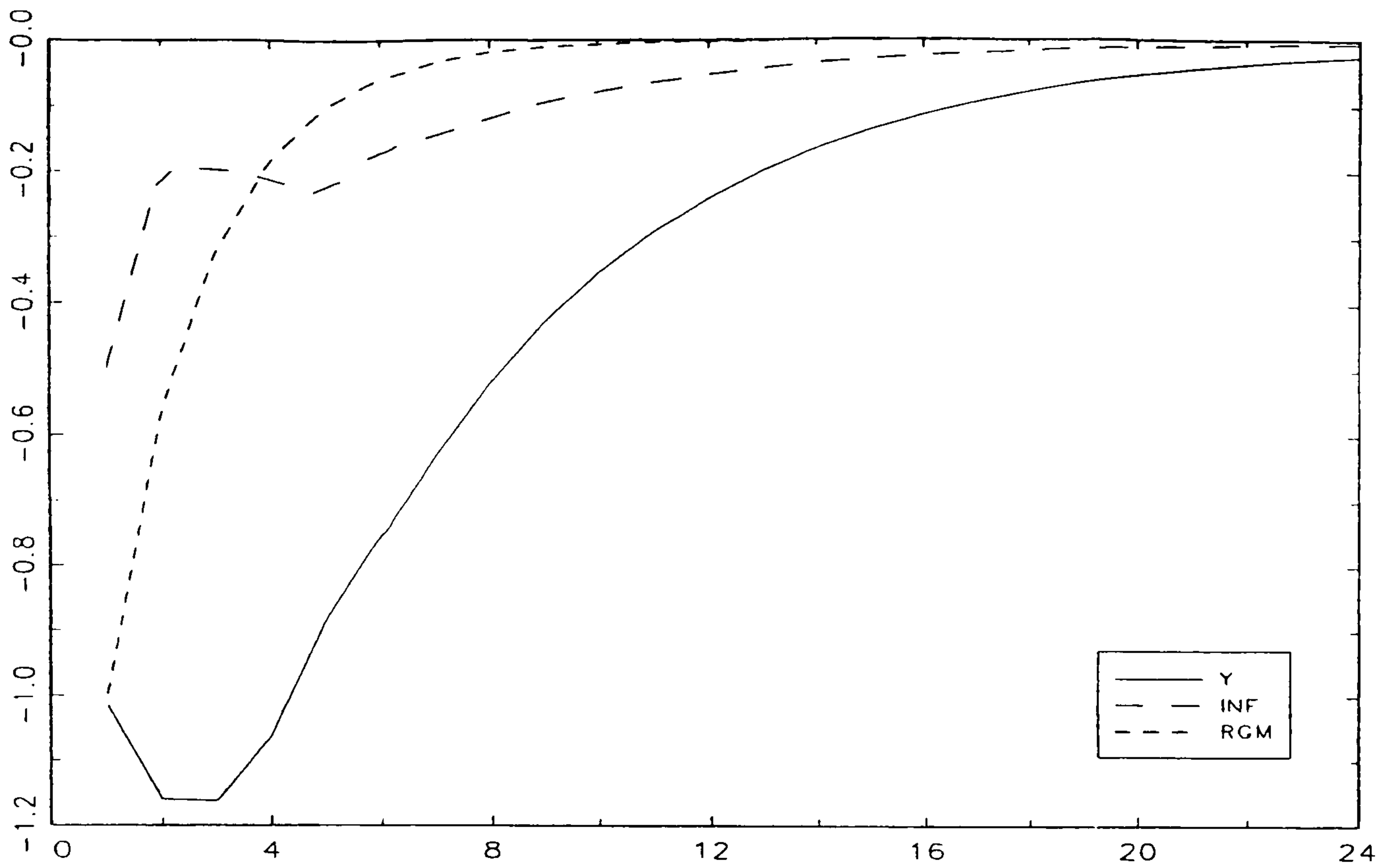

Figure 4.3 *Benchmark Case, 1% Money Shock: Output and Inflation.*

$\tau = 31.6279$, $\phi = 0.7588$.

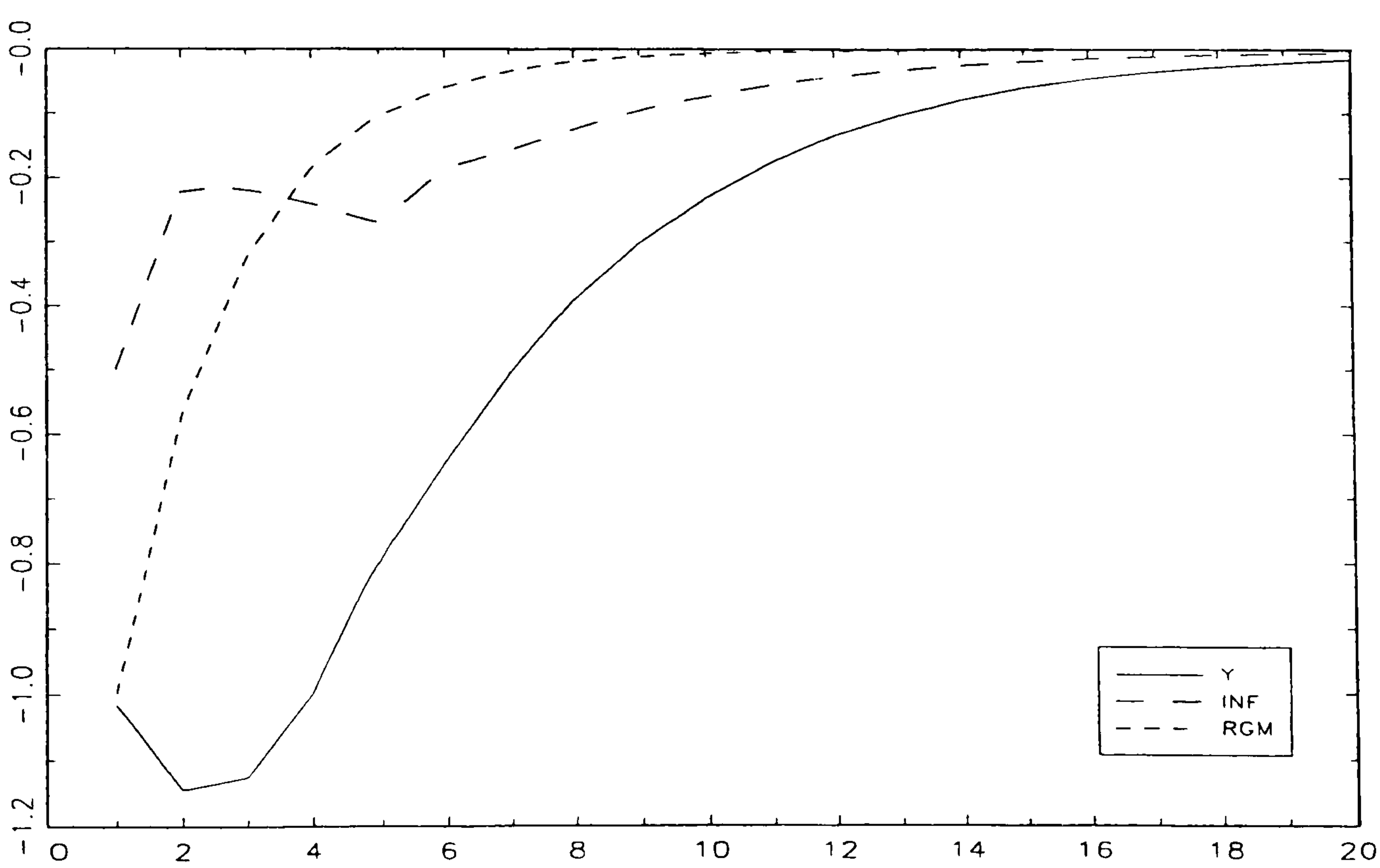

Figure 4.4 *Benchmark Case, 1% Money Shock: Output and Inflation.*

$\tau = 19.3767$, $\phi = 0.7588$.

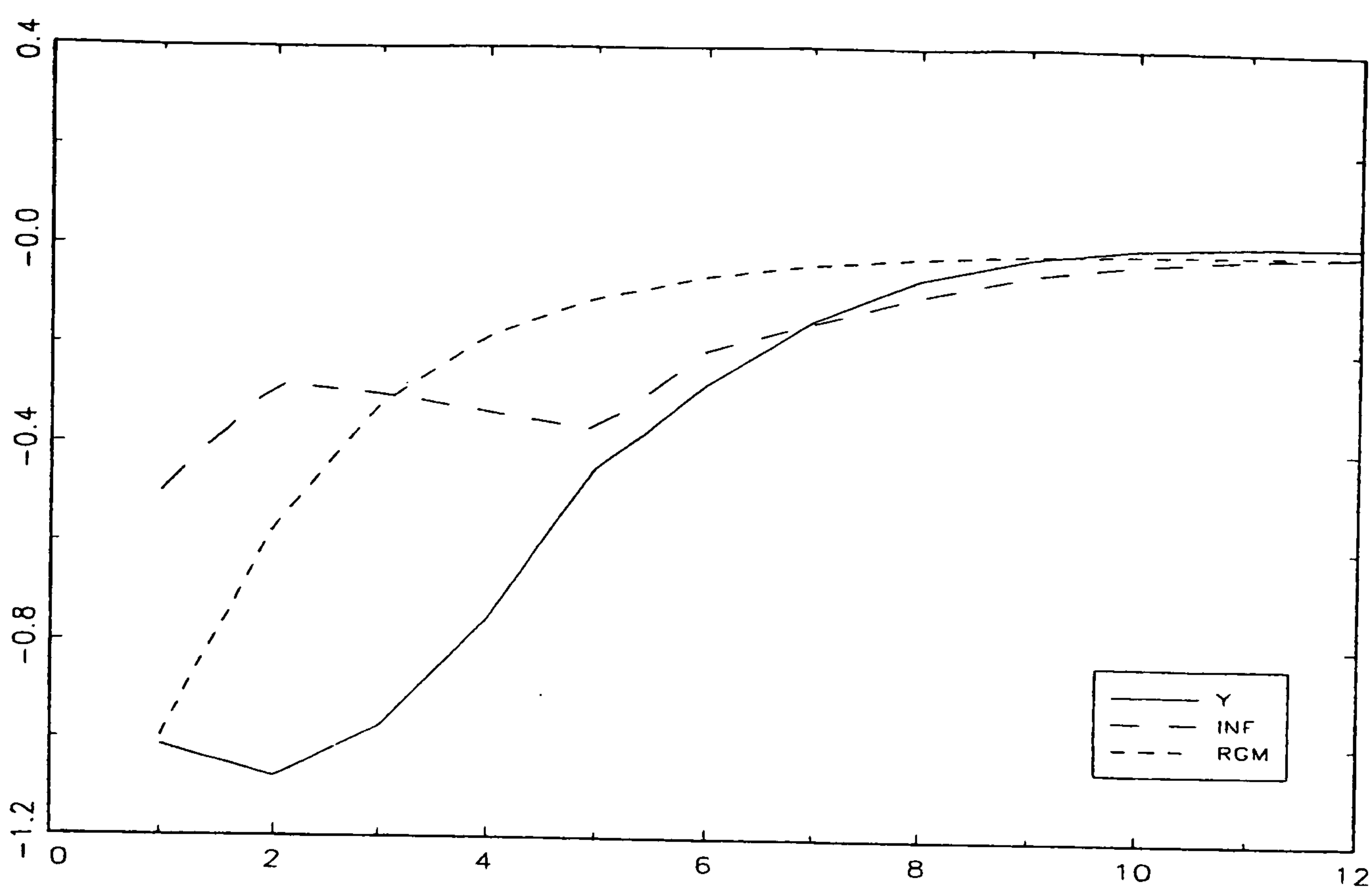

Figure 4.5 *Benchmark Case, 1% Money Shock: Output and Inflation.*

$\tau = 5.5942$, $\phi = 0.7588$.

In CKM's model: "*the persistence properties of output are highly nonlinear in γ, so that increasing γ to a small amount above 0.05 reduces persistence sharply. [...] even with values of γ as low as 0.25 output movements are not very persistent.*" (CKM [1996], p. 15). Values of γ higher than 0.25 also decrease persistence in our model. Nevertheless, the perspective changes: even with values of γ as **high** as 0.25, our staggered wage model is still able to generate output persistence. As discussed in Section 4.4.1, empirical estimates put 0.25 among the highest possible values for γ. CKM argue that only values of γ greater than one are compatible with sound microfoundations in staggered wage models. However, that may not be necessarily the case, as shown in Section 4.4.2. On the contrary, our model suggests that traditional staggered wage models omit fundamental features of the wage setting.[23] Once the relative wage concern is incorporated, it solves the data inconsistency of microfounded staggered wage models with respect to the calibration of γ. We investigate further the relationship between γ and the key parameter τ. Figure 4.6 shows the trade-off between the values of γ and τ. This relationship is highly non-linear. It implies that fairly small departures from our benchmark parameter choices can increase persistence sharply. Inflation persistence is, on the other hand, not very sensitive to changes in τ. The effects of money shocks on inflation die away in all cases after 10/12 quarters, as in the base case.

4.6.2 Sensitivity of Persistence with respect to ϕ

In the previous section, we set $\Omega = 0$ in our wage setting rule and calibrated ϕ to be 0.76. However, our money-wage setting equation (4.18) incorporates two elements: (i) the absolute real wage concern (weighted by Ω); (ii) the relative wage concern (weighted by Γ). In this section we analyse the impli-

[23] In fact, some of the results they report are quite puzzling : "*It turns out that if we assume a labor supply elasticity large enough to get γ down to 0.05, the model generates ridiculously large output effects in the impact period. [...] following a shock which raises the growth rate of money supply by 1% after one year [...] output rises of 30%.*" (CKM [1996], p. 16). This is instead not true in our model.

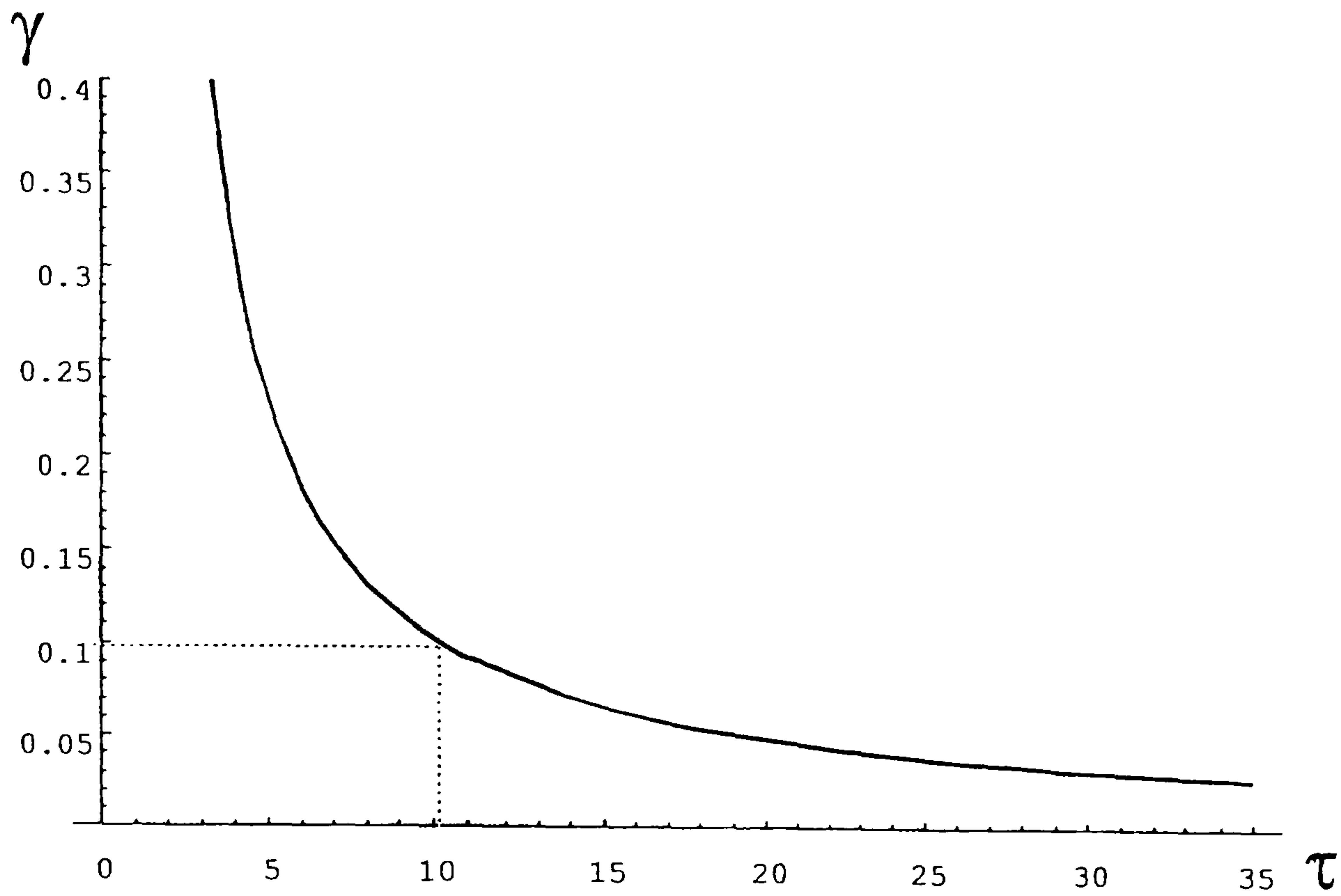

Figure 4.6 $\gamma - \tau$ *trade-off.*

cations of both relative wage and level of own real wage considerations for wage setting decisions.

Recall that equation (4.18) can be written as (4.20). We consider two alternative cases. In the first case $\Gamma = 3\Omega$. The parameter on the indexes of real wages in the other sectors $(\sum_{i=0}^{3} E_t v_{t+i})$ in equation (4.20) above is equal 3/4. Thus, there is no more one-to-one following behaviour: a 10% increase in the sum of the future indexes of real contract prices leads to a 7.5% in the current contract price, CP. The implied value for ϕ in this case is 0.62. Output and inflation persistence decrease to 9 quarters (see Figure 4.7 below).

In the second case we set $\Gamma = \Omega$. There is then equal weighting of the

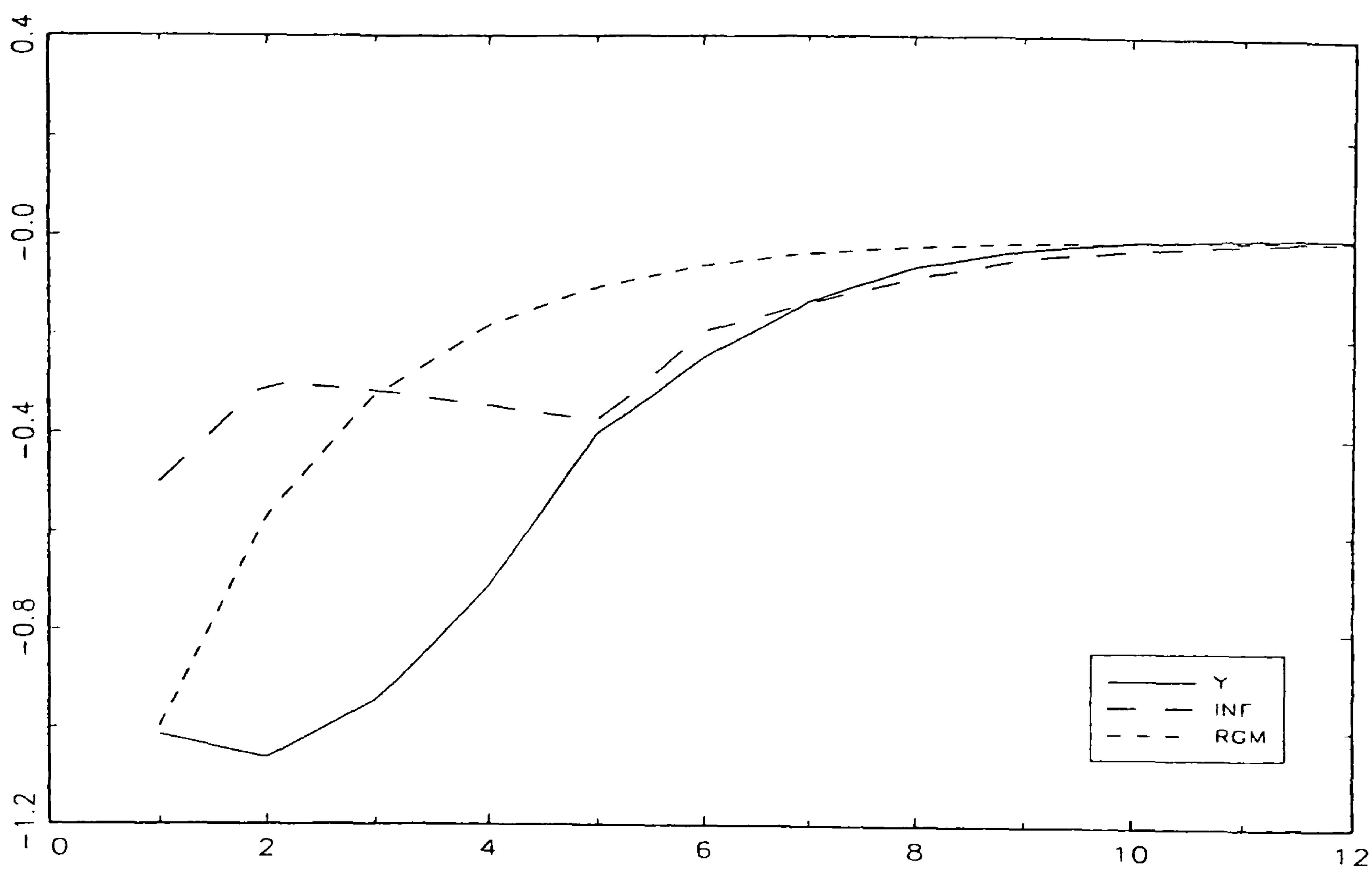

Figure 4.7 *Benchmark Case, 1% Money Shock: Output and Inflation.*

$\tau = 10.1884$, $\phi = 0.6192$.

absolute and the relative real wage considerations in wage setting. Now a 10% increase in the sum of the future indexes of real contract prices leads only to a 5% in the contract price, CP. The implied value for ϕ in this case is extremely low and equal to 0.2. Persistence in both inflation (2 years) and output (7 quarters) decreases further (see Figure 4.8).

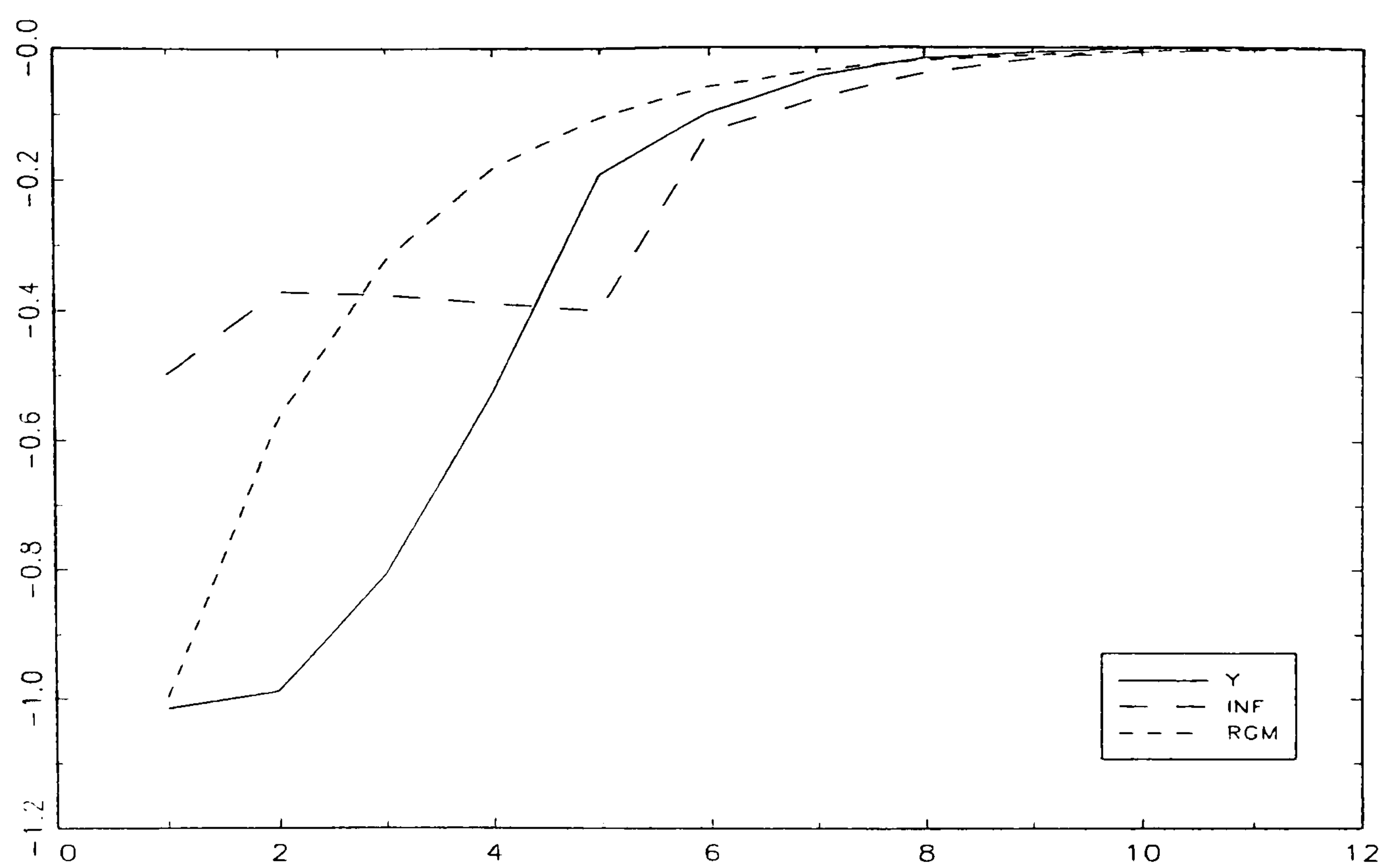

Figure 4.8 *Benchmark Case, 1% Money Shock: Output and Inflation.*

$\tau = 10.1884$, $\phi = 0.2032$.

Both output and inflation persistence therefore decrease with ϕ. The intuition is simple. If $\Omega = 0$ wage setting is mainly influenced by relative wage considerations. Persistence is then a likely outcome. Yet, as Ω increases, note that we get back to Taylor's model, that we already know generates neither output nor inflation persistence.

4.6.3 Sensitivity of Persistence with respect to σ

A final remark concerns the sensitivity of output and inflation response to σ. Our stylised production function should be taken as a short-run production function where capital is fixed. We thus calibrate $\sigma = 0.67$. This implies $(1-\sigma)/\sigma \simeq 0.5$. Hence a 10% increase in output automatically leads to a 5%

increase in prices. However, factor hoarding and inventory stocks may limit the impact of increased output on prices, leading to nearly constant returns to scale in the short-run, that is, $\sigma \simeq 1$. For illustrative purposes, Figure 4.9 shows the impulse responses of output and inflation for $\sigma = 1$.[24]

Inflation becomes much more sluggish: it peaks after 5 quarters and then gradually returns to its steady state level. As a result, the shape of the impulse response function for output also changes: after 6 quarters from the shock the economy would enter a little expansion which peaks after 8 quarters. This shows how this model can generate strong inflation persistence in contrast to most monetary dynamic general equilibrium macromodels (see Nelson [1998]).

4.7 Alternative Specifications of the Relative Wage

We here consider two additional definitions of the value of a contract and hence of RW. We also drop the distinction between the indexes s and t introduced before for explanatory purposes. We highlight the differences on the RW_t^j faced by the union j arising in these cases so we also drop the

[24]In this case, some values of the parameters change: $\tau = 10.67$ (to keep $\gamma = 0.1$) and $\phi = 4.2$ (to keep $\Omega = 0$). Note that also the upper value on ϕ changes, i.e. $\overline{\phi}$ is now equal to 4.82: the value of ϕ above is thus still consistent.

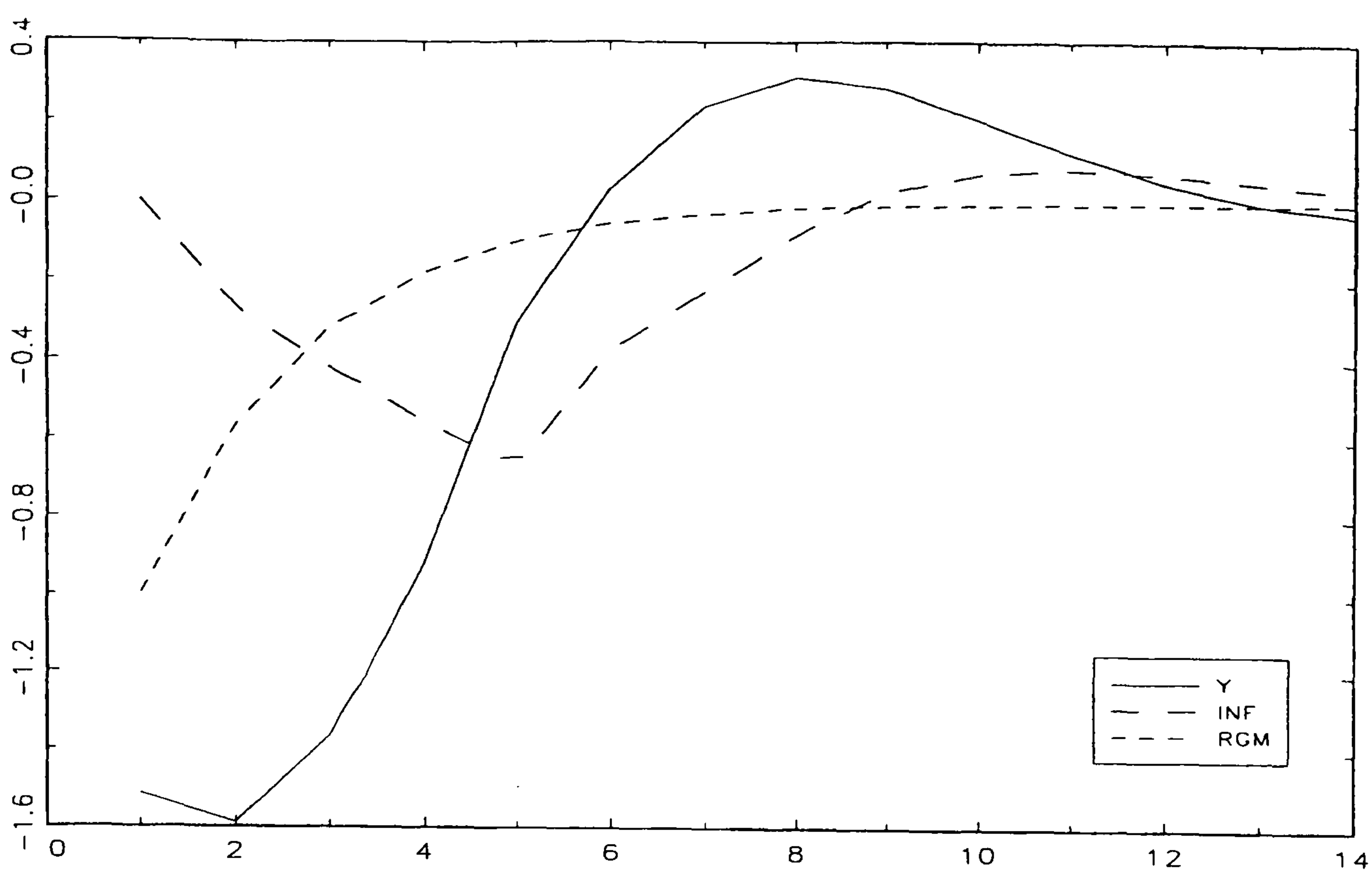

Figure 4.9 *Benchmark Case, 1% Money Shock: Output and Inflation.*

$\sigma = 1$, $\tau = 10.7$, $\phi = 4.2$.

superscript j.

4.7.1 Case A: *Current Value Relative Real Wage Concern*

In this case agents compare the real wage they earn in period t with the average of the real wages earned by the other workers *in period t*. Then all the nominal wages are deflated by the same price index P_t. It follows that the price level cancels out in the definition of RW_t and we are left only with nominal wages. Hence, in every period the wage-setters behave as comparing their "money wage" with the average "money wage" of the *other* sectors. Then,

$$CP_t = X_t \ ; \quad RW_t = \frac{X_t}{(1/3)(X_{t-3} + X_{t-2} + X_{t-1})} \ .$$

4.7.2 Case B: *Simplified Relative Real Wage Concern*

Workers care about the relative real wage unions manage to attain at the negotiation table. CP is therefore defined as the money wage deflated only by the aggregate price level in the period the wage was negotiated. that is:[25]

$$CP_t = \frac{X_t}{P_t} \ ; \quad RW_t = \frac{X_t/P_t}{(1/3)\left(\frac{X_{t-3}}{P_{t-3}} + \frac{X_{t-2}}{P_{t-2}} + \frac{X_{t-1}}{P_{t-1}}\right)} \ .$$

To sum up, in Case A workers are comparing their real wage period by period, in Case B they compare the real wage they manage to attain at the time they negotiated. In the case presented in the main text, our benchmark case, they instead compare their real wage over the whole life of the contract.

[25] Suppose a union negotiates in period t and succeeds to get a real wage X_t/P_t in period t. Then, in the next period, i.e. $t+1$, another union will negotiate a new wage. This union does not want to leave the negotiation table with a real wage for that period lower than the one negotiated last period by the previous union. In other words, the real wage the unions obtain in the negotiation is seen by the members as a sign of their bargaining power. This approach to the wage bargaining process implies a degree of myopic behaviour from the union since the wage contract lasts four periods. Even if theoretically unsatisfactory, this behavioural hypothesis: (i) could be interpreted as a simplified case of the one considered in the main text; (ii) it is probably not far from actual unions' behaviour.

Figures 4.10 and 4.11 present the impulse responses to a 1% money shock for these two additional cases. Case A (the Current Value Real Wage Concern) exhibits the lowest degree of output persistence equal to 11 quarters. Persistence increases to 18 quarters in Case B (the Simplified Relative Real Wage Concern)[26], above that of our benchmark case.

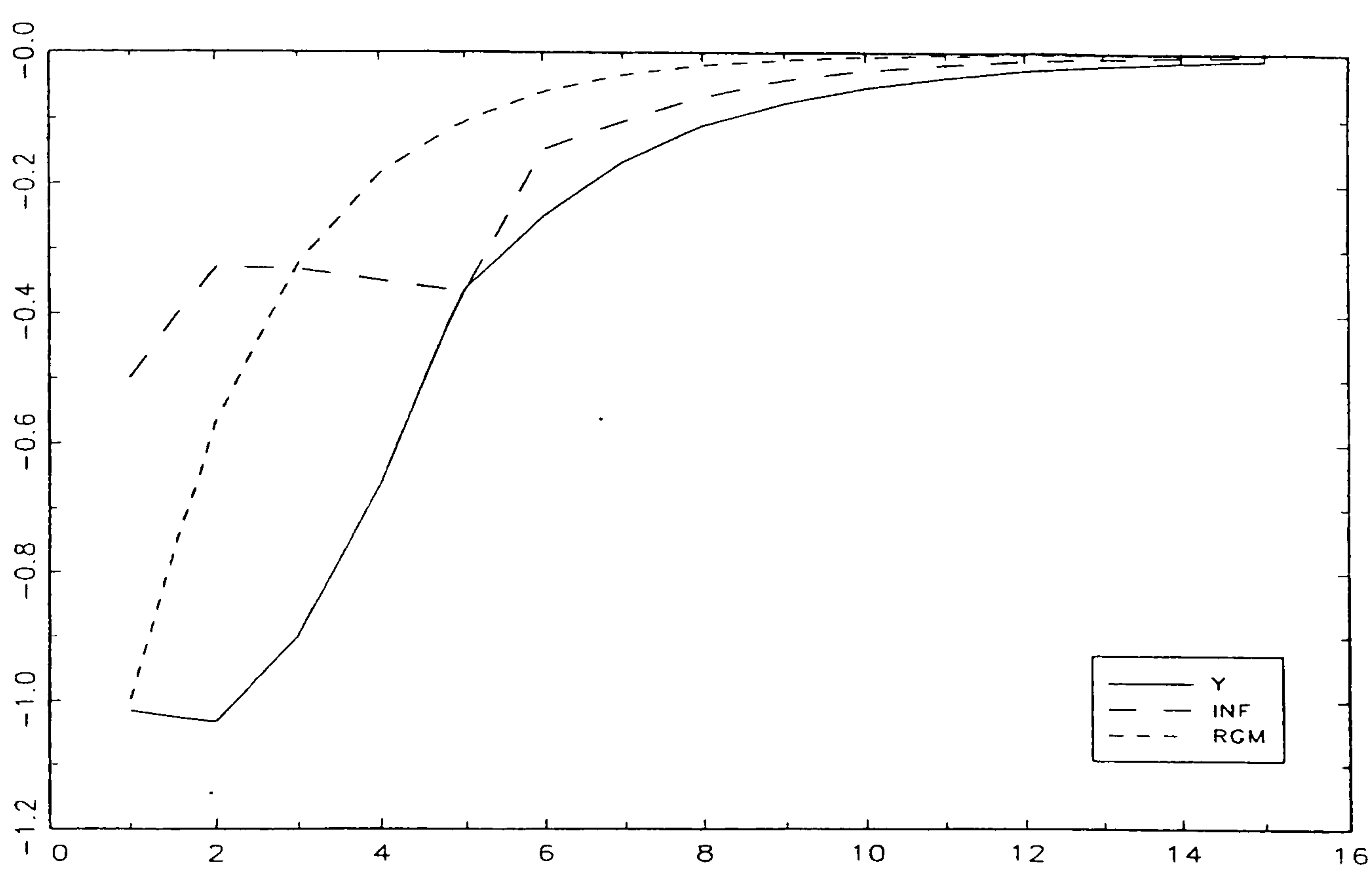

Figure 4.10 *Current Value Relative Wage Concern, 1% Money Shock:*

$\tau = 10.1884,\ \phi = 0.7588.$

[26]After ten quarters, output actually lies above the steady state value.

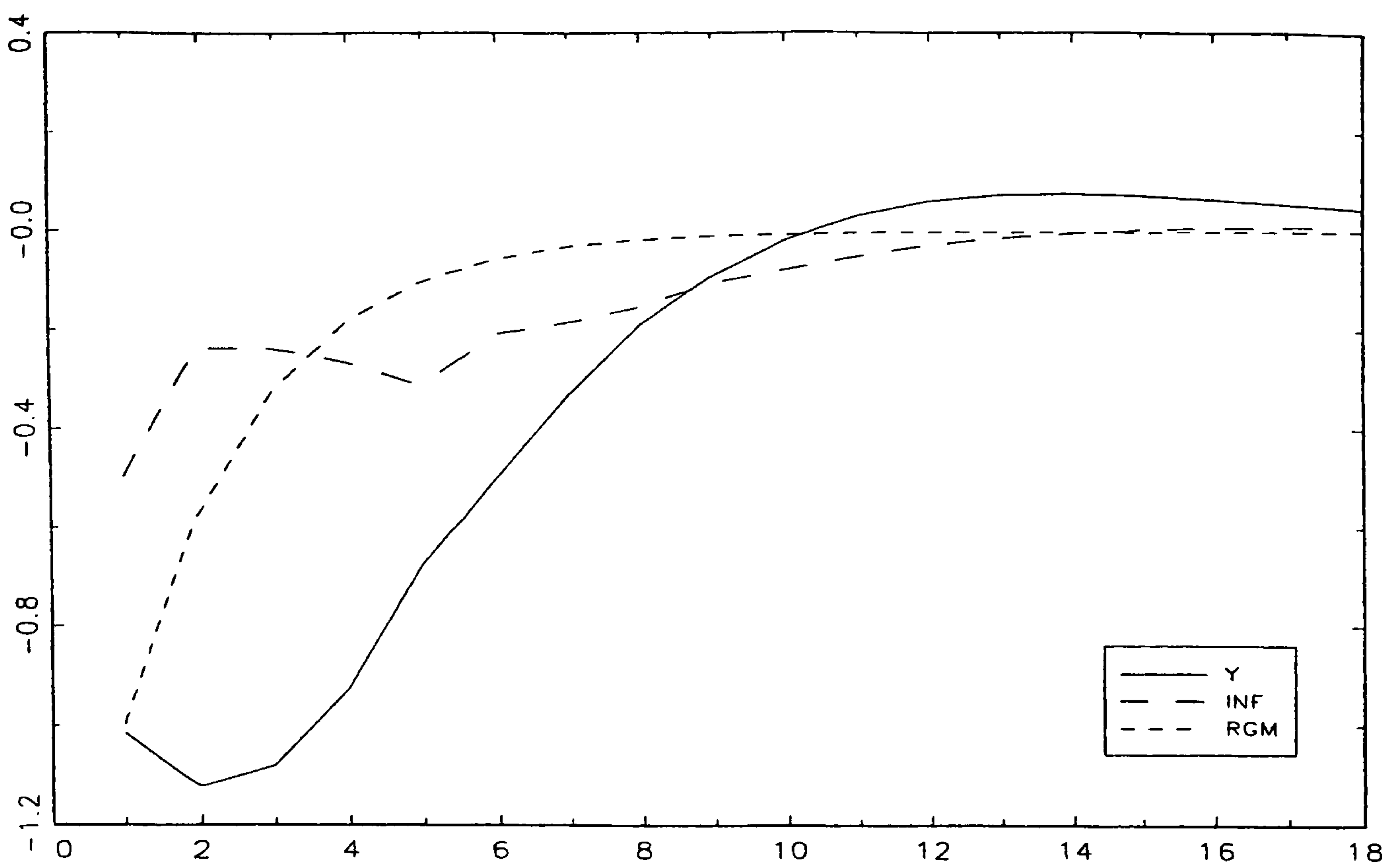

Figure 4.11 *Simplified Relative Real Wage Concern, 1% Money Shock:*

$\tau = 10.1884,\ \phi = 0.7588$

There is an intuitive reason for those differences. Case A implies the lowest order of dynamics in the model, since the price level is absent from CP. Agents look backward the same degree they look forward, but both these degrees are limited with respect to the two other cases. That is, substituting the definitions of CP and the equation for the price level[27] in equation (4.18), the highest lagged nominal wage term is x_{t-3}, while the highest lead nominal wage term is x_{t+3}. The dynamics instead goes from x_{t-6} to x_{t+3} in Case B in this section and from x_{t-6} to x_{t+6} in the Theoretically Preferable Case presented in the main text. In fact, in the Simplified Case, the price level

[27] The log-linearised formula for the price level is $p_t = \left(\frac{1-\sigma}{\sigma}\right) y_t + \sum_{i=0}^{3} q^i x_{t-i}$ where $q^i = \mu^{i(\varepsilon-1)} / \sum_{i=0}^{3} \mu^{i(\varepsilon-1)}$.

enters the specification of CP and hence, since V_t includes CP_{t-3}, X_{t-6} enters equation (4.18). However, since future prices do not enter the specification of CP_t, V_{t+3} brings in only p_{t+3} and hence x_{t+3}. In the theoretically preferable case, instead, agents are less myopic and CP includes future prices through $\overline{p}$. It follows that v_{t+3} depends on $\overline{p}_{t+3}$ and hence x_{t+6}. To sum up, in Case A agents basically care about their relative nominal wages over the length of the contract and hence the order of the dynamics is limited with respect to the other two cases, since the price level does not enter CP. In Case B agents are only concerned about the real wage attained in the negotiation period and hence they myopically look backward more than they look forward. In our benchmark case agents instead compare relative real wages over the whole length of the contract and hence look backward the same degree they look forward. This implies a higher degree of inertia in Case B with respect to our benchmark case and hence an higher degree of persistence, as shown in the figures.[28]

[28]Higher dynamics do not necessarily imply higher persistence. It mainly depends on the relative weights on backward *vs* forward looking variables. Hence, it seems that the relative weight of backward and forward looking variables is not the same in the three models. This suggests that the different specifications do not simply spread the same relative weights over higher order dynamics.

4.8 Conclusions

We have reconsidered the presence of a contract multiplier as a potential nominal propagation mechanism in staggered wage economies. Recent research has questioned the existence of such a multiplier because their microfounded staggered wage models have failed to generate persistence of the effects of money shocks on output and inflation persistence. We built a DGE model with staggered wage setting and relative real wage concern on the part of the workers and found that this combination of nominal and real rigidities generates a substantial amount of endogenous stickiness, even with a very inelastic intertemporal elasticity of labour supply. As a result, output and inflation persistence are a likely outcome in our framework. Moreover, our results show that failing to account for this specific source of real rigidity might be an important weakness of previous staggered wage models, responsible for their negative results concerning output and inflation persistence.

The relative wage concern on the part of workers is the key feature of the model. The notion of relative wage concern is not new for economists. It goes back a long way, at least to J.M. Keynes, and has substantial support from empirical work. Introducing relative wage concern in the analysis places our work within the growing economic literature that drops the assumption of methodological individualism to explain some puzzles that standard economic framework has trouble with. The explicit account of relative wage concern allows us to provide clear analytical insights of its effects and rely on a key parameter to assess the importance of its omission for the quantitative results of Chari *et al.* [1996]. Our analysis can be seen as a first step towards a deeper understanding of the effect of relative wage concern on the monetary propagation mechanism.

Our analysis also highlights the mechanism by which our specific combination of nominal and real rigidities contributes to the presence of endogenous stickiness. We analyse this mechanism by focusing on the elasticity of the wages with respect to the business cycle conditions, i.e., the famous parameter γ in Taylor's wage setting rule specification. Only for relatively low values of that parameter does output persistence arise (in the order of 0.05, the benchmark Taylor's estimate). From a log-linearized version of the wage setting equation around a deterministic steady-state with constant money supply, CKM have proved the dependence of γ on the intertemporal elasticity of labour supply and intertemporal elasticity of consumption. According to well-established micro evidence, CKM calibrated $\gamma = 1.22$ for their price-staggering model, in sharp contrast to numerous empirical studies that place it around 0.1. They conclude by discarding completely staggered wages as relevant propagation mechanism *"...because γ is necessarily greater than 1"*. In our staggered-wage model, from a log-linearized version of the wage setting rule once relative wage concern is introduced in the analysis, we instead show that $\gamma \geqslant 1$ *is **not** necessarily the case.* Nor are the estimated values of the empirical literature incompatible with sound microfoundations at all. High values of γ may well arise, however, from an oversimplified account of the wage setting decisions.

Our model delivers a substantial amount of persistence both in output and inflation. This result is very robust to different specifications of the model. Moreover, we derive a simple relationship between the key parameter and the value of γ. This relationship is highly non-linear. It implies that fairly small departures from our conservative parameter choices can increase persistence sharply. Given the substantial amount of empirical evidence supporting a relative wage concern on the part of workers, our analysis leads us to conclude that this may well be the missing piece in the money shocks persistence puzzle.

4.9 Appendix: The Solution Method and the GAUSS Codes

The procedure used to simulate the model is the one employed by King *et al.* [1988] and has become fairly standard in the related literature. We would like to thank Dr. Morten Ravn who gave a course at Warwick University on simulation methods in the summer of 1997. Our codes are largely based on the sample programmes supplied during the course.

The procedure rests on the following steps: (i) solve for the steady state of the model; (ii) linearise the model around the steady state;[29] (iii) build the dynamic system distinguishing among control, state (or predetermined at period t), and costate variables (or non-predetermined at period t); (iv) apply the Blanchard and Kahn [1980] methodology for solving linear dynamic system with forward-looking variables to the dynamic system just built; (v) simulate the model to produce impulse response functions. The last three stages correspond to the three GAUSS codes below which are the codes we used to simulate the Case presented in the main text.[30]

[29] Given that the model deals with nominal variables and that the money supply follows a certain rate of growth, we need to make the system stationary. We did that dividing all period t variables by M_{t-1}.

[30] Even if what distinguishes Case A and Case B in the second Appendix from the case presented in the main text is only the definiton of CP, the dynamic systems are

The first code implements step (iii) and part of (iv). The dynamic system for this particular version of our model is made up by 29 control variables (Y_t, Y_{t+1}, Y_{t+2}, Y_{t+3}, Y_{t+4}, Y_{t+5}, P_t, P_{t+1}, P_{t+2}, P_{t+3}, P_{t+4}, P_{t+5}, $Z_{t,}$ Z_{t+1}, Z_{t+2}, Z_{t+3}, Z_{t+4}, $\overline{P}_t$, $\overline{P}_{t+1}$, $\overline{P}_{t+2}$, CP_t, CP_{t+1}, CP_{t+2}, CP_{t-3}, CP_{t-2}, CP_{t-1}, $\overline{P}_{t-3}$, $\overline{P}_{t-2}, \overline{P}_{t-1}$), 6 state variables ($P_{t-3}$, P_{t-2}, P_{t-1}, X_{t-3}, X_{t-2}, X_{t-1}), 7 costate variables (X_t, X_{t+1}, $X_{t+2}X_{t+3}$, X_{t+4}, X_{t+5}, Z_{t+5}) and one exogenous variable (μ).[31] The code is then divided in several parts: (i) defines the parameter values and all of the auxiliary variables we find convenient to build so as to build the equations later; (ii) defines the steady state relations and other useful variables based on the steady state values; (iii) defines the dynamic system, defining the equations for the control, state and costate variables plus other variables one wants to build for interest (e.g., inflation); (iv) transforms the model according to the algorithm proposed by Blanchard and Kahn.

The second code calculates the optimal decision rules which are the solution for the perfect foresight model. They express all the variables as function of the predetermined (state) variables and the exogenous variables.

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quite different in their order. The different definitions of CP imply different lag and lead structure and hence a different number of state and costate variables in the system. However, the codes for Case A and Case B are very similar to the codes for our benchmark case, once the corresponding log-linearised dynamic system is built. That is the reason why those codes are not presented here.

[31] All the variables are normailsed according to what reported in footnote 29.

We suppose that households decide about the wage before the realisation of the shock, while the equilibrium values of the other variables in the model are defined after the realisation of the shock. Since wages are set before the realisation of the shock, we can easily calculate the impact effect of a shock. Then, for the period thereafter, we can use the optimal decision rules to calculate the adjustment dynamics of the model from the point in which the system is pushed to by the impact effect. Since we are just interested in the impulse response function of the model, this procedure is applicable. The impulse responses are plotted thorough the third code.

FIRST CODE

```
CLEAR ALL;
@ DIMENSION OF CONTROL SPACE (NC), PREDETERMINED (NK),AND NON-PREDETERMINED
VECTORS (NS),EXOGENEOUS STATE VECTOR (NN) @
@ ORDERING OF VARIABLES:
PREDETERMINED=ENDOGENOUS STATE=K :
PIII | PII | PI | XIII | XII | XI
NON-PREDETERMINED = COSTATES = L:
X | X1 | X2 | X3 | X4 | X5 | Z5
EXOGENOUS VARIABLES=N:
RGM
FLOWS=CONTROLS=C:
Y | Y1 | Y2 | Y3 | Y4 | Y5 | P | P1 | P2 | P3 | P4 | P5 | Z | Z1 | Z2 | Z3 | Z4 | AP | AP1 | AP2 | CP
| CP1 | CP2 | CPIII | CPII | CPI | APIII | APII | API @
@ DIMENSION AND NAME OF CONTROL SPACE (NC), PREDETERMINED (NK), AND NON-
PREDETERMINED VECTORS (NL), EXOGENEOUS STATE VECTOR (NN) @
NC=29;NK=6;NL=7;NN=1;
NAMEC="Y"|"Y1"|"Y2"|"Y3"|"Y4"|"Y5"|"P"|"P1"|"P2"|"P3"|"P4"|"P5"|
"Z"|"Z1"|"Z2"|"Z3"|"Z4"|"PA"|"PA1"|"PA2"|"CP"|"CP1"|"CP2"|
"CPIII"|"CPII"|"CPI"|"APIII"|"APII"|"API"; @ CONTROLS @
NAMEK="PIII"|"PII"|"PI"|"XIII"|"XII"|"XI"; @ ENDOGENOUS STATES @
NAMEL="X"|"X1"|"X2"|"X3"|"X4"|"X5"|"Z5"; @ COSTATES @
NAMEE="RGM"; @ EXOGENOUS STATES (SHOCKS) @
@ ========================================= @
@ ECONOMIC PARAMETER VALUES @
@ ========================================= @
@TRANSITION MATRIX@
RAA=0.57;
RHO=ZEROS(NN,NN);
RHO[1,1]=RAA;
RGMBAR=1.06^(0.25);
```

```
NUBAR=1/RGMBAR;
T=6;
E=6;
GAM=0.1;
S=0.67;
B=0.73;
V=-17.52;
BETA=0.96^(0.25);
EPS=T/(S+(1-S)*T);
ZBAR=((B*(1-BETA*NUBAR))/(1-B))^(1/(V-1));
U1=1+((1-B)/B)*ZBAR^V;
ZNU1=((B*(1-BETA))/(1-B))^(1/(V-1));
ASS=1+((1-B)/B)*ZNU1^V;
PSI=(S*(EPS-1)*(EPS*(E-1)+1))/(EPS*E*ASS);
TAU=1+((EPS*E*(T-1))/(GAM*T*(EPS*(E-1)+1)));
@case gamma=3omega@
@psi=3*(s*(eps-1)*(1+eps*(e-1)))/((tau-1)*ASS+3*e*eps*ASS);@
@case gamma=omega@
@psi=(s*(eps-1)*(1+eps*(e-1)))/((tau-1)*u1+3*e*eps*u1);@
G0=(NUBAR+NUBAR^2+NUBAR^3)^(-1);
G1=(1+NUBAR^2+NUBAR^3)^(-1);
G2=(1+NUBAR+NUBAR^3)^(-1);
G3=(1+NUBAR+NUBAR^2)^(-1);
VOBAR=1;
V1BAR=1;
V2BAR=1;
V3BAR=1;
FNU=(VOBAR)^(1-TAU)+BETA*(V1BAR)^(1-TAU)+
BETA^2*(V2BAR)^(1-TAU)+BETA^3*(V3BAR)^(1-TAU);
A11=1+BETA*NUBAR^(-E*EPS)+(BETA*NUBAR^(-E*EPS))^2+(BETA*NUBAR^(-E*EPS))^3;
A12=1+BETA*NUBAR^(RO)+(BETA*NUBAR^(RO))^2+(BETA*NUBAR^(RO))^3;
A1=A11/A12;
A2=FNU/A12;
A3=1+NUBAR^RO+NUBAR^(2*RO)+NUBAR^(3*RO);
A4=4*S*(EPS-1)-PSI*A3*A2*U1;
PUB=4*S*(EPS-1)/(A3*A2*U1);
A7=1+RGMBAR^EPS+RGMBAR^(2*EPS)+RGMBAR^(3*EPS);
FBN=1+(BETA/NUBAR)+(BETA/NUBAR)^2+(BETA/NUBAR)^3;
JB0=FBN^(-1);
JB1=BETA/(NUBAR*FBN);
JB2=((BETA/NUBAR)^2)/FBN;
JB3=((BETA/NUBAR)^3)/FBN;
JB4=(JB1+JB2+JB3)*RAA+(JB2+JB3)*(RAA^2)+JB3*(RAA^3);
PIP=((4/3)^(-E))*(A7^E)/(A3*A1);
DI=1/E;
A5=(DI*E*EPS*U1)/(A4);
ALPHA=(4^(S-S/RO))*(A5^(S/E))*(A3^(S/RO+S*(1-E)/E))*(A1^(S/E));
EBAR=RGMBAR/ZBAR;
@ ======================================== @
@ STEADY STATE CALCULATIONS @
@ ======================================== @
@ AGGREGATE VARIABLES @
XBAR=4*S*(A5^(1/E))*EBAR*A3^((1-E)/E)*A1^(1/E);
PBAR=ALPHA^(-1)*S^(-S)*(0.25)^(S/RO)*EBAR^(1-S)*XBAR^S*A3^(S/RO);
YBAR=EBAR/PBAR;
RBAR=1/(BETA*NUBAR);
LAMBAR=1/(PBAR*YBAR*U1);
APBAR=PBAR*FNU*FBN;
CPBAR=XBAR/APBAR;
@ SECTORS' VARIABLES @
XIBAR=XBAR*NUBAR;
XIIBAR=XIBAR*NUBAR;
XIIIBAR=XIIBAR*NUBAR;
X1BAR=XBAR*RGMBAR;
X2BAR=X1BAR*RGMBAR;
X3BAR=X2BAR*RGMBAR;
X4BAR=X3BAR*RGMBAR;
X5BAR=X4BAR*RGMBAR;
PIBAR=PBAR*NUBAR;
PIIBAR=PIBAR*NUBAR;
PIIIBAR=PIIBAR*NUBAR;
```

```
P1BAR=PBAR*RGMBAR;
P2BAR=P1BAR*RGMBAR;
P3BAR=P2BAR*RGMBAR;
P4BAR=P3BAR*RGMBAR;
P5BAR=P4BAR*RGMBAR;
APIBAR=APBAR*NUBAR;
APIIBAR=APIBAR*NUBAR;
APIIIBAR=APIIBAR*NUBAR;
AP1BAR=APBAR*RGMBAR;
AP2BAR=AP1BAR*RGMBAR;
XPBAR=XBAR/PBAR;
WBAR=(XBAR+XIBAR+XIIBAR+XIIIBAR)/(4*PBAR);
PABAR=(4*EBAR/A3)^(1-S)*ALPHA^(-1)*S^(-S)*XBAR^S;
PBBAR=PABAR*NUBAR^(EPS*S/T);
PCBAR=PABAR*NUBAR^(2*EPS*S/T);
PDBAR=PABAR*NUBAR^(3*EPS*S/T);
YABAR=ALPHA*A5^(-S/E)*A3^(-S/E)*A1^(-S/E);
YBBAR=YABAR*RGMBAR^(EPS*S);
YCBAR=YABAR*RGMBAR^(2*EPS*S);
YDBAR=YABAR*RGMBAR^(3*EPS*S);
LABAR=A5^(-1/E)*A3^(-1/E)*A1^(-1/E);
LBBAR=LABAR*RGMBAR^EPS;
LCBAR=LABAR*RGMBAR^(2*EPS);
LDBAR=LABAR*RGMBAR^(3*EPS);
LBAR=(1/4)*LABAR*A7;
/*
@ PARAMETERS MODEL AND WAGE RULE @
@ LHS WAGE RULE @
*/
K1=-RO/A12;
K2=BETA*K1*NUBAR^RO;
K3=BETA^2*K1*NUBAR^(2*RO);
K4=BETA^3*K1*NUBAR^(3*RO);
K5=((EPS/T)-1)/A12;
K6=BETA*K5*NUBAR^RO;
K7=BETA^2*K5*NUBAR^(2*RO);
K8=BETA^3*K5*NUBAR^(3*RO);
K9=-K2-K3-K4;
K10=-K3-K4;
K11=-K4;
K29=-(V*(1-BETA*NUBAR)*ZBAR/(U1*A12));
K30=BETA*NUBAR^(1-EPS)*K29;
K31=BETA*NUBAR^(1-EPS)*K30;
K32=BETA*NUBAR^(1-EPS)*K31;
@ RHS WAGE RULE@
OM1=DI*E*EPS*(ALPHA*S)^(E*EPS)*ALPHA^(-E*EPS/T);
OMBAR1=OM1*PBAR^(E*EPS)*YBAR^(E*EPS/T)*A11;
OMBAR2=XBAR^(E*EPS)*PSI*FNU;
OMBAR=OMBAR1+OMBAR2;
K12=(OM1*E*EPS*PBAR^(E*EPS)*YBAR^(E*EPS/T))/OMBAR;
K13=K12*BETA*NUBAR^(-E*EPS);
K14=K12*BETA^2*NUBAR^(-2*E*EPS);
K15=K12*BETA^3*NUBAR^(-3*E*EPS);
K16=K12/T;
K17=K13/T;
K18=K14/T;
K19=K15/T;
K20=-K13-K14-K15;
K21=-K14-K15;
K22=-K15;
K23=(1-TAU)*OMBAR2/OMBAR;
K24=(XBAR^(E*EPS)*PSI*(TAU-1)*VOBAR^(1-TAU))/OMBAR;
K25=(XBAR^(E*EPS)*PSI*(TAU-1)*BETA*V1BAR^(1-TAU))/OMBAR;
K26=(XBAR^(E*EPS)*PSI*(TAU-1)*BETA^2*V2BAR^(1-TAU))/OMBAR;
K27=(XBAR^(E*EPS)*PSI*(TAU-1)*BETA^3*V3BAR^(1-TAU))/OMBAR;
K28=E*EPS*OMBAR2/OMBAR;
@OTHER USEFUL COSTANTS@
J0=1/A3;
J1=(NUBAR^RO)/A3;
J2=(NUBAR^(2*RO))/A3;
```

```
J3=(NUBAR^(3*RO))/A3;
B1=-1+(ZBAR*V*(1-BETA*NUBAR)/(1+ZBAR*(1-BETA*NUBAR)))+
((V-1)*(1-BETA*NUBAR)/(BETA*NUBAR));
B2=1-(ZBAR*V*(1-BETA*NUBAR)/(1+ZBAR*(1-BETA*NUBAR)));
SS=PABAR*YABAR+PBBAR*YBBAR+PCBAR*YCBAR+PDBAR*YDBAR;
SSS=PBAR*YBAR;
@NOTE: MUST BE SS=SSS=EBAR @
SS1=PABAR*YABAR/SS;
SS2=PBBAR*YBBAR/SS;
SS3=PCBAR*YCBAR/SS;
SS4=PDBAR*YDBAR/SS;
@SSVAL=ENDSTATES|COSTATES|EXSTATES|CONTROLS|EXTRACONTROLS @
SSVAL=PIIIBAR|PIIBAR|PIBAR|XIIIBAR|XIIBAR|XIBAR|XBAR|X1BAR|X2BAR|
X3BAR|X4BAR|X5BAR|ZBAR|
RGMBAR|YBAR|YBAR|YBAR|YBAR|YBAR|PBAR|P1BAR|P2BAR|P3BAR|P4BAR|P5BAR|
ZBAR|ZBAR|ZBAR|ZBAR|ZBAR|APBAR|AP1BAR|AP2BAR|CPBAR|CPBAR|CPBAR|
CPBAR|CPBAR|CPBAR|APIIIBAR|APIIBAR|APIBAR|
PABAR|PBBAR|PCBAR|PDBAR|YABAR|YBBAR|YCBAR|YDBAR|
LABAR|LBBAR|LCBAR|LDBAR|LBAR|RBAR|LAMBAR|
0|0|0|0|0|0|0|0|0;
@ ===================================== @
@BUILDING THE DYNAMIC SYSTEM: EQUATIONS FOR CONTROLS, (CO)STATES AND
AUXULIARY (FLOW) VARIABLES@
@ ===================================== @
@ MATRICES IN CONTROL SYSTEM: MCC*C(t)=MCS*S(t)+MCE*E(t)+ MCEI*E(t-1)+MCEII*E(t-
2) @
MCC=ZEROS(NC,NC);
MCC[1,1]=1;
MCC[1,7]=1;
MCC[1,13]=1;
MCC[2,2]=1;
MCC[2,8]=1;
MCC[2,14]=1;
MCC[3,3]=1;
MCC[3,9]=1;
MCC[3,15]=1;
MCC[4,4]=1;
MCC[4,10]=1;
MCC[4,16]=1;
MCC[5,5]=1;
MCC[5,11]=1;
MCC[5,17]=1;
MCC[6,6]=1;
MCC[6,12]=1;
MCC[7,7]=1;
MCC[7,1]=-(1-S)/S;
MCC[8,8]=1;
MCC[8,2]=-(1-S)/S;
MCC[9,9]=1;
MCC[9,3]=-(1-S)/S;
MCC[10,10]=1;
MCC[10,4]=-(1-S)/S;
MCC[11,11]=1;
MCC[11,5]=-(1-S)/S;
MCC[12,12]=1;
MCC[12,6]=-(1-S)/S;
MCC[13,13]=B1;
MCC[13,14]=B2;
MCC[14,14]=B1;
MCC[14,15]=B2;
MCC[15,15]=B1;
MCC[15,16]=B2;
MCC[16,16]=B1;
MCC[16,17]=B2;
MCC[17,17]=B1;
MCC[18,18]=1;
MCC[18,7]=-JB0;
MCC[18,8]=-JB1;
MCC[18,9]=-JB2;
```

```
MCC[18,10]=-JB3;
MCC[19,19]=1;
MCC[19,8]=-JB0;
MCC[19,9]=-JB1;
MCC[19,10]=-JB2;
MCC[19,11]=-JB3;
MCC[20,20]=1;
MCC[20,9]=-JB0;
MCC[20,10]=-JB1;
MCC[20,11]=-JB2;
MCC[20,12]=-JB3;
MCC[21,21]=1;
MCC[21,18]=1;
MCC[22,22]=1;
MCC[22,19]=1;
MCC[23,23]=1;
MCC[23,20]=1;
MCC[24,24]=1;
MCC[24,27]=1;
MCC[25,25]=1;
MCC[25,28]=1;
MCC[26,26]=1;
MCC[26,29]=1;
MCC[27,27]=1;
MCC[27,7]=-JB3;
MCC[28,28]=1;
MCC[28,7]=-JB2;
MCC[28,8]=-JB3;
MCC[29,29]=1;
MCC[29,7]=-JB1;
MCC[29,8]=-JB2;
MCC[29,9]=-JB3;
MCS=ZEROS(NC,(NK+NL));
MCS[6,13]=-1;
MCS[7,4]=J3;
MCS[7,5]=J2;
MCS[7,6]=J1;
MCS[7,7]=J0;
MCS[8,5]=J3;
MCS[8,6]=J2;
MCS[8,7]=J1;
MCS[8,8]=J0;
MCS[9,6]=J3;
MCS[9,7]=J2;
MCS[9,8]=J1;
MCS[9,9]=J0;
MCS[10,7]=J3;
MCS[10,8]=J2;
MCS[10,9]=J1;
MCS[10,10]=J0;
MCS[11,8]=J3;
MCS[11,9]=J2;
MCS[11,10]=J1;
MCS[11,11]=J0;
MCS[12,9]=J3;
MCS[12,10]=J2;
MCS[12,11]=J1;
MCS[12,12]=J0;
MCS[17,13]=-B2;
MCS[21,7]=1;
MCS[22,8]=1;
MCS[23,9]=1;
MCS[24,4]=1;
MCS[25,5]=1;
MCS[26,6]=1;
MCS[27,1]=JB0;
MCS[27,2]=JB1;
MCS[27,3]=JB2;
```

```
MCS[28,2]=JB0;
MCS[28,3]=JB1;
MCS[29,3]=JB0;
MCE=ZEROS(NC,NN);
MCE[1,1]=1;
MCE[2,1]=1+RAA;
MCE[3,1]=1+RAA+RAA^2;
MCE[4,1]=1+RAA+RAA^2+RAA^3;
MCE[5,1]=1+RAA+RAA^2+RAA^3+RAA^4;
MCE[6,1]=1+RAA+RAA^2+RAA^3+RAA^4+RAA^5;
MCE[13,1]=RAA;
MCE[14,1]=(RAA^2);
MCE[15,1]=(RAA^3);
MCE[16,1]=(RAA^4);
MCE[17,1]=(RAA^5);
@ MATRICES IN STATE EQUATIONS @
@ MSS0*E(S(t+1))+MSS1*S(t)=MSC0*E(C(t+1))+MSC1*C(t)+MSE0*E(E(t+1)) + MSE1*E(t)
@
MSS0=ZEROS((NK+NL),(NK+NL));
MSS0[1,1]=1;
MSS0[2,2]=1;
MSS0[3,3]=1;
MSS0[4,4]=1;
MSS0[5,5]=1;
MSS0[6,6]=1;
MSS0[7,7]=1;
MSS0[8,8]=1;
MSS0[9,9]=1;
MSS0[10,10]=1;
MSS0[11,11]=1;
MSS0[13,13]=B2;
MSS1=ZEROS((NK+NL),(NK+NL));
MSS1[1,2]=-1;
MSS1[2,3]=-1;
MSS1[4,5]=-1;
MSS1[5,6]=-1;
MSS1[6,7]=-1;
MSS1[7,8]=-1;
MSS1[8,9]=-1;
MSS1[9,10]=-1;
MSS1[10,11]=-1;
MSS1[11,12]=-1;
MSS1[12,7]=1+EPS*(E-1)-K28;
MSS1[13,13]=B1;
MSC0=ZEROS((NK+NL),NC);
MSC0[12,23]=K27/3;
MSC1=ZEROS((NK+NL),NC);
MSC1[3,7]=1;
MSC1[12,1]=K16-K5;
MSC1[12,2]=-K6+K17;
MSC1[12,3]=-K7+K18;
MSC1[12,7]=K12-K1;
MSC1[12,8]=-K2+K13;
MSC1[12,9]=-K3+K14;
MSC1[12,10]=-K4+K15;
MSC1[12,4]=-K8+K19;
MSC1[12,13]=-K29;
MSC1[12,14]=-K30;
MSC1[12,15]=-K31;
MSC1[12,16]=-K32;
MSC1[12,21]=K23;
MSC1[12,22]=(K25+K26+K27)/3;
MSC1[12,23]=(K26+K27)/3;
MSC1[12,24]=K24/3;
MSC1[12,25]=(K24+K25)/3;
MSC1[12,26]=(K24+K25+K26)/3;
MSE0=ZEROS((NK+NL),NN);
MSE0[13,1]=(RAA^5);
```

```
MSE1=ZEROS((NK+NL),NN);
MSE1[1,1]=-1;
MSE1[2,1]=-1;
MSE1[3,1]=-1;
MSE1[4,1]=-1;
MSE1[5,1]=-1;
MSE1[6,1]=-1;
MSE1[7,1]=-1;
MSE1[8,1]=-1;
MSE1[9,1]=-1;
MSE1[10,1]=-1;
MSE1[11,1]=-1;
@ AUXILIARY FLOW VARIABLES@
NXF=24; @ DIMENSION AND NAMES OF EXTRA FLOWS @
NAMEXC="PA"|"PB"|"PC"|"PD"|"YA"|"YB"|"YC"|"YD"|
"LA"|"LB"|"LC"|"LD"|"L"|"R"|"LAM"|"C1"|"C2"|"C3"|"C4"|
"C5"|"C6"|"C7"|"C8"|"C9";
@ MF*XC(t) = MFC*C(t) + MFKE*[K(t)|E(t)]' + MFL*L(t) @
MF=ZEROS(NXF,NXF);
MF[1,1]=1;
MF[2,2]=1;
MF[2,1]=-1;
MF[3,3]=1;
MF[3,1]=-1;
MF[4,4]=1;
MF[4,1]=-1;
MF[5,5]=1;
MF[5,1]=S/(S-1);
MF[6,6]=1;
MF[6,5]=-1;
MF[6,1]=-T;
MF[6,2]=T;
MF[7,7]=1;
MF[7,5]=-1;
MF[7,1]=-T;
MF[7,3]=T;
MF[8,8]=1;
MF[8,5]=-1;
MF[8,1]=-T;
MF[8,4]=T;
MF[9,9]=1;
MF[9,1]=1/(1-S);
MF[10,10]=1;
MF[10,2]=1/(1-S);
MF[11,11]=1;
MF[11,3]=1/(1-S);
MF[12,12]=1;
MF[12,4]=1/(1-S);
MF[13,13]=1;
MF[13,9]=1/A7;
MF[13,10]=(RGMBAR^EPS)/A7;
MF[13,11]=(RGMBAR^(2*EPS))/A7;
MF[13,12]=(RGMBAR^(3*EPS))/A7;
MF[14,14]=1/(RBAR-1);
MF[15,15]=1;
MF[16,16]=1;
MF[16,5]=1;
MF[16,1]=T;
MF[17,17]=1;
MF[17,6]=1;
MF[17,2]=T;
MF[18,18]=1;
MF[18,7]=1;
MF[18,3]=T;
MF[19,19]=1;
MF[19,8]=1;
MF[19,4]=T;
MF[20,20]=1;
```

```
MF[20,1]=SS1;
MF[20,5]=SS1;
MF[20,2]=SS2;
MF[20,6]=SS2;
MF[20,3]=SS3;
MF[20,7]=SS3;
MF[20,4]=SS4;
MF[20,8]=SS4;
MF[21,21]=1;
MF[21,14]=1;
MF[22,22]=1;
MF[22,6]=1;
MF[22,2]=S/(S-1);
MF[23,23]=1;
MF[23,7]=1;
MF[23,3]=S/(S-1);
MF[24,24]=1;
MF[24,8]=1;
MF[24,4]=S/(S-1);
CAZ=INV(MF);
MFC=ZEROS(NXF,NC);
MFC[1,1]=1-S;
MFC[1,7]=1-S;
MFC[14,13]=V-1;
MFC[15,1]=-1;
MFC[15,7]=-1;
MFC[15,13]=-V*(U1-1)/U1;
MFC[16,1]=1;
MFC[16,7]=T;
MFC[17,1]=1;
MFC[17,7]=T;
MFC[18,1]=1;
MFC[18,7]=T;
MFC[19,1]=1;
MFC[19,7]=T;
MFC[20,1]=1;
MFC[20,7]=1;
MFC[21,2]=1;
MFC[21,1]=-1;
MFC[21,7]=-1;
MFC[21,8]=1;
MFC[21,13]=-V*(U1-1)/U1;
MFC[21,14]=V*(U1-1)/U1;
MFKE=ZEROS(NXF,NK+NN);
MFKE[1,4]=-(1-S)*RO*J3;
MFKE[1,5]=-(1-S)*RO*J2;
MFKE[1,6]=-(1-S)*RO*J1;
MFKE[2,6]=EPS*S/T;
MFKE[3,5]=EPS*S/T;
MFKE[4,4]=EPS*S/T;
MFKE[10,6]=1/(S-1);
MFKE[11,5]=1/(S-1);
MFKE[12,4]=1/(S-1);
MFKE[22,6]=S/(S-1);
MFKE[23,5]=S/(S-1);
MFKE[24,4]=S/(S-1);
MFL=ZEROS(NXF,NL);
MFL[1,1]=(1-S)*RO*(1-J0)+S;
MFL[2,1]=-EPS*S/T;
MFL[3,1]=-EPS*S/T;
MFL[4,1]=-EPS*S/T;
MFL[5,1]=S/(S-1);
MFL[9,1]=1/(S-1);
@ FVC LINKS EXTRA CONTROLS TO FUNDAMENTAL CONTROLS @
FVC=(INV(MF))*MFC;
@ FVC LINKS EXTRA CONTROLS TO ENDOGENOUS STATES AND EXOGENOUS STATES
@
FVKE=(INV(MF))*MFKE;
@ FVL LINKS EXTRA CONTROLS TO COSTATES @
```

```
FVL=(INV(MF))*MFL;
@ ========================================== @
@ FUNDAMENTAL STATE-COSTATE DIFFERENCE EQUATION @
@ ========================================== @
MSss0 = MSS0 - MSC0*(INV(MCC))*MCS;
MSss1 = MSS1 - MSC1*(INV(MCC))*MCS;
MSse0 = MSE0 + MSC0*(INV(MCC))*MCE;
MSse1 = MSE1 + MSC1*(INV(MCC))*MCE;
W = -(INV(MSss0))*MSss1;
R = (INV(MSss0))*MSse0;
Q = (INV(MSss0))*MSse1;
@ ===================================== @
@ EIGENVECTOR-EIGENVALUE DECOMPOSITION OF STATE TRANSITION MATRIX @
@ ===================================== @
@ FIRST WE FIND THE REAL PARTS OF THE EIGENVALUES (X1)
AND EIGENVECTORS (X3) @
{X1,X3}=EIGV(W);
X11=REAL(X1);
AMU=ABS(X11);
@ SECOND WE ORDER THE EIGENVALUES@
IN=SORTC(AMU,1);
IND1=INDNV(IN,AMU);
I=1;
DO UNTIL I>(NK+NL)-1;
IF IND1[I,1] == IND1[I+1,1];
IND1[I+1,1] = 1+IND1[I,1];
ENDIF;
I=I+1;
ENDO;
@ THIRD WE ORDER THE COLUMNS OF THE EIGENVECTORS (X3) BY THE
INDICATOR RESULTING FROM THE ORDERING OF THE EIGENVALUES@
P=ZEROS((NK+NL),(NK+NL));
I=1;
DO UNTIL I>(NK+NL);
P[1:(NK+NL),I]=X3[1:(NK+NL),IND1[I,1]];
I=I+1;
ENDO;
@ FINALLY WE FORM A DIAGONAL MATRIX (MU) IN WHICH THE DIAGONAL HAVE THE
EIGENVALUES IN ASCENDING ABSOLUTE VALUE@
MU=ZEROS((NK+NL),(NK+NL));
I=1;
DO UNTIL I>(NK+NL);
MU[I,I]=X1[IND1[I,1],1];
I=I+1;
ENDO;
@ WE NOW HAVE P AND MU FOR WHICH WE KNOW THAT P*MU*P^-1=W (ALSO
X3*DIAG(X1)*X3=W) @
@ ==================================== @
@ PARTITIONING THE MATRICES @
@ ==================================== @
MU1=MU[1:NK,1:NK];
MU2=MU[NK+1:NK+NL,NK+1:NK+NL];
P11=P[1:NK,1:NK];
P12=P[1:NK,NK+1:NK+NL];
P21=P[NK+1:NK+NL,1:NK];
P22=P[NK+1:NK+NL,NK+1:NK+NL];
PS=INV(P);
PS11=PS[1:NK,1:NK];
PS12=PS[1:NK,NK+1:NK+NL];
PS21=PS[NK+1:NK+NL,1:NK];
PS22=PS[NK+1:NK+NL,NK+1:NK+NL];
RKE=R[1:NK,1:NN];
RLE=R[NK+1:NK+NL,1:NN];
QKE=Q[1:NK,1:NN];
QLE=Q[NK+1:NK+NL,1:NN];
@ ================================== @
@ COMPOSITE EXPRESSIONS @
@ ================================== @
SP1=-(INV(MU2))*(PS21*RKE+PS22*RLE);
SP2=-(INV(MU2))*(PS21*QKE+PS22*QLE);
KLK=P11*MU1*(INV(P11));
KTL=(P11*MU1*PS12+P12*MU2*PS22)*(INV(PS22));
NAME=NAMEK|NAMEE|NAMEL|NAMEC|NAMEXC;
```

SECOND CODE

```
@ ==================================== @
@ COMPUTATION OF DECISION RULES @
@ ==================================== @
@ IN THIS PROGRAM WE WILL COMPUTE MARKOV DECISION RULES (MDR)
FOR THE LINEAR DYNAMIC MODEL@
FL = SP1*RHO + SP2;
IRHO=EYE(ROWS(RHO));
I=1;
LEE=ZEROS(NL,NN);
DO UNTIL I>NL;
Q=FL[I,1:NN];
MU2I=1/MU2[I,I];
DSUM=INV((IRHO-MU2I*RHO));
LEE[I,1:NN]=Q*DSUM;
I=I+1;
ENDO;
@ ==================================== @
@ STATE DECISION RULES @
@ ==================================== @
KEC=RKE*RHO+QKE+KTL*LEE;
ULE=(INV(PS22))*LEE;
ULK=-(INV(PS22))*PS21;
@ ================================== @
@ SYSTEM DECISION RULES @
@ ================================== @
MKE=ZEROS(ROWS(KLK)+NN,COLS(KLK)+COLS(KEC));
MKE[1:ROWS(KLK),1:COLS(KLK)]=KLK;
MKE[ROWS(KLK)+1:ROWS(KLK)+NN,1:NK]=ZEROS(NN,NK);
MKE[1:ROWS(KEC),COLS(KLK)+1:COLS(KLK)+COLS(KEC)]=KEC;
MKE[ROWS(KEC)+1:ROWS(KEC)+ROWS(RHO),COLS(KLK)+1:COLS(KLK)+COLS(KEC)]=RHO;
@ ================================== @
@ INCORPORATION OF SHADOW PRICE, CONTROLS AND OTHER FLOWS @
@ ================================== @
LKE=ZEROS(NL,NK+NN);
LKE[.,1:COLS(ULK)]=ULK; LKE[.,COLS(ULK)+1:COLS(ULK)+COLS(ULE)]=ULE;
Z=(INV(MCC))*MCS;
M0CK=Z[1:NC,1:NK];
M0CL=Z[1:NC,NK+1:NK+NL];
M0CE=(INV(MCC))*MCE;
M0CKE=(M0CK+M0CL*ULK)~(M0CE+M0CL*ULE);
FKE=FVC*M0CKE+FVKE+FVL*LKE;
@RRKE=(ULK-ULK*KLK)~(ULE-(ULK*KEC+ULE*RHO));@
H=LKE|M0CKE|FKE;
@==============================@
@ THE IMPACT PERIOD @
@==============================@
B3=(-B2/B1);
@ SHOCK @
RGMT=0.01;
ZT=RGMT*RAA/(B1*(1-B3*RAA));
ELT=ZEROS(2,1);
ELT[1,1]=RGMT;
ELT[2,1]=ZT;
@ VARIABLES: Y|P|L|R|LAM @
VIP=ZEROS(5,2);
VIP[1,1]=S;
VIP[1,2]=-S;
VIP[2,1]=1-S;
VIP[2,2]=-1+S;
VIP[3,1]=1;
VIP[3,2]=-1;
VIP[4,2]=(RBAR-1)*(V-1);
VIP[5,1]=-1;
VIP[5,2]=1-V*(U1-1)/U1;
IP=VIP*ELT;
@ IP = Y|P|L|R|LAM COLUMN VECTOR @
MKE=REAL(MKE);
LKE=REAL(LKE);
M0CKE=REAL(M0CKE);
```

```
H=REAL(H);
FKE=REAL(FKE);
LOCATE 1,1;
FORMAT /LDS 4,3;
OUTPUT ON;
OUTPUT FILE=CKTPFM.OUT RESET;
"-------------------------------------------------";
" IMPACT EFFECT ";
"-------------------------------------------------";
"-------------------------------------------------";
" ------- RGM(t)----------";
"Z ";;ZT;
"Y ";;IP[1,1];
"P ";;IP[2,1];
"L ";;IP[3,1];
"R ";;IP[4,1];
"LAM ";;IP[5,1];
WAIT;
"-------------------------------------------------";
" NEAR STEADY STATE DYNAMICS AFTER FIRST PERIOD";
"-------------------------------------------------";
"-------------------------------------------------";
" --------- PI'S ------ -";
" ";;$NAME[1:NK+NN,1]';
I=1;
DO UNTIL I>NK;
$NAME[I,1];;MKE[I,.];
I=I+1;
ENDO;
I=1;
DO UNTIL I>NL;
$NAME[I+NN+NK,1];;LKE[I,.];
I=I+1;
ENDO;
I=1;
DO UNTIL I>NC;
$NAME[I+NK+NL+NN,1];;MOCKE[I,.];
I=I+1;
ENDO;
I=1;
DO UNTIL I>NXF;
$NAME[I+NK+NL+NN+NC,1];;FKE[I,.];
I=I+1;
ENDO;
"-------------------------------------------------";
WAIT;
FORMAT 4,4;
"-------------------------------------------------";
" ------- PARAMETERIZATION ------------------";
"-------------------------------------------------";
"-------------------------------------------------";
" PARAMETERS";
"-------------------------------------------------";
"DISCOUNT FACTOR ";;BETA;
"B ";;B;
"V ";;V;
"ALPHA ";;ALPHA;
"DI ";;DI;
"PSI ";;PSI;
"RELATIVE WAGE RISK AVERSION (TAU) ";;TAU;
"SIGMA ";;S;
"THETA ";;T;
"INTERTEMPORAL ELASTICITY OF LABOUR SUPPLY ";;1/(E-1);
"TREND IN THE MONEY SUPPLY PROCESS ";;RGMBAR;
"AUTOCORRELATION MONEY SUPPLY PROCESS ";;RAA;
WAIT;
"-------------------------------------------------";
" STEADY STATE: AGGREGATE VARIABLES";
"-------------------------------------------------";
"STEADY STATE OUTPUT ";;YBAR;
"STEADY STATE VELOCITY OF MONEY ";;1/ZBAR;
"STEADY STATE PRICE LEVEL ";;PBAR;
"STEADY STATE AGGREGATE EMPLOYMENT ";;LBAR;
"STEADY STATE NOMINAL INTEREST RATE ";;RBAR;
```

```
"SS REAL INTEREST RATE ";;RBAR/RGMBAR;
"SS LAMDBA ";;LAMBAR;
WAIT;
"--------------------------------------------------------";
" STEADY STATE: SECTORS' VARIABLES";
"--------------------------------------------------------";
"STEADY STATE WAGE SECTOR A ";;XBAR;
"STEADY STATE WAGE SECTOR B ";;XIBAR;
"STEADY STATE WAGE SECTOR C ";;XIIBAR;
"STEADY STATE WAGE SECTOR D ";;XIIIBAR;
"STEADY STATE OUTPUT SECTOR A ";;YABAR;
"STEADY STATE OUTPUT SECTOR B ";;YBBAR;
"STEADY STATE OUTPUT SECTOR C ";;YCBAR;
"STEADY STATE OUTPUT SECTOR D ";;YDBAR;
"STEADY STATE PRICE SECTOR A ";;PABAR;
"STEADY STATE PRICE SECTOR B ";;PBBAR;
"STEADY STATE PRICE SECTOR C ";;PCBAR;
"STEADY STATE PRICE SECTOR D ";;PDBAR;
"STEADY STATE EMPLOYMENT SECTOR A ";;LABAR;
"STEADY STATE EMPLOYMENT SECTOR B ";;LBBAR;
"STEADY STATE EMPLOYMENT SECTOR C ";;LCBAR;
"STEADY STATE EMPLOYMENT SECTOR D ";;LDBAR;
"--------------------------------------------------------";
"--------------------------------------------------------";
OUTPUT OFF;
```

THIRD CODE

```
@STARTING POINT AFTER THE IMPACT EFFECT @
S=-RGMT|-RGMT|IP[2,1]-RGMT|-RGMT|-RGMT|-RGMT|RGMT*RAA;
@ FORECAST HORIZON @
NIR=11;
@ GENERATING IMPULSES @
TI=SEQA(1,1,NIR+1);
IR=ZEROS(ROWS(MKE)+ROWS(H),NIR);
I=1;
DO UNTIL I>NIR;
IR[1:ROWS(MKE),I]=S;
IR[ROWS(MKE)+1:ROWS(IR),I]=(H*S);
S=MKE*S;
I=I+1;
ENDO;
IR=REAL(IR);
IRI=ZEROS(ROWS(IR),1);
IRI[7,1]=RGMT;
IRI[15,1]=IP[1,1];
IRI[21,1]=IP[2,1];
IRI[27,1]=ZT;
IRRI=ONES(4,1);
IRI[44:47,1]=IP[2,1]*IRRI;
IRI[48:51,1]=IP[1,1]*IRRI;
IRI[52:55,1]=IP[3,1]*IRRI;
IRI[56,1]=IP[3,1];
IRI[57,1]=IP[4,1];
IRI[58,1]=IP[5,1];
@------------------------------------------@
@ THE GROSS INFLATION SERIES @
@------------------------------------------@
INF=ZEROS(1,NIR+1);
INF[1,1]=IP[2,1];
INF[1,2]=IRI[7,1]+IR[21,1] -IP[2,1];
INF[1,3:NIR+1]=IR[7,1:(NIR-1)]+IR[21,2:NIR]-IR[21,1:(NIR-1)];
IRII=IRI~IR;
IR=IRII|INF;
```

```
IR=IR*100;
@ PLOT IMPULSE RESPONSES @
LIBRARY PGRAPH;
GRAPHSET;
_PLEGCTL={2,3,6,4.5};
_PCOLOR={15};
_PLTYPE={1,6,3};
_PDATE="";
_PLEGSTR=
"INF\000"\
"Y\000"\
"RGM\000";
XY(TI,IR[68,.]'~IR[15,.]'~IR[7,.]');
```

Conclusions

In this thesis we have analysed three potential sources of inflation persistence. The importance of investigating in detail the source of inflation inertia arises from the fact that it is that persistence which drives the costs in terms of output of disinflationary policies. As a consequence, the optimal monetary policy strategy aimed at avoiding those costs should take into account the reason why inflation is persistent. Along this thesis we have considered two different frameworks in which different sources of inflation persistence can be easily incorporated

We have started our analysis by considering the lack of credibility of monetary policy. The framework developed in the first chapter has allowed us both to easily incorporate it and to analyse the strategy of pegging the exchange rate to a low-inflation economy so as to counteract the effects of that lack of credibility. Our model has provided a better description of the actual EMS as part of that strategy. Specifically we have modelled the European Monetary System (EMS) as an adjustable peg regime. This is the reason why some factors not previously considered in the previous literature on the EMS collapse in the summer of 1992 have been studied here. The result is what we believe is a better description of the crisis in 1992 and its driving forces. Specifically, we have shown that uncertainty about the future of EMU may have played an important role, as unanimously emphasised by the earliest interpretations of the crisis.

The second part of the thesis incorporates relative wage concern into a dynamic general equilibrium macromodel. Chapter 2 has motivated the approach we have taken on the basis of the available support both from the economic literature and empirical evidence on the topic. The purpose of Chapters 3 and 4 has been to investigate its effects on two stylised facts of U.S. macrodata: (i) the inertia component that characterises the actual inflation dynamics (ii) the persistence of the real effects of money shocks.

In chapter 3 we have introduced a wage setting rule which is derived under intertemporal optimisation by wage setters under the assumptions of staggered wage setting and the existence of relative wage concern. We have then employed the structure of that contracting equation to analyse a competing hypothesis on the source of inflation inertia supported by recent empirical results, namely the existence of non-fully-rational expectations of inflation. By employing the same approach of Roberts [1997], we have however shown that the existence of non-fully-rational expectations is not enough to discard relative wage concern as source of inflation inertia.

Chapter 4 has mainly focused on the search for reasonable values for the parameters governing relative wage concern in a fully-calibrated version of the model. The purpose is to analyse whether the omission of relative wage concern can be an explanation for the lack of persistent real effects following money shocks in macromodels with staggered wage setting. The main reason why such lack of persistent arises is because such contracting schemes do not incorporate enough endogenous stickiness in the sense that wage setting agents choose not to change their wages by much when they have the chance to re-set their wages. Relative wage concern can in principle provide the motivation for such endogenous stickiness to arise. Assessing how strong that relative wage concern needs to be so as to allow for persistent real effects of money shocks is then fundamental. That is the purpose of the calibration and simulation exercises carried out in chapter 4. Our results show that for a benchmark calibration of the parameters governing relative wage concern in our framework there is substantial output and inflation persistence. Moreover, persistence also arises for alternative specifications of the relative wages the agents are concern with and for alternative calibration of the parameters governing relative wage concern

In sum, the results in this second part of the thesis have highlighted the potential role of relative wage concern to explain two puzzles raised by recent literature. Firstly, the existence of substantial inertia in the inflation dynamics. We have shown that it may well arise as a result of the wage contracting behaviour. Secondly, the endogenous stickiness necessary for the persistence of the real effects of money shocks may also arise from the existence of relative wage concern. We believe that those results clearly show that relative wage concern should be an avenue to explore in models incorporating nominal rigidities by imposing staggered wage setting. Our results are strongly supportive for such an approach. Further analysis is however needed before a full assessment of relative wage concern can be made. In particular, two obvious avenues should be explored to investigate the robustness of our results.

First of all, the modelisation of relative wage concern should be improved. Introducing the existence of status concern in the structure of preferences of the agents has the obvious limitation that the results rely on how justifiable the assumption is by itself. We do agree on the limitations of such an approach, and that is the reason why we have devoted an entire chapter to motivate the study of relative wage concern by reporting evidence that supports it. There is an obvious need for further microfoundations of relative wage concern. In the terminology introduced by Cole *et al.* [1993] our model can be however considered as a reduced form of a fully-microfounded model in which status concern in the form of relative wages arises. However, it is precisely this reduced-form analysis those authors advocate for in their attempt to "provide some macrofoundations to microeconomics". Our approach has allowed us to obtain clear insights on the effects of the existence of relative wage concern. It is precisely the potential importance of our results which demand the search for sound microfoundations of relative wage concern. An investigation into the circumstances in which it may arise will improve our position to assess its implications. In our opinion, there are at least two promising lines for research in that direction. Firstly, the analysis of wage staggering in an environment with limited information on the shocks affecting workers' productivity may give rise to direct comparison with other sector wages so as to infer information on the actual productivity level. Secondly, there is substantial evidence pointing at a strong relationship between relative wages an effort supply by workers. Explicit bargaining over hours and effort could also give rise to the presence of relative wages as a fundamental element in the labour supply function.

Finally, we would like to express our support for the use of surveys as a potential new source of information to guide economic research. We made intensive use of evidence from surveys both to motivate the existence of relative wage concern and the fact that inflation expectations may suffer from lack of rationality. It cannot be denied that survey information may suffer from the usual caveats, in particular the lack of incentive of survey participants to provide true information. We however believe that enough evidence nowadays exists on their usefulness for economic analysis, and that further research on them should be carried out so as to extract the information they contain. Specifically, the surveys on inflation expectations are a remarkable data source to which apply recent contributions on adaptive learning. We also plan to follow this line of research in a near future.

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