CIRPÉE
Centre interuniversitaire sur le risque, les politiques économiques et l'emploi

Cahier de recherche/Working Paper **03-20**

Fair Wages in a New Keynesian Model of the Business Cycle

Jean-Pierre Danthine
André Kurmann

Avril/April 2003

Danthine: Université de Lausanne, FAME and CEPR
Contact address : Jean-Pierre Danthine, École des Hautes Études Commerciales, Université de Lausanne, BFSH1, CH-1015 Lausanne, Switzerland
Jean-Pierre.Danthine@hec.unil.ch
Kurmann : Université du Québec à Montréal and CIRPÉE
Contact address : André Kurmann, Université du Québec à Montréal, Department of Economics, P.O. Box 8888, Downtown Station, Montréal (QC), H3C 3P8, Canada
kurmann.andre@uqam.ca

Earlier versions of this paper circulated under the title "Completing the New Neoclassical Synthesis: the Promise of Fair Wages". We thank Jean-Pascal Bénassy, Bob King, Jinill Kim, Louis Phaneuf, Chris Otrok and two anonymous referees for very helpful suggestions. The paper has been presented at the Lausanne Macro Workshop, the ZEI-University of Bonn conference on "Interactions between financial and labour markets", the University of Cyprus, the 2002 meeting of the Société Canadienne des Sciences Économiques, the SED 2002 meeting, Queen's University, the University of British Columbia, and the Columbia Business School Macro Lunch. We thank the seminar participants for their comments. We also gratefully acknowledge financial support from the Bankard Fund of the University of Virginia (Kurmann) and the Swiss National Science Foundation (Kurmann: bourse de jeune chercheur; Danthine: subside #12-65038.01).

Abstract: We build a New Keynesian model of the business cycle with sticky prices and real wage rigidities motivated by efficiency wages of the gift exchange variety. Compared to a standard sticky price model, our Fair Wage model provides an explanation for structural unemployment and generates more plausible labor market dynamics – notably accounting for the low correlation between wages and employment. The fair wage induced real wage rigidity also significantly reduces the elasticity of marginal cost with respect to output. The smoother dynamics of real marginal cost increase both amplification and persistence of output responses to monetary shocks, thus remedying the well-known lack of internal propagation of standard sticky price models. We take these improvements as a strong endorsement of the addition of real wage rigidities to nominal price rigidities and conclude that the fair wage extension of this paper constitutes a promising platform for an enriched New Keynesian synthesis.

Keywords: Efficiency wages, Business cycles, Sticky prices, Persistence

JEL Classification: E24, E32, E52

1 Introduction

The gap between most dynamic models of the business cycle and economic reality is arguably largest in the labor market. In standard models, the labor market is described in Walrasian terms: wages adjust rapidly to economic events because they are competitive spot market prices; households are always on their labor supply schedules; and unemployment is absent. In reality, wage determination is more complicated, wages are sluggish and unemployment is a pervasive feature of modern industrial economies. The Walrasian view of the labor market was originally incorporated into equilibrium models of the business cycle in the 1970s;[1] was taken into real business cycle (RBC) models in the 1980s;[2] and is nearly omnipresent in stochastic general equilibrium models featuring sticky prices and imperfect competition as they have been developed in the 1990s (sometimes labeled models of the "New Neoclassical Synthesis" (NNS)).[3] Yet many studies have documented that each of these strands of research implies labor market dynamics that are sharply at variance with key stylized facts of modern economies.[4]

In this paper, we propose a New Keynesian sticky price model that features a very different vision of the labor market, based on the "partial gift exchange" efficiency wage theory introduced by Akerlof (1982). The central idea behind partial gift exchange is that workers dislike providing effort. They will, however, work harder than some required minimum (the gift by workers) in exchange for a real wage above some reference compensation level that is considered as "fair" (the gift by the firm). In such a context, firms may find it optimal to pay a real wage that exceeds the market-clearing level, therefore inducing structural unemployment. They may also be skeptical of large wage changes because of the potentially important effects on worker morale and consequently on the level of effort provided. In response to external shocks, firms are thus inclined to adjust their labor input by hiring additional workers from the "reserve army" of the unemployed rather than asking their existing employees to increase their work hours in return for a higher hourly wage.

The gift exchange view of labor relations is largely motivated by behavioral considerations about fairness and reciprocity. Such considerations have recently obtained important empirical support from a host of evidence in micro surveys and experimental studies documenting that workers often reciprocate extra pay with extra effort even when no quid pro quo is explicitly required (see Fehr

[1]See Lucas (1979), Sargent (1976) and Barro (1981).

[2]See Kydland and Prescott (1982), Long and Plosser (1983) or King, Plosser and Rebello (1988).

[3]See Goodfriend and King (1997).

[4]Besides their failure to accommodate structural unemployment, most of these models have difficulties replicating the low correlation between real wages and employment, the high variability and procyclicality of employment and the low variability and relative acyclicality of real wages that one finds in the data. See for example King and Watson (1996) in the context of a standard sticky price model or King and Rebelo (2000) in the RBC context. Also see Hall (1999) for a general survey on the deficiences of models with frictionless labor markets and on the importance of taking into account of unemployment to arrive at a realistic description of the business cycle.

and Gächter, 2001, Howitt, 2002, or Bewley, 2002 for surveys). The fair wage idea was first introduced in a dynamic stochastic general equilibrium (DSGE) context by Danthine and Donaldson (1990). Within the confines of a RBC model, these authors find that if the reference compensation level includes contemporaneous variables only, fair wage labor market frictions generate structural unemployment but do not translate into equilibrium wage sluggishness and therefore cannot resolve the wage-employment puzzle.[5] Kiley (1997) is similarly negative in his assessment about the potential of the effort efficiency wage story. In his stylized framework, acyclical real wages (in line with the data) require countercyclical effort, thus inducing a highly volatile and procyclical real marginal cost and preventing any strengthening of the internal propagation mechanism of the model. More recently however, Collard and de la Croix (2000) have shown, in a RBC model context, that if the reference compensation level of the effort function not only consists of contemporaneous variables but also includes comparisons between current and past compensation levels, acyclical real wages can coexist with cyclical or even procyclical effort. This intertemporal view of effort determination is supported by survey results of Bewley (1998) who argues that "...[Akerlof's model] is correct in emphasizing morale, and errs only if importance is attached to wage levels rather than to changes in them."

We consider a generalized version of the intertemporal gift exchange formulation by Collard and de la Croix and incorporate it into a standard DSGE framework with monopolistic competition in the goods market and infrequent price adjustment by firms along the lines of Calvo (1983). Thus we provide an answer to the call by Romer (1993) and others for combining labor market rigidities with sticky prices.

The implications of our gift exchange addition are striking. Estimation of the fair wage function derived from the model for quarterly U.S. data between 1953 and 2001 supports the view that firms are highly reluctant to change wages. Our model rationalizes this result as the consequence of firms taking into account the excessive effects large wage changes would have on workers' morale (and consequently on the level of effort). We evaluate the dynamic effects of the estimated fair wage function on the economy by comparing a variety of impulse response functions and unconditional moments for our Fair Wage model with the data as well as with a benchmark NNS sticky price model (without labor market frictions). Four results stand out on the labor market side. First, our Fair Wage model generates structural unemployment; second, it implies a form of real wage rigidity that permits replicating the near-zero correlation between the real wage and employment in the data; third, it substantially reduces the variability and procyclicality of real wages; and fourth, it

[5] The reason for this result is that while employers indeed tend to be cautious when adjusting wages in response to shocks (because doing so would affect workers' morale and effort level and could thus cost more than it would save), it remains optimal in equilibrium to adjust wages as the incentive effect of variations in unemployment more than compensates for the morale effect of wage changes.

makes employment both more procyclical and more variable. The intertemporal view of fair wage considerations in the labor market therefore offers an explanation for why real wages are not only rigid in the sense of preventing labor market clearance but also sluggish in their adjusting to new economic conditions.

Moreover, our Fair Wage model leads to markedly amplified and more persistent responses of output to monetary shocks. This finding is of special interest because NNS models with nominal rigidity in prices alone have been faulted by Chari, Kehoe and McGrattan (2000) or Huang and Liu (2002) for their weak propagation mechanism. These authors have demonstrated that under plausible assumptions about the degree of price fixity, the elasticity of labor supply and intertemporal links in the economy, the impact of monetary shocks on output remains limited and of insufficient duration. The lack of internal propagation can be traced to the fact that, in these models, marginal cost is extremely sensitive to changes in output. As a result, the price changes of firms adjusting to aggregate demand shocks is large despite their knowing that a certain number of their competitors keep their prices constant. By contrast, real wage rigidity as introduced by our Fair Wage mechanism makes real wages and thus real marginal cost much less sensitive to variations in aggregate output. Smaller variations in marginal cost lead firms to make smaller price adjustments and to increase their output response. As a result, the response of aggregate output to aggregate demand shocks is amplified and more persistent and the time-series properties of output and prices generated by the Fair Wage model are more in line with business cycle observations. In addition of being consistent with more plausible labor market characteristics, our Fair Wage model thus appears to resolve one of the principal defect of New Keynesian sticky price models.

We are not the first to reach the conclusion that real rigidities substantially enhance the performance of DSGE models with nominal rigidities.[6] In fact, we join a growing strand of literature anticipated by Jeanne (1998). Jeanne studied an abbreviated NNS sticky price model with a reduced-form wage equation. He found that real rigidities lead to more persistent output fluctuations in response to a monetary shock. However, his real wage rigidity was not motivated by an explicit underlying theory. Closer to the present study and more structurally explicit than Jeanne are models combining sticky prices with (exogenously imposed) staggered nominal wage contracts (Christiano, Eichenbaum and Evans (2001) and others); with efficiency wage of the shirking variety (Alexopoulos, 2001 or Felices, 2002); or with search and matching frictions (for example Walsh,

[6] An alternative remedy to the excess sensitivity of marginal cost has been proposed by Dotsey and King (2001) who supplement a standard NNS model with variable capital utilization, produced intermediate inputs and employment variations on the extensive margin. These real (quantity) flexibilities lead to smaller factor price fluctuations, thus dampening the response of real marginal cost to aggregate demand fluctuations and generating amplified and more persistent output responses. The present paper exploits the alternative route consisting of augmenting the NNS framework with "real (wage) rigidities", i.e. labor market frictions limiting the adjustment of real wages after an external shock.

2002). Section 6 of the present paper undertakes some limited comparisons of the empirical predictions of our model and of some of the just cited competitors. While it is, in our view, premature to single out one form of real frictions over all others, our fair wage approach compares well with the alternatives. Besides displaying dynamic properties that are in line with the data on many accounts, the fair wage concept also has the advantage of being well supported by micro evidence and of giving rise to a relatively parsimonious form of modelling. An important additional distinction in light of available evidence (Fuhrer and Moore, 1995) is that the intertemporal wage comparisons of our fair wage construct provide a natural rationalization for the presence of backward-looking features in the wage equation, and thus indirectly in the price equations of the reduced form solution to the model.

The rest of the paper is organized as follows. Section 2 presents our Fair Wage model. Section 3 summarizes the calibration of the model parameters and documents the estimation of the fair wage function. The performance of the model is evaluated in Section 4, while Section 5 checks the robustness of our results with respect to changes in the calibration. Finally, Section 6 contrasts our results to other studies that introduce rigidities in the labor market and Section 7 concludes.

2 The model

The proposed fair wage model contains the standard elements of a NNS model such as described by Goodfriend and King (1997) but is amended with a partial gift exchange effort component. The model is populated by three types of agents, which we will describe in turn: families of consumer-workers, monopolistically competitive firms and a monetary authority.

2.1 Families and individuals

Preferences and effort decisions. Our fair wage economy is inhabited by a [0-1] continuum of families, each composed of a [0-1] continuum of infinitely-lived individual family members. Families are assumed to make all key intertemporal decisions and to redistribute consumption equally among its members. Hence, individuals are identical ex-ante. However, they differ ex-post in that some of them are unemployed while the others are working (we assume random, costless and time-independent matching with firms). Families remain identical ex-post in that employment is randomly allocated among workers and that the fraction of unemployed members is the same across families.[7]

Individuals have preferences over consumption and effort, but not leisure. This implies that in each period, every consumer-worker inelastically supplies one unit of time for work (or unemployment related activities) and that the traditional consumption-leisure trade-off is absent from our

[7] See Alexopoulos (2001) for the use of a similar construct.

analysis. The expected discounted lifetime utility of a typical family is assumed to be of the form

$$U = E_0 \sum_{t=0}^{\infty} \beta^t \left[\log c_t - n_t G(e_t)\right] \ , \tag{1}$$

where E is the expectations operator, β is the discount factor, c_t is the aggregate family consumption at date t, n_t is the fraction of family members working at date t and $G(e_t)$ is the disutility of effort of the typical working family member.[8]

Effort is assumed to be determined by fairness considerations along the lines of the partial gift-exchange idea of Akerlof (1982). Specifically, workers dislike efforts but they are willing to provide some effort beyond some norm to the extent that they feel well treated by their employer. Extra effort (the gift by the worker) thus comes in exchange for a remuneration w_t that exceeds some reference compensation level (the gift of the firm). This reference level has traditionally been interpreted as summarizing what a given employed worker would receive were she not employed by her current employer. Such a definition includes the wage paid by other firms in the economy, a measure of the current (un-)employment situation (representing the probability of being hired by another employer), and possibly a measure of unemployment compensation.This formulation is strongly supported by empirical evidence from Bewley's (1998) survey study, with the added qualifyer that *changes* in compensation from one period to the next appear to be key in explaining motivation and effort. Following Collard and de la Croix (2000), we therefore include individual past real wage $w_{t-1}(j)$ as another determinant of effort and – anticipating the log-linear form of our model to be imposed later – express worker j's effort function $G(e_t(j))$ as[9]

$$G(e_t(j)) = (e_t(j) - (\phi_0 + \phi_1 \log w_t(j) + \phi_2 \log n_t + \phi_3 \log w_t + \phi_4 \log w_{t-1}(j)))^2 \, ,$$

where $e_t(j)$, $w_t(j)$ and $w_{t-1}(j)$ stand for *individual* j's current effort and her current and last period's real wage level, respectively; while w_t and n_t represent the *aggregate* real wage and employment level in the economy, respectively.

The specification of preferences in (1) implies that consumption and effort considerations are separable. The supply of effort is thus wealth-independent, hence optimal effort $e_t(j)$ for an employed individual j given $w_t(j)$, $w_{t-1}(j)$, w_t and n_t (all of which the individual considers as exogenous by assumption) satisfies

$$e_t(j) = \phi_0 + \phi_1 \log w_t(j) + \phi_2 \log n_t + \phi_3 \log w_t + \phi_4 \log w_{t-1}(j). \tag{2}$$

[8]The consumption part of the period utility function could, with no consequences, be written as $\int_0^1 logc_t(j)dj$, thus permitting a strict interpretation of the family utility as the equally weighted sum of its members' utilities

[9]One could imagine including higher-order lags of the individual's real wage in (2). We examine this issue in Section 3 where we estimate the parameters of the effort function.

A priori, we expect that effort depends positively on the individual's current real wage ($\phi_1 > 0$) but negatively on the current aggregate compensation level, the tightness of the labor market and the individual's past real wage ($\phi_2 < 0$, $\phi_3 < 0$, $\phi_4 < 0$). Intuition also suggests that $\phi_1 + \phi_3 > 0$. That is, the positive incentive effect of a larger own wage is stronger than the negative effect of a higher comparison wage. The selection of the various parameter values is, however, an empirical matter that we address in Section 3.

Our effort function (2) represents a generalization of the effort functions proposed in the representative agent context by Danthine and Donaldson (1990) and Collard and de la Croix (2000). In particular, Collard and de la Croix specify $e_t(j) = \phi + \gamma \log[w_t(j)/(w_t n_t)] + \psi \log[w_t(j)/w_{t-1}]$, which is almost equivalent to (2). We differ in that their effort function imposes the restrictions $\phi_1 = \gamma + \psi > 0$, $\phi_2 = \phi_3 = -\gamma < 0$ and $\phi_4 = -\psi < 0$. These restrictions will be tested in Section 3. In addition, effort $e_t(j)$ in our setup depends, in principle, on individual j's past real wage $w_{t-1}(j)$ rather than on the economy-wide real wage w_{t-1}.[10]

It may be noted that the present set-up is observationally equivalent to one where families are abstracted from. In that alternative framework, adopted among others by Danthine and Donaldson (1990) and Collard and de la Croix (2000), workers themselves make the intertemporal decisions and inelastically supply one unit of labor. To bypass the problem of ex-post heterogeneity due to the fact that workers will be either employed or unemployed, the authors assume the existence of perfect insurance contracts. Risk averse workers choose to perfectly insure themselves against the risk of being unemployed, thus restoring ex-post homogeneity.[11]

Cash-in-advance and budget constraints. Savings is decided at the family level. It takes the form of either monetary or non-monetary, interest-bearing assets. Money is by definition a dominated asset but positive holdings are motivated by a cash-in-advance constraint applying to both consumption c_t and investment i_t; i.e.

$$a_t \geq c_t + i_t \ , \tag{3}$$

with a_t representing real monetary assets at the beginning of period t. It consists of end of last period's monetary holdings m_{t-1} at current prices plus a lump sum transfer t_t from monetary authorities

$$a_t = \frac{m_{t-1}}{\pi_t} + t_t \ , \tag{4}$$

[10] Assuming that individual effort is a function of the individual's past wage is arguably more reasonable. For tractability, we will however invoke a special case that allows replacing $w_{t-1}(j)$ with w_{t-1}.

[11] In our framework, since the effort function always peaks at zero, the family compact also corresponds to an optimal insurance contract and the unemployed are no better or worse off than the employed. In both set ups, it is assumed that the existence of these insurance payments does not affect the attitude of workers with respect to their employer, i.e., their perception of the gift of the firm.

where $\pi_t = P_t/P_{t-1}$ stands for the gross rate of inflation between $t-1$ and t based on an aggregate price index P.

Imposing a CIA constraint on both c *and* i is logically consistent in a one-good model where consumer-workers are responsible for consumption and physical investment. Such a modelling choice is also desirable because, in the absence of utility for leisure or other alternatives to purchasing the marketed good for consumption, variations in the inflation tax would otherwise induce implausible and systematic distortions in the investment vs. consumption decisions.

Non-monetary savings take the form of investment i_t into physical capital that is rented to firms on a period-by-period basis for a gross real rental r_t^k.[12] Investment into physical capital is transformed into usable capital according to

$$\gamma k_{t+1} = (1-\delta)k_t + i_t \ , \tag{5}$$

where δ is the depreciation rate of physical capital, assumed constant over time, and γ denotes the steady state growth rate of real variables.[13] Given these savings and investment alternatives, the budget constraint for the representative family can be expressed as

$$m_t + c_t + i_t = w_t(1-u_t) + r_t^k k_t + a_t + q_t \ , \tag{6}$$

where $r_t^k k_t$ and q_t are capital income and the representative family's share of firms' profits, respectively.

Consumption/savings decision. Maximizing the expected discounted lifetime utility (1) subject to the constraints (3), (4), (5) and (6) leads to the following combined first-order conditions, describing the family's consumption/savings decision

$$\frac{\gamma}{c_t} = \beta E_t \left(\frac{1}{c_{t+1}}(1-\delta) + \lambda_{t+1} r_{t+1}^k \right) \tag{7}$$

$$\lambda_t = \beta E_t \left(\frac{1}{\pi_{t+1} c_{t+1}} \right), \tag{8}$$

where λ_t denotes the Lagrangian multiplier on the budget constraint.

Comparison to a basic NNS model. By contrast to our Fair Wage model, the supply of labor in a basic NNS framework with a Walrasian labor market is variable and depends

[12] Danthine and Donaldson (2002) are critical of this (standard) way of introducing physical capital in NNS models.

[13] Following the tradition of the RBC literature, all real aggregates of our model are transformed into stationary variables by normalizing them with the labor augmenting rate of technological progress and the steady state growth rate of population. See Appendix A.2 for a detailed explanation of this transformation.

on the representative agent's consumption-leisure trade-off. On the other hand, effort is assumed to be constant and unaffected by either the wage level or the employment situation. A standard way of expressing the expected discounted lifetime utility function of such a model is $U = E_0 \left[\sum_{t=0}^{\infty} \beta^t \left(\log(c_t) + \theta \log(1-n_t)\right)\right]$ and the effort function (2) is replaced by a Walrasian labor supply condition of the form

$$\frac{\theta}{1-n_t} = \lambda_t w_t. \tag{9}$$

All other first-order conditions and the different constraints remain the same.

2.2 Firms

Production and cost minimization. Given some demand $y_t(z)$, an individual firm $z \in [0,1]$ will hire capital $k_t(z)$ and labor input $n_t(z)$ to produce the demanded quantity by means of a standard Cobb-Douglas technology[14]

$$y_t(z) = A_t k_t(z)^{\alpha} \left[e_t(z) n_t(z)\right]^{1-\alpha}. \tag{10}$$

A_t is a common-to-all firms productivity shock and α is the capital factor share parameter. This production function differs from the standard NNS technology insofar as labor $n_t(z)$ is augmented by the level of effort $e_t(z)$, which is uniformly supplied by the employed workers. Firm z therefore faces the cost minimization problem

$$\min_{k_t(z), n_t(z), w_t(z)} tc_t(z) = r_t^k k_t(z) + w_t(z) n_t(z)$$

$$\begin{aligned} s.t.\ y_t(z) &\leq A_t k_t(z)^{\alpha} \left[e_t(z) n_t(z)\right]^{1-\alpha} \\ e_t(z) &= \phi_0 + \phi_1 \log w_t(z) + \phi_2 \log n_t + \phi_3 \log w_t + \phi_4 \log w_{t-1}. \end{aligned}$$

Note that we have replaced the individual's past wage in the effort function with the aggregate past wage w_{t-1}. This can be interpreted as anticipating the fact that in equilibrium all firms will pay identical wages. It is also in line with the implicit assumption of a high worker mobility economy where firms face a random sample of new workers in each period, with the typical worker's past wage corresponding to the economy's last period average. Under this assumption, firms also ignore the impact a higher wage offer today has on future effort, i.e. they treat w_{t-1} as an externality. In Becker's (1996) terminology, this is the so-called social norm case.[15]

[14] Implicit in this formulation is the assumption that firms always find it optimal to meet demand $y_t(z)$.

[15] The arguably more realistic alternative – the personal norm case – assumes that firms internalize the negative influence that a higher wage has on future effort. In such an environment, firms would have to keep track of the distribution of past wages of the individuals that they employ in the current and future periods. Solving for the personal norm case involves analyzing the distribution of wages and its dependency on price setting, a non-trivial task we leave for further work.

Given these assumptions, cost minimization yields

$$r_t^k = \alpha mc_t(z) \frac{y_t(z)}{k_t(z)} \tag{11}$$

$$w_t(z) = (1-\alpha)\, mc_t(z) \frac{y_t(z)}{n_t(z)} \tag{12}$$

$$n_t(z) = (1-\alpha)\, mc_t(z) \frac{y_t(z)}{e_t(z)} \frac{\phi_1}{w_t(z)} \ , \tag{13}$$

where $mc_t(z)$ denotes firm z's period t real marginal cost – corresponding to the Lagrangian multiplier for the output constraint.

Combining (12) and (13), we obtain the Solow (1979) condition

$$\frac{w_t(z)}{e_t(z)} \frac{\partial e_t(z)}{\partial w_t(z)} = 1 \Longleftrightarrow e_t(z) = \phi_1. \tag{14}$$

Firms in the social norm case of our model thus find it optimal to set wages so as to elicit a constant level of effort.[16] Substituting this condition into the effort function, we can derive the so-called fair wage function, i.e. the wage level consistent with the optimal level of effort $e_t = \phi_1$

$$\log w_t(z) = (1 - \phi_0/\phi_1) - \phi_2/\phi_1 \log n_t - \phi_3/\phi_2 \log w_t - \phi_4/\phi_1 \log w_{t-1}.$$

The real wage $w_t(z)$ is seen to entirely depend on factors that the firm considers exogenous. Therefore, every firm will pay the same wage $w_t(z) = w_t$, which simplifies the fair wage function to

$$\log w_t = \frac{\phi_1 - \phi_0}{\phi_1 + \phi_3} - \frac{\phi_2}{\phi_1 + \phi_3} \log n_t - \frac{\phi_4}{\phi_1 + \phi_3} \log w_{t-1}. \tag{15}$$

This important equation highlights that aggregate real wage dynamics in our Fair Wage model are a function of aggregate employment and last period's aggregate real wage. We will rely on (15) for the calibration of the parameters of the effort function.[17]

Optimal price setting. Following Blanchard and Kiyotaki (1987) and Rotemberg (1987), we assume monopolistic competition in the goods market and let the demand $y_t(z)$ for firm z's product be determined by

$$y_t(z) = \left(\frac{P_t(z)}{P_t}\right)^{-\mu} y_t \ . \tag{16}$$

[16] Collard and de la Croix consider the personal norm case under the hybrid assumption that individual effort does not depend on the individual's past wage but rather on the economy-wide average past wage. They find that in such a case, effort becomes procyclical.

[17] Note that our model nests an alternative view of efficiency wages where effort depends on the absolute real wage level and not on relative wage comparisons. Our estimation of the fair wage function in Section 3 will inform to what extent this alternative is relevant in the data.

The ratio $P_t(z)/P_t$ denotes firm z's price relative to the aggregate price index P_t, $\mu > 1$ is the constant elasticity of substitution between the different goods, and y_t is an aggregate demand index defined as $y_t = \left(\int_0^1 y_t(z)^{(\mu-1)/\mu} dz\right)^{\mu/(\mu-1)}$.

As for price setting, we adopt Calvo's (1983) partial adjustment mechanism on the grounds that it leads to a particularly tractable pricing relationship and that it has been used extensively in previous literature.[18] Accordingly, there is an (unspecified) source of nominal rigidity that is approximated by assuming that, in any given time period, the typical firm faces the constant probability κ of keeping its price constant and the complementary probability $(1-\kappa)$ of being free to adjust.[19] Given this setup, the average duration of price fixity can be derived as $1/(1-\kappa)$.

A firm that does adjust in period t sets its new optimal price $P_t(z)$ so as to maximize the discounted sum of current and expected future real profits

$$\max_{P_t(z)} \sum_{j=0}^{\infty} \kappa^j \beta^j E_t \left[(\lambda_{t+j}/\lambda_t) q_{t+j,t}(z)\right] \ .$$

In this expression, $q_{t+j,t}(z)$ stands for the period $t+j$ real profit conditional on firm z not having adjusted its price after t, $\beta^j E_t(\lambda_{t+j}/\lambda_t)$ represents the expected discount factor with which shareholders (i.e. the consumer-workers) value date $t+j$ profits and κ^j denotes the probability that the firm in question will keep its new price $P_t(z)$ unchanged from t through $t+j$. It can be shown that this optimization problem leads to the following first-order condition[20]

$$\log P_t(z) = (1-\beta\kappa) \sum_{j=0}^{\infty} (\beta\kappa)^j E_t \left[\log(mc_{t+j}(z)/mc(z)) + \log P_{t+j}\right], \tag{17}$$

where $(mc_{t+j}(z)/mc(z))$ is the period $t+j$ aggregate real marginal cost of firm z relative to its steady state value. Condition (17) highlights that firm z's new optimal price is entirely determined by expectations about future real marginal costs and future aggregate prices, and by the probability κ^j that the firm will keep its new price unchanged for j periods.

¿From the above exposition, we also know that all firms face the same constant return to scale production function and charge the same factor prices w_t and r_t^k (by assumption, firms are price takers in the capital market). As a consequence, marginal cost is the same for all firms, $mc_t(z) = mc_t$, which in turn implies that every adjusting firm charges the same new optimal price

[18] See for example King and Wolman (1996), Yun (1996), Woodford (1996), Rotemberg and Woodford (1997), McCallum and Nelson (1998) or Bernanke, Gertler and Gilchrist (1998).

[19] The assumption of a fixed probability of changing prices regardless of the number of periods since the last adjustment is admittedly a simplification. Recent work by Kiley (2002) and Wolman (1999) suggests that the price dynamics implied by a DSGE model with more realistic adjustment processes may differ substantially from a DSGE model with Calvo pricing. Investigating the impact of alternative pricing mechanism on our Fair Wage model is left for future research.

[20] See for example King and Wolman (1996) or Wolman (1999).

$P_t(z) = P_t^*$ regardless of its pricing history. This implication allows us to express the law of motion for the aggregate price index as:

$$\log P_t = (1-\kappa)\log P_t^* + \kappa \log P_{t-1}. \tag{18}$$

Real wage rigidity and the effects on real marginal cost and the labor market. Equation (15) highlights the dependence of current on past real wages in our Fair Wage model. Such an intertemporal link has the potential to decrease the sensitivity of real wages and real marginal cost to output fluctuations, thus providing the internal propagation mechanism that Romer (1993) and others emphasize as being crucial for small nominal price rigidities to have sizable real effects. To illustrate this point, combine the cost-minimizing conditions (11) and (12) with the production function (10) and the Solow condition. Real marginal cost can then be written as

$$\log(mc_t/mc) = \alpha \log(r_t^k/r^k) + (1-\alpha)\log(w_t/w) - \log(A_t/A)\ ,$$

where variables without time subscripts designate steady state values. Everything else constant, if real wages turn out to be sufficiently rigid (a property that would arise in our context because of the dependence of current wages on past wages), the sensitivity of real marginal cost with respect to output *is* lower. In turn, the optimal price setting equation (17) implies that a decreased responsiveness of real marginal cost induces adjusting firms to make smaller and more gradual price changes, thus leading to larger and more persistent output responses to exogenous shocks. Of course, a crucial issue is the extent to which the output elasticity of r^k is altered by changes in the degree of real wage rigidity. In other words, greater real wage rigidity only leads to less responsive real marginal cost dynamics if it is not offset by an increase in the sensitivity of the rental rate of capital. Whether this is the case or not may well depend on the model context and its parametrization. We return to this question in Sections 4 and 5.

Compared to the basic NNS model, our Fair Wage framework carries with it a non-trivial change in the interpretation of employment fluctuations. This is because the representative firm z hires $n_t(z)$ workers, each of them *inelastically* supplying one unit of labor, subject to the labor demand condition (12) and the fair wage function (15). Aggregate employment then simply equals $n_t = \int_0^1 n_t(z)dz$ and nothing guarantees that in equilibrium, all workers are effectively hired. Hence, there is a clear sense in which there is unemployment at the equilibrium of our Fair Wage model with the unemployment rate being defined as

$$u_t = 1 - n_t.$$

Furthermore, under the hypothesis that all individuals work full time or not at all, the employment level n_t is interpreted as the fraction of consumer-workers employed and all employment fluctuations can be viewed as movements on the *extensive* margin. By contrast, all labor market fluctuations in the basic NNS model happen on the intensive margin and equilibrium employment is determined by the intersection of the labor supply condition (9) and the labor demand equation (12). Since effort is constant by assumption and real wages always adjust to clear the market, there is no unemployment.[21]

2.3 Money supply

Monetary authorities exogenously set the (net) growth rate of money η_t, such that the supply of real balances evolves according to

$$m_t = (1+\eta_t)\frac{m_{t-1}}{\pi_t}. \tag{19}$$

The seigniorage from this money growth is redistributed lump-sum to consumer-workers yielding real monetary transfers of

$$t_t = \eta_t m_{t-1}\frac{1}{\pi_t}\,. \tag{20}$$

2.4 Aggregation and equilibrium

In equilibrium, all money available will be used for consumption and investment. Thus,

$$m_t = a_t = c_t + i_t\ . \tag{21}$$

Following Yun (1996), equilibrium aggregate output y_t can be linked to aggregate inputs k_t and n_t by

$$y_t = \left(\frac{\bar{P}_t}{P_t}\right)^{\mu} A_t k_t^{\alpha}\left[\phi_1 n_t\right]^{1-\alpha}, \tag{22}$$

where the alternative price index $\bar{P}_t$ is defined as

$$\bar{P}_t^{-\mu} = (1-\kappa)P_t^{*-\mu} + \kappa\bar{P}_{t-1}^{-\mu}. \tag{23}$$

[21] We stress, however, that, in the Fair Wage model, the indivisibility assumption does not play any role in generating a larger intertemporal substitution in leisure and labor as is the case in the Rogerson-Hansen indivisible labor model. This is why we consider the standard NNS model without indivisibility as the relevant benchmark in our analysis. Indeed, our family construct guarantees that the decision making unit is not affected by the interpretation that individuals work full time or not at all, and nothing substantive or quantitative depends on this interpretation. Rather, it is the existence of involuntary unemployment resulting from efficiency wages that is key in generating a high responsiveness of employment or hours to exogeneous shocks.

Likewise, aggregate firm profits can be expressed as

$$q_t = y_t \left[1 - mc_t \left(\frac{\bar{P}_t}{P_t} \right)^{-\mu} \right]. \tag{24}$$

Finally, combining the representative budget constraint (6) with the firm cost minimization conditions (11) and (12), the equilibrium real balances condition (21) and the profit function (24), we obtain the national income identity

$$y_t = c_t + i_t. \tag{25}$$

The dynamics of the Fair Wage model are described by the system of equations (4), (5), (7), (8), (11), (12), (15) and (17) – (25). The system of equations corresponding to the dynamics of the standard NNS models is the same with the exception that the fair wage function (15) is replaced by the labor supply condition (9). We solve the model with the numerical mechanism developed by King and Watson (1998) after log-linearizing all equations.[22]

3 Parametrization and exogenous driving processes

3.1 Calibration of standard parameters

We choose to calibrate the standard parameters of our Fair wage and benchmark NNS models as follows:

Calibration of standard parameters	
Preferences	$\beta = 0.99$, $\mu = 10, \theta = 1.51$ (NNS model only)
Production function	$\alpha = 0.33$
Depreciation rate	$\delta = 0.025$
Growth rate of real variables	$\gamma = 1.0049$
Fraction of price adjusting firms	$(1 - \kappa) = 0.3$
Steady state technology and money growth	$A = 1$, $\eta = 0$

The value for β implies a steady state risk free real interest rate of 6.5% in annualized terms, while $\delta = 0.025$ leads to an annualized depreciation rate of effective capital of 10%. Both of these calibrations are standard (King, Plosser and Rebelo, 1988). The weight on leisure in the specification of preferences valid for the benchmark NNS model is set to $\theta = 1.51$, resulting in a steady state fraction of hours worked of one-third (Cooley and Prescott, 1995).

The growth rate of real variables for our sample is estimated to be $\gamma = 1.0049$.[23] The elasticity of substitution between goods is set to $\mu = 10$, as suggested by Basu (1996) and Basu and Kimball

[22]We thank Bob King for providing us with the relevant solution code.

[23]See Appendix A.2 for details.

(1997), implying a steady state markup of price over marginal cost of 11%. With this mark-up, a labor income share of 0.60 – as estimated by Cooley and Prescott (1995) – obtains if the production function parameter is set to $\alpha = 0.33$.

Setting the fraction of price adjusting firms in the Calvo pricing framework $(1-\kappa) = 0.3$ leads to an average price duration of 3.3 quarters. This value is within the range of industry-specific estimates as summarized by Taylor (1998). Finally, the steady state values of the productivity shock and the money growth rate are calibrated so as to produce a zero steady-state rate of inflation for our transformed economy. This calibration considerably simplifies the log-linearization and may be considered as a useful approximation for the analysis of business cycle dynamics.

3.2 Estimation of the fair wage function

As discussed in the previous section, the gift exchange view of labor relations is largely based on behavioral considerations about fairness and reciprocity. Unfortunately, neither micro surveys nor experimental studies have produced quantitative estimates of the relevant elasticities permitting the type of calibration exercise that underlies modern business cycle research. In our view this lack of precise knowledge about the relative importance of the different factors affecting effort does not mean that we should not submit our model to the usual tests.

The approach we choose to address this challenge is as follows. Instead of attempting to directly calibrate the structural parameters of the effort function, we observe that, if the view of the world presented in Section 2 is a good depiction of reality, the interaction of workers' and firms' optimizing behaviors should produce a wage dynamics that is well approximated by the fair wage function (15). We therefore choose to calibrate (combinations of) the effort parameters *indirectly* by estimating the parameters of the fair wage function in two distinct steps.[24] First, we set the constant $(\phi_1 - \phi_0)/(\phi_1 + \phi_3)$ such that the average unemployment rate in our model economy equals 5.63%, which corresponds to the average rate of U.S. unemployment between 1953 and 2001. This value is substantially lower than the more European level of 10% used in the study by Collard and de la Croix.[25]

Second, we determine the elasticities $-\phi_2/(\phi_1 + \phi_3)$ and $-\phi_4/(\phi_1 + \phi_3)$ by estimating the fair wage function without the constant term, using linearly detrended quarterly U.S. data on the real

[24] We are aware that this calibration approach does not permit recovering all the primitive parameter values of the effort function. However, we believe that our parameter identification occurs sufficiently "upstream" for the validity of the analysis performed in the next section to be assured. Furthermore one should keep in mind that the only purpose of our estimation is to determine plausible values for the parameters of the fair wage function. In Section 5, we assess the robustness of our model to alternative calibrations.

[25] Notice that for our log-linearized solution approach, the choice of steady-state unemployment does not affect the model dynamics but only the dynamics of unemployment itself.

wage and employment over the same time period.[26] An important concern in this exercise is the potential for simultaneous equation bias because the explanatory variable $\log n_t$ is endogenous and depends, among other things, on the real wage. We circumvent this problem by resorting to a two-stage-least-square (2SLS) procedure (see Hamilton (1994), chapter 9). The instruments we employ in the first stage regression are $\log w_{t-1}$ and $\log n_{t-1}$. The estimates of the second stage regression are

$$\log w_t = \underset{(0.0129)}{0.0348} \log n_t + \underset{(0.0065)}{0.9912} \log w_{t-1} + \epsilon_t,$$

with the numbers in parenthesis representing the asymptotic standard errors of the 2SLS approach. The R^2 for this regression is 0.99, indicating a high degree of linear fit while the Breusch-Godfrey LM test statistic of 5.55 for 10 lags provides no significant evidence against the hypothesis of uncorrelated errors ϵ_t (p-value of 0.85).

The estimated elasticity with respect to $\log n_t$ is small but according to a one-sided t-test signficantly different from zero at the 99.6% level. Concurrently, the estimated elasticity with respect to $\log w_{t-1}$ is much more important and close to unity. However, a one-sided t-test rejects the hypothesis of a unit value at the 91.1% significance level. Conditional on $(\phi_1 + \phi_3) > 0$ (the incentive effect of a larger own wage is stronger than the negative effect of a higher comparison wage), the positive estimates of both elasticities indicates that the data is consistent with our intuition that both labor market tightness and past compensation levels exert upward pressure on current real wages. Furthermore, the large estimate on $\log w_{t-1}$ highlights the crucial role past wages play in the determination of effort, lending indirect empirical support to Bewley's micro-based argument that "...[Solow's and Akerlof's fair wage idea] is correct in emphasizing morale, and errs only if importance is attached to wage levels rather than *changes* in them."

The results reported here are also helpful in appreciating the calibration that Collard and de la Croix choose for their effort function in the first part of their paper. They impose $-\phi_2/(\phi_1 + \phi_3) = \gamma/\psi = 0.9/2.8 = 0.3214$ and $-\phi_4/(\phi_1 + \phi_3) = \psi/\psi = 1$ (the first ratio being chosen such that their RBC model exactly replicates the correlation between output and employment). As our estimates show, both of these restrictions can be independently rejected at high significance levels (the rejection is also strongly confirmed by a F-test of the joint hypothesis that both restrictions hold). Hence, while the data attributes great importance to the intertemporal view of effort determination that Collard and de la Croix emphasize in their work, our results cast serious doubt on their calibration of the relationship between labor market tightness and the current real wage. Moreover, we reject the hypothesis of additional lags of the real wage in the effort function (i.e. habit persistence) that Collard and de la Croix introduce in the second part of their paper. For example, when regressing

[26] Appendix A.2 explains why linear detrending of the logged variables involved in the estimation of the fair wage function naturally follows from the stationarity transformation underlying our model.

the real wage on employment and four lags of the real wage, $\log w_t = c_0 \log n_t + \sum_{i=1}^{4} c_i \log w_{t-i} + \epsilon_t$, we find that all but the first lag of the real wage are highly insignificant and a F-test of the null that the coefficients on all but the first lag of the real wage are jointly zero cannot be rejected at the 95% significance level.

3.3 Form and estimation of the driving processes

Two goals underlie the specification of the driving processes. On the one hand, we want the driving processes to match the autocovariance properties of the data counterparts of the technology shock A_t and the money growth shock η_t as closely as possible. On the other hand, we intend to keep our framework as stylized and easily interpretable as possible.

Form. Following the RBC literature, the log of the technology shock is assumed to follow an AR(1) process:[27]

$$\log(A_t) = \rho_A \log(A_{t-1}) + \varepsilon_{At} \ . \tag{26}$$

Similarly, the dynamics of the money growth rate is approximated by:

$$\eta_t = \rho_\eta \eta_{t-1} + \varepsilon_{\eta t} \ . \tag{27}$$

Furthermore, we specify the two innovations ε_{At} and $\varepsilon_{\eta t}$ as a bivariate process $(\varepsilon_{At}\ \varepsilon_{\eta t})\ \tilde{}\ (0, \Omega)$ with the off-diagonal elements of the variance-covariance matrix Ω left unrestricted. Thus, we allow for contemporaneous correlation between the innovations.

Estimation. The series corresponding to the technology shock is constructed by taking logged data on output and employment, removing a linear trend from each of the series and then computing $\log A_t = \log y_t - (1-\alpha) \log n_t$. As in King and Watson (1996), we thus exclude fluctuations of the capital share because this term has a very small variance and is poorly measured in the data.[28] Concurrently, a series for money growth is obtained by approximating the net growth rate η_t by $\log(1+\eta_t) = \log(M_t) - \log(M_{t-1})$.

With these two series at hand, we estimate ρ_A and ρ_η from (26) and (27) with ordinary least squares. The elements of the sample variance-covariance matrix are computed as $\hat{\Omega} = \frac{1}{T} \sum_{t=1}^{T} \hat{\varepsilon}_t^2$ where $\hat{\varepsilon}_t = [\hat{\varepsilon}_{At}\ \hat{\varepsilon}_{\eta t}]'$ are the sample residuals of the two regressions. For our sample period, this leads to the following results:

$\hat{\rho}_A$	$\hat{\rho}_\eta$	$\hat{\sigma}_A$	$\hat{\sigma}_\eta$	$cor\hat{r}_{A,\eta}$
0.96	0.67	2.54	1.12	0.05

[27] See King and Rebelo (2000) for a discussion.

[28] Note that this shock process is consistent with the aggregate production function in (22) because in our zero inflation steady-state setup, $\bar{P}_t/P_t$ is constant and $e_t = \phi_1$ in equilibrium. Both of these constants are (presumably) removed from the data when applying the linear trend.

where σ_A, σ_η and $corr_{A,\eta}$ are the standard deviation of $\log(A)$, the standard deviation of η and the correlation between the two, respectively. The estimates of the autoregressive coefficients and the standard deviations closely match the empirical evidence reported in other studies (see for example King and Rebelo (2000) for the values of ρ_A, σ_A and Yun (1996) for the values of ρ_η, σ_η). We interpret the estimate $\hat{corr}_{A,\eta} = 0.05$ as an indicator that monetary policy (which is not explicitly modeled here) has historically been mildly accommodative of real-side supply shocks.

4 Simulation results

The empirical performance of the Fair Wage model is analyzed in two stages. First, we consider impulse response functions (IRFs) of different aggregates with respect to a money growth and a technology shock. The goal of this exercise is (i) to graphically illustrate the effects of introducing real wage rigidity; and (ii) to perform a quality check in the sense of Gali (1999) who argued that reporting unconditional second moments alone may disguise important model deficiencies in terms of responses conditional on a particular shock. In the second stage, we report a variety of unconditional second moments. Presumably, the evaluation of monetary business cycle models along this dimension has been stalled by the impossibility to reliably specify the joint behavior of *all* the disturbances influencing the model. While it is certainly true that important assumptions underlie any calculation of unconditional moments, we argue that these assumptions are no stronger than the ones taken for the identification of structural VARs necessary to quantify the model performance in terms of IRFs. Furthermore, unconditional moments are an illustrative measure of performance that allows us to compare the performance of our Fair Wage economy to different models of the RBC type.

4.1 Impulse response functions

IRFs with respect to a money growth shock. Figure 1 displays IRFs of several key variables over 20 quarters with respect to a 1% shock in money growth for both the Fair Wage model (solid lines) and the benchmark NNS model (dotted lines). One cannot fail noticing the weak response of output – both in terms of amplification and persistence – in the NNS economy relative to the responses for the Fair Wage specification. This observation will be confirmed by all the other empirical performance measures reported in this section. The response of output in the Fair Wage model peaks after three to four quarters and is roughly twice as large as the maximum output increase in the NNS case, which occurs after two quarters. Compared to evidence from structural VARs such as Christiano, Eichenbaum and Evans (2001), the hump-shape of the output response is thus slightly too concentrated but the fair wage addition moves the timing of the peak in the right direction.[29] As to persistence, we borrow Chari, Kehoe and McGrattan's (2000) contract multiplier as a useful yardstick.[30] Our Fair Wage model yields a contract multiplier of about 6, which – for our assumed average price fixity of 3.3 quarters – is roughly equal to the multiplier that these authors find in the data. By contrast, the contract multiplier corresponding to the NNS model is about 4 or roughly a third lower.

The key to understanding the powerful internal propagation mechanism of the Fair Wage model is – not surprisingly – the behavior of the real wage. The response of the real wage is much dampened and more gradual compared to the NNS model (center plot of Figure 1). Since the rental rate of capital remains virtually unchanged with the exception of a slightly smaller deviation on impact (not reported for space reasons), the response of real marginal cost is also much smaller and hump-shaped. This means that adjusting firms find it optimal to increase their prices to a smaller extent, which has the consequence that the aggregate price level adjusts more gradually to its new level while the response of output is both larger and longer-lasting. Finally, the amplified and persistent effect on output is naturally matched by larger consumption and investment responses, with the main effect being on investment because the temporary nature of the shock implies a smooth pattern for consumption in application of the permanent income hypothesis.

Chari, Kehoe and McGrattan (2000) recently stressed that insensitive real marginal cost dynamics seems indispensable for models with nominal price rigidities and intertemporal links (such as investment) to generate a plausibly persistent response of output to monetary shocks. The reported IRFs underline this argument and suggest that our specification of effort considerations offer a plausible mechanism to solve this "persistence problem". In this respect, our Fair Wage model represents an alternative to Dotsey and King's (2001) introduction of "real flexibilities" - i.e. produced inputs, variable capacity utilization, and labor supply variability along the extensive margin – which also lead to a reduced sensitivity of real marginal cost, reduced price variability

[29] Strictly speaking, our IRFs cannot be directly compared with the bulk of the structural VAR responses reported in the literature because most of them identify the monetary shock as an exogenous perturbation to a policy instrument other than the growth rate of money. Christiano, Eichenbaum and Evans (1998), however, argue that an AR(1) representation with a persistence of about 0.5 (which is roughly the same than our estimate) is a good approximation to the estimated IRF of money growth with respect to an exogenous shock in the monetary policy instrument. Such a money growth process can therefore be used indirectly as a "stand-in" monetary policy instrument. At the same time, IRFs from structural VAR responses are subject to a variety of criticisms on their own (identification assumptions, choice of variables and so forth). Hence, we emphasize that the main goal of our reporting IRFs is not to compare them with the data but rather to use them as a means of understanding the internal propagation mechanisms of our model.

[30] Chari, Kehoe and McGrattan's contract multiplier is defined as the ratio of the half-life of output after a monetary shock with nominal price rigidity to the corresponding half-life with flexible prices (with half-life being defined as the length of time after a shock before the deviation in output shrinks to half of its impact value). Since shocks occur randomly over any given period, the half-life with flexible prices should be roughly half of the average degree of exogenous price fixity.

and a prolonged output response.

Unsurprisingly, our stylized Fair Wage model cannot solve all the deficiencies of the benchmark NNS model in the context of a money growth shock. While the introduction of real wage rigidity reduces the response of both the aggregate price level and the rate of inflation, it does not come close to matching the very sluggish (and for the inflation rate humpshaped) response found in the data by, for example, Gali (1992), Christiano, Eichenbaum and Evans (1997) or Nelson (1998). Furthermore, our Fair Wage model does not succeed in generating a liquidity effect (i.e. an initial decrease of the nominal interest rate). This deficiency is intrinsically related to the counterfactual behavior of inflation in the model. Because inflation jumps up on impact, the response of expected inflation is also highest in the very first period, thus swamping the modest negative response of the real interest rate.[31]

IRFs with respect to a technology shock. Turning to Figure 2, the stronger amplification and persistence of output and other NIPA aggregates in the Fair Wage model is confirmed for the case of a technology shock (note that we report the different IRFs over 50 quarters since the large persistence of the technology shock by itself makes some of the deviations very long-lived). The source of this internal propagation is again the real wage rigidity, which is apparent from the very gradual response of the real wage and the accompanying larger response of employment in the Fair Wage model.

Gali (1999) and more recently Francis and Ramey (2002) have emphasized that in the data, employment decreases after a positive technology shock. Since their technology shock is permanent rather than transitory and identified differently than ours, it would be inappropriate to directly compare our IRFs with their results. Nevertheless, we interpret it as an encouraging sign that the initial response of employment is negative not only for the NNS but also for our Fair Wage economy despite the initially very small response of the real wage in the latter model. Also note that by contrast to the Fair Wage model, the NNS model generates a sizable negative yet short-lived decrease of the real wage upon impact. This appears counterfactual in light of the evidence in Francis and Ramey (who report a positive real wage response in the data). Again, a word of caution is in order because of the different nature of the technology shock in their study and ours.

[31] As mentioned before, we acknowledge that the assumed monetary transmission mechanism is excessively simplistic. Most central banks implement their policy decisions by targeting interest rates rather than by setting money growth rates. Moreover, different agents may be affected differently by interest rate fluctuations. Our conclusions regarding the liquidity effect would potentially be altered by the introduction of a more realistic description of monetary policy.

4.2 Unconditional second moments

Table 1 reports a host of unconditional second moments for U.S. data and contrasts them to the corresponding values simulated from the NNS and the Fair Wage model.[32] We extend our comparison to the unconditional moments reported by Cooley and Hansen (1989) for a monetary RBC model as well as Collard and De la Croix (2000) for their fair wage RBC economy.

Output volatility and persistence. The standard deviation of output in the NNS model stands at 1.01 while it is 1.66 in the data and 1.79 in the Fair Wage model. This difference in volatility forcefully highlights the already noted lack of internal propagation in the NNS benchmark model. As is well known, the problem of weak amplification would also apply to the case of the monetary business cycle of Cooley and Hansen (1989) if it were not for their model's indivisible labor feature.

The Fair Wage model furthermore generates a first-order autocorrelation for output of 0.92, which is slightly larger than the value of 0.89 for the NNS model. Because the autocorrelation for the NNS model is already surprisingly high, this actually represents a move away from the autocorrelation in the data of 0.85. The former borrows from the estimated properties of Solow residuals which have been widely questioned, however. We thus tend to view as positive the capacity of our model to generate persistent reactions to the external shocks. Overall, we consider the increased output volatility as one of the prime success stories of the fair wage construct.

Consumption and investment. The relative volatility and cross-correlation with output of both consumption and investment are virtually the same for the Fair Wage and the NNS model. While the relative standard deviation for consumption is slightly too low, investment is a bit too volatile compared to the data. This last feature can be traced to the fact that, for the sake of simplicity, we have refrained from incorporating costs of adjusting capital into our models.

Real wages and employment. The relative standard deviation of the real wage and its cross-correlation with output is much too high in the NNS model while the cross-correlation between employment and output is counterfactually low. By contrast, the (estimated) strong dependence of current on past compensation levels in our Fair Wage economy enables firms to adjust labor input without excessive variations in its price. This greatly reduces the sensitivity of the real wage and simultaneously increases the responsiveness of employment to output fluctuations. Furthermore, the benchmark NNS economy as well as Cooley and Hansen's monetary RBC model generate a real wage that is too highly correlated with employment. Concurrently and very much analogous to Collard and de la Croix' fair wage RBC economy, our Fair Wage model comes much closer to

[32]Theoretical moments are computed from the model solutions using the spectral method described in King and Watson (1996). We thank Bob King for kindly supplying this code. All moments are reported after Hodrick-Prescott filtering.

the near-zero correlation between the real wage and employment observed in our data sample and first noticed by Dunlop (1938) and Tarshis (1938). We interpret this last result as an additional important feature in favor of the fair wage labor market framework.

Aside from these positive results, there are also dimensions of the labor market along which our stylized Fair Wage model performs unsatisfactorily: the real wage rate is not variable enough;[33] the standard deviation of employment is somewhat too high; and unemployment is excessively variable. This last result is due to the fact that unemployment in our stylized economy is (counterfactually) modeled as the mirror image of employment and that we calibrated its average rate to 5.63% rather than the 10% chosen by Collard and de la Croix. Despite these deficiencies, we believe that the dramatic change in real wage and employment dynamics illustrate well how the introduction of effort considerations may offer a solution to the real wage and employment puzzle of the NNS and RBC frameworks.

Real marginal cost. Notice that the smoothened real wage and the associated ability of firms to adjust their labor input also stabilizes the rental price of capital in the Fair Wage model (relative to the benchmark NNS). Altogether, the volatility of real marginal cost relative to output is much reduced (from a ratio of 1.53 to 0.60), a fact that underlies the strength of the internal propagation mechanism of our model.

The stabilizing impact of fair wage considerations on the real marginal cost contradicts Kiley's (1997) message that efficiency wage models are unlikely to achieve additional amplification in models with nominal price rigidities. His argument was derived from a very simple framework with neither intertemporal wage comparisons in the effort function nor variable capital. For real wages to be acyclical under his assumptions, effort had to be low when output and employment were high, forcing real marginal cost to be highly volatile and procyclical.[34] The evidence presented here is much more favorable to the efficiency wage view. The intertemporal dimension of our fair wage construct is key in explaining the difference. With the comparison between current and past wages playing a dominant role in the determination of effort, the link between acyclical real wages and procyclical real marginal cost is severed.

Prices and Inflation. As discussed above, a direct consequence of a less elastic real marginal cost dynamics is that adjusting firms change their prices to a smaller extent in response to a shock. It is thus not unexpected that we observe a substantial decrease in the relative volatility of both

[33] When comparing the real wage moments of our Fair Wage model with the data, one should keep in mind that different measures of the real wage may lead to quite different data moments. Furthermore, there may also be some important subsample instability. For example, Cooley and Prescott (1995) report moments for two measures of the real wage. The first (from the Establishment Survey, 1964:1-1991:2) implies a relative standard deviation of 0.44. By contrast, the second measure (from the National Income Accounts, 1954:1-1991:2) produces a relative standard deviation of 0.32.

[34] Uhlig and Xu (1996) also develop an efficiency wage model with a *static* effort function and countercyclical effort.

the aggregate price level (from a ratio of 2.13 to 1.19) and the inflation rate (from a ratio of 0.77 to 0.39) in the fair wage economy. The price level also becomes more countercyclical. While moments for the aggregate price and inflation do not perfectly match respective data counterparts, they definitely go in the right direction when compared to the NNS model. The same comparison is also unfavorable to the monetary RBC model, where money is a "pure veil" and price reactions are excessive.

Finally, notice that Fair Wage model generates a slightly larger first-order autocorrelation for inflation than the NNS model. By contrast, the data display a much more moderate degree of inflation persistence at business cycle frequencies. This finding is somewhat unexpected given the empirical literature arguing that models incorporating Calvo pricing cannot generate sufficient inflation persistence (see for example Fuhrer and Moore, 1995 or Fuhrer, 1997). Most of these studies refer to overall and not cyclical inflation, however. In our view, this is not entirely appropriate since the log-linearized inflation equation derived from the Calvo framework should be considered as a cyclical description of price dynamics.

5 Robustness of results

As mentioned in the preceding discussion, it is important to evaluate the robustness of the models to various parameter changes. We consider in turn the impact of assuming a smaller degree of nominal price rigidity; of changing the calibration of the effort function; and of altering the correlation between the two driving processes. For space reasons, the discussion of the results will be limited to a few key aspects.

5.1 Assuming a smaller degree of price rigidity

Figure 3 displays IRFs with respect to a 1% money shock for the case of a smaller average price rigidity of two quarters ($1-\kappa = 0.5$) rather than the 3.3 quarters ($1-\kappa = 0.3$) of our baseline case. The impact of this change is striking for the performance of the basic NNS model. Specifically, it loses virtually all of its ability to produce any real effects in response to the nominal shock (dotted lines). The Fair Wage model, in contrast, remains capable of generating sizable and persistent reactions for the different real variables (solid lines). This result accords with the conclusion of Chari, Kehoe and McGrattan that with a small degree of price rigidity alone, the NNS all but fails to generate the sort of business-cycle non-neutralities it was designed for. The result further underlines the fact that the adjunction of real rigidities originating from gift exchange efficiency wages is a powerful remedy to this problem.

Turning to the unconditional moments, Table 2 shows that the decrease in price rigidity also worsens the performance of the NNS model on the labor market front. In particular, the relative volatility of employment falls from a ratio of 0.95 in the benchmark case to 0.43, which is much lower than what is observed in the data. The relative volatility of the real wage and its cross-correlation somewhat improve but the correlation between employment and real wages remains far too high. Concurrently, the performance of the Fair Wage model along the labor market dimension remains quite convincing. In fact, the performance even improves as the variability of employment decreases to a more plausible ratio of 0.98 and the wage rate becomes more procyclical than in the baseline case. At the same time, the correlation between employment and wages remains reasonably low.

Finally and as expected, prices and inflation become more variable for both the NNS and the Fair Wage model (a move in the wrong direction). However, while the cyclicity of prices and inflation improves in the fair wage economy, inflation becomes counter-cyclical in the case of the NNS. In sum, these observations highlight that the Fair Wage model appears substantially more robust than the basic NNS to changing assumptions about the degree of price rigidity.

5.2 Changing the calibration of the effort function

How sensitive is our model to changes in the calibration of the effort function? To answer this question we report in Figures 4 and 6 the changes recorded for key second moments as the two slope coefficients take a range of conceivable values. We also display in Figures 5 and 7 the impulse response functions obtained for specific alternative values of the two key parameters.

We start by testing the sensitivity of our results to a change in the elasticity of current compensation with respect to labor market tightness ($-\phi_2/(\phi_1+\phi_3)$). Figure 4 reports the results obtained when varying this parameter over the range 0 to 1 (while keeping the elasticity with respect to the past wage fixed at 0.99). When effort becomes more sensitive to the current labor market situation (i.e. when variations in employment become relatively more important in motivating workers to provide a gift above norm efforts), firms are led to adjust real wages more rapidly (Figure 4, top right panel) and thus, the degree of real wage rigidity decreases[35]. The increase in the variability of real wages in turn leads to an increase in the relative variability of the real marginal cost (bottom left panel). The impact of the more sensitive real marginal cost dynamics on the degree of integral propagation is dramatic. The unconditional standard deviation of output falls (top left panel) and the relative volatility of the price level and inflation increases. At the same time, the top left panel of Figure 4 indicates that the ability of the fair wage model to generate a low correlation between employment and wages is robust to this parameter change.

To illustrate further, Figure 5 shows IRFs with respect to a money growth shock when $-\phi_2/(\phi_1+\phi_3) = 0.32$ (the value set by Collard and de la Croix). The Fair Wage model is no longer capable of generating amplified and long-lasting real responses to a 1% money growth shock. Its performance in terms of generating sizable and persistent non-neutralities becomes even less satisfactory than

[35]We conjecture that this tendency would be less marked in a personal norm formulation of our model.

the one of the NNS benchmark! These results highlight the crucial dependence of the Fair Wage model on the calibrated elasticity of the real wage to employment.[36] We stress, however, that our point estimate for this parameter is only 0.035, with a 95% confidence interval that is very tight, ranging from 0.009 to 0.061. Assuming an elasticity anywhere higher than 0.1 thus appears largely incompatible with the data under the fair wage hypothesis.

We now turn to the effects of toning down the importance of the past compensation level in the fair wage function. Figure 6 reports the impact of varying the elasticity of the real wage with respect to past wages ($-\phi_4/(\phi_1+\phi_3)$) between 0 to 1 (while leaving the elasticity with respect to employment at its estimated value of 0.035). Our model appears considerably more robust along this dimension. The top-right and bottom left panel show that the relative volatility of the real wage and consequently the relative volatility of marginal cost are little affected by these parameter changes (the scale of both graphs is an order of magnitude smaller than the scale of the corresponding panels in Figure 4). As a consequence there is little effect on the properties of output, employment or prices and inflation (again beware that the scaling of the vertical axes is adapted to the size of the recorded changes). The key unfortunate impact of decreasing this elasticity from its point estimate of 0.99 to lower values is to increase the correlation between the real wage and employment, thus making the model with elasticity of the past real wage smaller than approximately 0.9 prone to the Dunlop-Tarshis critique.

For the purpose of illustration, Figure 7 provides the IRFs with respect to a money growth shock for the case where the elasticity on past wages takes the arbitrarily extreme value of 0. Lowering the dependence of current on past compensation actually renders the responses of real variables with respect to a 1% monetary shock much more persistent. In particular, output returns to half its deviation on impact only after roughly 50 quarters! To explain this result, note that, given the near-zero elasticity of the fair wage to current employment, when the elasticity to past wage changes tends toward zero, our model in fact converges toward an efficiency wage model where effort depends on the *absolute* real wage level rather than on relative wage comparisons. With the adopted functional forms, the optimal wage policy consists in maintaining a constant real wage, so as to elicit a constant effort level. This explains the extremely low reaction of the real wage recorded in Figure 7 and the increased persistence of the response of real variables to monetary shocks. Recall however that, as before, this case is highly unlikely given the point estimate 0.99 obtained in Section 3.

5.3 Do assumptions about the driving processes matter?

It is widely accepted that basic business cycle properties of actual economies are to a large extent independent of time and place. Given the large differences in monetary policies followed across

[36] Danthine and Donaldson (1990) made a parallel observation in a RBC context.

countries or across time within a country, the presumption is that our models should not be overly sensitive to alternative assumptions about the money shock process, and its correlation with technology shocks in particular. The last robustness test thus consists in examining the impact on our Fair Wage model of arbitrarily setting the correlation between the technology innovation ε_A and the money growth innovation ε_η to -0.5 and +0.5 (before H-P filtering) rather than the estimated value of 0.09. This leads to the following correlation between the two technology shock A and the money growth rate η:

$corr_{\varepsilon_A,\varepsilon_\eta}$	0.09	-0.5	0.5
$corr_{A,\eta}$	0.05	-0.28	0.28

Table 3 reports the results of this exercise. Overall, the impact on real variables of the hypothetical changes in the correlation of the innovations is modest. The only substantial change in NIPA variables is a decrease in the standard deviation of output to 1.47% for the case when we arbitrarily set the correlations between the innovations to -0.5. This decrease in overall internal propagation can be attributed to the increase in relative volatility of real marginal cost from 0.60 to 0.87, which is mainly due to the increased variability of the rental rate of capital. For the case of a positive correlation of 0.5 between the innovations, the standard deviation of output rises to 1.99%, which is somewhat excessive.

The labor market performance of the Fair Wage model deteriorates somewhat for the negative correlation case: the relative volatility of employment increases to 1.41 and the real wage becomes mildly countercyclical. By contrast, the Fair Wage model would appear under an even more favorable light if the innovations displayed a stronger positive correlation than what we estimated. The relative volatility of employment decreases and the wage rate becomes more procyclical, bringing the model economy closer to the data.

6 Comparison to alternative theories of the labor market

The reported results suggest that introducing real rigidities in the form of Fair Wages greatly enhances the empirical properties of the NK framework. To place our contribution in perspective, we close our analysis with a brief comparison of our model with three closely related contributions incorporating alternative theories of the labor market into DSGE models with sticky prices. Two important caveats apply, however. First, the models discussed below are not built on the same structural base than ours and they are sometimes calibrated differently. This makes comparisons of the effects of different labor market theories tentative, at best.[37] Second, most of the studies

[37]For example, with the exception of Christiano, Eichenbaum and Evans (2001), none of the models under comparison allow for capital accumulation, thus omitting an important intertemporal link that may alter substantially the dynamics of the model (see Chari, Kehoe and McGrattan, 2000).

adopt a narrower perspective when discussing business cycle implications of their respective models. Assessing the overall relative performance of these models vs. ours is thus not possible.

Most closely related to our paper is a study by Felices (2002), which investigates the properties of a model economy where efficiency wages of the shirking variety are combined with a sticky price hypothesis à la Calvo. Felices models consumer behavior using a family structure similar to ours (or Alexopoulos, 2001) but with the added feature that the degree of income insurance among workers is allowed to vary. He finds that with little income insurance (close to zero), shirking efficiency wages substantially increase the persistence of output and inflation in response to a monetary shock while leading to a low correlation between employment and the real wage. These results are not robust, however, to an increase in the assumed level of risk sharing. Moreover, none of Felices' simulations displays the hump-shaped response of output to a monetary shock that seems to be a pervasive feature of the data and that our model successfully reproduces. The ability of our Fair Wage model to induce a low correlation between employment and the real wage does not depend on the degree of risk sharing among consumers. In fact, fairness considerations in our model lead to an intertemporal link between real wages, which we have estimated to be quite high. This breaks the contemporaneous relationship between employment and real wages (thus inducing real rigidity) – independently of the risk sharing arrangement. At another level, we note that recent experimental results and micro surveys appear to favor the fair wage hypothesis over the shirking hypothesis as the more relevant explanation for efficiency wages (see Bewley, 2002, for a summary of this argument).

Exogenously imposed staggered nominal wage contracts constitute another form of labor market frictions that have recently been combined with sticky prices. Such contracts lead to more sluggish wage dynamics and more persistent output fluctuations in response to aggregate demand shocks. In fact, work by Christiano, Eichenbaum and Evans (2001) shows that models with nominal wage contracts alone (without sticky prices) do almost as well in this respect as models with both types of rigidities.[38] However, these results are conditional on a number of other important additional features (habit persistence in consumption, adjustment cost in investment and variable capital utilization). Parallel research by Rabanal (2001) highlights the fact that, in itself and absent a large fraction of irrational backward-looking wage setters, the Calvo sticky wage framework implies counterfactual cross-correlations between output and inflation, output and the real wage as well as inflation and the real wage. Despite these reservations, we agree with Christiano, Eichenbaum and Evans' (2001) conclusion: the success of their reduced-form wage contracts in improving the performance of the basic NK sticky price framework underlines the key role played by sluggish wage adjustments in the U.S. business cycle and calls for a more structural modelling of the labor market. Our Fair Wage model can be viewed as a first response to this call.

[38] Bénassy (2001) and Huang and Liu (2002) are other examples that come to similar conclusions.

A third related contribution is by Walsh (2002) who introduces a labor market structure based on a Mortensen-Pissarides (1994, 1999) matching function into a Calvo sticky price model. For standard parameter values, he finds hump-shaped output and employment fluctuations in response to a monetary shock – similar to what our Fair Wage model delivers. These results are promising and suggest that search and matching frictions may play an important role in explaining key features of the cyclical labor market dynamics. At the same time, Walsh's results are surprisingly sensitive to the calibration of the share of surplus that a matched worker receives from his firm. This finding clearly deserves additional scrutiny and highlights the need for completing search and matching models with an explicit theory of wage determination.

7 Conclusions

In this paper, we have grafted an efficiency wage labor market friction onto a standard DSGE model with sticky prices, thus complementing the nominal price rigidities, which are the hallmark of recent New Keynesian models, with real wage rigidity. In particular, we have adopted a gift exchange efficiency wage framework where comparisons between past and current wages constitute an important determinant of effort. While there exists well-documented micro-evidence that intertemporal comparisons of wages play a significant role in determining effort, it is unclear from the outset how important that role is in an aggregate representative agent setting. The estimates we present in this paper indicate that if one is to make the proposed fair wage framework consistent with aggregate data, comparisons between the current and last period's real wage should actually constitute the major determinant of effort. Our framework thus offers an explanation for why real wages are not only rigid in the sense of preventing labor market clearance but also sluggish in the sense of dynamic adjustment to shocks.

Despite its parsimonious nature, the performance of our Fair Wage model is very satisfactory along two major dimensions at least. First, introducing fair wage considerations leads to substantial improvements on the labor market front. Specifically, the variability and procyclicality of real wages is markedly reduced while employment becomes more procyclical, thus better mimicking the properties of the data. Furthermore, our model is successful in generating the near-zero correlation between employment and real wages that is observed in the data and it provides a structural explanation for the existence of unemployment. These findings are in line with the results by Collard and de la Croix (2000) in the RBC context and confirm that fair wage efficiency wages have the potential to resolve the labor market puzzles that falsify many New Keynesian models of the business cycle. Second, the effort-induced real wage rigidity markedly smoothens the dynamics of real marginal cost. As a result, the Fair Wage model displays much stronger internal propagation to real and monetary shocks than the NNS benchmark – both in terms of amplification and persistence.

These important effects persist even for very moderate degrees of nominal price rigidity. Our fair wage addition thus offers a solution to the well-known persistence problem of standard sticky price models.

In sum, on almost all dimensions in which the Fair Wage model distinguishes itself from the benchmark NNS model with sticky prices only, it appears to perform better. The Fair Wage model also compares favorably with its main competitors although it is not possible at this stage to argue for the definitive superiority of one approach over all the others. The Fair Wage model features a strong intertemporal link for real wages, which is shown to substantially and robustly improve the performance of the standard sticky price model. We take these results as a strong endorsement of the adjunction of real rigidities in the form of effort efficiency wages to complete the New Keynesian synthesis.

References

[1] Akerlof, G. (1982), "Labor Contracts as Partial Gift Exchange," *Quarterly Journal of Economics*, **97**.

[2] Alexopoulos, M. (2001), "Shirking in a Monetary Business Cycle Model," University of Toronto, working paper.

[3] Barro, R. J. (1981), "The Equilibrium Approach to Business Cycle", in R.B. Barro, *Money, Expectations, and Business Cycles: Essays in Macroeconomics*, New York: Academic Press.

[4] Basu, S. (1996), "Procyclical Productivity: Increasing Returns or Cyclical Utilization?" *Quarterly Journal of Economics*, **111**.

[5] Basu, S. and M. S. Kimball (1997), "Cyclical Productivity with Unobserved Input Variation," NBER working paper 5915.

[6] Becker, G. (1996), *Accounting for Tastes*, Cambridge, MA: Harvard Univ. Press.

[7] Bénassy, J.-P. (2001), "Staggered Contracts and Persistence: Microeconomic Foundations and Macroeconomic Dynamics", mimeo.

[8] Bernanke, B., M. Gertler and S. Gilchrist (1998), "The Financial Accelerator in a Quantitative Business Cycle Framework", in J. B. Taylor and M. Woodford (eds.), *Handbook of Macroeconomics*, Amsterdam: Elsevier Science B.V.

[9] Bewley, T.F. (1998), "Why Not Cut Pay?" *European Economic Review*, **42** .

[10] Bewley, T.F. (2002), "Fairness, Reciprocity, and Wage Rigidity," Yale University, Cowles Foundation Discussion Paper 1383.

[11] Blanchard, O. and Kiyotaki, N. (1987), "Monopolistic Competition and the Effect of Aggregate Demand," *American Economic Review*, **77**.

[12] Calvo, G.A. (1983), "Staggered prices in a utility maximizing framework", *Journal of Monetary Economics*, **12**, 383-398.

[13] Chari, V.V., Kehoe, P.J. and McGrattan, E.R. (2000), "Sticky Price Models of the Business Cycle: Can the Contract Multiplier Solve the Persistence Problem?" *Econometrica*, **68**.

[14] Christiano, L. J., Eichenbaum, M. and Evans, C. L. (1997), "Sticky Prices and Limited Participation Models of Money : A Comparison", *European Economic Review*, **41** .

[15] Christiano, L. J., Eichenbaum, M. and Evans, C. L. (1998), "Modeling Money," NBER working paper 6371.

[16] Christiano, L. J., Eichenbaum, M. and Evans, C. L. (2001), "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy", mimeo.

[17] Collard, F. and de la Croix, D. (2000), "Gift Exchange and the Business Cycle: The Fair Wage Strikes Back," *Review of Economic Dynamics*, **3** .

[18] Cooley, T.F. and Hansen, G.D. (1989), "The Inflation Tax in a Real Business Cycle Model", *The American Economic Review*, **79**, 733-748.

[19] Cooley, T.F. and Prescott, E.C. (1995), "Economic Growth and Business Cycles", in T.F. Cooley (ed.), *Frontiers of Business Cycle Research*, Princeton, NJ: Princeton University Press.

[20] Danthine J.P. and Donaldson, J.B. (1990), "Efficiency Wages and the Real Business Cycles", *European Economic Review*, **34**.

[21] Danthine, J.P., and Donaldson, J.B. (2002), "A Note on NNS Models: Introducing Physical Capital; Avoiding Rationing", *Economics Letters* forthcoming .

[22] Dotsey M. and King, R.G. (2001), "Price, Production and Persistence," Federal Reserve Bank of Richmond and Boston University, mimeo.

[23] Dunlop, J. (1938), "The Movement of Real and Money Wage Rates", *Economimcs Journal*, **48**, 413-434.

[24] Erceg, C.J., Henderson, D.W., and Levin, A.T. (2000), "Optimal Monetary Policy with Staggered Wage and Price Contracts", *Journal of Monetary Economics*, **46:2**, 281-313.

[25] Fehr, E. and S. Gächter (2001), "Fairness in the Labour Market – A Survey of Experimental Results," in F. Bolle and M. Lehmann-Waffenschmidt (eds.), *Surveys in Experimental Economics. Bargaining, Cooperation and Election Stock Markets*, Physica.

[26] Felices, G. (2002), "Efficiency Wages in a New Keynesian Framework," New York University, mimeo.

[27] Francis, N. and Ramey, V.A. (2002), "Is the Technology-driven Real Business Cycle Hypothesis Dead? Shocks and Aggregate Fluctuations Revisited," National Bureau of Economic Research, working paper no. 8726.

[28] Fuhrer, J.C. and Moore, G. (1995), "Inflation Persistence," *Quarterly Journal of Economics*, **110**.

[29] Gali, J. (1992), "How Well does the IS-LM Model Fit Postwar U.S. Data ?", *Quarterly Journal of Economics*, 709-738.

[30] Gali, J. (1999), "Technology, Employment and the Business Cycle: Do Technology Shocks Explain Aggregate Fluctuations?", *American Economic Review*, **89:1**, 249-271.

[31] Goodfriend, M., and King, R.G. (1997), "The new neoclassical Synthesis and the role of monetary policy", *NBER macroeconomics annual*, Cambridge: MIT Press, 231-83.

[32] Hall, R. E. (1999), "Labor-Market Frictions and Employment Fluctuations," in J. B. Taylor and M. Woodford (eds.), *Handbook of Macroeconomics*, North-Holland: Elsevier Science B.V.

[33] Hamilton, J. (1994), *Time Series Analysis*, Princeton: Princeton University Press.

[34] Howitt, P. (2002), "Looking inside the Labor Market: A Review Article," *Journal of Economic Literature*, **15**, 125-138.

[35] Huang, K. X. D., and Z. Liu (2002), "Staggered Price-Setting, Staggered Wage-setting, and Business Cycle Persistence", *Journal of Monetary Economics*, **49**, 405-433.

[36] Jeanne O. (1998), "Generating real persistent effects of monetary shocks: How much nominal rigidity do we really need?", *European Economic Review*, **42**, 1009-1032.

[37] Kiley, M. T. (1997), "Efficiency Wages, Nominal Rigidities and the Cyclical Behavior of Real Wages and Marginal Cost", *Economic Letters*, **56**, 215-221.

[38] King, R.G. and Watson, M.W. (1996), "Money, Prices, Interest Rates and the Business Cycle," *Review of Economics and Statistics*.

[39] King, R.G. and Watson, M.W. (1998), "The solution of singular linear difference systems under rational expectations", *International Economic Review,* **39:4**, 1015-26.

[40] King, R.G., C.I. Plosser and Rebelo, S. (1988), "Production Growth and Business Cycle: I. The Basic Neoclassical Model," *Journal of Monetary Economics*, March/May.

[41] King, R.G., and Rebelo, S. (2000), "Resuscitating Real Business Cycles", in J. Taylor and M. Woodford (eds.) *Handbook of Macroeconomics*, ch. 14, vol. 1b, North-Holland: Elsevier Science.

[42] King, R.G., and Wolman, A.L. (1996), "Inflation Targeting in a St. Louis Model of the 21th Century," *Federal Reserve Bank of St. Louis Review*, **78**.

[43] Kollmann, R. (2001), "The Exchange Rate in a Dynamic-Optimizing Business Cycle Model with Nominal Rigidities: a Quantitative Investigation", *Journal of International Economics*, **55**, 243-262.

[44] Kydland, F.E., and Prescott, E.C. (1982), "Time to Build and Aggregate Fluctuations", *Econometrica*, **50**, 1345-1370.

[45] Long, J.B., and Plosser, C.I. (1983), "Real Business Cycles", *Journal of Political Economy*, **91**, 39-69.

[46] Lucas, R.E. Jr. (1979), "An Equilibrium Model of the Business Cycle", *Journal of Political Economy*, **83:1**, 1113-1144.

[47] McCallum, B.T. and Nelson, E. (1998), "Performance of Operational Policy Rules in an Estimated Semiclassical Structural Model," J.B. Taylor, ed., *Monetary Policy Rules*, Chicago: Chicago University Press.

[48] Mortensen, D. T. and C. A. Pissarides (1994), "Job Creation and Job Destruction in the Theory of Unemployment," *Review of Economic Studies*, **61(3)**, 397-416.

[49] Mortensen, D. T. and C. A. Pissarides (1999), "New Developments in Models of Search in the Labor Market," CEPR Discussion paper 2053.

[50] Nelson, E. (1998), "Sluggish Inflation and Optimizing Models of the Business Cycle", *Journal of Monetary Economics*, **42**, 303-322.

[51] Rabanal, P. (2001), "Real Wage Rigidities, Endogenous Persistence and Optimal Monetary Policy", New York University, Paper presented at the LACEA Winter Camp in Santiago, Chile, January 2001.

[52] Romer, R. (1993), "The New Keynesian Synthesis", *Journal of Economic Perspectives*, **7**, 5-22.

[53] Rotemberg, J. J. (1987), "The New Keynesian Microfoundations," in S. Fischer (ed.), *NBER Macro-economics Annual 1987*, Cambridge: MIT Press.

[54] Rotemberg, J. J. and Woodford, M. (1997), "An Optimization-Based Econometric Framework for the Evaluation of Monetary Policy," in *National Bureau of Economic Research Macroeconomics Annual*, Cambridge: MIT Press.

[55] Sargent, T.J. (1976), "A Classical Macroeconometric Model for the United States", *Journal of Political Economy*, **84:2**.

[56] Taylor, J.B. (1998), "Staggered Wage and Prices in Macroeconomics," in J. B. Taylor and M. Woodford (eds.), *Handbook of Macroeconomics*, Amsterdam: Elsevier Science B.V..

[57] Uhlig, H. and Xu, Y. (1996), "Effort and the Cycle: Cyclical Implications of Efficiency Wages," CentER (Tilburg), working paper.

[58] Walsh, C. E. (2002), "Labor Market Search and Monetary Shocks," in S. Altug, J. Chadha and C. Nolan (eds.), *Elements of Dynamic Macroeconomic Analysis*, forthcoming.

[59] Wolman, A. L. (1999), "Sticky Prices, Marginal Cost, and the Behavior of Inflation," *Federal Reserve of Richmond Economic Quarterly*, **85** .

[60] Yun, T. (1996), "Nominal price rigidity, money supply endogeneity, and business cycles", *Journal of Monetary Economics*, **37,** 345-370.

A Appendix

A.1 Data

All time series are quarterly, taken from the DRI Basic Economics database (formerly Citibase). The choice of variables is very similar to the one by Stock and Watson (1998). We restrict our statistical analysis to the sample 1953:2–2001:4 because the earlier post World War II years were dominated by unusual occurences that our model is not designed to capture, such as the peacetime conversion, the interest rate controls before the Federal Reserve-Treasury Accord in 1951 and the Korean war. The following table gives the definition and a short description of the different series (where the definition is given in actual DRI mnemonics):

Data

Variable	Definition	Description
y	log(gdpq-gpbfq)-log(p16)	real GDP (non-farm) per capita
c	log(gcnq+gcsq)-log(p16)	real per capita private consumption of non-durables and servics
i	log(gifq)-log(p16)	real per capita private fixed investment (incl. residential)
n	log(lpmhu)-log(p16)	total hours (non-farm) per capita
u	log(lhur)	unemployment rate (in %) of all workers 16 and older
w	log(lbcpu)-ln(gdc)	real hourly compensation (non-farm)
R	fygm3	3 months T-bill rate, in annual %
M	log(fm1)-ln(p16)	nominal money stock M1 per capita
P	log(lbgdpu)	implicit (non-farm) price deflator
π	log(lbgdpu)-log(lbgdpu(-1))	gross inflation rate

Note that with the exception of the nominal interest rate R, all the data series are reported in logarithms.

A.2 Stationarity transformation and detrending

The purpose of this appendix is twofold. First, it describes the normalization procedure that makes it possible to map a model economy where real aggregates display zero steady state growth with US data where both population and technology are growing. Second, it explains why linear detrending of the variables used in the estimation of the fair wage function naturally follows from this normalization procedure.

Consider the production function

$$Y_t = A_t F(K_t, X_t N_t e_t).$$

The variables Y_t, K_t, and N_t are real output, capital, and labor input as observed in the economy, while e_t denotes the (unobserved) level of effort. A_t represents total factor augmenting (Hicks-neutral) technological progress, and X_t labor augmenting (Harrod-neutral) technological progress. This latter component of productivity is assumed to evolve at a deterministic rate $\gamma_x > 1$; i.e.

$$X_{t+1} = \gamma_x X_t.$$

Likewise, we assume that the labor force or population Z_t grows at a deterministic rate $\gamma_z > 1$; i.e.

$$Z_{t+1} = \gamma_z Z_t.$$

These are standard assumptions.[39]

Under certain regularity conditions about preferences (see King, Plosser and Rebelo (1988) for details) – which are satisfied in our case – it is possible to transform this economy by scaling all of the real aggregates by $X_t Z_t$ so that steady state growth is eliminated. Assuming $F(\cdot)$ to be homogenous of degree 1, we obtain the production function of our model, equation (10)

$$y_t = A_t F(k_t, n_t e_t),$$

where $y_t \equiv Y_t/X_t Z_t$, $k_t \equiv K_t/X_t Z_t$, $n_t \equiv N_t/Z_t$. The same normalization procedure turns the original capital accumulation equation

$$K_{t+1} = (1-\delta)K_t - I_t$$

into the capital accumulation equation (5) of the model

$$\gamma k_{t+1} = (1-\delta)k_t - i_t,$$

where $\gamma \equiv \gamma_x \gamma_z$ is the combined growth rate of technology and population.

Next, we show why linear detrending of the logarithms of the real wage and employment prior to estimating the fair wage function is consistent with the normalization procedure just described. Our starting point is a basic tenet of the modern business cycle literature: the labor share of income $W_t N_t / Y_t$ fluctuates around a constant mean over the post World War II period (see King and Rebelo (2000) for a review). It follows that the unconditional mean of real wage growth equals the deterministic growth rate of labor augmenting technological progress

$$E\left[\frac{W_{t+1}}{W_t}\right] = E\left[\frac{N_t}{N_{t+1}}\frac{Y_{t+1}}{Y_t}\right] = \frac{\gamma_x \gamma_z}{\gamma_z} = \gamma_x \ .$$

Hence, for the real wage w_t of our model to display zero steady state growth, the following definition must hold: $w_t \equiv W_t/X_t$; or equivalently in logarithms

$$\log w_t \equiv \log W_t - \log X_t = \log W_t - \log(\gamma_x^t X_0) = \log W_t - (\log X_0 + t \log \gamma_x).$$

To be consistent with this definition, we extract a linear trend from the logarithm of the observed real wage to obtain the normalized wage series prior to estimating the fair wage function,

$$\log w_t = \log W_t - (-0.4981 + 0.0039)t.$$

[39] Most RBC models implement the stationarity transformation by only considering labor augmenting productivity. Our normalization procedure is identical with the exception that we do not impose population to be constant (see King and Rebelo (2000), footnote 21 for this point).

The growth rate of labor augmenting technological progress equals $\gamma_x = \exp(0.0039) = 1.0039$. We apply the same detrending method to obtain the normalized employment series $n_t \equiv N_t/Z_t$ that is consistent with our model

$$\log n_t = \log N_t - (-7.0050 + 0.0010)t \ ,$$

which implies a population growth rate of $\gamma_z = \exp(0.001) = 1.0010$. The combined growth rate of labor augmenting technology and population is thus $\gamma = \gamma_x \gamma_z = 1.0049$.

Figure 1: **Impulse response functions with respect to a 1% money growth rate shock for Fair Wage model (solid) and benchmark NNS model (dashed).**

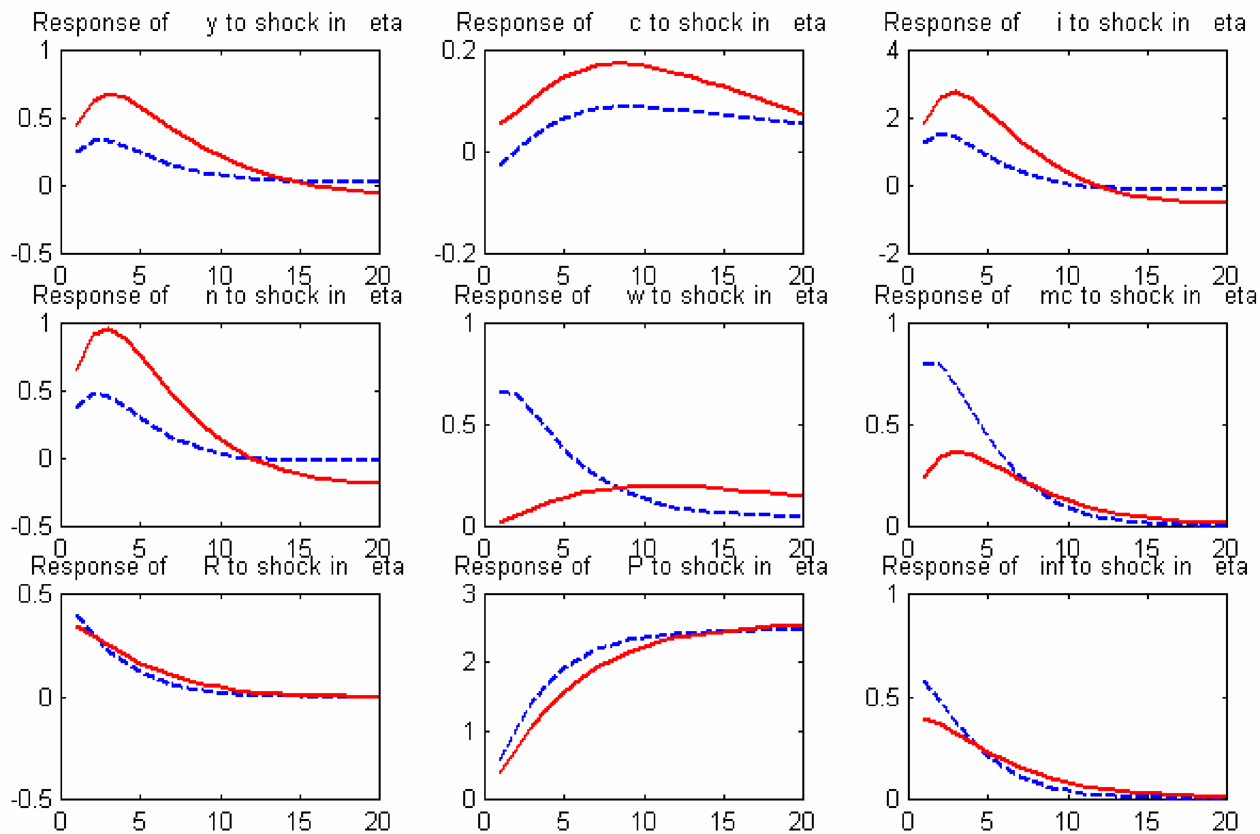

Figure 2: **Impulse response functions with respect to a 1% technology shock for Fair Wage model (solid) and benchmark NNS model (dashed).**

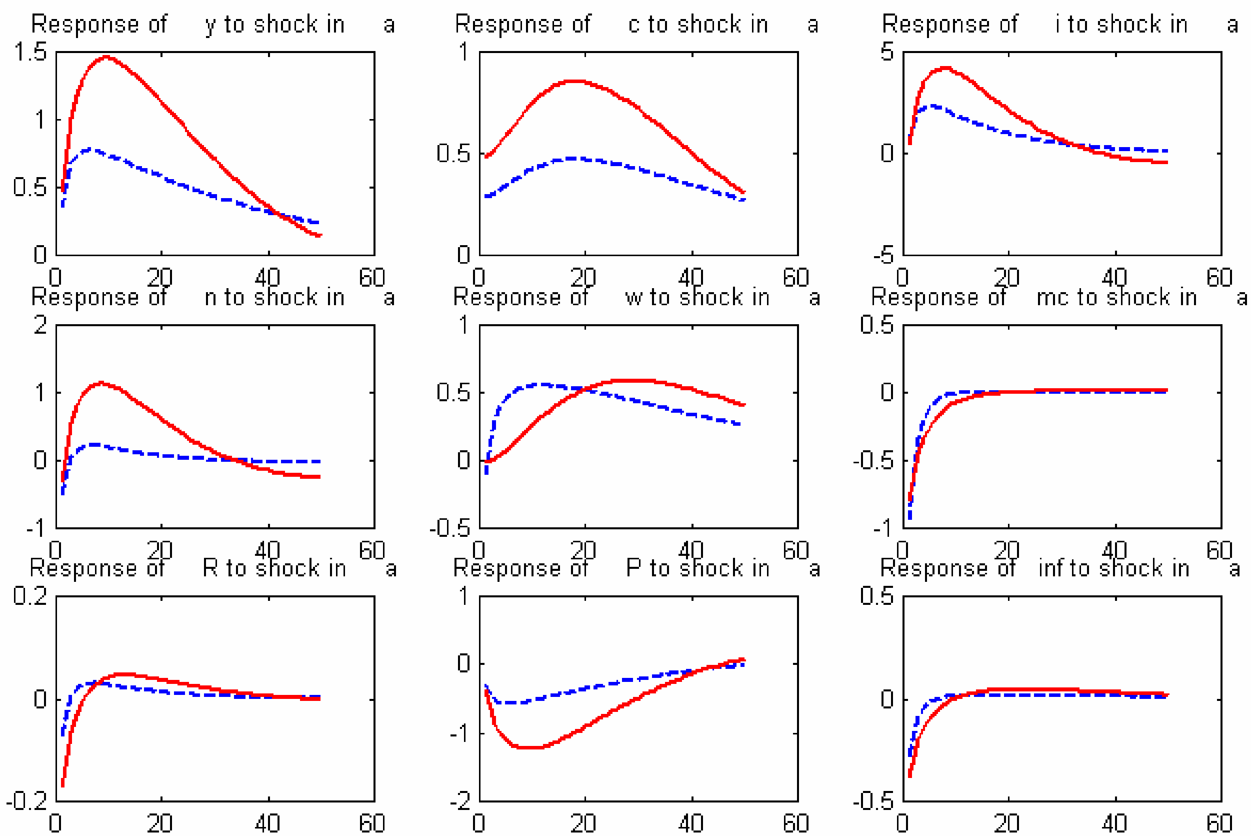

Figure 3: Impulse response functions with respect to a 1% money growth rate shock for Fair Wage model (solid) and benchmark NNS model (dashed) for the case of smaller price rigidity (κ=0.5).

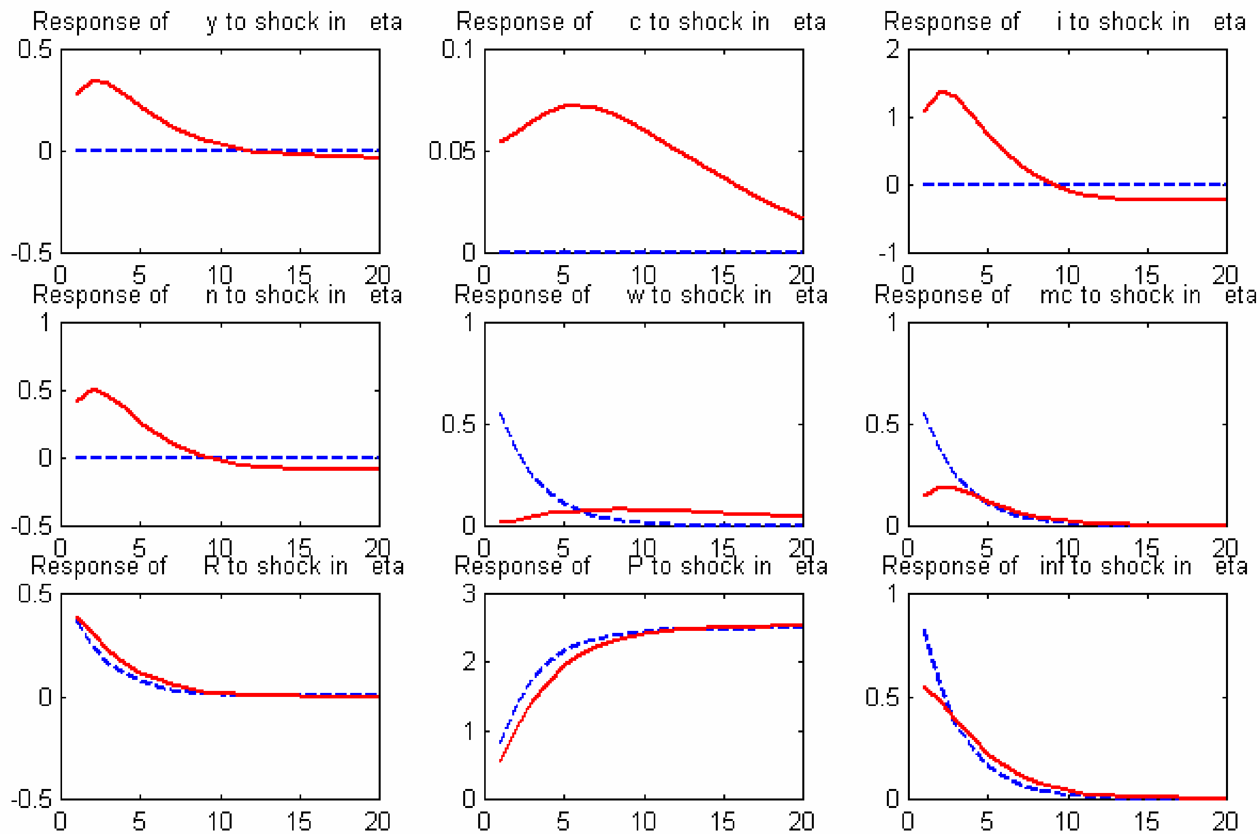

Figure 4: Sensitivity of key second moments with respect to the slope coefficient on log[n(t)] of the fair wage function.

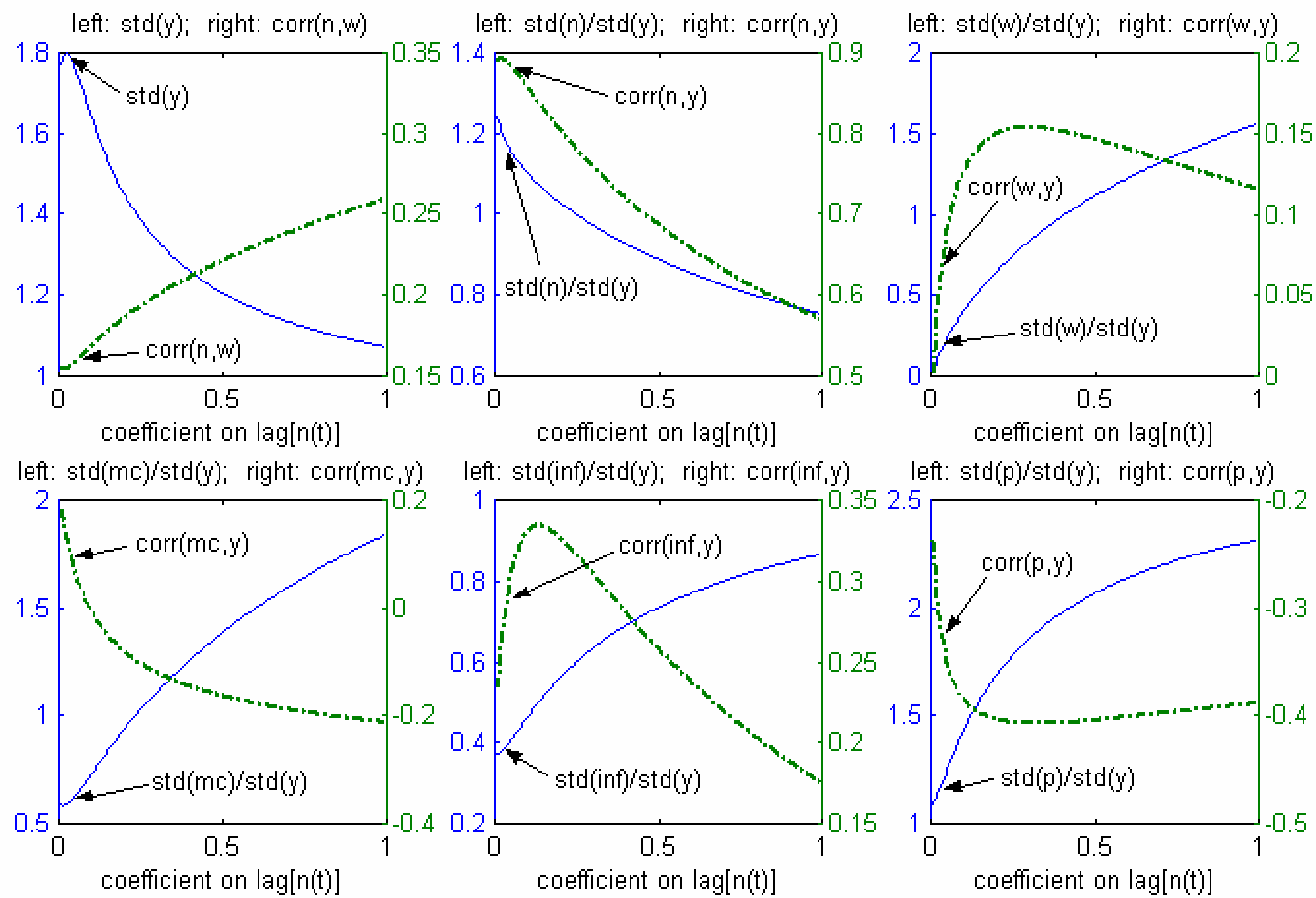

Figure 5: **Impulse response functions with respect to a 1% money growth rate shock for Fair Wage model (solid) and benchmark NNS model (dashed) for the case of a stronger dependence of the real wage on employment.**

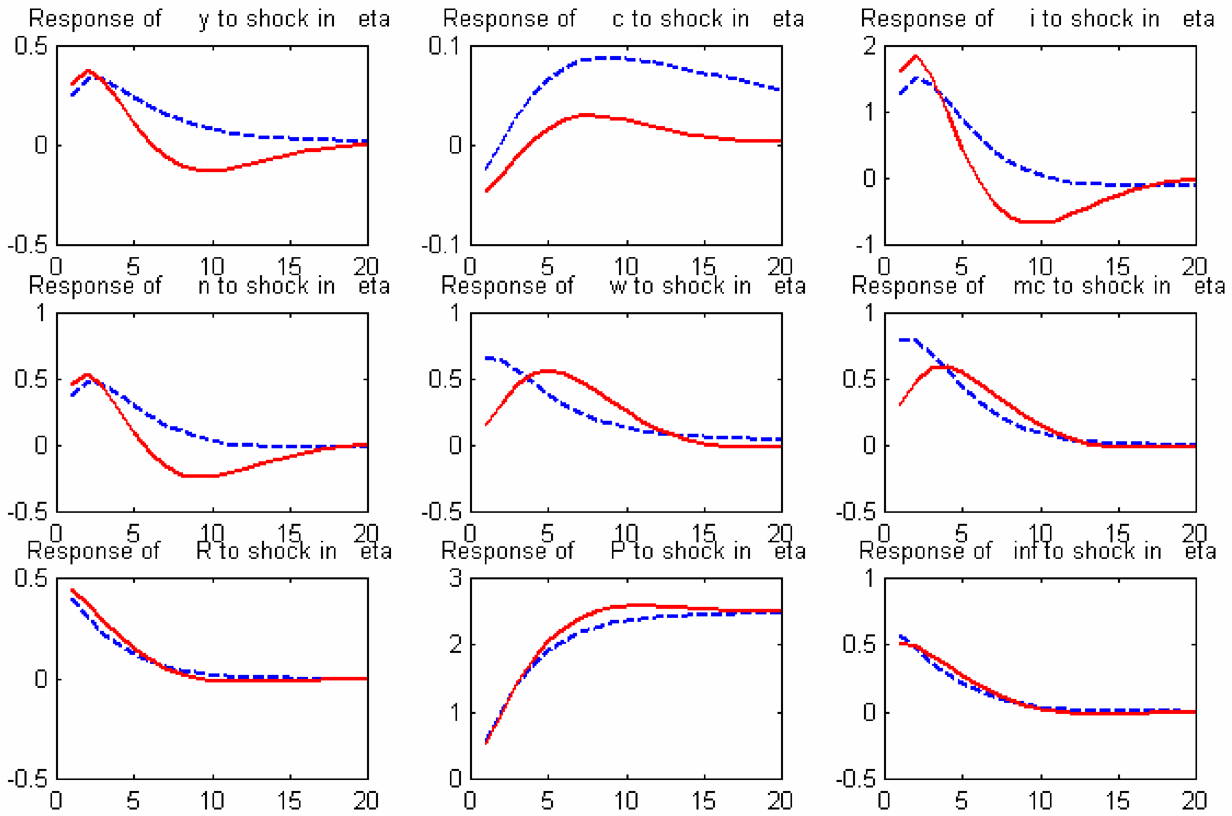

Figure 6: **Sensitivity of key second moments with respect to the slope coefficient on log[w(t-1)] of the fair wage function.**

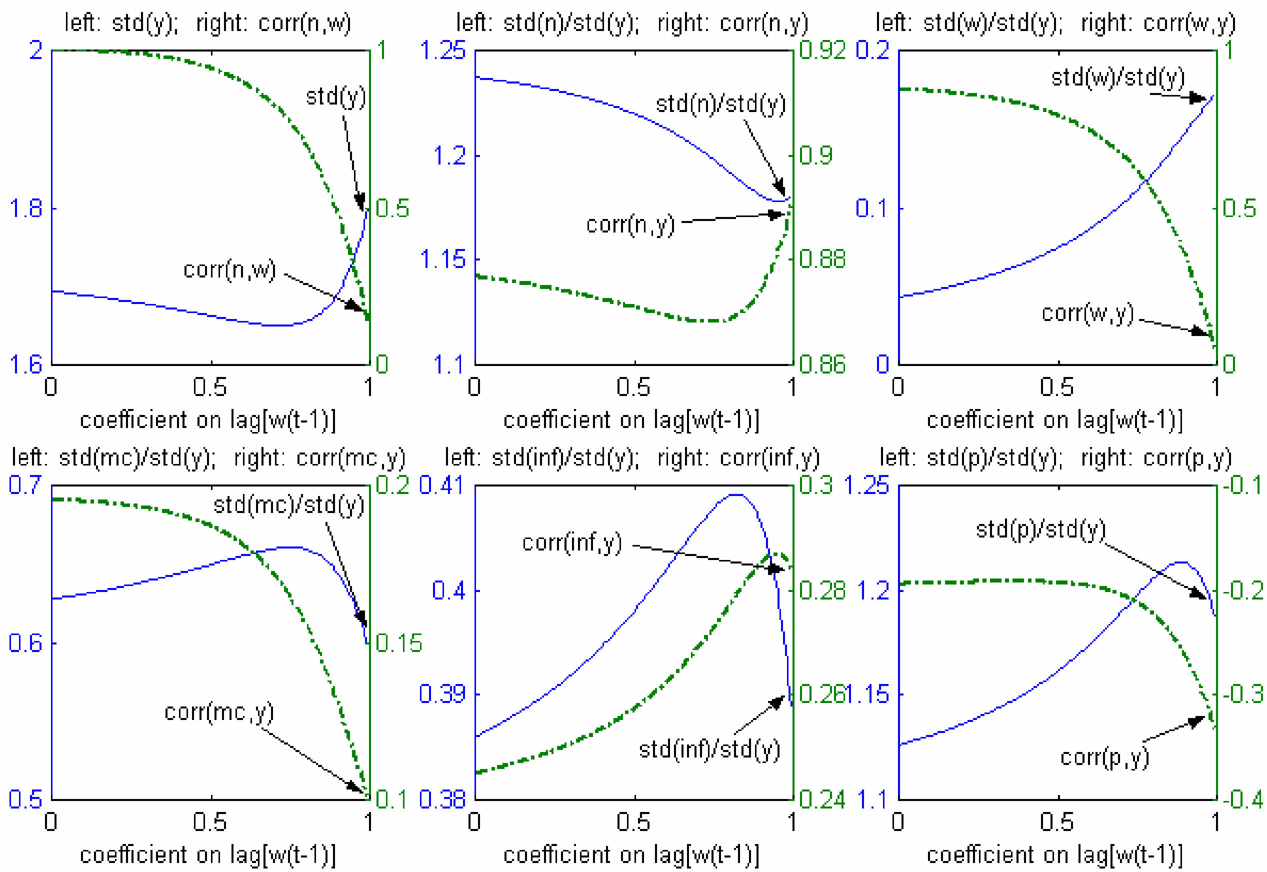

Figure 7: **Impulse response functions with respect to a 1% money growth rate shock for Fair Wage model (solid) and benchmark NNS model (dashed) for the case of independence of the real wage on last period's real wage.**

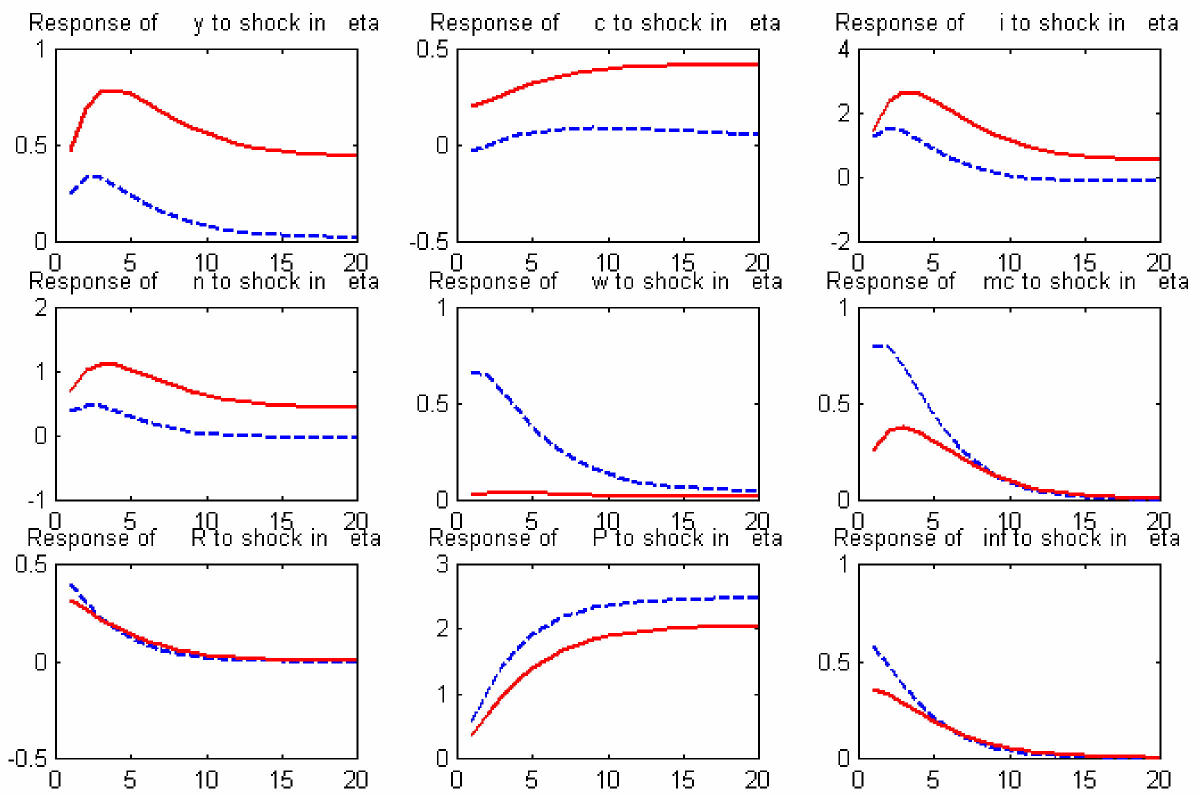

Table 1: Performance for baseline calibration

	US data (i)		Fair Wage model		Benchmark NNS		Monetary RBC (ii)		Fair Wage RBC (iii)	
	a	b	a	b	a	b	a	b	a	b
c	0.57	0.69	0.38	0.78	0.40	0.76	0.36	0.72	0.26	0.79
i	2.95	0.88	3.68	0.97	3.67	0.97	3.29	0.97	3.33	0.99
n	0.94	0.87	1.18	0.89	0.95	0.52	0.77	0.98	0.74	0.86
u	7.43	-0.86	19.78	-0.89					6.66	-0.86
w	0.44	0.13	0.17	0.07	1.08	0.74			0.52	0.69
r^k			1.18	0.88	1.93	0.66				
mc			0.60	0.10	1.53	0.20				
R	0.71	0.37	0.28	0.45	0.48	0.44				
P	0.67	-0.57	1.19	-0.33	2.13	-0.08	1.7	-0.27		
π	0.30	0.11	0.39	0.28	0.77	0.33				
A			0.49	0.59	0.88	0.75				
η			0.52	0.37	0.92	0.40				
$\sigma(y)$	1.66		1.79		1.01		1.72			
$corr(n_t, w_t)$	0.02		0.16		0.90		0.74		0.23	
$corr(y_t, y_{t-1})$	0.85		0.92		0.89					
$corr(\pi_t, \pi_{t-1})$	0.20		0.67		0.62					

a. Standard deviation relative to output.
b. Contemporaneous correlation with output.
All moments are Hodrick-Prescott filtered.
Data sources: (i) DRI Basic Economics; see Appendix A.1 for details
(ii) Cooley and Hansen (1989)
(iii) Collard and de la Croix (2000)

Table 2: Robustness to smaller price rigidity

	US data (i)		Fair Wage model with smaller price rigidity (1-κ) = 0.5		NNS with smaller price rigidity (1-κ) = 0.5	
	a	b	a	b	a	b
c	0.57	0.69	0.37	0.91	0.40	0.94
i	2.95	0.88	3.45	0.99	3.32	0.99
n	0.94	0.87	0.98	0.95	0.43	0.66
u	7.43	-0.86	16.51	-0.95		
w	0.44	0.13	0.15	0.14	0.85	0.63
r^k			0.99	0.92	1.12	0.70
mc			0.36	-0.13	0.86	-0.21
R	0.71	0.37	0.26	0.29	0.40	0.12
P	0.67	-0.57	1.35	-0.56	2.32	-0.35
π	0.30	0.11	0.52	0.02	1.00	-0.10
A			0.44	0.83	0.84	0.95
η			0.46	0.24	0.88	0.05
σ(y)	1.66		2.01		1.05	
$corr(n_t, w_t)$	0.02		0.15		0.65	
$corr(y_t, y_{t-1})$	0.85		0.90		0.85	
$corr(\pi_t, \pi_{t-1})$	0.20		0.56		0.46	

a. Standard deviation relative to output.
b. Contemporaneous correlation with output.
All moments are Hodrick-Prescott filtered.
Data sources: (i) DRI Basic Economics; see Appendix A.1 for details

Table 3: Robustness to alternative correlations between innovations

	Baseline Fair Wage corr(ε_A,ε_η)=0.09		Positive correlation corr(ε_A,ε_η)=0.50		Negative correlation corr(ε_A,ε_η)=-0.50	
	a	b	a	b	a	b
c	0.38	0.78	0.37	0.85	0.40	0.61
i	3.68	0.97	3.58	0.98	3.94	0.96
n	1.18	0.89	1.08	0.93	1.41	0.84
u	19.78	-0.89	18.10	-0.93	23.60	-0.84
w	0.17	0.07	0.16	0.12	0.20	-0.04
r^k	1.18	0.88	1.08	0.91	1.39	0.83
mc	0.60	0.10	0.46	0.04	0.87	0.20
R	0.28	0.45	0.20	0.53	0.41	0.43
P	1.19	-0.33	0.82	-0.21	1.84	-0.53
π	0.39	0.28	0.27	0.31	0.60	0.31
A	0.49	0.59	0.45	0.72	0.60	0.34
η	0.52	0.37	0.47	0.37	0.63	0.40
σ(y)	1.79		1.99		1.47	
corr(n_t, w_t)	0.16		0.15		0.16	
corr(y_t, y_{t-1})	0.92		0.91		0.93	
corr(π_t, π_{t-1})	0.67		0.67		0.67	

a. Standard deviation relative to output.
b. Contemporaneous correlation with output.
All moments are Hodrick-Prescott filtered.
Data sources: (i) DRI Basic Economics; see Appendix A.1 for details