Inflation Persistence and Labour Market Frictions: An Estimated Efficiency Wage Model of the Australian Economy

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Abstract

The purpose of this paper is to evaluate whether adding labour market frictions improves the basic New Keynesian model's ability to generate greater inflation persistence and plausible labour market dynamics. This paper builds and compares two sticky price models, one of which is augmented by an efficiency wage model of the labour market. The efficiency wage model is motivated by fair wage considerations, which add a real rigidity to the model that complements nominal price rigidities common to both models. The two models are then extended to capture a series of backward looking behaviours typically used to generate inflation persistence. The key contribution of this paper is that the proposed models are estimated using Bayesian maximum likelihood techniques and Australian data. The results presented show that by adding real wage rigidity, the models' internal propogation and labour market dynamics are significantly improved. The results also demonstrate that the conclusions made elsewhere in the literature using simulated models can be extended to models estimated using Bayesian methods.
Keywords: Efficiency Wage, effort, inflation persistence.
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1 Introduction

There exists a body of New Keynesian literature that attempts to address the lack of inflation persistence in sticky price models by adding price level inertia through nominal frictions and modelling backward looking behaviour. This paper presents a simple New Keynesian business cycle model that is augmented by labour market frictions motivated by workers' fair wage considerations. The purpose of this model is to investigate whether modelling labour market frictions improves dynamics in the

labour market, and whether the real friction added by the efficiency wage component generates greater inflation persistence.

Dynamic models of the business cycle typically produce labour market and price level dynamics that do not match observed characteristics. Standard business cycle models contain Walrasian labour markets in which wages adjust instantaneously in reaction to exogenous shocks so as to equate labour supply and demand. These models fail to generate the levels of inflation persistence, as well as key labour market features observed in the data. Structural unemployment is a common feature of all industrialised economies, wages are sluggish in adjusting to new economic conditions and households do not always find themselves on their labour supply schedules. Models with Walrasian labour markets typically generate employment series that are less volatile and wage series that are more volatile than is observed in the data. In addition, these models typically return a stronger correlation between wages and employment and a more procyclical real wage than the data allows. These shortcomings are often referred to as the labour market puzzle.

Business cycle models with unemployment motivated by efficiency wage considerations have produced promising results in both Real Business Cycle (RBC) (Collard & de la Croix, 2000) and New Keynesian environments (Danthine & Kurmann, 2004; de la Croix *et al.*, 2009). This paper builds and compares two sticky price New Keynesian models. The basic model corresponds to the standard New Keynesian framework of a Walrasian labour market and price adjustment costs (Gali, 2008; Goodfriend & King, 1997). The fair wage model places workers and firms in a partial gift exchange economy along the lines of Akerlof (1982). In this setting, firms minimise costs by not only choosing their labour quantity, but also by posting a wage that achieves optimal worker productivity. It is potentially optimal for firms to offer a wage above the labour market clearing rate due to worker morale and productivity considerations. This setup addresses elements of the labour market puzzle by giving firms a second mechanism through which they can react to demand and supply shocks, lowering the volatility of wages and increasing employment volatility. The form of the household's labour effort function introduces real wage rigidity, improving the model's inflation persistence and internal propagation of exogenous shocks.

To date, the literature in this area has drawn conclusions from calibration and simulation of similar models. The key contribution of this paper is that the proposed models are estimated using Bayesian maximum likelihood techniques and Australian data. The real wage rigidity generated by fair wage considerations greatly improves the internal

propagation mechanisms of the model. The fair wage model displays more sluggish responses in the price level and the wage to exogenous shocks when compared to the basic New Keynesian model. Similarly, output and employment show more amplified responses to shocks. Whilst the fair wage model fails to match the moments found in the data, there are significant improvements on the basic model. Contemporaneous correlations between wage and employment are weaker and the wage is less procyclical in the fair wage models. These results indicate that the fair wage models go at least part of the way towards resolving the labour market puzzle. The results presented are broadly consistent with those produced by the simulated models in the literature.

Section 2 presents the fair wage model, along with a benchmark, basic New Keynesian model and their solutions. These models are then extended to include a host of backward looking behaviours. Section 3 briefly details the methodology of Bayesian estimation and presents the prior distributions and posterior distribution estimates. Section 4 evaluates the performances of the models by assessing their reactions to exogenous shocks and the volatilities and correlations of key variables. Section 5 derives a Phillips Curve in the style of Phillips' original work and presents it alongside the typical new-Keynesian Phillips Curve. Concluding remarks are provided in Section 6.

2   The Models

The fair wage model presented possesses the standard features of a New Keynesian model outlined in Goodfriend and King (1997), but is altered to include a partial gift exchange relationship between workers and firms. The model can be separated into four components: households, final good firms, intermediate good firms and a monetary authority. Households consume final goods, hold one-period bonds and supply labour to and own the intermediate good firms. The final good firms combine intermediate goods through a technology process to produce the final consumption good. The final goods market is assumed to be perfectly competitive. Intermediate good firms operate in a monopolistically competitive environment and face quadratic price adjustment costs. The monetary authority sets the nominal interest rate as a weighted combination of a simple Taylor Rule and the previous period's interest rate. The basic model referred to in this section is the standard New Keynesian framework without fair wage considerations. Departures of the basic model from the fair wage model are explained throughout. Lowercase variables indicate log deviations from the steady state.

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2.1 Households

2.1.1 Household Problem

The economy contains a continuum of homogenous, infinitely lived households uniformly distributed on $[0, 1]$. Households have preferences over consumption and labour effort. Unlike most of the standard RBC and New Keynesian literature, households do not have preferences over leisure. As a result, the representative household inelastically supplies an infinitesimal amount of time to each intermediate good firm in the continuum of firms. In turn, some fraction of this labour is employed by each intermediate good firm. Consequently, the usual labour supply condition that comes from the tradeoff between consumption and leisure is absent in the fair wage model. The representative household maximises their discounted expected future utility according to the following problem

$$\max_{C_t B_t E_t} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\log(C_t) \Upsilon_t - \int D_t(i) \Big(E_t(i) - E_t^*(i) \Big)^2 di \right). \tag{1}$$

where $\mathbb{E}$ is the expectations operator, β is the discount factor and C_t is consumption. Υ_t is a preference shock that follows a stationary, exogenous $AR(1)$ process

$$\log(\Upsilon_t) = \rho_\Upsilon \log(\Upsilon_{t-1}) + \varepsilon_t^\Upsilon, \tag{2}$$

$$\varepsilon_t^\Upsilon \sim \mathbb{N}(0, \sigma_\Upsilon^2). \tag{3}$$

$D_t(i)$ is a binary variable that indicates whether or not the household is employed by intermediate good firm i in the current period. $E_t(i)$ is the effort given by the household to the intermediate good firm i. $E_t^*(i)$ is the level of effort the household deems is fair. Following Collard and de la Croix (2000), $E_t^*(i)$ is given by

$$E_t^*(i) = \phi_0 + \gamma \log \left(\frac{W_t(i)}{W_t^a} \right) + \psi \log \left(\frac{W_t(i)}{W_t^s} \right). \tag{4}$$

This determination of a fair level of effort follows from the idea of a partial gift exchange between workers and firms (Akerlof, 1982). (1) shows that workers receive disutility from providing a labour effort that deviates from what they believe to be fair. Thus, although workers dislike providing labour effort, they are willing to give extra effort to their employer in exchange for a higher real wage $W_t(i)$. In addition to some baseline or minimum level of labour effort ϕ_0, workers are willing to give extra effort in exchange for a wage premium above the current alternative W_t^a and a social norm W_t^s. The alternative wage summarises what a worker could earn if they were not working for their current employer. This term is given by the average of current wages available in the economy and unemployment compensation,

which is set to zero

$$W_t^a = \int N_t(i)W_t(i)di. \tag{5}$$

In the initial specification of the fair wage model, the social norm is the previous period wage

$$W_t^s = W_{t-1}. \tag{6}$$

Survey data in Bewley (1998) emphasises the importance of changes in the wage rate on worker morale and effort. Parameters γ and ψ determine how responsive a worker's effort is to being paid a wage relative to the alternative wage and the social norm. To avoid heterogeneity between employed and unemployed workers across time, the existence of costless insurance contracts is assumed. Workers are risk averse and thus choose to completely insure themselves against unemployment. As a result, all households are faced with the same problem in every period regardless of their employment history.

The household problem is solved subject to the following wealth constraint

$$C_t + \frac{B_t}{P_t} \le \int \left(N_t(i)W_t(i) \right) di + \frac{R_{t-1}B_{t-1}}{P_t} + \int \Delta(i)di, \tag{7}$$

where B_t is the quantity of one-period bonds purchased in period t, R_t is the return on these bonds, given by $(1 + i_t)$, $N_t(i)$ is the fraction of time spent working for intermediate good firm i, $\Delta(i)$ is the profit of intermediate good firm i and P_t is the price of the consumption good.

2.1.2 Basic model

In the basic model with no labour market friction, households receive disutility from labour. The following problem is solved subject to the identical wealth constraint.

$$\max_{C_t B_t N_t} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\log(C_t)\Upsilon_t - \varrho \frac{N_t^{1+\vartheta}}{1+\vartheta} \right). \tag{8}$$

2.2 Final Good Firms

2.2.1 Final Good Firm Problem

Final good firms are price takers and maximise profits according to the following problem

$$\max_{Y_t(i)} P_t Y_t - \int P_t(i)Y_t(i)di, \tag{9}$$

subject to the following production constraint

$$Y_t = \left(\int Y_t(i)^\theta di \right)^{\frac{1}{\theta}}, \tag{10}$$

where Y_t is the output of the final good firm and $P_t(i)$ and $Y_t(i)$ are the price and output of intermediate good firm i. θ gives the elasticity of substitution between intermediate goods in production of the final consumption good.

2.3 Intermediate Good Firms

2.3.1 Intermediate Good Firm Problem

There is a continuum of intermediate good firms uniformly distributed on the interval $[0, 1]$ in the economy. Each intermediate good firm faces the following production function

$$Y_t(i) \leq A_t \Big(E_t(W_t(i)) N_t(i) \Big), \tag{11}$$

where $N_t(i)$ is the fraction of the households' inelastically supplied labour that the intermediate good firm chooses to employ. A_t is an exogenous technology shock common to all intermediate good firms and follows an $AR(1)$ process

$$\log(A_t) = \rho_A \log(A_{t-1}) + \varepsilon_t^A, \tag{12}$$

$$\varepsilon_t^A \sim \mathbb{N}(0, \sigma_A^2). \tag{13}$$

The productivity of the firm's chosen labour input is augmented by the effort $E_t(W_t(i))$ received from each worker. Given the form of the effort function specified above, effort is a convex function of the wage offered by the firm. As the labour market is non-Walrasian, given a level of demand for their good, intermediate good firms choose their labour input and nominal wage $\hat{W}_t(i)$ that satisfies the following cost minimisation problem

$$\min_{N_t(i)\hat{W}_t(i)} TC_t(i) = \hat{W}_t(i) N_t(i), \tag{14}$$

subject to the production constraint (11). In addition to the cost minimisation process, firms choose the price for their good that maximises current and expected future profits

$$\max_{P_t(i)} \mathbb{E}_0 \sum_{t=0}^{\infty} \Phi_t \left(P_t(i) Y_t(i) - \hat{W}_t(i) N_t(i) - P_t Y_t \frac{\varphi}{2} \left[\frac{P_t(i)}{P_{t-1}(i)} - \overline{\overline{\Pi}} \right]^2 \right), \tag{15}$$

where Φ_t is the firms' stochastic discount factor. As in Rotemberg (1982), intermediate good firms face quadratic price adjustment costs in adjusting the price of their good in any way that deviates from steady state inflation

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$\overline{\Pi}$. The parameter φ indicates how costly price adjustments are. The firm's pricing problem is solved subject to the demand for its good and the production constraint.

Intermediate good firms can increase their output either by hiring extra workers or by eliciting extra effort from their workers by offering a higher wage. At the optimum, firms equate the marginal cost of extra production by both means, resulting in the following statement for the optimal level of worker effort

$$E_t(i) = \gamma + \psi. \tag{16}$$

It is optimal for the intermediate good firms to induce a constant level of effort from their workers in each period.[1] As a result, the model satisfies the Solow (1979) condition, which asserts that for a firm to minimise the cost per unit of effective labour, the elasticity of effort with respect to wage should equal unity.

The key feature of the model is that because of the link between wages, effort and productivity, firms can offer a real wage above the Walrasian rate. As a result, aggregate period unemployment is given by

$$U_t = 1 - \int N_t(i)di. \tag{17}$$

2.3.2 Basic Model

As the basic model has a Walrasian labour market, intermediate good firms only optimise with respect to labour in their cost minimisation problem.

2.4 Monetary Authority

2.4.1 Monetary Authority Rule

The monetary authority sets the nominal interest rate through a variant of a simple Taylor rule. The interest rate in the current period is a function of inflation, the output gap and a one period lag of the interest rate

$$i_t = \tau i_{t-1} + (1-\tau)(\phi_\pi \pi_t + \phi_{\tilde{y}} \widetilde{y}_t) + \nu_t, \tag{18}$$

$$\nu_t \sim \mathbb{N}(0, \sigma_\nu^2), \tag{19}$$

where π_t is current period inflation, $\tilde{y}$ is the output gap and ν_t is an exogenous 'white-noise' variable. As in Smets and Wouters (2003), $\tilde{y}$ is defined as the difference between current output and output in an identical

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[1]Note that because W^a and W^s are not fixed, holding effort constant across time is not the same as holding wages constant across time.

economy with completely flexible prices

$$\tilde{y}_t = y_t - y_t^f. \tag{20}$$

2.5 Solving the model

A symmetric equilibrium is imposed whereby all firms make the same wage and employment decisions in every period. Defining inflation as $\Pi_t = \frac{P_t}{P_{t-1}}$, the system is closed by the following resource constraint

$$Y_t = C_t + P_t Y_t \frac{\varphi}{2} \left[\Pi_t - \overline{\Pi} \right]^2. \tag{21}$$

The log-linearised system is presented in Appendix A. Equations (25) to (33) determine the nine endogenous variables of the system: $n_t, w_t, y_t, \pi_t, i_t, mc_t, u_t, \tilde{y}_t$ and y_t^f. The stochastic behaviour of the system is driven by three exogenous shock variables: x_t, a_t and ν_t. The first two follow independent first-order autoregressive processes, whilst the third is assumed to be independent, identically distributed.

2.6 Alternative Specifications

2.6.1 Fair Wage and Basic Model II: Hybrid Phillips Curve and Consumption Habit Case

As in Gali and Gertler (1999), backward-looking price-setting behaviour by intermediate good firms is introduced into the model. In doing so, a degree of price level inertia is added to the model. This is achieved by changing the adjustment cost term in the intermediate good firm's price setting problem to allow for a degree of price indexing

$$P_t Y_t \frac{\varphi}{2} \left[\frac{P_t(i)}{P_{t-1}(i)} - \overline{\Pi}^{1-\kappa} \Pi_{t-1}^{\kappa} \right]^2.$$

In addition to this, habit persistence in consumption is added by altering the consumer's objective function to

$$\max_{C_t B_t E_t} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(U(C_t - b\widetilde{C}_{t-1}) \Upsilon_t - \int D_t(i) \Big(E_t(i) - E_t^*(i) \Big)^2 \right), \tag{22}$$

where $\widetilde{C}_{t-1}$ is the average consumption level in the economy last period.

2.6.2 Fair Wage Model III: Social Norm Persistence

Following Collard and de la Croix (2000), to allow for slower adjustment of the social norm in the effort function, it is re-specified as a weighted sum of

all past realisations of the wage

$$W_t^s = \mu \sum_{i=0}^{\infty} (1-\mu)^{i-1} W_{t-i}. \tag{23}$$

Note that when $\mu = 1$, this expression is identical to the previous specification of the social norm. Results presented in Collard and de la Croix suggest that this new statement for the social norm improves the performance of the fair wage model across the business cycle. As this last specification modifies the effort function, it has no effect on the basic model.

3 Estimation

The models presented are estimated using Bayesian methods. This section briefly outlines the estimation methodology used and presents the prior and posterior distributions of the estimated parameters.

3.1 Methodology

Bayesian estimation combines the use of prior information, 'inherited' from calibration methods, with maximum likelihood techniques through Bayes' theorem. Hence, Bayesian estimation methods have been presented in the literature as somewhat of a halfway point between full calibration and maximum likelihood estimation methods (Smets & Wouters, 2003, 2007; Lubik & Schorfheide, 2004; An & Schorfheide, 2007).

The method can be summarised as follows. Expressing the vector of parameters to be estimated as Θ and the data set as $\mathcal{Z}$, using Bayes' theorem the following statement about the parameters conditional on the data is obtained

$$g(\Theta|\mathcal{Z}) = \frac{g(\Theta)f(\mathcal{Z}|\Theta)}{f(\mathcal{Z})}.$$

$g(\Theta|\mathcal{Z})$ is the posterior distribution of the parameters, $g(\Theta)$ is prior information about the parameters, chosen to reflect entirely objective or subjective information, or a combination of both. $f(\mathcal{Z}|\Theta)$ is the joint density of the data, which can also be interpreted as a function that gives the likelihood of different values of the parameters conditional on the data

$$f(\mathcal{Z}|\Theta) = \mathcal{L}(\Theta|\mathcal{Z}).$$

Subsequently, this function is computed using maximum likelihood estimation. Solving the following problem returns the vector of parameters

evaluated at their most probable value $\widehat{\mathcal{L}}$

$$\max_{\Theta} \mathcal{L}(\Theta|\mathcal{Z}) = \widehat{\mathcal{L}}.$$

Initially, the primary object of interest is the posterior kernel $\breve{g}(\Theta|\mathcal{Z})$ which is equal to the product of the prior distribution and the maximised likelihood function

$$\breve{g}(\Theta|\mathcal{Z}) = g(\Theta)\widehat{\mathcal{L}}.$$

From this posterior kernel, the posterior modes of the parameters are obtained. The posterior kernel is also required to build the posterior distribution. The posterior distributions presented in this section are generated using MCMC sampling methods, specifically the Metropolis-Hastings algorithm with $100,000$ draws.

3.2 Parameter Estimates

3.2.1 Prior Distributions

Before discussing the choice of prior distributions used in estimating the parameters of the model, it should be noted that two parameters must be calibrated. To remain consistent with the literature, in the fair wage models $\overline{N}$ is set to 0.9, giving a steady state unemployment level of 10%. To allow for the proper identification of the effort function, it is necessary to calibrate either γ or ψ, or calculate a ratio of the two. ψ is estimated in order to assess the effects of adding persistence to the social norm variable in the third specification of the fair wage model. Taking the value from Danthine and Donaldson (1990), γ is set to 0.9.

The prior distributions presented in Table 1 are common across all specifications of the fair wage and basic models where applicable. A reasonably restrictive prior distribution is set for the parameter in the effort function that relates household effort response to the social norm. The prior is set as a gamma distribution with mean 2.2 and standard deviation 0.5. The mean is chosen based on the results in Collard and de la Croix (2000), which uses the same calibration of γ. The mean of the gamma prior distribution on $\overline{R}$ is set to 4 to return a value of β that is close to one. The parameters for habit persistence in consumption and the social norm b and μ are set at 0.5 and 0.8 with standard deviation 0.05 and 0.1 respectively. The prior on b is a beta distribution and μ follows a gamma distribution. The disutility of labour parameter ϑ is set at one with a fairly loose gamma distributed prior with standard deviation 0.75. The Phillips curve parameters δ and κ are beta and gamma distributed, with means set to 0.1 and 0.5 respectively.

Table 1: Prior Distribution of Parameters

Parameter	Distribution	Mean	Std. Dev.
Households and Firms			
ψ	gamma	2.2	0.5
$\overline{R}$	gamma	4	1
b	beta	0.5	0.25
μ	gamma	0.8	0.1
ϑ	gamma	1	0.75
δ	beta	0.1	0.01
κ	gamma	0.5	0.2
Taylor Rule			
τ	beta	0.5	0.25
ϕ_π	gamma	1.5	0.5
$\phi_{\tilde{y}}$	gamma	0.12	0.025
Exogenous Persistence			
ρ_Υ	beta	0.5	0.15
ρ_A	beta	0.5	0.15
Exogenous Shock Variances			
σ_x	inv gamma	0.01	∞
σ_A	inv gamma	0.01	∞
σ_ν	inv gamma	0.01	∞

The parameters on interest rate smoothing, policy reaction to inflation and reaction to the output gap in the Taylor rule τ, ϕ_π and $\phi_{\tilde{y}}$ are set with means of 0.5, 1.5 and 0.12 respectively. This is broadly in line with other estimates of the Taylor rule using Australian data (Nimark, 2007). τ follows a beta distribution with standard deviation 0.25, whilst the other two parameters on inflation and the output gap are gamma distributed with standard deviation 0.5 and 0.025 respectively. The persistence of the exogenous processes are beta distributed with mean 0.5 and standard deviation 0.15 for both ρ_Υ and ρ_A. The priors on the stochastic disturbances are set identically in order to allow the magnitude of the disturbances to come from the data. The standard errors of the processes σ_x, σ_A and ν are given loose priors with mean 0.01 and infinite standard deviation. They are assumed to follow inverse gamma distributions.

3.2.2 Posterior Distributions

To estimate the structural parameters of the models presented in Section 2, Australian data from the inflation targetting period 1993:3-2007:4 for real GDP, the GDP deflator and the nominal interest rate are used[2]. The real GDP time series is passed through a Hodrick-Prescott (HP)

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[2]Data used comes from the OECD's Economic Outlook database (OECD, 2009)

filter set to frequency 1600. All time series are treated as deviations from the sample mean. The mode, the mean and the 5th and 95th percentiles of the posterior distributions of the parameters obtained by the Metropolis-Hastings algorithm for all specifications of the fair wage and basic models are presented in Tables 2 and 3.

In all specifications of the fair wage model, the estimated value of ψ appears to be well identified and significantly lower than the mean of the prior distribution. These data suggest that the effect of a change in wage on worker effort is less pronounced than those found in Collard and de la Croix (2000). As expected, the estimates of $\overline{R}$ return a value of β that is approximately equal to one.

Consumption habit formation b varies significantly between the fair wage and basic models. The fair wage models indicate that modelling consumption habits has a strong impact on the household's consumption - savings decision, whereas only a small degree of consumption smoothing is added to the basic model. The fair wage models return values of b much higher than other Bayesian models using Australian data over a longer sample period, whereas the value returned by the basic model is more consistent with the literature (Justiniano & Preston, 2008). The data appears to be informative for the social norm persistence parameter μ and returns a weaker effect than is found in Collard and de la Croix (2000) . The basic model returns an extremely high value for the elasticity of labour supply parameter ϑ.

The low values of κ suggest that backward-looking price indexing does not capture the price setting behaviour of firms in the data. The estimates of κ all fall within the range of values found in Gali and Gertler (1999), who conclude that price indexing behaviour is quantitatively unimportant.

The high estimated values of τ in the Taylor rule indicate that monetary policy responds very gradually to changes in inflation and output over the sample. These policy changes are driven primarily by deviations in inflation and respond very little to deviations in output. The small values for the standard error of the monetary policy disturbance ν suggests that the estimates of the Taylor rule fit the data reasonably well. The strength of the response to inflation is stronger than is found elsewhere. However, the degree of interest rate smoothing and emphasis on responses to inflation rather than output is consistent with existing Bayesian Taylor rule estimates for Australia (Justiniano & Preston, 2008; Nimark, 2007).

The estimates of ρ_Υ and σ_x suggest that the preference shock process is highly persistent with weak disturbances in the basic models and the

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first specification of the fair wage model. The persistence of the preference shock falls significantly in the second and third specifications of the fair wage models, indicating the greater internal propogation of shocks in these models. In both the fair wage and basic models, the standard error of the technology process possesses similar volatility. However, the persistence of the process is quite different between the two models. The persistence parameter is significantly greater in the basic models. Once again, this is a promising result as it shows greater internal propogation in the fair wage models. The fair wage models' technology persistence parameter is also significantly lower than other Australian estimates (Justiniano & Preston, 2008; Nimark, 2007).

The log data densities presented at the bottom of Table 2 indicates that adding backward-looking behaviours to the models improve their performance.

Table 2: Posterior Distribution of Parameters in Fair Wage Models

Parameter	Model I Mode	Model I Mean (90 percent interval)	Model II Mode	Model II Mean (90 percent interval)	Model III Mode	Model III Mean (90 percent interval)
		Households and Firms				
ψ	1.01	1.11 (0.65, 1.56)	1.73	1.79 (1.12, 2.45)	1.64	1.72 (1.02, 2.36)
$\overline{R}$	3.70	3.96 (2.39, 5.52)	3.88	4.02 (2.35, 5.60)	3.78	4.07 (2.37, 5.70)
b	-	-	0.75	0.71 (0.56, 0.85)	0.76	0.72 (0.58, 0.87)
μ	-	-	-	-	0.73	0.74 (0.59, 0.88)
δ	0.11	0.11 (0.10, 0.13)	0.11	0.11 (0.09, 0.12)	0.11	0.11 (0.09, 0.12)
κ	-	-	0.10	0.12 (0.04, 0.19)	0.12	0.12 (0.05, 0.20)
		Taylor Rule				
τ	0.90	0.90 (0.86, 0.94)	0.94	0.93 (0.91, 0.96)	0.93	0.93 (0.90, 0.96)
ϕ_π	2.31	2.35 (1.61, 3.12)	2.29	2.44 (1.54, 3.27)	2.14	2.22 (1.38, 3.01)
$\phi_{\tilde{y}}$	0.09	0.10 (0.06, 0.13)	0.09	0.09 (0.06, 0.13)	0.09	0.10 (0.06, 0.13)
		Exogenous Persistence				
ρ_Υ	0.70	0.68 (0.58, 0.77)	0.26	0.30 (0.12, 0.52)	0.27	0.32 (0.12, 0.53)
ρ_A	0.28	0.32 (0.12, 0.51)	0.29	0.33 (0.12, 0.55)	0.27	0.32 (0.11, 0.52)
		Exogenous Shocks				
σ_x	0.003	0.003 (0.002, 0.004)	0.018	0.018 (0.007, 0.028)	0.019	0.018 (0.006, 0.030)
σ_A	0.013	0.013 (0.010, 0.016)	0.015	0.016 (0.012, 0.020)	0.016	0.017 (0.013, 0.021)
σ_ν	0.002	0.002 (0.002, 0.002)	0.002	0.002 (0.001, 0.002)	0.002	0.002 (0.001, 0.002)
		Log Data Densities				
		724.3		724.5		726.4

Table 3: Posterior Distribution of Parameters in Basic Models

| Parameter	Model I Mode	Model I Mean (90 percent interval)	Model II Mode	Model II Mean (90 percent interval)
		Households and Firms		
$\overline{R}$	3.74	3.96 (2.27, 5.47)	3.76	3.99 (2.36, 5.54)
b	-	-	0.08	0.15 (0.00, 0.28)
ϑ	4.47	4.77 (2.78, 6.66)	4.84	5.28 (3.10, 7.41)
δ	0.11	0.10 (0.09, 0.12)	0.11	0.11 (0.09, 0.13)
κ	-	-	0.16	0.20 (0.07, 0.32)
		Taylor Rule		
τ	0.84	0.84 (0.79, 0.90)	0.85	0.85 (0.79, 0.90)
ϕ_π	1.71	1.83 (1.09, 2.53)	1.67	1.73 (1.00, 2.32)
$\phi_{\tilde{y}}$	0.11	0.12 (0.08, 0.16)	0.11	0.12 (0.08, 0.15)
		Exogenous Persistence		
ρ_Υ	0.68	0.66 (0.56, 0.76)	0.68	0.65 (0.55, 0.75)
ρ_A	0.54	0.54 (0.38, 0.70)	0.47	0.45 (0.27, 0.62)
		Exogenous Shocks		
σ_x	0.003	0.003 (0.002, 0.004)	0.003	0.003 (0.002, 0.004)
σ_A	0.008	0.009 (0.006, 0.011)	0.010	0.011 (0.007, 0.014)
σ_ν	0.002	0.002 (0.002, 0.002)	0.002	0.002 (0.002, 0.002)

4   Results

Evaluation of the models' performance is carried out in two stages. The first is through graphical analysis of the models' reactions to exogenous shocks. Impulse responses are presented to identify the propagation and amplification mechanisms in the models, as well as to support the second order moments that follow.   The second stage of the analysis is the presentation of the models' second order moments. These moments further illustrate differences in the internal propogation mechanisms between the fair wage and basic models.

4.1   Impulse Response Functions

Figures 1 and 2 present the mean of the relative impulse responses of several key variables to one standard deviation shocks to the exogenous element of the Taylor rule ν. Figure 1(a) shows the reactions of the three specifications of the fair wage model to a contractionary monetary policy shock. The shaded areas represent 95% confidence bands around the model with the highest log data density, given in Table 2. Figure 1(a) clearly illustrates that by modelling consumption habits and price indexing firms, that internal propagation mechanisms of the model are greatly improved. In particular, output and the two labour market variables display much more sustained responses to a monetary shock. Adding habit formation in the social norm does not alter the model's response to a monetary shock in a statistically significant fashion. Figure 1(b) replicates the previous figure for the two specifications of the basic model. Once again, modelling consumption habits and price indexing firms greatly increases the propagation of the exogenous shock. This difference is particularly noticeable in the reaction of inflation to the monetary policy shock.

Figure 1: Comparing Fair Wage and Basic Models
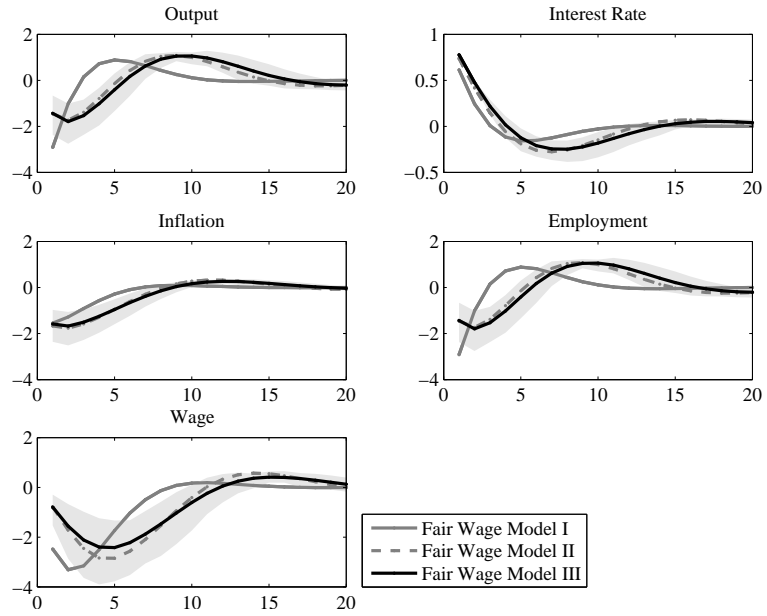
(a) Fair Wage Models
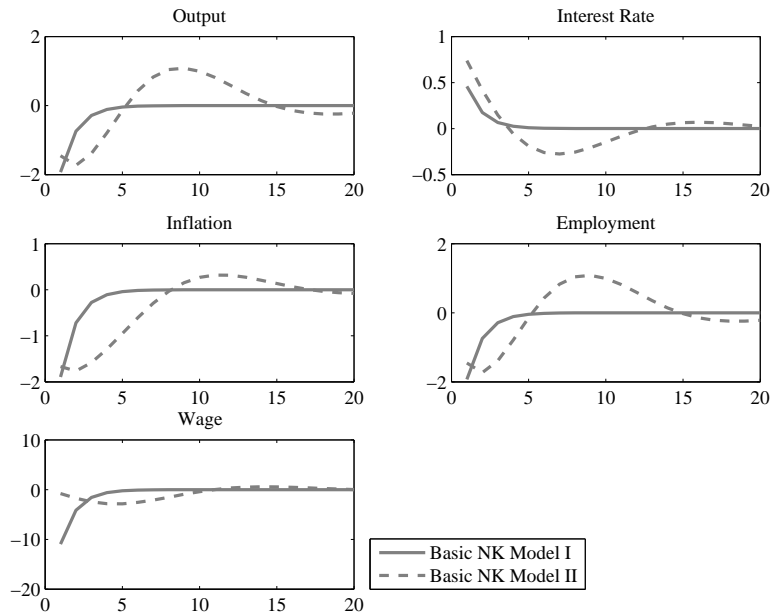
(b) Basic Models

Figure 2 directly compares the corresponding specifications of the fair wage and basic models with one another. The response of output to the tightening of monetary policy in the fair wage models is persistent, especially in the second specification of the model. In the fair wage model, firms have a lower elasticity of marginal cost with respect to output. Relaxing this link between costs and output allows for a more reactive output series in the fair wage model. The wage rigidity added by the efficiency wage component of the fair wage model is clear to see from the reaction of the wage on impact in each model. Firms are reluctant to move away from offering a wage that satisfies the cost minimisation problem for effective labour: the wage that satisfies the Solow condition. As such, the negative response of the wage to the shock is much smaller in the fair wage models. Due to the fall in output caused by contractionary monetary policy, in order to maintain a clear labour market in the basic models, the real wage drops significantly. The wage rigidity caused by workers' responses to changes in the wage generates the greater persistence in the labour market variables in the fair wage models. The difference in the negative movements in inflation from steady state can be attributed to this discrepancy in the behaviour of the real wage on impact between the two models. The less amplified response of marginal cost in the fair wage model makes it optimal for firms to adjust prices more gradually over time, leading to the persistent response of inflation in the fair wage model.

Figure 2: Comparing Real Frictions
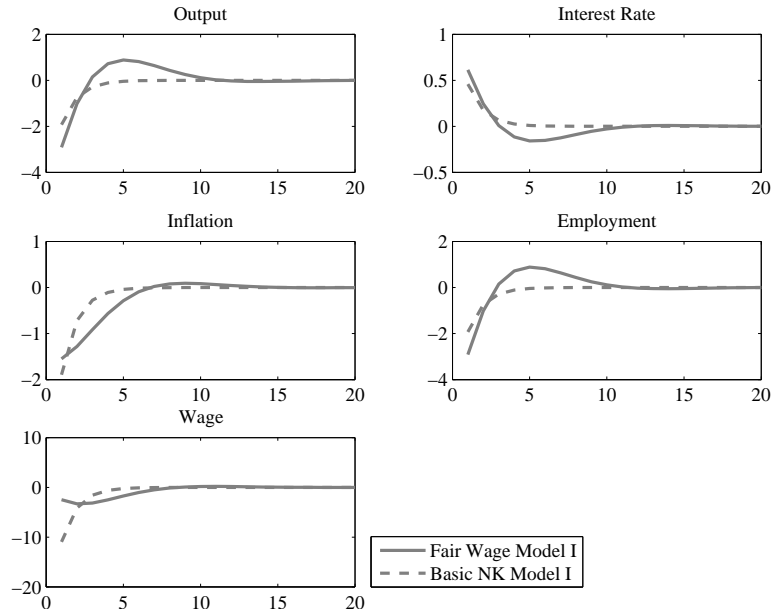
(a) Model I
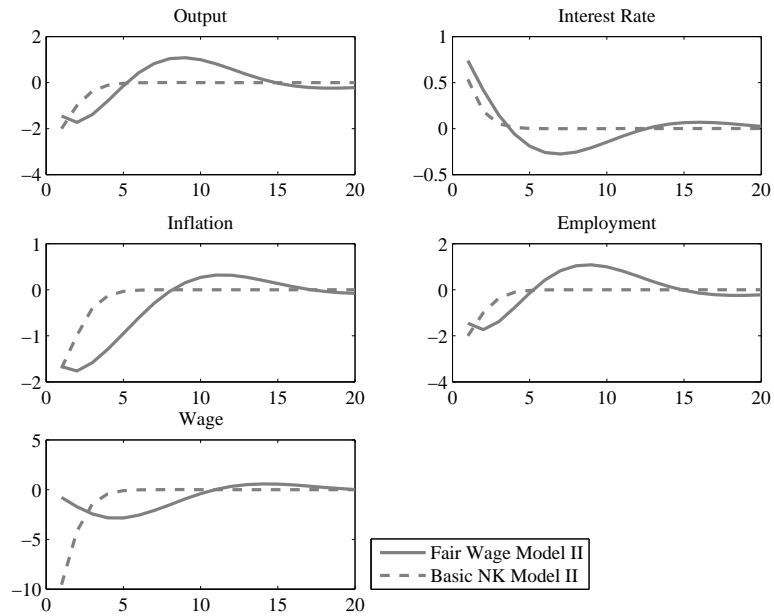
(b) Model II

4.2 Second Order Moments

Table 4 presents HP filtered second order moments from Australian data and those generated by simulated models that take the posterior mean estimates in Tables 2 and 3 as parameter values. Wage and employment data are taken from the same source as the data used to estimate the models (OECD, 2009). There are a number of features of Table 4 that further indicate that the fair wage models outperform the basic New Keynesian framework.

The fair wage models' ability to lower the volatility of the wage series is further demonstrated by the wage to output volatility ratio reported in Table 4. The basic models generate a wage series close to four times as volatile as output, whereas the fair wage models generate wage series that are slightly less volatile than the data with roughly the same volatility as output. The basic models do a more credible job of replicating the employment to output volatility ratio found in the data, whilst the fair wage models produce slightly more volatile employment series. The reported volatilities of the wage and employment series show that the fair wage models lower wage volatility and increase employment volatility, which addresses a well known deficiency of modern business cycle models. The greater volatility of output in the fair wage models largely accounts for their lower inflation to output ratios.

The fair wage models that allow for price indexing and habit formation in consumption and the social norm generate greater output growth persistence than both the data and the basic models. All of the fair wage models produce more persistent inflation and wage series than found in the data. The entire suite of models fail to capture the level of employment persistence in the data, however the additional frictions in the second and third specifications of the fair wage model increase persistence significantly.

All of the models return an inflation-output and interest rate-output correlation that is not found in the data. The fair wage model's correlation between employment and output further illustrate the effects of the Solow condition. As firms are constrained by significant wage inertia, fluctuations in output are largely matched by movements in employment. Additionally, movements in output are not positively matched by the real wage in the fair wage models, unlike the basic models. The wage-inflation, employment-inflation and wage-employment correlations illustrate that the fair wage model weakens the almost perfect co-movement exhibited by these series in the basic model. The fair wage models do a fairly poor job of matching the data in these areas. However, by relaxing the assumption of Walrasian labour markets and dampening the models' response to demand

shocks, they do represent a significant improvement on the basic models.

Table 4: Second Order Moments

| | Aus Data | Basic Model | | Fair Wage | | |
		Model I	Model II	Model I	Model II	Model III
$\sigma(\pi)/\sigma(y)$	0.87	0.61	0.62	0.47	0.58	0.54
$\sigma(w)/\sigma(y)$	2.27	3.99	3.72	1.24	1.28	1.11
$\sigma(n)/\sigma(y)$	0.58	0.90	1.06	1.06	1.39	1.42
$100\sigma(y)$	0.60	0.82	0.86	1.20	1.40	1.49
$\rho(y_t, y_{t-1})$	0.59	0.45	0.52	0.54	0.81	0.82
$\rho(\pi_t, \pi_{t-1})$	0.33	0.19	0.29	0.53	0.69	0.67
$\rho(w_t, w_{t-1})$	0.59	0.20	0.16	0.76	0.85	0.81
$\rho(n_t, n_{t-1})$	0.87	0.25	0.20	0.25	0.45	0.45
$\rho(\pi, y)$	-0.02	0.31	0.28	0.18	0.49	0.54
$\rho(r, y)$	-0.01	-0.41	-0.54	-0.77	-0.54	-0.54
$\rho(w, y)$	0.13	0.39	0.27	-0.15	-0.11	0.00
$\rho(n, y)$	0.07	0.28	0.20	0.47	0.64	0.62
$\rho(w, \pi)$	0.07	0.99	0.98	0.86	0.70	0.74
$\rho(n, \pi)$	0.28	0.94	0.94	0.75	0.81	0.84
$\rho(n, w)$	-0.30	0.97	0.97	0.35	0.27	0.42

5 Phillips Curves: Responses to a monetary shock

5.1 A Traditional Phillips Curve

Through the addition of labour market frictions, the fair wage models generate structural unemployment. As such, it is possible to rearrange the Philips curve to show the relationship between changes in the nominal wage and unemployment in the spirit of Phillips' original work (Phillips, 1958). Change in the nominal wage is defined as

$$\Delta \hat{w}_t = w_t + p_t - w_{t-1} - p_{t-1}$$
$$= w_t - w_{t-1} + \pi_t.$$

Thus, the expression for employment (25) can be expressed as

$$\gamma n_t = \psi(\Delta \hat{w}_t - \pi_t).$$

Making use of the relationship between employment and unemployment (28), rearranging the preceding equation for π_t and substituting these into the standard New Keynesian Phillips curve gives the following relationship between changes in nominal wage and unemployment for the first specification of the fair wage model

$$\Delta \hat{w}_t = \delta mc_t - \frac{\gamma(1 - \overline{N})}{\psi \overline{N}} u_t + \frac{1}{\overline{R}}\left(\mathbb{E}_0 \left(\Delta \hat{w}_{t+1} - \frac{\gamma(1 - \overline{N})}{\psi \overline{N}} u_{t+1} \right) \right). \quad (24)$$

(24) shows that changes in the nominal wage are negatively related to unemployment and are also a function of marginal cost. Owing to the wage rigidity in the model, the wage-unemployment relationship is augmented by considerations for future wage changes and unemployment.

Figure 3(a) plots the relationship between changes in the nominal wage and unemployment in response to a monetary policy shock for all specifications of the fair wage model. The data points at the bottom right corner of the figure correspond to log deviations of the series from steady state on impact of shock. The data points then follow a counter-clockwise path back to steady state. The extra persistence created by consumption and social norm habit formation and price indexing in specifications II and III of the models can be seen in speed of adjustment of the nominal wage back to steady state. The initial specification returns to steady state after two periods, one period ahead of the other models. All of the models slightly overshoot the nominal wage steady state before gradually returning after around 15-18 periods. The magnitude of the effect on unemployment is far more pronounced. Unemployment increases by roughly the same amount in each specification of the model. Once more, the first specification of the model returns to the steady state around one period ahead of the alternative specifications. The unemployment series moves below its steady state level, before converging back to steady state after 10-12 periods.
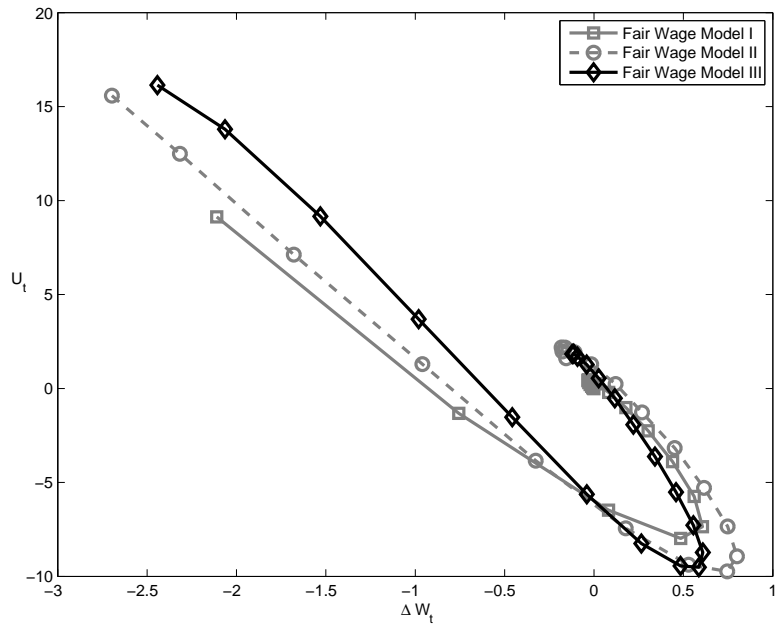
5.2   New-Keynesian Phillips Curve

Figure 3(b) replicates the preceding figure for the standard new-Keynesian Phillips curve expressed as an output-inflation relationship. In this figure, the data points in the bottom left corner show the movements in output and inflation away from steady state upon impact of the shock. The data points follow a clockwise path back toward steady state. Once again, the greater persistence generated by the second and third specifications of the fair wage models can be observed in the models' convergence back to the steady state. All of the models overshoot the steady state output level after output initially falls after the tightening of monetary policy. The first

specification of the model shows a smaller fall in output and returns to steady state the first time after one period, whereas the other two models return after around four periods. Output falls back to its steady state level after around 7 periods for the first specification, and after 12-13 periods for the other two models. Inflation only slightly overshoots its steady state in specifications of II and III, and returns to steady state around 2-3 periods earlier in the first specification of the model.

Figure 3: Phillips Curves

(a) Traditional Phillips Curve
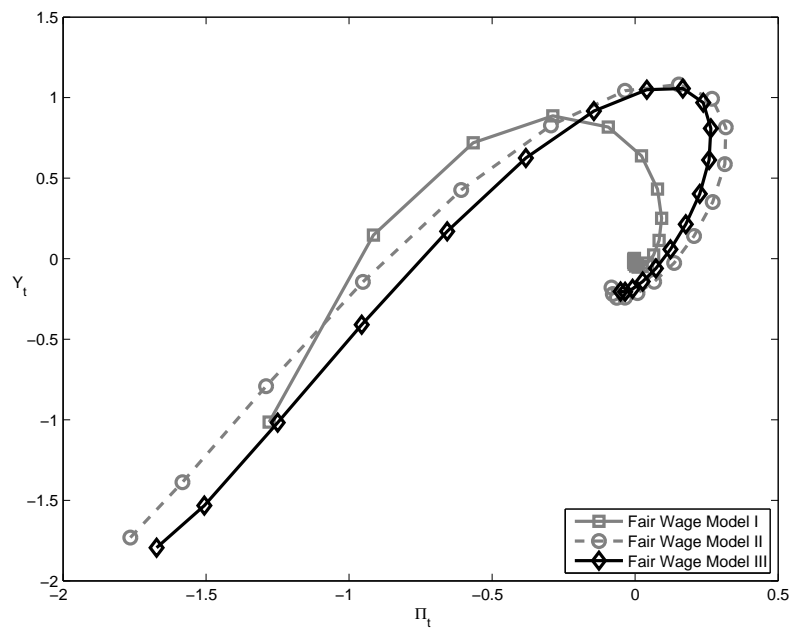
(b) New-Keynesian Phillips Curve

6   Conclusion

In this paper, two sticky price DSGE models were built with one augmented by an efficiency wage labour market friction. The efficiency wage condition is motivated by a gift exchange relationship between firms and workers based on fair wage considerations. Households receive disutility from providing labour effort that deviates from a perceived fair level. Firms can raise productivity by offering higher wages, leading the fair wage model labour market to non-Walrasian outcomes. These models are then extended to allow for habit formation and price indexing firms.

The reaction of wage and employment to exogenous shocks varies significantly between the two models. The fair wage models generate wage rigidity, which lowers the volatility of the wage response and increases the volatility of employment response to exogenous shocks. This helps address a well known deficiency of existing business cycle models by reducing the elasticity of marginal cost with respect to output. The added wage rigidity also augments the persistence of shocks to the price level. Although the fair wage and basic models possess identical Phillips curves, they exhibit different price level responses to shocks. This is due to differences in the behaviour of marginal cost in the presence of labour market frictions.

The persistence of inflation is significantly increased in the fair wage models. Across all specifications of the models, the fair wage models generate greater amplification and persistence of exogenous shocks. The second order moments of the models further show the improved performance of the models with labour market frictions.

Results found elsewhere in the literature have shown that fair wage considerations improve the performance of business cycle models (Collard & de la Croix, 2000; Danthine & Kurmann, 2004). This paper has corroborated these findings using Australian data. Furthermore, it has shown that these conclusions extend to estimated models.

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Appendix A: Log-Linearised Equations

Fair Wage Model

Making use of the model's steady state relationships and log-linearising around the steady state, the following sytem of equations is obtained[3,4]

$$\gamma n_t = \psi(w_t - w_{t-1}). \tag{25}$$

$$y_t = \mathbb{E}_t(y_{t+1} + \pi_{t+1}) - x_t - i_t. \tag{26}$$

$$w_t = mc_t + a_t. \tag{27}$$

$$u_t = -\frac{\overline{N}}{1 - \overline{N}} n_t, \tag{28}$$

$$y_t = a_t + n_t. \tag{29}$$

$$\pi_t = \delta mc_t + \frac{1}{R}\mathbb{E}_t\pi_{t+1}, \tag{30}$$

$$i_t = \tau i_{t-1} + (1 - \tau)(\phi_\pi \pi_t + \phi_{\tilde{y}}\widetilde{y}_t) + \nu_t, \tag{31}$$

$$\tilde{y}_t = y_t - y_t^f, \tag{32}$$

$$y_t^f = \frac{(\gamma + \psi)}{\gamma}a_t - \frac{\psi}{\gamma}a_{t-1}. \tag{33}$$

$$x_t = \rho_\Upsilon x_{t-1} + \varepsilon_{x,t}, \tag{34}$$

$$a_t = \rho_a a_{t-1} + \varepsilon_{A,t}. \tag{35}$$

Basic Model

In the basic model, the equation for unemployment is removed and (25) is replaced by

$$\vartheta n_t = w_t + \frac{x_t}{\rho_\Upsilon - 1} - y_t. \tag{36}$$

Output under flexible prices becomes

$$y_t^f = a_t + \frac{x_t}{(\rho_\Upsilon - 1)(\vartheta + 1)}. \tag{37}$$

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[3]Note that in (26) $x_t = \mathbb{E}_t(v_{t+1}) - v_t = (\rho_\Upsilon - 1)v_t$. This new expression for the preference shock is made to aid identification.

[4]$\delta = \frac{\theta}{(1-\theta)\varphi\overline{\pi}^2}$.

Alternative Specifications

Fair Wage Model II: Hybrid Phillips Curve and Consumption Habit Case

The Phillips curve (30) becomes

$$\pi_t = \frac{\overline{R}\delta}{\overline{R}+\kappa}mc_t + \frac{\overline{R}\kappa}{\overline{R}+\kappa}\pi_{t-1} + \frac{\overline{R}}{\overline{R}(\overline{R}+\kappa)}\mathbb{E}_t\pi_{t+1}. \tag{38}$$

The linear Euler equation is changed from (26) to

$$y_t = \frac{1}{1+b}\left(\mathbb{E}_t(y_{t+1} + (1-b)(\pi_{t+1})) + by_{t-1} - (1-b)(x_t + i_t)\right). \tag{39}$$

Basic Model II

In the basic model, the employment condition (36) becomes

$$\vartheta n_t = \frac{1}{(1-b)^2}\left(\frac{x_t}{(\rho\Upsilon - 1)} + w_t + (1-b)(by_{t-1} - y_t)\right). \tag{40}$$

This changes the statement for flexible price output to

$$y_t^f = a_t + \left(\frac{1}{(1-b)(1+\vartheta(1-b))}\right)\left(\frac{x_t}{(\rho\Upsilon - 1)} + b(a_t + (1-b)(y_{t-1}^f))\right). \tag{41}$$

Fair Wage Model III: Social Norm Persistence

Under this new specification of the model, (25) becomes

$$\gamma n_t = \psi(w_t - w_t^s), \tag{42}$$

where

$$w_t^s = (1-\mu)w_{t-1}^s + \mu w_{t-1}. \tag{43}$$

As a result of this new specification of the social norm, flexible price output becomes

$$y_t^f = \frac{\gamma + \psi}{\gamma}a_t - \frac{\psi}{\gamma}((1-\mu)w_{t-1}^s + \mu a_{t-1}). \tag{44}$$