Optimal Monetary Policy with Fair Wage Considerations *

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Abstract

This paper studies the optimal monetary policy in the baseline New Keynesian model with a non Walrasian labor market based on the Fair Wage hypothesis. The divine coincidence property collapses with fair wages, and strict inflation targeting becomes a suboptimal monetary policy choice. The policymaker undertakes active and often procyclical policy, for it accommodates inflation deviations from steady-state to boost aggregate demand and stabilize the welfare-relevant output gap. A welfare evaluation of simple and implementable Taylor rules suggests that monetary authority should aim to target real variables along with inflation to close the gap with the Pareto efficient frontier.

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1 Introduction

In the last quarter of a century the literature on optimal monetary policy has delivered robust policy prescriptions for the conduct of monetary policy. According to these, policymakers can put the economy on its potential output trajectory by adhering to a rule of price stability. This prescription is mainly derived within the context of the New Neoclassical Synthesis (NNS) paradigm where the main imperfections are monopolistic competition and sticky prices (see Goodfriend and King (1997, 2001) and Goodfriend (2002)). This prescription has survived in richer environments of the NNS.[1] The underlying reason for the robustness of price stability as the central goal of monetary policy is the "divine coincidence" property of the New Keynesian model (see Blanchard and Galí (2007)). The monetary authority can implement the efficient (or first best) allocation with strict inflation stability, since the gap between the natural or flexible price allocation (second best) and the efficient one is constant and invariant to exogenous disturbances.

A key assumption of many early contributions is a frictionless (or Walrasian) labor market. Under this assumption there is no equilibrium unemployment. It is thus unclear how the strong price stability prescription highlighted by the earlier literature is affected when unemployment becomes an equilibrium phenomenon. As a result, most of the early literature of optimal monetary policy has neglected the potential short run tradeoff between unemployment and price stability. As Rotemberg and Woodford (1997) pointed out, strict price stability might be sensitive to labor market distortions.[2]

Equilibrium unemployment can be generated from different types of labor market frictions, e.g. search and matching, labor unions, efficiency wages. Surprisingly, there is almost a complete neglect for the efficiency wage structure of the labor market in the optimal monetary policy literature. According to Shapiro and Stiglitz (1984, pg.443) however, unemployment attributed to efficiency wages *"...is the most important source of unemployment in practice ..."* and *"...it may well be more important than frictional or search unemployment in many labor markets."* The goal of this paper is to study optimal monetary policy in a New Keynesian environment with efficiency wages. To this end, we employ the gift exchange set up of the efficiency wage theory proposed by Akerlof (1982). The NK model with fair wages we use has been shown by Danthine and Kurmann (2004) to improve upon the performance of the baseline NK model with a frictionless labor market and bring its predictions more in line with the data.[3] Therefore, we believe exploring the normative implications of this model is a first order priority. In this model unemployment arises from two considerations. First, there is an effort level judged fair by workers. This effort level is a function of outside wages offered and labor market conditions. We parameterize this effort function by generalizing the logarithmic effort function previously used by Danthine and Donaldson (1990), Collard and de la Croix (2000), Danthine and Kurmann (2004) and recently employed by Croix et al. (2007, 2009).[4] Second, this fair effort level will only be exerted

[1] Recent advances in business cycle modeling have motivated researchers to investigate the optimality of monetary policy in more complex environments of the NNS. Optimal monetary policy was studied in medium and large-scale models that incorporated a combination of nominal and real rigidities, such as nominal wage stickiness, money balances, habit formation in consumption, capital accumulation and investment adjustment costs, variable capacity utilization, etc. These richer environments enhanced the traditional transmission mechanism of the NNS and rendered policy decision making more complicated. Price stability, however, remained the central goal of monetary authorities, and under particular circumstances strict inflation targeting retained its optimal character (Schmitt-Grohé and Uribe 2004a, 2006, 2007a).

[2] King and Wolman (1999) provide a series of issues that normative analysis should be aware of for further investigation, such as the real wage rigidities present in non-clearing labor markets. In the same spirit, Woodford (2002) placed the variation of the wage premium among the disturbances that cause deviations of the natural allocation from the efficient one. More recently, Levin et al. (2005) highlighted the importance of conducting additional research with respect to the implications of the labor market structure for optimal monetary policy.

[3] In addition to generating structural unemployment, it can replicate quite well the low correlation between employment and real wages, generate a low volatility of the real wage, generate more procyclical and volatile employment.

[4] The effort function relates the effort level judged fair by workers with outside alternative wage opportunities and the labor

in equilibrium if firms offer a higher than the market clearing wage rate, i.e. a fair wage. The model with fair wages introduces a real wage rigidity which has implications for optimal policy. Real wages are rigid because firms are averse to large wage changes which affect morale and hence effort provided by workers. This form of rigidity generates a trade-off between inflation and output gap stabilization and renders strict inflation targeting a suboptimal monetary policy choice. While the flexible-price allocation of the model economy is always attainable, the efficient allocation, which matters for welfare is infeasible, and thus the divine coincidence property of the baseline New Keynesian model collapses.

We calibrate and simulate the model economy with fair wages and use the concept of the Ramsey planner to investigate the nature of the tradeoff between inflation and unemployment. The planner faces a trade-off between inflation and (welfare-relevant) output gap stabilization because fair wages introduce an endogenous cost-push term in the New Keynesian Philips curve, so that the monetary authority cannot target both policy objectives with strict inflation stability. The dynamic adjustment under the Ramsey planner suggests a role for procyclical monetary policy. In response to technology shocks, the Ramsey planner allows for significant deviations from price stability in order to push the economy close to the efficient allocation. A welfare evaluation of alternative specifications of contemporaneous Taylor-type rules verifies the sub-optimality of strict inflation targeting: Taylor rules with non-zero policy coefficients on arguments associated with the real economy, such as employment or real wage growth, perform better than strict inflation targeting rules in minimizing the welfare cost of the business cycle. This result is robust to an extensive sensitivity analysis with respect to various parameterizations of the effort function.

To the best of our knowledge, Nakajima (2010) is the only study which employs a version of the shirking approach of the efficiency wage theory, based on the model of Alexopoulos (2004), that seeks to investigate whether and to what extent the incomplete insurance against unemployment affects the traditional optimal monetary policy hold within the baseline NK model. Our paper however, differs from Nakajima (2010) in three respects. First, in contrast to the shirking variety of the efficiency wage theory followed by Nakajima (2010), we employ the gift exchange variety and this constitutes the main contribution of our paper. We do this for three reasons: fairness considerations seem to be a more relevant explanation for efficiency wages (Danthine and Kurmann 2004) [5]; the shirking variety seems to have many sunspot equilibria (Kimball 1994) which complicates the analysis; and more importantly the normative analysis within the gift exchange variety environment is still unexplored. Second, we assume complete insurance against unemployment. This allows us to test whether the optimality of strict inflation targeting, as shown by Nakajima (2010) in the shirking version of the NK model with complete insurance, holds under the alternative specification of efficiency wages. Third, we abstain from fiscal policy considerations, and focus on the unconstrained Ramsey approach rather than the Linear Quadratic method, which assumes a complementary role for fiscal policy in the long-run.

There is a small but growing literature that studies the consequences of labor market frictions for the conduct of optimal monetary policy. Most of this literature introduces those frictions via the search and matching framework developed by Mortensen and Pissarides (1999). There is also a limited number of studies that introduce other forms of frictions: unions, labor turnover costs, and wage bargaining agreements (see Faia and Rossi (2012) and Faia et al. (2011) and Gnocchi (2009)). Within the search and matching approach no consensus for the consequences of labor market imperfections on optimal monetary policy seems to have emerged yet. In the context of the linear quadratic approach, Thomas (2008) reports that zero inflation becomes nearly optimal for any degree of real wage rigidity within the New Keynesian model. By contrast, under the Ramsey approach, Faia (2009) reports that optimal mone-

market tightness. In equilibrium, exerted effort of workers is equal with its fair level, while unemployed agents exert zero effort. Recently, Danthine and Kurmann (2007) and Danthine and Kurmann (2010) provide micro-foundations for the effort specification in this class of models.

[5] Danthine and Kurmann (2004) provide a coherent comparison of alternative theories of the labor market introduced in DSGE models with sticky prices: efficiency wages, staggered nominal wage contracts, and search and matching frictions.

tary policy deviates from price stability when the Hosios - Mortensen condition does not hold. Specifically, whenever the bargaining power of workers is not equal with the elasticity of the matching function with respect to vacancies, within the Nash bargaining process of wage and employment determination, the unemployment level of the labor market becomes Pareto suboptimal. In this sense, the monetary authority faces a tripodal trade off between inflation, monopolistic competition, and inefficient unemployment fluctuations that rationalize deviations from strict inflation targeting. According to Faia (2009), search and matching frictions generate congestion externalities, which induce the monetary authority to deviate from strict price stability.[6] This result is in line with the welfare evaluation of simple and implementable Taylor-type rules conducted within the search and matching frictions framework by Faia (2008b).

Blanchard and Galí (2010) develop a version of the search and matching approach of the New Keynesian model, where labor market frictions take the form of hiring costs. In this non Walrasian framework, they introduce three inefficiencies, namely, labor market frictions, real wage rigidities and staggered price setting, and show the monetary authority faces two competing objectives that determine social welfare: the stabilization of inflation and unemployment. Strict inflation targeting implies inefficient fluctuations of unemployment, while unemployment targeting generates inflation volatility which leads to misallocation of resources. In the context of the linear quadratic approach, optimal monetary policy strikes a balance between these stabilization objectives: policymaker accommodates inflation to minimize unemployment fluctuations. However, as they point out, the rationale behind the sub-optimality of strict inflation targeting is the existence of real wage rigidity rather than labor market frictions per se. This result was recently underlined by Galí (2010) who investigated the role and the policy implications of labor market frictions in a New Keynesian model with variable labor market participation and unemployment.

The rest of the paper proceeds as follows. Section 2 describes the baseline NK model with fair wage considerations based on the effort function developed by Croix et al. (2007, 2009). Section 3 describes the calibration of the model. Section 4 and 5 describe the natural and efficient allocation of the model economy and section 6 discusses the notion of the real wage rigidity and the implications on the divine coincidence property of the baseline NK model. Section 7 studies the positive properties of the model, and its performance in resolving the wage-employment variability puzzle. Normative discussion begins from section 8, where we describe the Ramsey optimal plan, both in the long run and over the business cycle driven by supply and demand-side disturbances. Section 9 evaluates in the context of the public finance approach the performance of contemporaneous Taylor-type rules in replicating the Ramsey optimal plan. Finally, section 10 concludes.

2 The Model

We use a baseline New Keynesian model with fair wage considerations based on the effort function developed by Croix et al. (2007, 2009) that relates effort considered fair by workers with two arguments: the wage rate paid to worker, and the outside labor market conditions, as the latter are reflected by the current and lagged period aggregate wage rate, and the labor market tightness as well. So far, fair wage DSGE models employed a linear-logarithmic expression of the effort function (Danthine and Donaldson 1990, Collard and de la Croix 2000, Danthine and Kurmann 2004) which delivers a constant effort over the business cycle.

In the present analysis, we incorporate the non-logarithmic effort function of Croix et al. (2007, 2009) for two reasons. First, it constitutes a generalization of the log-linear expression of previous analyses, allowing effort to vary procyclically over the business cycle. Indeed, the effort function of Croix et al. (2007, 2009) nests the logarithmic counterpart under a specific parameterization. This allows us to conduct the normative analysis with alternative

[6]The optimality of price stability found by Thomas (2008) was mainly attributed by Faia (2008a) on the fact that Thomas's analysis was implemented around an efficient steady-state where the Hosios condition is met. As a result, there were no congestion externalities in the notion described by Faia (2009), and strict inflation targeting remains optimal.

assumptions with respect to effort response over the business cycle, preserving simultaneously the simplicity of introducing fair wage considerations with a reduced form expression for effort. Second, by including the lagged aggregate wage, the effort function incorporates the original idea of Akerlof (1982), i.e., it relates the fair effort with the comparison between the current and past average wage.

2.1 Household

The model economy is populated by a continuum $j\epsilon[0,1]$ of households each of which is composed by a continuum of infinitely lived agents. Within a household, family-members differ ex-ante and ex-post. First, a fraction $n_{j,t}$ of members are employed through a random selection process while the rest one remain in the unemployment pool. Second, utility differs between family members in terms of the disutility from working. The representative household has preferences over consumption and effort rather than leisure. During every period each household maximizes the lifetime utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\ln\left(c_{j,t}\right) - n_{j,t}\, \left(e_{j,t} - e^*_{j,t}\right)^2 + \left(1 - n_{j,t}\right)\, \left(e^*_{j,t}\right)^2 \right]$$

where $c_{j,t}$, $e_{j,t}$ and $e^*_{j,t}$ denote consumption, exerted and fair effort of household $j\epsilon[0,1]$, respectively, subject to a time period budget constraint and the effort function.

The above momentary utility assumes perfect insurance against unemployment which implies identical consumption for all family members both employed and unemployed. Employed family members derive utility from consumption but suffer a disutility from exerting effort around the fair wage level $e^*_{j,t}$. Unemployed family members consume the same level of consumption as employed members (due to the perfect insurance scheme) and gain indeed an opportunity benefit in terms of effective leisure obtained by staying home and undertaking pleasurable home activities. The individual agent by remaining in the unemployment pool looses its salary independence, because her income depends thoroughly on her family's total income, but gains in terms of effective leisure because she does not exert effort in working activities which reduce utility. This effective or opportunity benefit can be approximated relative to the rest family members by the fair level of effort which is always exerted in equilibrium by the working members of the household.[7]

The fair effort $e^*_{j,t}$ is determined by the function of Croix et al. (2007, 2009) with arguments the wage rate $w_{j,t}$, the labor market tightness ($1/(1-n_t)$), and the aggregate wage of the current and previous period, given by w_t and w_{t-1}, respectively.[8] Using the notation of Croix et al. (2007, 2009), we write the fair effort function as follows:

$$e^*_{j,t} = \phi_1\, \frac{w^{\psi}_{j,t} - \phi_2\, \left(\frac{1}{1-n_t}\right)^{\psi} - \phi_3\, w^{\psi}_t - \phi_4\, w^{\psi}_{t-1} - \left(\phi_0 - \phi_2 - \phi_3 - \phi_4\right)}{\psi}$$

where $\phi_0 \epsilon R$, $\phi_1 > 0$ are scale parameters, $\phi_2 > 0$, $\phi_3 \epsilon [0,1)$, and $\phi_4 \epsilon [0,1)$ measure the effects of the external labor market conditions, i.e., of the labor market tightness, and the aggregate (or outside average) real wage of the current

[7]The opportunity benefit of unemployed members of the family has been ignored by fair wage DSGE models which assume that unemployed agents do not encounter effort decisions, so that the quadratic term referring to the unemployed fraction of family is set equal to zero. Contrary to the present analysis, however, fair wage literature was concerned with positive rather that normative issues. As it is shown below, the opportunity benefit of unemployed family members in terms of effective leisure is considered necessary for the derivation of an economically plausible efficient allocation and the micro-founded social welfare function.

[8]We insert lagged aggregate wage (w_{t-1}) in effort function to allow for wage sluggishness in the model, because we abstain from nominal wage stickiness assumed by Croix et al. (2007). The simplification to abstain from nominal wage stickiness comes from our intention to focus on the role of real wage rigidities attributed to the efficiency wage mechanism rather than the nominal wage stickiness á la Calvo.

and previous period on individual fair level of effort. Parameter $\psi \epsilon [0, 1)$ measures the degree of substitutability between the fair effort function arguments[9].

The above reduced form expression reveals that fair effort is positively related to the wage paid to family's $j\epsilon[0, 1]$ members, but negatively to the labor market tightness ($1/(1 - n_t)$) and the current and lagged aggregate wage (w_t and w_{t-1}). The higher is the real wage paid to household $j\epsilon[0, 1]$, the better is the morale of employed members to exert effort. A low labor market tightness, i.e., a high unemployment rate, increases the fair level of effort, because workers have low possibilities to find a job in case of being fired from their current employment activities. In other words, unemployment operates as a threat which induces workers to exert high effort during their employment and avoid a prolonged loss of their jobs. Fair effort is negatively related to the aggregate wage, because the latter reflects the average wage paid in labor market activities. High aggregate wage indicates improved external labor market conditions which reduce the motivation of those earning a wage less than the aggregate one. The lagged aggregate wage reflects the backward-looking behavior of households when they take effort decisions.

Employed members $n_{j,t}$ of the household $j\epsilon[0, 1]$ supply inelastically one unit of labor and earn a real wage $w_{j,t}$, which is considered net of insurance costs, as workers pay for unemployment insurance. The representative household invests in contingent bonds $b_{j,t} = B_{j,t}/P_t$ that return a gross nominal interest rate r_t. Household earns real dividends $d_{j,t}$ from the monopolistic sector and pays lump-sum taxes $\tau_{j,t}$ to the government. Thus, the time period budget constraint is given by

$$c_{j,t} + \frac{B_{j,t}}{P_t} \leq w_{j,t}\, n_{j,t} + r_{t-1}\, \frac{B_{j,t-1}}{P_t} + d_{j,t} - \tau_{j,t}$$

The first order necessary conditions of the family utility maximization problem with respect to consumption $c_{j,t}$, effort $e_{j,t}$ and real bond holdings $b_{j,t}$ are:

$$c_{j,t}^{-1} = \beta\, r_t\, E_t \left[c_{j,t+1}^{-1} \left(\frac{1}{\pi_{t+1}} \right) \right] \tag{2.1}$$

$$e_{j,t} = \phi_1\, \frac{w_{j,t}^{\psi} - \phi_2 \left(\frac{1}{1-n_t}\right)^{\psi} - \phi_3\, w_t^{\psi} - (\phi_0 - \phi_2 - \phi_3)}{\psi} \tag{2.2}$$

and a transversality condition that prevents Ponzi games. Condition (2.1) gives the standard Euler equation which describes the inter-temporal allocation of household's consumption spending. Condition (2.2) defines the effort function which equates the exerted effort of workers with its fair level.

2.2 The supply side

The supply side of the model is composed by final good firms, intermediate good-producing firms, and retail firms. Intermediate firms $s\epsilon[0, 1]$ use the efficient labor of employed workers (i.e., the hours of work along with the exerted effort) to produce and sell intermediate products $y_t(s)$ to retail firms $i\epsilon[0, 1]$ at a price formulated in competitive equilibrium product markets. Retail firms $i\epsilon[0, 1]$ purchase from intermediate firms $s\epsilon[0, 1]$ the product varieties $y_t(s)$ to sell them in turn to the final good firms at an optimal price formed by the monopolistically competitive retail market. Final good firms purchase the product variety $y_t(i)$ by retailers $i\epsilon[0, 1]$ as an input of production for the homogeneous final good y_t. The homogeneous product y_t is sold to households in a perfectly competitive market.

[9]For $\psi = 0$, the effort function of Croix et al. (2007, 2009) nests the logarithmic effort functions of the fair wage literature. That is, for $\psi = 0$, fair effort becomes equal to $e_t^*(j) = \phi_1\ [\ln w_t(j) - \phi_2 \ln(1/(1 - n_t)) - \phi_3 \ln w_t]$

2.2.1 Final good firm

The representative final good firm transforms $y_t(i)$ units of the intermediate good $i\epsilon[0,1]$ bought from retailers into y_t units of the homogeneous final good. The constant returns to scale production technology of the final good y_t takes the form of the Dixit and Stiglitz (1977) aggregate given by

$$y_t \leq \left[\int_0^1 y_t(i)^{\frac{\varepsilon-1}{\varepsilon}}\, di\right]^{\frac{\varepsilon}{\varepsilon-1}}$$

where $\varepsilon > 1$ denotes the elasticity of substitution among the intermediate products $i\epsilon[0,1]$. The higher is the elasticity $\varepsilon > 1$, the more competitive is the intermediate good market.

By operating in perfectly competitive market, the final good firm takes the price of the homogenous output as given and minimizes the cost of production. The cost minimization problem subject to the above constant returns to scale production technology delivers the demand for each intermediate good $i\epsilon[0,1]$ by the final good firm:

$$y_t(i) = \left[\frac{P_t(i)}{P_t}\right]^{-\varepsilon} y_t \tag{2.3}$$

for all $i\epsilon[0,1]$ and $t = 0,1,2,\ldots$ Due to the competitive nature of the final good market, there is a zero profit condition which delivers the following aggregate price index:

$$P_t = \left(\int_0^1 P_t(i)^{1-\varepsilon} di\right)^{\frac{1}{1-\varepsilon}} \tag{2.4}$$

where P_t and $P_t(i)$ denote the aggregate price level and the price of each intermediate good $i\epsilon[0,1]$, respectively.

2.2.2 Retail firm

Each retailer $i\epsilon[0,1]$ buys the intermediate product variety from the intermediate-good producing firms at the competitive price ω_t and sells to the final good firms at price $P_t(i)$, which is determined within a monopolistically competitive retail market. Retailers are subject to nominal price rigidities á la Calvo (1983), i.e., they reset their price $P_t(i)$ whenever receive a random signal with probability $1-\theta$, which is independent from the time elapsed since the last adjustment and the pricing decisions of the others. During every period t, a fraction $1-\theta$ of retailers receive the random signal and re-optimize the price $P_t(i)$, while the remaining fraction $\theta\epsilon(0,1)$ sets a price equal to the aggregate price index of the previous period according to the rule $P_t(i) = \overline{\pi}^{\chi}\, P_{t-1}$, with $\chi = 0$ (no price indexation condition[10]).

The representative retail firm chooses the price $P_t(i)$ to maximize the expected sum of future profits, discounted by the pricing kernel $[\Lambda_{t,T} = \beta^{T-t}\,(\lambda_T/\lambda_t)]$ and the probability $\theta\epsilon(0,1)$ that the optimal price will remain fixed for $1/(1-\theta)$ future periods. Thus, the pricing decision problem of firm $i\epsilon[0,1]$ can be written as,

$$\max_{\{P_T(i)\}} E_t \sum_{T=t}^{\infty} \theta^{T-t}\Lambda_{t,T}\, d_T(i)$$

where monopolistically real profits per period are defined by

$$d_t(i) = \left[\frac{P_t(i)}{P_t}\right] y_t(i) - \omega_t\, y_t(i)$$

The first term of the RHS above denotes total real revenues while the second term, i.e., $\omega_t\, y_t(i)$, denotes real total cost, since ω_t is the price at which intermediate firms purchase the product variety $y_t(i)$. The maximization of the expected discounted sum of firm's $i\epsilon[0,1]$ future real profits

[10]We consider no-price indexation for non-optimized prices, because there is available empirical evidence that supports this argument according to Schmitt-Grohé and Uribe (2007b, pg. 1709).

$$\max_{\{P_t(i)\}} E_t \sum_{T=t}^{\infty} \theta^{T-t} \Lambda_{t,T} P_T \left[\frac{P_t(i)}{P_T} y_T(i) - \omega_T \, y_T(i) \right]$$

subject to the demand (2.3) for the product variety $i\epsilon[0,1]$ by the final good firm, delivers the following first order condition:

$$E_t \sum_{T=t}^{\infty} \theta^{T-t} \Lambda_{t,T} \left[\frac{P_t^*(i)}{P_T} \right]^{-1-\varepsilon} y_T \left\{ \omega_T - \left(\frac{\varepsilon - 1}{\varepsilon} \right) \frac{P_t^*(i)}{P_T} \right\} = 0 \tag{2.5}$$

The pricing decision condition (2.5) reveals that the firm $i\epsilon[0,1]$ will choose a price equal to a markup over a weighted sum of current and expected nominal marginal cost.

2.2.3 Intermediate-good firm

Each intermediate good firm $s\epsilon[0,1]$ produces the variety $y_t(s)$ according to the linear production technology,

$$y_t(s) = z_t \, e_t(s) \, n_t(s) \tag{2.6}$$

where the exerted effort $e_t(s)$ is always equal with its fair level given by the effort function (2.2). The exogenous variable z_t denotes the aggregate neutral productivity shock, which follows an exogenous stationary AR(1) process of the form

$$\ln(z_t) = \rho_z \, \ln(z_{t-1}) + \varepsilon_{z,t} \tag{2.7}$$

with $|\rho_z| < 1$ and $\varepsilon_{z,t} \sim iid(0, \sigma_z^2)$.

The intermediate good firm chooses employment and the wage rate $w_{j,t}$ to persuade workers into exerting the desired level of effort. In this sense, the wage rate chosen by firms is set above the labor market clearing level which generates an equilibrium unemployment equal to,

$$u_t = 1 - n_t \tag{2.8}$$

The product variety $y_t(s)$ is sold to the retailers at the competitive equilibrium product price ω_t. The profit maximization problem determined by

$$\max E_t \sum_{T=t}^{\infty} \beta^{T-t} \Lambda_{t,T} \, [\omega_T \, y_T(s) - w_T(s) \, n_T(s)]$$

subject to the linear production technology $y_t(s) = z_t \, e_t(s) n_t(s)$ and the effort function (2.2) is stationary. The first order necessary conditions with respect to employment $n_t(s)$ and wages $w_t(s)$ are given by

$$w_t(s) = \omega_t \, \frac{y_t(s)}{n_t(s)} \tag{2.9}$$

$$n_t(s) = \omega_t \, \frac{y_t(s)}{e_t(s)} \, \phi_1 w_t(s)^{\psi - 1}$$

The combination of the above conditions delivers the Solow (1979) equation, according to which the exerted effort of workers is positively related to the real wage as follows,

$$e_t(s) = \phi_1 w_t(s)^{\psi} \tag{2.10}$$

If $\psi = 0$, the effort function (2.2) is logarithmic and the exerted effort of workers is constant over the business cycle, i.e., $e_t(s) = \phi_1$.

2.3 Market Clearing and Aggregation

We drop the indexes $j\epsilon[0,1]$, $i\epsilon[0,1]$ and $s\epsilon[0,1]$ from the above optimality conditions in a symmetric equilibrium where all households and firms take identical decisions, and all product markets clear. The product technology becomes

$$y_t = \left(\frac{1}{s_t}\right) z_t \, e_t \, n_t \tag{2.11}$$

where $n_t = \int_0^1 n_t(i)\, di$ and $s_t = \int_0^1 \left[P_t(i)/P_t\right]^{-\varepsilon} \, di$ give the aggregate employment and the price dispersion measure across firms, respectively.[11] Following Schmitt-Grohé and Uribe (2007a), the price dispersion definition can be written in recursive form as,

$$s_t = (1-\theta)\left(p_t^*\right)^{-\varepsilon} + \theta\left(\pi_t\right)^{\varepsilon} s_{t-1} \tag{2.12}$$

We abstain from fiscal policy considerations by assuming zero net supply of bonds in equilibrium, i.e., $b_t = b_{t-1} = 0$. In this case, government expenditure (g_t) is financed by lump sum taxes (τ_t) only, paid by households, i.e., the government budget constraint is given by $g_t = \tau_t$ for every period $t > 0$. The combination of the time period budget constraints of representative household and government along with the definition of monopolistic real profits, the zero net supply of bonds condition and the marginal cost expression delivers the following aggregate resource constraint of the model economy,

$$y_t = c_t + g_t$$

where government spending g_t follows the exogenous stationary AR(1) process

$$\ln\left(\frac{g_t}{\overline{g}}\right) = \rho_g \, \ln\left(\frac{g_{t-1}}{\overline{g}}\right) + \varepsilon_{g,t} \tag{2.13}$$

with $|\rho_g| < 1$ and $\varepsilon_{g,t} \sim iid(0, \sigma_g^2)$.

Also, in symmetric equilibrium the pricing decision condition (2.5) takes the form

$$x_t^1 = \left(\frac{\varepsilon - 1}{\varepsilon}\right) x_t^2 \tag{2.14}$$

where x_t^1 and x_t^2 denote the present discounted value of total cost and total revenues, respectively, defined in recursive form as follows:

$$x_t^1 = \left(p_t^*\right)^{-\varepsilon-1} y_t \, mc_t + \theta E_t \Lambda_{t,t+1} \pi_{t+1}^{\varepsilon+1} \left[\frac{p_t^*}{p_{t+1}^*}\right]^{-\varepsilon-1} x_{t+1}^1 \tag{2.15}$$

and

$$x_t^2 = \left(p_t^*\right)^{-\varepsilon} y_t + \theta E_t \Lambda_{t,t+1} \pi_{t+1}^{\varepsilon} \left[\frac{p_t^*}{p_{t+1}^*}\right]^{-\varepsilon} x_{t+1}^2 \tag{2.16}$$

The variable $p_t^* = P_t^*/P_t$ denotes the optimal price set by firms relatively to the aggregate price index P_t. The price index definition (2.4) along with the no-price indexation rule $P_t(i) = P_{t-1}$ delivers the following law of motion of the aggregate price level:

$$1 = \theta\left(\pi_t\right)^{\varepsilon-1} + (1-\theta)\left(p_t^*\right)^{1-\varepsilon} \tag{2.17}$$

[11]Details are provided in Appendix A.

2.4 Monetary policy

A central bank conducts the monetary policy by setting the short-term nominal interest rate according to a contemporaneous Taylor-type rule of the form,

$$\frac{r_t}{\overline{r}} = \left(\frac{r_{t-1}}{\overline{r}}\right)^{\alpha_r} \left(\frac{\pi_t}{\overline{\pi}}\right)^{\alpha_\pi} \left(\frac{y_t}{\overline{y}}\right)^{\alpha_y} \left(\frac{n_t}{\overline{n}}\right)^{\alpha_n} (g_t^w)^{\alpha_w} \tag{2.18}$$

where $g_t^w = w_t/w_{t-1}$ is the gross growth rate of real wage, and $\{\overline{y}, \overline{\pi n}\}$ denote the Ramsey steady-state levels of the corresponding variables. Parameters $\alpha_\pi \epsilon [1,3]$ and $\{\alpha_y, \alpha_n,\} \epsilon [-0.5, 0.5]$ and $\alpha_w \epsilon [0,3]$ are the policy response coefficients pertaining to the corresponding Taylor rule argument of the real economy. Parameter $\alpha_r \geq 0$ determines the degree of interest rate inertia.

The above interest rate rule is simple and implementable in the notion described by Schmitt-Grohé and Uribe (2007b). That is, it involves few and readily available macroeconomic measures; its parameterization ensures local uniqueness of the rational expectations equilibrium and prevents non-negative equilibrium dynamics for the nominal interest rate. The Taylor rule contains policy arguments referring to the labor market, such as employment and real wage growth, because efficiency wages generate real wage rigidities in the economy. Insofar as the monetary authority intends to eliminate the inefficiencies appeared in the model economy–nominal price stickiness, monopolistic competition, and real wage rigidity– we expect that the policy concern for eliminating the additional inefficiency associated with efficiency wages will be reflected by non zero policy response coefficients for the labor market variables.

In conducting a welfare evaluation of alternative specifications of the above feedback interest-rate rule, we search for the optimal values of the policy response coefficients $\{\alpha_r, \alpha_\pi, \alpha_y, \alpha_n, \alpha_w\}$ that maximize the welfare of the representative household, provided that the determinacy of the rational expectations equilibrium is satisfied.[12]

2.5 Competitive Equilibrium

A stationary competitive equilibrium with zero net supply of bonds ($b_t = b_{t-1} = 0$) is the set of processes $\{y_t,\, c_t,\, n_t,\, u_t,\, w_t,\, e_t,\, x_t^1,\, x_t^2,\, p_t^*,\, s_{t+1},\, mc_t,\, \pi_t,\, r_t\}_{t=0}^{\infty}$ that satisfy the first order conditions of the representative household (2.1), (2.2), the unemployment rate definition (2.8), the supply-side optimality conditions (2.9), (2.10), the pricing decision condition defined by (2.14), (2.15), (2.16), the aggregate price index (2.17), the price dispersion measure (2.12), the market clearing condition (A.1) and the aggregate resource constraint (2.3), for a given interest-rate rule (2.18), and the exogenous stochastic processes (2.13), (2.7) pertaining to the aggregate neutral technology and the government spending shocks. [13]

3 Calibration

We calibrate the model in quarterly frequency and set the values for the structural parameters as described in Table 1.

We consider a distorted steady-state with positive inflation rate equal with 4.2% annually (Schmitt-Grohé and Uribe 2007b). The subjective discount factor is set equal to 0.99, which implies an annual real interest rate of 4% (or 1% in quarterly frequency).

Each employed agent supplies hours of work inelastically in the labor market, which are normalized to unity. In this sense, there is no labor - leisure trade off decisions for agents, and employment evolves over the business cycle at the extensive margin only.

[12] The determinacy areas of alternative specifications of the Taylor rule (2.18) are depicted in figure 23.

[13] The complete set of equilibrium conditions is provided in Appendix B.

The elasticity of substitution among intermediate products and the probability that each firm retains its price unchanged within a given period are set equal to $\varepsilon = 6$ and $\theta = 0.75$. The price elasticity $\varepsilon = 6$ implies an inefficient static markup of prices over marginal cost equal to $\mu^p = 1.2$. Accordingly, the Calvo (1983) price rigidity parameter $\theta = 0.75$ implies an average price duration of four quarters. These values are consistent within the range of estimates reported in recent studies (Smets and Wouters 2007, Justiniano et al. 2010).

We set values for the parameters of the effort function motivated by three main concerns. First, to assure an upward sloping wage setting curve which requires a positive elasticity of real wage with respect to employment, i.e., $\Omega_1 > 0$. Second, to guarantee a stable natural allocation and a wage setting curve, which necessitates an elasticity of real wage with respect to past aggregate wage less than unity, i.e., $\Omega_2 < 1$. Third, to match as close as possible the wage setting equation estimated in Danthine and Kurmann (2004) with quarterly US data[14]. Under the baseline calibration we set $\psi = 0.1$, $\phi_2 = 0.001$, $\phi_3 = 0.25$, and $\phi_4 = 0.6$. These values fall within the range of estimated values reported in Croix et al. (2007) and give a calibrated Wage Setting equation equal to $\hat{w}_t = 0.063963\, \hat{n}_t + 0.92308\, \hat{w}_{t-1}$ which is quite close to estimated equation of Danthine and Kurmann (2004)[15]. Indeed, given the lack of quantitative evidence on the effort function parameters, we perform an extensive sensitivity analysis with respect to those coefficients in the Ramsey optimal plan section. The coefficients $\{\phi_0, \phi_1\}$ are free nuisance parameters that guarantee a steady-state value of exerted effort and unemployment rate equal to unity and 5% respectively, as in Croix et al. (2007).

The exogenous AR(1) processes associated with technology (z_t) and government spending (g_t) variables are parameterized so that $(\rho_z, \sigma_z) = (0.95, 0.008)$ and $(\rho_g, \sigma_g) = (0.9, 0.0074)$. Also, the steady-state value of the neutral technology parameter equals unity ($\overline{z} = 1$) and the government to output ratio is set equal with $\overline{g}/\overline{y} = 0.25$. These values are standard in the RBC and NNS literature and have been undertaken by similar analyses (Faia 2008b,c, 2009, 2012, Faia et al. 2011, Faia and Rossi 2012).

Using the above calibrated parameters and the competitive equilibrium conditions in steady-state, we derive the steady-state values of the endogenous variables and the rest structural parameters of the model.[16]

4 Flexible price allocation

In the present section we search whether the natural allocation is feasible. In the New Keynesian model the second-best equilibrium is described by the flexible price allocation. If the monetary authority can eliminate the inefficiencies caused by monopolistic competition and efficiency wages, attaining the natural equilibrium is an optimal policy choice. In the standard New Keynesian model with Walrasian labor market, the natural equilibrium is always attainable if the monetary authority sets the real interest rate equal to its natural counterpart. In this case, the strict inflation targeting is optimal, for it allows monetary authority to obtain both inflation and output gap stabilization. If the flexible-price allocation is infeasible, the policymaker confronts a short-run trade-off between inflation and output gap stabilization, and inflation targeting in suboptimal.

Faia (2009) showed that the flexible price allocation is not attainable in non Walrasian NK model where unemployment is generated by search and matching frictions á la Mortensen and Pissarides (1999). In this environment, the marginal cost incorporates the future value of a match which varies to exogenous disturbances and acts as a cost-push shock component in the New Keynesian Phillips curve (NKPC). In the search and matching frictions framework, the natural equilibrium is unattainable and the monetary authority deviates from strict inflation targeting. Similarly, in

[14]The estimated Wage Setting curve of Danthine and Kurmann (2004, pg. 121) is given by $\log(w_t) = 0.0348 \log(n_t) + 0.9912 \log(w_{t-1}) + \epsilon_t$

[15]Under the competitive equilibrium steady-state, the WS condition is equal to $\hat{w}_t = 0.040208\, \hat{n}_t + 0.92308\, \hat{w}_{t-1}$. In the Ramsey steady-state in which employment is endogenously derived, the WS condition is parameterized as $\hat{w}_t = 0.063963\, \hat{n}_t + 0.92308\, \hat{w}_{t-1}$

[16]Appendix C provides the complete derivations of the competitive equilibrium steady-state in successive order.

non Walrasian NK models with unionized labor markets (Faia and Rossi 2012) or labor turnover costs (Faia et al. 2011), the flexible-price allocation remains infeasible.

To determine the implementability of the flexible price allocation in the non-Walrasian NK model with fair wage considerations, we examine the non-policy block of the model: the NKPC and the dynamic IS equation. The IS condition is the combination of the Euler equation (2.1) with the aggregate resource constraint (2.3), and in log-linearized terms is given by

$$\hat{x}_t^n = E_t\left(\hat{x}_{t+1}^n\right) - s_c\left[\hat{r}_t - E_t\left(\hat{\pi}_{t+1}\right) - \hat{\rho}_t^n\right] \tag{4.1}$$

where $\hat{x}_t^n = \hat{y}_t - \hat{y}_t^n$ denotes the natural output gap, $\hat{y}_t$ is the output in log-linear deviation from its steady-state level, $\hat{y}_t^n$ is the natural output, and $\hat{\rho}_t^n$ is the natural interest rate given by

$$\hat{\rho}_t^n = \left(\frac{1}{s_c}\right) E_t\left(\Delta\, \hat{y}_{t+1}^n\right) + \left(\frac{1-s_c}{s_c}\right)(1-\rho_g)\,\hat{g}_t$$

with $s_c = c/y$, i.e., the steady-state consumption to output ratio. The dynamic IS equation reveals the natural level of output is always attainable whenever the the real interest rate ($\hat{\rho}_t = \hat{r}_t - E_t(\hat{\pi}_{t+1})$) is equal to its natural counterpart ($\hat{\rho}_t^n$).

Accordingly, a log-linearization of the pricing decision condition (2.14) delivers the NKPC expression

$$\hat{\pi}_t = \beta E_t\left(\hat{\pi}_{t+1}\right) + \lambda\,\hat{mc}_t \tag{4.2}$$

The parameter $\lambda = (1-\theta)(1-\beta\theta)/\theta$ denotes the sensitivity of current inflation rate to real marginal cost, which is strictly decreasing with respect to the Calvo price rigidity parameter $\theta\epsilon(0,1)$. We rewrite the above NKPC as a relation between inflation and the natural output gap to find out whether the flexible-price allocation is attainable with zero inflation targeting policies. For this purpose we employ the relation[17]

$$\hat{mc}_t = \Psi\,\hat{x}_t^n \quad \text{with} \quad \Psi = \frac{(1-\psi)\,\Omega_1}{1+\psi\,\Omega_1 - \Omega_2\,L}$$

where the parameters $\Omega_1 > 0$ and $0 < \Omega_2 < 1$ denote the elasticities of real wage to employment and to past real wage respectively, defined by the wage setting equation[18]

$$\hat{w}_t = \Omega_1\,\hat{n}_t + \Omega_2\,\hat{w}_{t-1} \tag{4.3}$$

and the equations

$$\Omega_1 = \left(\frac{\phi_2}{1-\psi-\phi_3}\right)\frac{(1-\psi-\phi_3-\phi_4)\,n\,(1-n)^{-1-\psi}}{\phi_2\,(1-n)^{-\psi} + (\phi_0-\phi_2-\phi_3-\phi_4)} \quad \text{and} \quad \Omega_2 = \frac{\phi_4}{1-\psi-\phi_3}$$

In flexible-price allocation, the real marginal cost is equal to the static markup $\mu^p = \varepsilon/(\varepsilon-1)$, and the natural levels of output and employment are given in log-linear terms by

$$\hat{y}_t^n = \frac{(1+\Omega_1)\;\hat{z}_t - \Omega_2\,\hat{z}_{t-1}}{(1-\psi)\,\Omega_1} \quad \text{and} \quad \hat{n}_t^n = \frac{\hat{z}_t - \Omega_2\,\hat{z}_{t-1}}{(1-\psi)\,\Omega_1}$$

so that the NKPC condition (4.2) becomes a function of the natural output gap as follows:

[17] A combination of the cost minimization condition with the production technology, the Solow and wage-setting equation, and the pricing decision condition delivers the relation between the real marginal cost and the natural output gap

[18] A combination of the Solow condition (2.10) with effort function (2.2) delivers the fair wage equation or the wage setting condition which describes the evolution of real wage and replaces the standard labor supply of the Walrasian (neoclassical) labor market.

$$\hat{\pi}_t = \beta\, E_t\left(\hat{\pi}_{t+1}\right) + \lambda\, \Psi\, \hat{x}_t^n \tag{4.4}$$

The NKPC (4.4) indicates two main results. First, the flexible price allocation remains feasible in the fair wage version of the NK model. Thus, the natural allocation is always attainable with inflation stability. Namely, strict inflation targeting ($\hat{\pi}_t = 0$) allows the monetary authority to obtain the natural level of aggregate output and stabilize the natural output gap by setting the real interest rate equal to its natural counterpart during every period. Second, the fair wage hypothesis affects the slope of the NKPC and reduces the sensitivity of inflation to natural output gap ($\Psi < 1$) under the specified parameterization ($\Omega_1 > 0$ and $0 < \Omega_2 < 1$) that assures upward sloping wage setting curve and guarantees the stability of natural allocation. Indeed, we describe below that the higher is the real wage rigidity measure, the lower is the slope of the NKPC condition. The marginal cost sensitivity to output (Ψ) declines with real wage rigidity. This means that the responsiveness of marginal cost to real economy is lower if exogenous shocks drive the business cycle, which entails in turn that firms do not undertake significant price changes through their pricing decision condition. Hence, higher and more persistent output changes come along with low effects on inflation rate. In this sense, fair wages enhance the transmission mechanism of the baseline NK model, as Danthine and Kurmann (2004) initially pointed out.

5 Efficient Allocation

The first-best or efficient allocation is derived by the optimization problem of the benevolent social planner. The social planner maximizes the expected discounted sum of the family's average utility flows, measured conditionally on the equilibrium level of effort, subject to the aggregate resource constraint of the model economy. Namely, the social planner maximizes

$$W_t = E_0 \sum_{t=0}^{\infty} \beta^t \left[\ln(c_t) + (1 - n_t)\,(e_t^*)^2\right]$$

subject to the aggregate resource constraint,

$$c_t + g_t \leq z_t\, e_t\, n_t$$

and the restriction

$$0 \leq n_t \leq 1$$

where the exerted effort of workers is determined by[19]

$$e_t = \xi\, z_t^{\frac{\psi}{1-\psi}} \quad \text{with} \quad \xi = \left[\mu^p\right]^{\frac{\psi}{\psi-1}}\, \phi_1^{\frac{1}{1-\psi}}$$

or $e_t = e(z_t)$. The constrained-efficient allocation of the model economy is determined conditionally on the equilibrium level of effort and on the assumption of perfectly flexible prices, so that there is no inefficient price dispersion in social planner's problem and the WS-PS labor market framework is always in equilibrium.

The first order conditions[20] deliver the efficient allocation of the model economy described by[21]

[19]The equilibrium level of effort in Social Planner's problem is determined by a combination of the Solow equation (2.10) with the cost minimization condition (2.9), the production technology (2.6), and the natural equilibrium condition $mc_t = 1/\mu^p$.

[20]Appendix D provides in detail the solution of the Social Planner's problem.

[21]Efficiency conditional on the equilibrium level of effort means that the marginal rate of substitution between consumption and employment is equal with the marginal rate of transformation, which coincides with the marginal product of labor; i.e, the efficient allocation is characterized by $mpn_t = -u_{n,t}/u_{c,t}$.

$$n_t^* = 1 \quad \text{and} \quad y_t^* = \xi \, z_t^{\frac{1}{1-\psi}}$$

This indicates that unemployment is Pareto sub-optimal in the present non Walrasian version of the NK model, because it reduces aggregate output below the efficient level, which is given in log-linear terms by,

$$\hat{y}_t^* = \left(\frac{1}{1-\psi} \right) \hat{z}_t$$

In other words, although the unemployed members of the household are perfectly insured against unemployment and indeed benefit an effective leisure from staying home, the overall income of the household declines whenever the portion of unemployed to employed family members increases. This reduces in turn the average income for each family member which decreases consumption and thus utility. In the trade-off between effective leisure and consumption, the reduced average income for each family member, which is translated to a reduced consumption per agent, overcomes the benefit of effective leisure from abstaining from employment activities. Hence, unemployment is Pareto suboptimal, and the social planner will always choose an equilibrium allocation where $n_t = 1$. Figure 1 plots the social welfare and the aggregate resource constraint of the economy, and shows that the Pareto optimal allocation is associated with $n_t = 1$.

6 Fair Wages and Real Wage Rigidity

In the present section we describe the real wage rigidity measure, its relation with the slope of the NKPC in more detail, and the consequences on the divine coincidence property of the benchmark NK model.

6.1 Real Wage Rigidity

The real wage rigidity generated by fair wages is a significant measure in the present model for two reasons. First, it enhances the models' transmission mechanism by altering the slope of the NKPC. Second, it generates a wedge between the natural and the efficient allocation, which alters in turn the optimal nature of monetary policy hold in baseline NK models with neoclassical labor markets.

According to the efficiency wage literature, the slope of the incentive compatibility (Gomme 1999), or the wage setting curve (Croix et al. 2007, 2009) determines the degree of real wage rigidity in the sense of preventing labor market clearance. By employing the lag operator, the wage setting condition (4.3) is simplified to

$$\hat{w}_t = \Omega \, \hat{n}_t \quad \text{where} \quad \Omega = \frac{\Omega_1}{1 - \Omega_2 \, L}$$

so that the inverse of elasticity Ω, i.e.,

$$\frac{1}{\Omega} = \frac{1 - \Omega_2 \, L}{\Omega_1} \equiv \frac{1 - \Omega_2}{\Omega_1} \tag{6.1}$$

measures the real wage rigidity attributed to the efficiency wage hypothesis. The elasticity of real wage to employment (Ω_1) affects the real wage rigidity measure negatively ($\partial(1/\Omega)/\partial\Omega_1 < 0$), because by assumption $0 < \Omega_2 < 1$. Accordingly, the elasticity of current wage to past real wage (Ω_2), i.e., the real wage sluggishness, affects the real wage rigidity negatively ($\partial(1/\Omega)/\partial\Omega_2 < 0$). Hence both $\Omega_1 > 0$ and $0 < \Omega_2 < 1$ increase the slope of the wage setting curve, so that a given change in the employment level (or the labor market tightness)– driven by exogenous terms– generates higher real wage fluctuations on impact which implies a lower real wage rigidity.

One would expect that real wage sluggishness intensifies the real wage rigidity measure. This is not precise however. In the efficiency wage model, the elasticity of current to past aggregate real wage generates real wage sluggishness in the sense that wages exhibit an inertial or backward-looking behavior during the business cycle adjustment. The real wage sluggishness, however, affects the real wage rigidity measure $1/\Omega$ negatively, because it makes the labor supply decisions of workers depend not only on current employment but also on the labor market tightness of previous periods. This can be uncovered by the following expression of the wage setting condition:

$$\hat{w}_t = \Omega_1 \, \hat{n}_t + \Omega_1 \sum_{j=1}^{\infty} \Omega_2^j \, \hat{n}_{t-j} \tag{6.2}$$

The elasticity $\Omega_1 > 0$ measures the sensitivity of real wage to current employment and the aggregated influence of past labor market tightnesses. The elasticity $0 < \Omega_2 < 1$ weights the sensitivity of current real wage to each labor market tightness of previous periods. According to (6.2), the past labor market tightnesses affect the labor supply decisions of workers in the present positively ($\Omega_1 > 0$), as current employment does. The higher is the real wage sluggishness ($0 < \Omega_2 < 1$), the higher is the backward looking behavior of workers in determining current labor supply, and the higher is the elasticity of real wage to past employment levels. Insofar as labor market tightness determines the labor supply decisions of workers, the stronger is the influence of past labor market tightnesses, the more elastic is the current labor supply.

The positive relation between the slope of the wage setting curve (Ω) and the elasticities $\Omega_1 > 0$ and $0 < \Omega_2 < 1$ justifies the inverse relation between the slope of the NKPC condition ($\lambda \, \Psi$) and the real wage rigidity measure ($1/\Omega$).

6.2 Divine Coincidence

Following the methodology of Blanchard and Galí (2007), we show that the divine coincidence property of the baseline NK model collapses in the present framework. The natural equilibrium is always attainable, but the efficient allocation remains infeasible. Fair wage considerations generate a wedge between the policy objectives of the monetary authority so that strict inflation targeting becomes a suboptimal policy choice. Specifically, the welfare-relevant output gap, defined by $\hat{x}_t^* = \hat{y}_t - \hat{y}_t^*$, where $\hat{y}_t^*$ denotes the efficient output in log-linear terms, no longer coincides with the natural output gap ($\hat{x}_t^n = \hat{y}_t - \hat{y}_t^n$), and an endogenously determined cost-push component appears in the NKPC condition. The difference between the two output gap measures is given by,

$$\hat{x}_t^* - \hat{x}_t^n = \left[\frac{1+\Omega_1}{(1-\psi)\,\Omega_1} - \left(\frac{1}{1-\psi} \right) \right] \hat{z}_t - \frac{\Omega_2}{(1-\psi)\,\Omega_1} \, \hat{z}_{t-1}$$

The NKPC (4.4) as a function of the welfare-relevant output gap becomes as follows:

$$\hat{\pi}_t = \beta \, E_t \left(\hat{\pi}_{t+1} \right) + \lambda \, \Psi \, \hat{x}_t^* + \lambda \, \Psi \, f \left(\hat{z}_t, \hat{z}_{t-1} \right) \tag{6.3}$$

where the cost-push component $f(\hat{z}_t, \hat{z}_{t-1})$ is a function of the current and past neutral technology shock, given by,

$$f \left(\hat{z}_t, \hat{z}_{t-1} \right) = \left[\left(\frac{1}{1-\psi} \right) - \frac{1+\Omega_1}{(1-\psi)\,\Omega_1} \right] \hat{z}_t + \frac{\Omega_2}{(1-\psi)\,\Omega_1} \, \hat{z}_{t-1}$$

The non-zero difference between the welfare-relevant and the natural output gap indicates that the divine coincidence property of the baseline NK model collapses if we introduce fair wage or efficiency wage considerations in the labor market. The collapse of the divine coincidence remains valid even if we consider the exerted effort of workers constant over the business cycle, as the previous literature assumed (Danthine and Donaldson 1990, Collard and de la Croix 2000, Danthine and Kurmann 2004), i.e., if we set $\psi = 0$. In both cases, the monetary authority can always attain the natural allocation with zero inflation policies but not the constrained efficient one. The higher is the gap between the natural and efficient allocation, the stronger is the cost-push term appeared in the NKPC condition, and the higher is the deviation from strict inflation targeting policies.

In the context of the Linear Quadratic (LQ) approach, described in Appendix F, we show that the objective of the policymaker is twofold: to stabilize the inflation rate around the zero steady-state level, and stabilize the real economy around a Pareto optimal allocation that maximizes the lifetime utility of the representative family. The micro-founded social welfare loss function is described by

$$W_t = -\left(\frac{1}{2}\right) E_0 \sum_{t=0}^{\infty} \beta^t \left[\left(\frac{\varepsilon}{\lambda}\right) \hat{\pi}_t^{\,2} + \left(\frac{1}{s_c}\right) \left\{\hat{y}_t - \hat{y}_t^{*g}\right\}^2\right] \tag{6.4}$$

where $\hat{y}^{*g}$ denotes the equilibrium level of output associated with the global maximum of the lifetime utility function of representative family. The policymaker maximizes the social welfare subject to the NKPC condition. The appearance of the cost-push term in aggregate supply condition (6.3) indicates that the policymaker encounters wedges during the optimal decision making which prevents him to attain both policy objectives described by social loss function (6.4). Hence, the monetary authority must decide for an optimal trade-off between output and inflation stabilization to maximize social welfare.

6.3 Nesting the Baseline NK Model

In the context of a search and matching frictions version of the NK model, Blanchard and Galí (2010) pointed out that the rationale behind the sub-optimality of strict inflation targeting is the existence of real wage rigidity rather than the labor market frictions per se. Our model shows clearly that Blanchard and Galí (2010) argument remains robust in the efficiency wage version of the NK model. By eliminating the real wage rigidity from the present model, we eliminate the difference between the natural and efficient allocation and obtain a resurgence of the divine coincidence property of the benchmark NK economy.

This can be easily obtained with a simple parameterization of the model rather than by altering the model's specification: by setting $1/\Omega = 0$, we nest the policy implications of the baseline NK model with two imperfections, i.e., nominal price stickiness and monopolistic competition. Insofar as the real wage rigidity measure $(1/\Omega)$ is defined by

$$\frac{1}{\Omega} = \frac{1-\Omega_2}{\Omega_1}$$

we eliminate the real wage rigidity in the labor market by assuming either $\Omega_1 = \infty$ and $\Omega_2 \epsilon (0,1)$, or $\Omega_1 > 0$ and $\Omega_2 = 1$. The Wage Setting (WS) condition $\hat{w}_t = \Omega_1 \, \hat{n}_t + \Omega_2 \, \hat{n}_{t-1}$, however, indicates that the essential component of real wage rigidity is the elasticity of the current wage to employment rate (Ω_1) rather than the real wage sluggishness elasticity (Ω_2). Hence, to eliminate the real wage rigidity we choose $\Omega_1 = \infty$, and allow for a positive though less than unity real wage sluggishness $\Omega_2 \epsilon (0,1)$.

Under this parameterization, we obtain two main results. First, the sensitivity of real marginal cost to output (Ψ) becomes

$$\Psi = \frac{1-\psi}{\psi} \tag{6.5}$$

which lies within the interval $(0,+\infty)$. This shows in turn that if there is no real wage rigidity, in the sense that the WS condition is inelastic to employment $(\Omega = +\infty)$, the elasticity of the real marginal cost to output (Ψ) and hence the slope of the NKPC depends on the degree of substitutability between the effort function arguments (ψ). Indeed, under specific parameterization of the substitutability parameter ψ $(\psi = 0.5)$, the elasticity Ψ becomes equal to unity and the model replicates the standard NKPC condition of the baseline NK model: the slope of the NKPC becomes equal to $\lambda = (1-\theta)(1-\beta\theta)/\theta$.

Second, in case where $1/\Omega = 0$ the divine coincidence re-emerges, because the cost-push term of the NKPC condition disappears. This is easily noticeable by comparing the natural and efficient allocations of the model economy for $\Omega_1 = \infty$. Specifically, the natural aggregate output ($\hat{y}_t^n$) becomes equal to

$$\hat{y}_t^n = \left(\frac{1}{1-\psi}\right)\hat{z}_t \tag{6.6}$$

and the distance between the welfare-relevant and the natural output gaps is eliminated, i.e.,

$$\hat{x}_t^* - \hat{x}_t^n = \hat{y}_t^n - \hat{y}_t^* = 0$$

because the efficient level of output is still $\hat{y}_t^* = (1/(1-\psi))\hat{z}_t$. Under this parameterization, the policymaker can always attain the efficient allocation with strict inflation targeting, because the flexible price and the first-best allocations coincide.

The intuition behind this result lies on the elimination of the third inefficiency present in the model, and indeed in the labor market. The tripodal trade off between nominal price stickiness, monopolistic competition, and real wage rigidity, encountered by the monetary authority, is reduced to a simple one, which is resolved with strict inflation targeting. In other words, in the nested case where there is no real wage rigidity, there is no wedge in the aggregate supply condition, which allows in turn the policymaker to attain both policy objectives by targeting the inflation rate in every period. This result is also consistent with Faia (2009) and shows that efficiency wage considerations always call for a deviation from price stability if the associated real wage rigidity is non trivial.

7 Dynamic Properties of the Model

We begin the analysis with the dynamics properties of the model when the monetary authority follows a cyclical Taylor rule with coefficients $\alpha_\pi = 1.5$ and $\alpha_y = 0.5/4$, i.e., a feedback rule proposed by Taylor (1993, 1999) and described the monetary policy of the US Fed under the chairmanship of Allan Greenspan. For this purpose, we analyze the impulse response functions of the variables of the model to one percent standard deviation of the two main drivers of the business cycle: the neutral technology (z_t), and the government expenditure (g_t) shock. We compute the policy functions of the model around the Ramsey steady-state (described below) using the perturbation method developed by Schmitt-Grohé and Uribe (2004b).

7.1 Technology Shock

Figure 2 depicts impulse responses in percentage deviations to one percent increase of the neutral technology shock. The productivity improvement shifts the labor demand and the price setting curve of the labor market upwards. The change in labor demand along with an upward sloping wage-setting curve increases employment and real wage. The employment increases at the extensive margin only since all workers supply a constant fraction of their time endowment. As a result, the employment increase indicates a reduction of unemployment as the total labor force is always constant and normalized to unity. Both employment (unemployment) and real wage remain above (below) their steady-state value until the productivity shock has vanished. The impact increase (decrease) of employment (unemployment) to productivity shock comes along with a hump-shaped response of real wage over the cycle. This is attributed to the real wage rigidity of the fair wage hypothesis and the real wage sluggishness, measured by the inverse of the wage setting curve ($1/\Omega > 0$) and the elasticity of current to past real wage ($0 < \Omega_2 < 1$), respectively.

The real marginal cost declines on impact, because the increase of productivity along with the hump-shaped response of exerted effort overcome the increase of real wage. Exerted effort exhibits a hump-shaped response because it is positively related to real wage according to the Solow condition (2.10). As the real marginal cost is the driving force of the inflation rate according to the NKPC condition (4.2), technology shock reduces inflation rate on impact.

The positive response of employment and real wage due to labor market adjustment increases households' labor income which allows for more consumption spending. Consumption contributes to aggregate demand and market clearing implies an upward response of output during the business cycle. As monetary policy reacts according to the contemporaneous cyclical Taylor rule, the fall of the nominal interest rate is attributed to the decline of the inflation rate. From the policymaker's perspective, a decrease of the nominal interest rate alters the intertemporal allocation of consumption and calls for an increase of current consumption and output. Finally, the real interest rate declines on impact and returns steadily to steady-state as the gross growth rate of the private consumption decreases according to Fisher equation.

7.2 Government Spending Shock

Figure 3 describes the impulse responses to one percentage increase of the government expenditure shock. According to the aggregate resource constraint of the model (2.3), a temporary increase of government spending boosts aggregate demand and output on impact. The increase of government spending, however, takes place at the cost of less private consumption. Insofar as government finances its expenditures with lump-sum taxes levied on households' total income in every period (balanced-budget fiscal policy), a positive government spending shock intensifies the tax burden for private sector, which in turn reduces households' wealth and justifies the sudden decrease of consumption. The decline of consumption offsets the impact increase of government spending and lessens the aggregate output expansion.

The higher aggregate demand calls for a higher production, because in symmetric equilibrium all good markets clear. The improvement of the external labor market conditions induce firms to pay higher wages to employees to improve their morale and avoid any deterioration of exerted effort. Real wages and accordingly effort (through the Solow condition) exhibit a hump-shaped response due to real wage rigidity ($1/\Omega > 0$) and sluggishness ($0 < \Omega_2 < 1$). The procyclical effort response mitigates rather than offsets the positive effect of real wage on real marginal cost, so that the latter increases over the business cycle. The positive response of the real marginal cost implies a negative response of the average markup which shifts the labor demand upwards towards the price-setting curve of the labor market. As a result, the real wage and employment increase while unemployment declines.

According to the NKPC (4.2) the real marginal cost drives inflation rate which returns to steady-state within 40 quarters. The weighted response of inflation rate and aggregate output with the policy response coefficients of the cyclical Taylor rule generate a positive response of the nominal interest rate. The real interest rate, measured by the gross growth rate of consumption according to the Euler-Fisher equation, increases on impact and returns steadily to steady-state due to consumption adjustment over the business cycle.

7.3 Fair Wage and Benchmark NK Model

The fair wage set up of the efficiency wage theory was embedded in the NNS framework to improve the qualitative characteristics of the baseline NK model in three respects. First, to provide a rationale for positive unemployment rate in the labor market and allow for employment changes at the extensive rather than the intensive margin. Second, to improve the positive performance of the model in terms of replicating the empirically observed wage sluggishness and resolve to this aim the so-called wage-employment variability puzzle. Third, to enhance the transmission mechanism of the model by generating endogenous price stickiness.

In the present analysis, we introduce fair wage considerations in the standard NK framework with the baseline distortions of monopolistic competition and nominal price stickiness, because the employment of a more complex, medium-scale policy environment, with nominal and real rigidities such as habit formation, transaction frictions, capital accumulation, and variable capacity utilization, assumed by Croix et al. (2007), would render the analysis rather complicated. The standard NK model with fair wages makes the comparison with the baseline NK model with neoclassical labor market plausible, and allows for an evaluation of fair wages' contribution to the positive performance of the model.

In the benchmark NK framework with fair wages á la Croix et al. (2007, 2009), the demand and supply-side disturbances generate a hump-shaped response of real wage, so that under the baseline calibration that approximates the wage setting equation of Danthine and Kurmann (2004) there is a non trivial real wage rigidity. Table 2 gathers the simulated moments of interest, calculated with the second order perturbation method of Schmitt-Grohé and Uribe (2004b) where simulations involve a time horizon of 100 quarters and 1000 number of iterations when both technology and government spending shocks hit the model economy.

We find that fair wage considerations, generated by the effort function of Croix et al. (2007, 2009), reduce the variability of real wages over the business cycle significantly, and increase the volatility of employment. In comparison to the baseline NK model, fair wages reduce the standard deviation of real wage relatively to output (σ_w/σ_y) from 1.034 to 0.2101 when simulations are generated by both technology and government spending shocks. Accordingly, the standard deviation of employment relative to output increases from 0.3129 to 0.4937. A similar change in the volatility of real wage and employment is also observed when the business cycle is driven by neutral technology shock. The relative standard deviation of real wage declines from 0.8895 to 0.2134, while the relative standard deviation of employment increases from 0.1105 to 0.5084.

The model replicates also the stylized facts of the US data: the high and low procyclicality of employment and real wage, respectively (Danthine and Kurmann 2004). In the baseline NK model with neoclassical labor market, hours of work are countercyclical as the correlation with output is -0.82. With fair wages, the correlation between employment and output becomes 0.96 so that employment is highly procyclical. Accordingly, fair wages reduce the correlation of real wage with output from 0.99 to 0.52.

We also notice that the model reduces the contemporaneous correlation of real wage to employment to 0.32, which remains however quite above zero. Hence, under the baseline parameterization fair wages approximate rather than match the almost zero correlation between wages and employment observed in US data according to Danthine and Kurmann (2004).

8 Ramsey Optimal Plan

In this section, we proceed to the consequences of the fair wage hypothesis on optimal monetary policy. We begin with the derivation of the unconstrained Ramsey plan, which constitutes the optimal allocation of the model economy and becomes the benchmark for the evaluation of alternative monetary policy choices. Then, we evaluate the performance of simple and implementable interest rate feedback rules in replicating the Ramsey benchmark with the public finance approach as in Schmitt-Grohé and Uribe (2007b) and Faia (2008a).

In the context of the Ramsey approach, the monetary authority maximizes the lifetime utility of the representative household subject to the complete set of the competitive equilibrium conditions. Formally, the policymaker chooses a sequence of the endogenous variables of the model $\{ y_t, c_t, n_t, u_t, w_t, e_t, x_t^1, x_t^2, p_t^*, s_{t+1}, mc_t, \pi_t, r_t \}_{t=0}^{\infty}$ and the Lagrange multipliers associated with the competitive equilibrium conditions to maximize the lifetime utility defined by

$$W_t \equiv E_0 \sum_{t=0}^{\infty} \beta^t \left[\ln(c_t) + (1-n_t)\,(e_t^*)^2 \right] \tag{8.1}$$

subject to the complete set of the private sector equilibrium conditions (2.1), (2.2), (2.8), (2.9), (2.10), (A.1), (2.12), (2.3), (2.14), (2.15), (2.16), and (2.17), the non-negativity constraint for the policy instrument ($r_t \geq 1$), and the equations describing the exogenous processes (2.7), (2.13).

The social welfare function (8.1) coincides with the lifetime utility of the representative household conditional on the equilibrium level of effort by the employed ($e_t = e_t^*$) and the unemployed members ($e_t = 0$) of the family. The quadratic approximation of the lifetime utility (8.1), using the methodology described by Rotemberg and Woodford (1997) and Woodford (2003), delivers the social welfare loss which constitutes the objective function minimized within the Linear Quadratic (LQ) approach.[22]

We give priority to the unconstrained Ramsey method rather than the LQ approach for the reasons pointed out by Schmitt-Grohé and Uribe (2004a) and Faia (2008b): the LQ approach analyzes optimal policy around an undistorted steady-state which necessitates specific parameter spaces or complementary fiscal policy measures that eliminate the long-run inefficiencies. To investigate, however, the normative implications of the fair wage hypothesis thoroughly, we derive the optimal monetary policy within this framework by employing the LQ approach in Appendix F.

Insofar as we assume a balance-budget fiscal policy in every period, the inflation rate becomes the only available policy instrument for the policymaker. Optimal monetary policy is described by the process of the nominal interest rate $\{r_t\}$ associated with the competitive equilibrium that maximizes the social welfare above. We take second order approximations of the first order conditions of the above problem around the Ramsey steady state using the second order perturbation method described by Schmitt-Grohé and Uribe (2004b).

8.1 Long Run Policy

The steady-state inflation rate of the Ramsey allocation describes the optimal monetary policy in the long-run. We can compute this steady-state inflation rate either by solving the first order condition of the Ramsey problem with respect to inflation (in steady-state), or by computing this variable numerically, by employing the complete set of first order conditions of the Ramsey problem. The first method allows for an explicit derivation of the optimal long-run policy, provided however that the competitive equilibrium conditions have been transformed to a minimal set of relations between real allocations (primal form approach), as described explicitly by Faia (2008b,c, 2009, 2012). The numerical computation of inflation rate in the Ramsey steady-state is being used in the context of large and medium scale models, in which the system of the competitive equilibrium conditions is large enough so that the explicit derivation of inflation is computationally demanding. For those models, the inflation rate of the Ramsey optimal allocation is derived numerically using the algorithms described by Levin et al. (2005), and Schmitt-Grohé and Uribe (2006, 2007a,b), as it is the case for the present analysis.

Table 3 reports the Ramsey and the competitive equilibrium steady-state values of the model selected variables. Optimal inflation rate reduces from $\pi = 1.042$ in quarterly frequency under the competitive equilibrium, to $\pi = 1.00$ under the Ramsey optimal allocation. The reduction from positive to zero inflation rate shows that the policymaker commits to inflation stability in the long run. The intuition behind this result lies on two reasons. First, the zero inflation rate eliminates the distortion of nominal price stickiness, price dispersion, and hence resource misallocations. The price dispersion measure becomes equal to unity under price stability, and the end use value of output increases. Second, the zero inflation rate minimizes the average markup[23], which in turn increases the labor demand close to the Price Setting (PS) equation. In fact, for zero inflation rate, the average markup coincides with the static one ($\mu^p = \varepsilon/(\varepsilon - 1)$), and the labor demand equation coincides with the Price Setting condition, which gives the labor demand under the natural allocation. In other words, by reducing the average markup close to the static one, the policymaker reduces the tax markup on the real sector, so that the labor demand shifts upwards. In the labor market where the Wage Setting curve is upward sloping, an upward shift of the labor demand is associated with

[22]The derivation of the social welfare loss function is provided in Appendix E.

[23]Recall that the average markup is a convex function of inflation rate, i.e., $\mu_t^p = \left(\frac{\varepsilon}{\varepsilon-1}\right)\left(\frac{1-\beta\,\theta\,\pi^{\varepsilon}}{1-\beta\,\theta\,\pi^{\varepsilon+1}}\right)\left(\frac{1-\theta}{1-\theta\,\pi^{\varepsilon-1}}\right)^{1/(1-\varepsilon)}$.

higher employment and real wage. The positive influence of zero inflation policy in the long-run to the labor market equilibrium is depicted in figure 4.

Table 3 reports that for $\pi = 1.00$ the employment rate increases from 0.95 to 0.96673. Insofar as the labor force in the model is constant to unity, the unemployment rate declines from 5% to 3.33%. Accordingly, the real wage increases from 0.82481 to 0.83429. Exerted effort increases from 1.00 to 1.0011, because it is positively related to real wage through the Solow condition (2.10). Aggregate output increases from 0.94517 to 0.96783 for three reasons. First, the zero inflation rate eliminates nominal price stickiness and hence the negative influence of price dispersion on aggregate output. Price dispersion measure declines from 1.0051 to unity, and the end-use value of output increases according to (A.1). Second, the upward shift of the labor demand due to zero inflation rate increases the employment rate which contributes to aggregate output according to production technology. Third, the increased real wage in the Ramsey steady-state boosts exerted effort which contributes to aggregate output. Since, the government expenditure is retained constant between the competitive and the Ramsey steady-state, the increased aggregate output implies a higher consumption for households.

The zero inflation rate in the Ramsey optimal steady-state is consistent with the Ramsey optimal monetary policy literature where the standard trade-off between monopoly power and price stickiness is augmented with an additional distortion Faia (2008b,c, 2009, 2012). We notice, however, that zero inflation rate improves the labor market equilibrium as it shifts the labor demand curve towards the PS, and increases the exerted effort along with employment, which both contribute to aggregate output. With zero inflation rate the inefficiency of monopoly power remains (i.e., the average markup is reduced to the static level), but the gap between the competitive equilibrium allocation and the natural one, where PS intersects the WS curve, is eliminated. With zero inflation rate in the long run, the Ramsey planner attains the natural (flexible-price) allocation.

8.2 Optimal Adjustment

We showed that zero inflation rate is optimal in the long-run, as it eliminates the price dispersion attributed to nominal price rigidities and closes the gap between the labor demand and the price setting equation. This allows for higher employment, real wage and exerted effort which increases in turn the inefficiently low level of output associated with a competitive equilibrium allocation with positive inflation.

The zero inflation policy becomes suboptimal over the business cycle, however. The dynamic adjustment of the model economy to technology and government expenditure shocks under the Ramsey optimal plan shows that inflation rate deviates from its optimal steady-state level.[24]

8.2.1 Technology Shock

Figure 5 shows the impulse response functions of selected variables of the model to one percentage positive productivity shock under both the Ramsey optimal plan (solid blue line) and the contemporaneous cyclical Taylor rule (red dashed line). The impact decrease of inflation at around 1.5 percentage points under the Ramsey allocation indicates the deviation of optimal monetary policy from strict inflation targeting. The monetary authority accommodates inflation to take advantage of the productivity improvement. Technology shock increases employment and output and pushes the economy close to the Pareto efficient allocation. The Ramsey planner accommodates inflation rate to allow for a decline of the real interest rate, boost the aggregate demand and clear the goods market. Contrary to the contemporaneous cyclical Taylor rule which allows for significant deviations of inflation rate from steady-state, the Ramsey planner expands the real economy with mild deviations of inflation rate. This entail that the Ramsey

[24]We test the robustness of Ramsey optimal monetary policy over the business cycle by implementing the Linear Quadratic (LQ) approach in Appendix F. The optimal dynamic adjustment under the LQ method is depicted by figure 22.

plan strikes a balance between stabilizing the output gap and minimizing the inefficient price dispersion. Also, the adjustment of the average markup under the Ramsey plan is lower relative to the competitive equilibrium with cyclical Taylor rule, so that the negative influence of average markup on supply side is relatively restrained. Under the Ramsey optimal plan, inflation declines on impact and after an overshooting effect [25] returns to steady-state. The sudden decrease of inflation strengthens the positive response of real wage over the business cycle, which in turn contributes to the strongly procyclical response of exerted effort. The impulse response function of effort under the Ramsey optimal plan exhibits higher amplitude and persistence, which allows for a similar increase of output along with mild deviation of inflation over the business cycle. Overall, the hump-shaped response of employment and output is attributed to the policymaker's perspective to take advantage of the productivity increase and push the economy close to Pareto frontier.

In the methodology of Blanchard and Galí (2007), the deviation of optimal inflation response from steady-state is attributed to the wedge between the natural (second-best) and efficient (first-best) allocation. The fair wage hypothesis generates real wage rigidity in the labor market which lies behind the collapse of the divine coincidence property of the baseline NK model. The gap between the efficient and the natural allocation takes the form of a cost-push component appeared in the NKPC. This prevents the monetary authority to close the welfare-relevant output gap with strict inflation targeting. The policymaker has to undergo mild price dispersion to gain in terms of higher employment and output over the business cycle.

Figure 6 compares the impulse responses of selected variables of the benchmark (solid blue line) NK model with the fair wage counterpart (red dashed line) under the Ramsey optimal plan and when the business cycle is driven by one percentage increase of the neutral technology shock. In the baseline NK model the monetary authority targets inflation rate, while in the fair wage economy the policymaker accommodates inflation changes to gain in terms of real economy adjustment. The figure shows the amplitude and persistence differences between the output, consumption, wage, and employment responses. Those variables exhibit a hump-shaped adjustment in the fair-wage version of the NK model which indicates the monetary authority's concern to take advantage of the productivity increase and push the economy close to the Pareto efficient allocation. In the baseline NK model instead, the policymaker faces a simple trade-off between monopolistic competition and nominal price stickiness, which is resolved in favor of price stability: the annual inflation rate is always equal with the Ramsey steady-state during the business cycle.

The active nature of monetary policy over the business cycle driven by neutral technology shock becomes also noticeable by comparing the optimal standard deviations of output and (annual) inflation rate between the fair wage and the benchmark NK model. According to table 4, the standard deviation of inflation rate to technology shocks is zero in the benchmark NK model while it becomes positive and equal to 1.89 in the fair wage counterpart. The higher optimal inflation volatility under the fair wage assumption is associated with increased output volatility (in comparison to the standard NK model), which rises from 1.99 to 5.46, indicating the objective of monetary authority to augment output close to efficient level. In sum, the policymaker accommodates inflation to push output to the Pareto optimum and close the welfare-relevant output gap.

8.2.2 Government Spending Shock

Figure 7 depicts the impulse response functions of selected variables of the fair wage NK model under the Ramsey optimal plan (solid line) and the contemporaneous cyclical Taylor rule (dashed line), to one percentage increase of the government expenditure shock. The optimal deviation of inflation rate from steady-state is rather insignificant because there is no contribution of the government expenditure shock on productivity improvement. An active

[25] The overshooting effect in optimal inflation response to productivity shock is pointed out by Faia (2009), Faia and Rossi (2012) and *"...captures the value of commitment as the monetary policy tries to influence future expectation to obtain faster convergence toward the steady-state..."* (Faia and Rossi 2012, pg. 22).

monetary policy would be rather ineffective in closing the welfare-relevant output gap under this shock. In effect, optimal policy targets the inflation rate to eliminate the resource misallocations attributed to nominal price stickiness. The impact response of real wage, exerted effort, and aggregate output is rather insignificant.

According to table 4, the optimal standard deviations of output and (annual) inflation rate to government spending shocks are close to zero (i.e., 0.02 in percentage terms). During the business cycle driven by government spending, the Ramsey planner targets inflation rate to eliminate the price dispersion inefficiency, and optimal monetary policy is rather neutral. Policy neutrality is also translated to a low standard deviation of aggregate output, which falls below the Pareto efficient level.

8.2.3 Simulated Time Series

In figures 8-9 we plot the HP-filtered simulated time series for selected macro-variables of interest under the optimal monetary policy, when the business cycles are driven by both technology and government expenditure shocks. We plot the simulated time series for three reasons. First, to show the active nature of monetary policy and the relative volatility of inflation rate to aggregate output and the welfare-relevant output gap. Second, to disentangle the contribution of each driving shock to the nature of optimal policy and the welfare policy objectives. Third, to evaluate the contribution of exerted effort to the welfare-relevant output gap and the real economy in general.

Figure 8 plots the simulated series of output, the (quarterly) inflation rate, and the two driving variables of the business cycles, (technology and government spending). The upper subplot shows that inflation rate has low volatility relative to aggregate output, but exhibits non trivial and frequent percentage changes from steady-state. Indeed, there is a negative correlation between output and inflation series: output increases are associated with inflation reductions, and vice versa. This verifies the sharp disinflation observed under the Ramsey optimal plan to technology improvements. The policymaker accommodates inflation rate to allow for an output increase, and close the gap between the competitive and the efficient allocation. The second and third subplots of figure 8 reveal that active monetary policy is mainly exercised by the policymaker whenever the business cycle is driven by technology shocks. The time series of aggregate output and neutral technology almost coincide. The amplitude differences observed between the time series of the two variables are attributed to inflation responses. In contrast, the time series between output and government spending differ significantly from each other, and indeed they exhibit a rather countercyclical relation. This in turn indicates the minor role of government expenditure shocks on the nature of optimal monetary policy.

Figure 9 plots the simulated series of the welfare-relevant output gap ($\hat{x}_t^*$), the theoretical counterpart $\hat{x}_t^{*g}$ associated with the global maximum of the lifetime utility of the representative family, the exerted effort of workers, and the inflation rate. The business cycles observed in the time series of the welfare-relevant output gap are intense and prolonged relative to inflation rate, and they are attributed to the aggregate output time series. We also observe there is negative correlation between the output gap and inflation rate: whenever the output gap increases, the inflation rate declines, and vice versa. This reflects the active nature of optimal monetary policy within technology driven business cycles. Inflation rate has a low, but non trivial volatility which reveals the monetary authority's concern to strike a balance between inflation and welfare-relevant output gap stabilization. The policymaker accommodates inflation changes to close the gap between the competitive and the efficient allocation. Simultaneously, however, the policymaker intends to avoid significant inflation rate changes in order to avoid the cost of price dispersion due to the presence of nominal price stickiness.

The second and third subplots of figure 9 reveal the role of exerted effort as an endogenous stabilizer to the model economy, and its contribution to the nature of optimal monetary policy. The second subplot of figure 9 shows there is relatively low volatility of exerted effort over the business cycles in comparison to gross inflation rate under the baseline parameterization where the real wage rigidity is rather significant. If the real wage rigidity is non trivial, real wages adjust mildly over the business cycle, and the procyclicality of exerted effort is rather low. Indeed, with significant real wage rigidity the gap between the competitive and the first-best allocation increases, which in turn induces the policymaker to undertake more active monetary policies. Under the baseline parameterization where there is non trivial real wage rigidity, the time series of inflation rate exhibits frequent and sharp changes over the simulated time path, while the time series path of exerted effort is rather smooth.

In general, the exerted effort contributes to the expansion of the real economy, because it constitutes a main component of the production technology. Insofar as the exerted effort constitutes a rather endogenous stabilizer of the real economy, procyclical responses of exerted effort allow for mild inflation rate changes, and thus a rather neutral monetary policy. The policymaker takes advantage of the procyclicality of exerted effort to technology driven business cycles to stabilize the inflation rate and eliminate the cost of price dispersion. In this case, the lower contribution of a rather neutral monetary policy to the expansion of the real economy is mitigated by the endogenous procyclicality of exerted effort. By reducing the real wage rigidity in the labor market, the procyclicality of exerted effort is magnified, the gap between the efficient and competitive allocation declines, and the necessity for active monetary policy is lessened. The third subplot of figure 9 shows clearly that under a parameterization which entails low real wage rigidity, the inflation rate is almost stable over the simulated time horizon, while the time series path of exerted effort exhibits rather sharp and prolonged changes.

Finally, the bottom subplot of figure 9 compares the welfare-relevant output gap $\hat{x}_t^*$ with the theoretical counterpart $\hat{x}_t^{*g}$ which is associated with the global maximum of the social welfare function. The two time series almost coincide. This indicates that targeting the welfare relevant output gap, which has an intuitive meaning in monetary policy analysis, is equivalent to targeting the mathematical measure $\hat{x}_t^{*g} = \hat{y}_t - \hat{y}_t^{*g}$, associated with the global maximum of the social welfare.

8.3 Sensitivity Analysis

In the present subsection, we perform an extensive sensitivity analysis with respect to the deep parameters of model associated with the standard NK inefficiencies (i.e., the nominal price stickiness and monopolistic competition), and the effort function arguments, for two reasons. First, the sensitivity will uncover the role of each distortion to the optimal nature of monetary policy. Second, the fair wage literature does not provide sufficient evidence for empirical plausible values of effort function coefficients. Recall for example that Danthine and Kurmann (2004) estimate the wage setting condition directly, i.e., the elasticities Ω_1 and Ω_2 rather than the parameters of the effort function. In the sensitivity analysis, we take specific intervals for the deep parameters of the effort function to retain a positive slope of the wage setting curve ($\Omega_1 > 0$), and guarantee the uniqueness of the natural allocation ($0 < \Omega_2 < 1$).

The analysis will disentangle the role of each coefficient on the model's transmission mechanism and the dynamics of the Ramsey optimal plan as well. We first analyze the consequences of the deep parameters on the real wage rigidity which augments the traditional trade-off between the nominal price stickiness and monopolistic competition. Then, we relate the real wage rigidity and the rest distortions of the model with the optimal inflation volatility. Accordingly, we plot the impulse responses of the Ramsey optimal plan to positive technology shock for alternative values of each specified deep parameter to display the differences observed in the optimal adjustment. Impulse responses refer to positive technology shocks, since the government expenditure shock plays a minor role in the optimal policy formulation as described above. Results are gathered in tables 5-8 and are plotted in figures 10 to 15.

8.3.1 Effort sensitivity to labor market tightness (ϕ_2)

According to table 5 and the upper panel of figure 10, there is positive relation between the effort sensitivity to labor market tightness ($\phi_2 > 0$) and the elasticity of real wage to employment ($\Omega_1 > 0$). The real wage sluggishness measure remains constant ($\Omega_2 = 0.92308$) to ϕ_2 changes. The higher is the parameter ϕ_2, the higher is the elasticity Ω_1.

The intuition behind this relation lies on the interpretation of ϕ_2. This parameter gives the sensitivity of individual's exerted effort on labor market tightness. The higher is the labor market tightness, i.e., the higher is the aggregate employment, the lower is the exerted effort of the currently employed worker. This is so, because the low unemployment rate signals improved external labor market conditions which deteriorate in turn workers' morale during their current employment activities, and vice versa.[26] If workers are highly sensitive to labor market tightness (i.e., ϕ_2 takes high values), the firm must be sensitive to its wage payment policy to avoid any change of the workers' exerted effort caused by the influence of the external labor market conditions. The wage paid by firm $j\epsilon[0, 1]$ is rather volatile to external labor market situation, and in a symmetric equilibrium where all firms pay the same wage, the real wage rigidity is rather low. Hence, the higher is effort sensitivity to labor market tightness (ϕ_2), the higher is the wage elasticity to employment ($\Omega_1 > 0$), and the lower is the real wage rigidity ($1/\Omega$).

The positive relation between the elasticity Ω_1 and the effort sensitivity to labor market tightness entails a downward sloping curve for the real wage rigidity measure ($1/\Omega$). The real wage sluggishness $0 < \Omega_2 < 1$ is constant with respect to ϕ_2, so that there is no influence of Ω_2 on real wage rigidity $1/\Omega$. Accordingly, the lower is the real wage rigidity ($1/\Omega$), the higher is the sensitivity of real marginal cost to output (Ψ) and the slope of the NKPC ($\lambda\,\Psi$). As real marginal cost becomes sensitive to aggregate output, firms undertake large and instant price changes in response to exogenous disturbances. This generates price dispersion which induces the monetary authority to target inflation rate. The optimal inflation volatility decreases.

Also, the decline of optimal inflation variability with respect to effort sensitivity to labor market tightness (ϕ_2) has an additional interpretation. Insofar as workers' exerted effort is a positive function of the real wage in equilibrium (due to the Solow condition), the low real wage rigidity entails a significantly procyclical effort over the technology business cycle which contributes to aggregate output positively. This allows the monetary authority to avoid excessive changes of inflation rate [27] to gain in terms of less price dispersion. If real wage rigidity ($1/\Omega$) increases, the contribution of exerted effort to real economy diminishes. The monetary policy has to become more active, because along with inflation stabilization the policymaker intends to close the gap between the efficient and the suboptimal competitive equilibrium allocation. In this case, the optimal inflation volatility increases.

Overall, real wage rigidity is positively related to active monetary policy, because it reduces the effort contribution to aggregate output and magnifies the gap between the efficient and the competitive allocation. This is also revealed by the impulse responses of selected variables to technology business cycle under the Ramsey optimal plan. According to figure 13, the lower is parameter $\phi_2 > 0$, the higher is the real wage rigidity, and the stronger is the impact decrease of inflation to technology shock. In equilibrium, where real wage affects the exerted effort of workers positively, real wage rigidity lessens the procyclicality of effort and thus its contribution on aggregate output. The Ramsey planner undertakes more active policy by accommodating large inflation movements to boost aggregate demand and close the gap with the efficient allocation at the expense of higher price dispersion. Impulse responses show that active monetary policies are associated with output and employment responses that exhibit amplitude and persistence differences in comparison to rather neutral policies. If real wage rigidity is significant, the active nature of monetary policy is stronger. If the real wage rigidity is small, fluctuations of real wages to technology improvement drive similar increases of exerted effort via the Solow condition. The sharp positive response of exerted effort drives total output upwards, which allows in turn the monetary authority to target inflation and minimize the inefficient price dispersion. The Ramsey plan becomes more neutral in this sense, and employment response exhibits less amplitude and persistence over the business cycle.

[26] In case where workers reduce their exerted effort and become unemployed as a punishment from their employers, they will remain in the unemployment pool only in the short run, because the labor market tightness is high. Hence the punishment to be fired from their jobs is less intense.

[27] Recall that the Ramsey planner uses the inflation rate as a policy instrument.

8.3.2 Effort sensitivity to aggregate wage (ϕ_3)

Table 5 and the bottom panel of figure 10 show the positive relation between the effort sensitivity to aggregate wage $\phi_3 \epsilon [0, 1)$ with the wage elasticities to employment ($\Omega_1 > 0$) and past aggregate wage ($0 < \Omega_2 < 1$).

Parameter ϕ_3 measures the influence of the aggregate real wage on the exerted effort of currently employed workers. If the aggregate wage increases, workers' morale deteriorates because the alternative average wage payment indicates an improvement of the external labor market conditions. Namely, in case of being fired, workers expect to find a job with higher salary, since the average wage in the labor market is higher than their current wage compensation. Employers must increase the wage payment to their employees in order to avoid a deterioration of their morale and thus a potential decrease of exerted effort. If parameter ϕ_3 increases, workers' morale becomes more sensitive to the external labor market condition captured by the aggregate real wage. The higher is workers' sensitivity to aggregate wage, the higher is employers' willingness to change the wage payments to their workers to assure the desired exerted effort. In a symmetric equilibrium where all firms pay the same wage, the above reasoning entails volatile real wages to exogenous shocks, so that the real wage rigidity declines.

The real wage sluggishness measure (Ω_2) increases with parameter ϕ_3. If workers have a backward-looking behavior during their effort decisions (i.e., $\phi_4 > 0$), a strong influence of the current aggregate wage on workers' morale is more likely to be transmitted to future effort decisions. The workers' sensitivity to past aggregate wage is higher in this case and captured by the increase of the real wage sluggishness. As described in the real wage rigidity section, however, both Ω_1 and Ω_2 affect the slope of the labor supply (WS) curve positively, so that the real wage rigidity $1/\Omega$ declines monotonically. The elasticity Ω_2 increases the real wage sluggishness in terms of wage persistence, but it also reduces the real wage rigidity measure ($1/\Omega$) because it makes real wage sensitive no only to current labor market tightness but also to equilibrium employment levels of previous periods.

As the real wage rigidity declines with respect to ϕ_3, the sensitivity of real marginal cost to aggregate output (Ψ) and the slope of the NKPC condition ($\lambda \, \Psi$) increase. With more volatile though persistent real wages, the real marginal cost becomes more sensitive to aggregate output. The pricing decision condition entails that firms undertake higher price changes, so that the price dispersion increases. The Ramsey planner intends to stabilize inflation rate to eliminate the negative influence of nominal price stickiness. The optimal inflation volatility declines with respect to ϕ_3. Indeed, in a symmetric equilibrium, where exerted effort mimics the procyclical behavior of real wage via the Solow condition, the effort's contribution to aggregate output increases, because lower real wage rigidity entails highly procyclical real wage and exerted effort. The latter allows the policymaker to abstain from active monetary policies in order to gain in terms of lower price dispersion over the business cycle.

If $\phi_3 \epsilon [0.001, 0.05]$, i.e., the effort elasticity to real wage varies within the lower bound of the sensitivity interval, the optimal inflation volatility increases rather than declines. This comes as a direct consequence of the significant real wage rigidity measure ($1/\Omega$) for those values of ϕ_3 along with the real wage sluggishness which is around 0.7. If ϕ_3 exceeds the value of 0.05, real wage rigidity falls below a threshold value so that real wages become rather volatile and the optimal inflation variability starts declining. The real wage sluggishness ($0 < \Omega_2 < 1$) prolongs the procyclical response of real wages and hence exerted effort over the technology business cycle. In this sense, the real wage sluggishness intensifies the endogenous contribution of exerted effort to aggregate output, which explains the lower inflation volatility under the Ramsey plan.

The bottom panel of figure 13 shows the impulse response functions of selected macro-variables to 1% productivity shock when effort sensitivity to current aggregate real wage ($\phi_3 \epsilon [0, 1)$) ranges within [0.05, 0.25]. As described above, the higher is effort sensitivity to aggregate wage, the lower is the real wage rigidity measure ($1/\Omega$), and vice versa. In the symmetric equilibrium where exerted effort depends on aggregate real wage positively through the Solow condition (2.10), a productivity improvement drives a highly procyclical response of exerted effort over the business cycle when real wage rigidity falls. Exerted effort contributes to output increases and allows for a relatively neutral monetary policy. The impact decline of inflation rate is lower, while the return to steady-state takes place within a shorter period. In contrast, if real wage rigidity increases, the inflation decrease is stronger and more persistent, which in turn indicates higher accommodation of inflation rate by the Ramsey planner. The policymaker allows for higher deviations of inflation rate to boost aggregate demand and increase output.

8.3.3 Effort sensitivity to lagged aggregate wage (ϕ_4)

Effort sensitivity to lagged aggregate wage $\phi_4 > 0$ reflects the backward-looking behavior of each individual. The real wage sluggishness ($0 < \Omega_2 < 1$) is positively related to parameter ϕ_4, because effort sensitivity to lagged aggregate wage affects the current effort decisions of workers. On the one hand, real wage sluggishness increases the real wage rigidity in the sense that real wages become more persistent during the business cycle adjustment. On the other hand, real wage sluggishness increases the slope of the wage setting curve which implies in turn lower real wage rigidity in terms of labor market clearance. As described in the real wage rigidity section, the elasticity $0 < \Omega_2 < 1$ makes labor supply decisions of workers sensitive to labor market tightness of previous periods. If the wage setting curve ($\Omega_1 > 0$) is upward sloping, the real wage inertia reduces the real wage rigidity measure ($\partial(1/\Omega)/\partial\Omega_2 < 0$).

Table 6 and the upper panel of figure 11 show the trade-off between the influence of the real wage rigidity measure ($1/\Omega$) and real wage sluggishness ($0 < \Omega_2 < 1$) on optimal inflation volatility. For low values of effort sensitivity to past wage (ϕ_4), the real wage rigidity measure ($1/\Omega$) is significant and overcomes the low real wage sluggishness (Ω_2), so that the optimal inflation volatility increases with ϕ_4. For $\phi_4 \epsilon [0.05, 0.4]$, real wages are too rigid (though mildly persistent), and the policymaker has to undertake an active monetary policy to close the gap with the efficient allocation. If $\phi_4 > 0.4$, real wage sluggishness increases, the real wage becomes more persistent to exogenous disturbances, but the real wage rigidity declines below a threshold value. Real wages become rather volatile over the business cycle and the Ramsey planner take advantages of effort procyclicality to lessen the active nature of policy and reduce the optimal inflation volatility. Indeed, within the interval $\phi_4 \epsilon [0.4, 0.6]$, the slope of the NKPC increases significantly, i.e., the sensitivity of inflation to marginal cost and output rises sharply. Firms undertake high and prolonged price changes to exogenous disturbances inducing the policymaker to undertake neutral monetary policy. Hence, for $\phi_4 \epsilon [0.4, 0.6]$ the optimal inflation volatility declines.

The upper panel of figure 14 plots the impulse responses to positive productivity shock when the effort sensitivity to lagged aggregate real wage ranges within [0.4, 0.6]. The optimal inflation volatility declines within this interval, because the real wage rigidity measure ($1/\Omega$) falls short off a threshold value. Real wages become rather volatile though persistent over the business cycle. Effort's procyclicality contributes to aggregate output and allows for a mild accommodation of inflation rate. If real wage rigidity increases, the inflation response becomes stronger and more persistent; namely, monetary policy becomes more active.

8.3.4 Substitutability of effort function arguments (ψ)

Table 6 and the bottom panel of figure 11 show the positive relation between the substitutability of the effort function arguments $psi \epsilon [0, 1)$ and wage elasticities to employment ($\Omega_1 > 0$) and past real wage ($0 < \Omega_2 < 1$). Both elasticities increase the slope of the wage setting condition (Ω), and thus they reduce the real wage rigidity measure ($1/\Omega$). The real wage rigidity affects the sensitivity of real marginal cost and the slope of the NKPC negatively, so that the downward sloping real wage rigidity curve is associated with the upward sloping curves of the elasticity Ψ and the NKPC slope ($\lambda\,\Psi$).

If the substitutability between the effort function arguments increases, the influence of the labor market tightness or the aggregate wage on the exerted effort of workers can easily be mitigated by a rise of firm's wage payment. In contrast, if the substitutability between the effort function arguments is low, the exerted effort of workers cannot be easily restored by real wage changes undertaken by the employers. In this case, the influence of the external labor market conditions on the workers' exerted effort is rarely mitigated by employers' wage payments. Firms must adjust the wage payments to their employees appropriately to neutralize the consequences of aggregate labor market conditions on the moral of their workers. The real wage rigidity declines.

The downward sloping curve of the optimal inflation volatility under the Ramsey optimal plan is attributed two reasons. First, the high sensitivity of real marginal cost to aggregate output implies that firms undertake large price changes in response to exogenous shocks according to the pricing decision condition. This means that inflation rate is volatile over the cycle, generating welfare detrimental price dispersion. The Ramsey planner is concerned with all inefficiencies present in the model economy and for that purpose it undertakes a rather neutral monetary policy: the optimal inflation volatility declines. Second, the low real wage rigidity entails a strong contribution of exerted effort to real economy, since real wage and exerted effort respond procyclically to business cycle. Effort operates as an endogenous stabilizer that augments the real economy, allowing the Ramsey planner to turn to inflation stabilization. The optimal inflation variability declines.

The bottom panel of figure 14 shows the impulse responses to 1% technology shock when the degree of substitutability between the the effort function arguments (ψ) varies within [0.001, 0.1]. Parameter $\psi \epsilon (0, 1)$ is negatively related to real wage rigidity. In case of relatively flexible real wages, the exerted effort responds procyclically over the technology business cycle and pushes output close to Pareto efficient allocation, allowing for a more neutral response to inflation rate. For $\psi = 0.1$, the real wage rigidity ($1/\Omega$) is rather low, and the inflation response has lower impact decrease and persistence relative to impulse responses associated with $\psi < 0.1$. If parameter $\psi \epsilon (0, 1)$ decreases, the real wage rigidity increases and the response of real wage is milder over the business cycle. This indicates in turn a smooth response of exerted effort which induces the policymaker to accommodate higher inflation changes.

8.3.5 Market Power (μ^p)

Table 7 and the upper panel of figure 12 show the influence of the monopolistic competition on optimal monetary policy. Market power reduces the competitive equilibrium allocation below the Pareto efficient one. Since there are no fiscal policy measures available, monopolistic competition calls for an active monetary policy. The higher is the monopoly power in the goods market, the bigger is the gap between the competitive equilibrium and the modified golden rule, and the stronger is the necessity for active monetary policy. The positive relation between the static markup and optimal inflation volatility is in line with Faia (2012) and reveals that active monetary policy becomes more intense if monopolistic competition inefficiency is magnified. The changes observed in the elasticity of real wage to labor market tightness (Ω_1) are trivial and solely attributed to changes in the free nuisance parameter $\phi_0 \epsilon R$.

The upper panel of figure 15 shows the impulse responses of selected macro-variables to 1% positive technology shock for alternative values of the static markup (from $\mu^p = 1.1$ to $\mu^p = 1.5$, i.e., from $\varepsilon = 11$ to $\varepsilon = 3$). Operating as a tax on production, the markup implies an inefficiently low level of output which calls for an active monetary policy. The higher is the static markup, the stronger is monopolistic competition inefficiency and the higher is the deviation of inflation rate from Ramsey steady-state.

8.3.6 Nominal Price Stickiness (θ)

Table 8 and the bottom panel of figure 12 show the negative relation between nominal price stickiness and the optimal inflation variability. Sticky prices generate inefficient price dispersion which calls for inflation stabilization. The Calvo price rigidity parameter $\theta \epsilon (0, 1)$ influences the slope of the NKPC negatively through the standard elasticity of inflation rate to real marginal cost (λ). Specifically, the Calvo price rigidity parameter reduces the sensitivity of inflation rate to marginal cost, because firms receive the exogenous signal to reset their prices less frequently for high $\theta \epsilon (0, 1)$. In other words, in a sticky price environment á la Calvo (1983), firms retain their prices fixed for $1/(1 - \theta)$

next periods. Hence, the higher is $\theta\epsilon(0, 1)$, the higher is the time periods in which the prices remain fixed. The slope of the NKPC declines and changes of the marginal cost attributed to exogenous disturbances have less influence on inflation rate. If the nominal price stickiness however is intense, the cost of price dispersion is magnified. The Ramsey planner has to target inflation rate to eliminate the inefficiency of nominal price stickiness. The Calvo price rigidity parameter reduces optimal inflation volatility and monetary policy becomes neutral. For the empirically plausible interval $\theta\epsilon[0.5, 0.8]$ however (Schmitt-Grohé and Uribe 2007a), the optimal inflation volatility ranges from 7.9884 to 1.5483 percentage points, which is an economically significant deviation from price stability.

The Calvo price stickiness affects the elasticity of real wage to labor market tightness (Ω_1), and hence the real wage rigidity ($1/\Omega$) and the elasticity of marginal cost to output (Ψ) trivially, due to the changes of the free nuisance parameter $\phi_1 > 0$ that assures the parameterization of exerted effort equal to unity.

The bottom panel of figure 15 displays the impulse responses to 1% productivity shock when the Calvo (1983) price rigidity parameter ranges within the empirically plausible interval $\theta\epsilon[0.5, 0.8]$. [28] If the nominal price rigidity decreases, the inefficient price dispersion lessens. This in turn means that the cost of deviating from strict price stability declines as well, and allows the monetary authority to pursue more active policies to close the gap with the Pareto efficient allocation. For $\theta = 0.5$, inflation rate decreases on impact by 6 percentage points, and the policymaker obtains an output increase close to 3.5 percentage points. If the Calvo price rigidity parameter increases, the cost of price dispersion becomes significant and the monetary authority lessens inflation fluctuations. For $\theta = 0.8$, the inflation rate declines on impact at 1 percentage point, and output response is milder in amplitude and persistence.

9 Welfare Analysis

The Ramsey plan determines the optimal allocation of the model both in the long-run and over the business cycle but does not provid feedback about how the monetary authority can implemented it (Schmitt-Grohé and Uribe 2007a). Insofar as monetary policy takes the form of simple and implementable interest rate rules, we follow the public finance approach of the optimal monetary policy analysis and search for the most appropriate parameterization of contemporaneous simple Taylor rules of the form described by equation (2.18) that replicate as close as possible the Ramsey optimal adjustment of the economy.

We use the methodology proposed by Schmitt-Grohé and Uribe (2007b) to search numerically for the optimal values of the policy response coefficients for alternative specifications of the contemporaneous interest rate feedback rule (2.18). That is, we search for policy coefficients $\{\alpha_r, \alpha_\pi, \alpha_y, \alpha_n, \alpha_w\}$ that close the gap between the social welfare associated with the Ramsey optimal plan and the one computed under the specified Taylor-type policy. We include among the policy arguments of the Taylor rule (2.18) the employment and real wage growth variables, because both aggregate employment and real wage constitute the main arguments of effort function (2.2). This is so, because the effort function generates wage and employment externalities, described by Croix et al. (2007), which render the equilibrium suboptimal and call for deviations from price stability. The exerted effort cannot be considered a policy argument, because there is no empirical measure of this variable, and hence its use would violate the implementability property of the interest-rate feedback rule (i.e., the property that policy arguments must involve few and readily available measures).

To assess the performance of simple Taylor rules in replicating the Ramsey optimal plan, we compute to what extent the social welfare under a Taylor-type monetary policy falls short of the maximum social welfare, associated with the Ramsey optimal policy. This measure is expressed by the welfare cost (λ), which precisely is defined as the fraction of consumption that each representative household is willing to give up to be as well off under the allocation

[28] According to Schmitt-Grohé and Uribe (2007a), there is sufficient empirical evidence that the parameter referring to Calvo price rigidity for the US economy lies within the interval [0.5, 0.8].

attributed to Taylor type policy as under the Ramsey optimal one. Specifically, if we define the level of conditional social welfare under the Ramsey optimal plan as

$$W_{0,t}^{*} = E_0 \sum_{t=0}^{\infty} \beta^t u(c_t^*)$$

where c_t^* denotes the Ramsey optimal allocation for consumption, then the conditional welfare cost (λ^c) associated with the simple Taylor rule policy satisfies the condition

$$W_{0,t}^{T} = E_0 \sum_{t=0}^{\infty} \beta^t u\left((1-\lambda^c)c_t^*\right)$$

where $W_{0,t}^{T}$ denotes the conditional social welfare when monetary authority implements the Taylor-type policy. Since the momentary utility function is additively separable and logarithmic in consumption, the solution of the above condition with respect to the conditional welfare cost (λ^c) is given by

$$\lambda^c = 1 - \exp\left\{[1-\beta]\left(W_{0,t}^{T} - W_{0,t}^{*}\right)\right\} \tag{9.1}$$

We focus on the computation of conditional welfare and thus conditional welfare cost (λ^c) to take into account the transitional welfare effects, as explained by Woodford (2002) and Kim et al. (2005). Also, we use the second order perturbation method to obtain accurate measures of the social welfare and, thus, correct welfare rankings of Taylor-type policies (Kim and Kim 2003, Schmitt-Grohé and Uribe 2004b).

9.1 Welfare Loss Surfaces

We start the welfare evaluation of alternative specifications of the simple Taylor rule (2.18) by computing the associated conditional welfare cost when both technology and government spending shocks drive the model. Each policy response coefficient ranges within a intuitively plausible interval which also guarantees the existence of the rational expectations equilibrium. Namely, we take $\alpha_\pi \epsilon [1.5, 3]$, $\alpha_y \epsilon [-0.2, 0.5]$, $\alpha_n \epsilon [-0.2, 0.5]$, $\alpha_w \epsilon [0, 3]$, and $\alpha_r \epsilon [0, 1]$. Table 9 provides the minimum welfare cost and the associated policy response coefficients for each specification of the Taylor rule. Figures 16-20 plot the conditional welfare loss surfaces as a function of the policy response coefficients for each version of the Taylor rule.

In sum, we obtain four policy implications. First, strict inflation targeting feedback rules are not optimal, because they are associated with higher conditional welfare losses (λ^cx100) than interest rate rules with non-zero policy response coefficients referring to variables of the real economy. This indicates that policymaker is not solely concerned with inflation stabilization, as it is the case in the baseline NK model where the divine coincidence holds. Second, non-inertial, cyclical Taylor rules are always procyclical as the social welfare cost is minimized for a negative output response coefficient. This reveals the stabilization motive of the policymaker for the real economy. Third, contemporaneous Taylor rule with positive and strong response on real wage growth ($\alpha_w > 0$) always performs better than acyclical, cyclical or employment Taylor rules. If real wage growth is considered an indicator of the real wage rigidity distortion, then the significant response on this policy argument reflects the monetary authority's concern for all kinds of inefficiencies present in the model economy. Fourth, interest rate inertia always calls for a lower response coefficient on inflation rate, because it increases the policy aggressiveness to nominal price stickiness in the long run. The negative relation between interest rate inertia and the optimal response on inflation rate is explained by the suboptimality of strict inflation targeting, as the labor market wedge prevents the stabilization of both policy objectives with inflation stability. A high interest rate inertia along with a significant inflation response would not allow for an inflation accommodation that contributes to closing the gap with the efficient allocation.

Figure 16 plots the welfare loss surfaces of inertial and non-inertial cyclical Taylor rules. Both surfaces are convex with respect to output response coefficient. For the non-inertial Taylor rule, the minimum conditional welfare loss is attained for α_π=1.5 and α_y=-0.07. Namely, the optimal cyclical Taylor rule is procyclical in policymaking meaning. The policymaker magnifies the business cycle to close the gap between the competitive equilibrium allocation and the Pareto efficient one. Indeed, as described in the Ramsey optimal plan, the stabilization of the welfare-relevant output gap comes at the cost of higher inflation rate volatility. The Ramsey planner accommodates inflation to boost aggregate demand and close the gap with the Pareto efficient allocation. In terms of the interest rate rule, this is translated to lower inflation response coefficient which is equal to α_π=1.5.

If the cyclical Taylor rule becomes inertial with α_r=0.9, the policy response coefficient of output becomes positive (α_y=0.11), because a procyclical Taylor rule would generate in this case a significant and prolonged reduction on the nominal interest rate and drive in turn the aggregate demand excessively. The policymaker offsets this result with positive response on aggregate output. This can be also noticed by figure 17, which compares the conditional welfare cost surfaces for cyclical Taylor rules with alternative degrees of inertia. The relation between the interest rate smoothing and the policy response coefficient on aggregate output is positive. If the interest rate inertia is equal to α_r=0.32, the conditional welfare cost is minimized (λ^cx100=0.3633) for α_y=-0.01. If the degree of interest rate smoothing becomes equal to α_r=0.5, the minimum conditional welfare cost (λ^cx100=0.3788) is reached when the output response coefficient is equal to α_y=0.03. The inflation response coefficient remains equal to α_π=1.5 for alternative degrees of interest rate inertia, because inertial Taylor rules are by definition more aggressive to inflation rate in the long run, and strict inflation targeting rules are not optimal in the present model.

This is also revealed by figure 18, which evaluates the welfare performance of simple inertial or non-inertial Taylor rule with no policy arguments referring to the real economy. The welfare loss surface shows that the conditional welfare cost for a simple non-inertial Taylor rule is minimized (λ^cx100= 0.4566) for α_π=2.4. A policy response coefficient on inflation rate above this threshold value increases the conditional welfare loss. Indeed, an aggressive response to inflation rate (α_π=3) is not optimal if it comes along with interest rate smoothing ($\alpha_r > 0$). Increasing the inflation response coefficient from α_π=1.5 to α_π=3.0 raises the conditional welfare cost if the rule is inertial. This indicates that an aggressive response to inflation rate in every period generates higher welfare cost than a long run aggressive response attributed to the interest rate inertia. In other words, it is always better to follow an inertial Taylor rule with medium interest rate smoothing and lower inflation response coefficient, rather than committing to a strict inflation targeting and non-inertial counterpart. For α_π=1.5 and α_r=0.32, the minimum conditional welfare cost is equal to λ^cx100=0.3649, while a strict inflation targeting and non-inertial rule generates a welfare cost equal to λ^cx100= 0.4566. Indeed, an aggressive response to inflation rate (α_π=3.0) along with interest rate smoothing increases the conditional welfare cost significantly, because the welfare losses from the inefficiently low competitive equilibrium relative to the Pareto efficient allocation outweigh the gains obtained from the elimination of the price distortion.

Figure 19 plots the conditional social welfare cost surfaces associated with contemporaneous employment Taylor rules with and without interest rate inertia. The welfare cost surface for the employment Taylor rule is convex with respect to employment response coefficient. Indeed for α_π=1.5 the employment response coefficient is negative if there is no inertia, i.e., α_n=-0.11 for α_r=0. This signals a procyclical nature of the employment Taylor rule, which is not robust however, as it is the case for the cyclical interest rate counterpart. The social welfare cost is minimized for an aggressive inflation response along with a positive employment coefficient: for α_π=3.0 and α_n=0.3653 the minimum social welfare cost of the non-inertial rule is λ^cx100=0.3653. We expect that the weak robustness of the procyclicality of employment Taylor rule reveals two results. First, the policymaker is always concerned with inflation stabilization, although it encounters additional distortions in the model economy. Second, the employment argument is not the most appropriate policy variable that captures the real wage rigidity, which augments the traditional trade-off of the NK environment. In other words, the aggregate output, which lies below the Pareto efficient allocation, depends not only on the employment level but also on the exerted level of effort. Since, the labor market tightness influences the exerted effort negatively, a procyclical response to employment rather than to aggregate output would ignore the indirect effect of employment to effort and thus effort's contribution to real economy.

Introducing interest rate inertia ($\alpha_r > 0$) in the employment Taylor rule shifts the social welfare cost surface rightwards and downwards. For medium interest rate inertia , i.e., for α_r=0.5, the social welfare cost is minimized for α_π=1.8 and α_n=0.15. The decrease of inflation response coefficient with interest rate smoothing is intuitively plausible, because the interest rate inertia increases the aggressiveness of monetary policy to inflation rate. If we increase interest rate smoothing from α_r=0.5 to α_r=0.9, the inflation response coefficient declines even further from α_π=1.8 to α_π=1.5.

Finally, figure 20 plots the conditional welfare cost surfaces of the real wage growth Taylor rule. Strong response on real wage growth improves the welfare performance of both inertial and non-inertial rules. The welfare cost surfaces are decreasing with respect to $\alpha_w \epsilon [0, 3]$ and reach a minimum for α_w=3.0. Hence, responding to real wage growth is always welfare improving. Increasing the interval values for this policy response coefficient reduces the conditional welfare cost even further, but we expect that policy coefficients above the upper bound of this interval have practically no intuitive grounds. From figure 20, we also notice that inflation targeting oriented rules along with interest rate inertia are welfare detrimental. For positive interest rate inertia (α_r=0.9 or 0.5), the corresponding welfare cost surfaces are increasing with respect to inflation response coefficient for every value of the real wage growth parameter. Hence excessive inflation targeting both from short and long-run perspective is not optimal, as it undermines the real economy stabilization objective of the policymaker. In both cases, however, responding to real wage growth is welfare improving: all welfare cost surfaces, both for inertial and non-inertial rules reach a minimum for α_w=3, but inertial wage Taylor rules are better than non-inertial counterparts. The minimum conditional welfare cost for the non-inertial wage Taylor rule is λ^cx100=0.1972 for (α_π, α_w)=(2.4, 3), while for the inertial counterparts, the minimum social cost declines to λ^cx100=0.1086 and λ^cx100=0.1081 for (α_π, α_w)=$(1.5, 3)$ and interest rate smoothing $\alpha_r = 0.9$, and $\alpha_r = 0.5$, respectively.

9.2 Optimal Taylor rules

In the present section, we expand the welfare evaluation analysis in two respects. First, we include in the interest rate feedback rule more than one policy variables referring to the real economy. Second, we employ the optimization algorithm of Schmitt-Grohé and Uribe (2007b) which searches for the policy response coefficients that minimize the difference between the social welfare under the Ramsey optimal plan and the one associated with the competitive equilibrium allocation. In order to test the robustness of the optimal rules to the driving shocks of the business cycle we perform the welfare evaluation under two cases. First, when the model is simulated by both driving shocks, i.e., technology and government expenditure. Second, when simulations are performed with technology shocks only. The optimal policy response coefficients and the welfare costs associated with each Taylor rule specification are gathered in tables 10-11. This welfare evaluation exercise provides three main results.

First, Taylor rules with non-zero policy response coefficients referring to the real economy (α_y, α_n, α_w) always perform better than strict inflation targeting rules. Every optimal specification of contemporaneous Taylor rule with or without interest-rate inertia, but with at least one policy argument of the real economy, generates a conditional welfare cost lower than that of strict inflation targeting rule (λ^cx100=0.4566). Indeed, the highest welfare loss of all optimal Taylor rule specifications is equal to λ^cx100=0.3863 and corresponds to the non-inertial interest rate rule without real economy arguments where $\alpha_\pi = 2.1687$. This reveals that the policymaker has to strike a balance between inflation targeting and active monetary policy, due to the trade-off between inflation and output gap stabilization and the real wage rigidity wedge which prevents the attainment of both policy objectives with neutral policy.

Second, Taylor rules with additional policy arguments referring to the real economy perform better than the rest feedback rules. For example, a Taylor rule with both output and employment policy variables generates a conditional welfare cost equal to λ^cx100=0.0523, which lies below the welfare loss of cyclical, employment, or wage Taylor counterparts, given by 0.3007, 0.3653, and 0.1971, respectively. Taylor rules with output or employment and real wage growth arguments generate a welfare cost equal to 0.0908 and 0.1180 respectively, which also are lower than the welfare costs of the cyclical, employment or real wage growth counterparts. Indeed, a generalized Taylor rule which includes all policy response variables reduces the social welfare cost even further to λ^cx100=0.0367. It is also important to notice that all policy response coefficients of the generalized Taylor rule differ significantly from zero. Overall, including in the Taylor rule additional policy arguments improves the welfare performance of the feedback rule, because a general specification of the rule is better able to capture and mitigate the inefficiencies present in the model economy.

Third, the policy implications described in the first part of the welfare evaluation remain quite robust in the present analysis. The most important implication is the procyclical nature of cyclical Taylor rules. Under each specification of non inertial and cyclical Taylor rule (2.18), the optimal policy response coefficient of output remains negative. The procyclicality of Taylor rule becomes more intense when simulations are performed only with technology shocks. Table 11 shows that the optimal policy response coefficient of output is negative for all specifications of the Taylor rule. As described in the Ramsey optimal plan, the procyclicality of Taylor rule comes as a direct consequence of the policymaker's intention to magnify the business cycle caused by technological improvements. The policymaker takes advantage of the productivity increase to reduce the nominal interest rate, increase the aggregate demand and close the gap with the efficient allocation.

We also notice that the policy response coefficients referring to the labor market are always non zero. This indicates that the labor market inefficiency attributed to fair wages, influences the optimal nature of monetary policy. Indeed, the policy response coefficient of the real wage growth is close to the upper bound of the plausible interval assumed in the optimization routine, and the employment response coefficient is positive for most of the Taylor rule specifications. One would expect a negative employment response coefficient, as the employment argument should operate as a real activity indicator. This is not the case however, because aggregate employment has a twofold role in the model. On the one hand, it constitutes a measure of the real activity, as a main component of the production technology. On the other hand, it influences the exerted effort negatively. Since aggregate output depends both on employment and exerted effort positively, employment is rather an incomplete index of real activity. The employment response coefficient becomes negative only in case where the model is simulated by technology shocks, and there is no aggregate output among the policy arguments.

Finally, whenever the Taylor rule is inertial, the degree of interest rate smoothing hits frequently the upper allowed bound. This is explained by the contribution of the interest rate inertia to the stabilization properties of monetary policy. Indeed, we notice that interest rate smoothing comes along with a reduction of the optimal inflation response coefficient. If interest rate smoothing was combined with a strong inflation response coefficient, the strict and long run inflation stabilization would have undermined the active nature of monetary policy, which is considered necessary for the attainment of the second policy objective (i.e., the stabilization of the welfare-relevant output gap).

9.3 Optimal Taylor Rule and the Ramsey Plan

Finally, we compare in figure 21 the impulse responses of selected macro-variables to one percentage increase of technology and government spending shocks between the Ramsey optimal plan and the generalized optimal Taylor rule $\hat{r}_t = 0.9017\,\hat{r}_{t-1} + 1.5\,\hat{\pi}_t - 0.244\,\hat{y}_t + 0.5\,\hat{n}_t + 3.0\,\hat{g}_t^w$. The dynamic adjustment of the model under the optimal Taylor rule resembles quite well the Ramsey plan if the business cycle is driven by productivity shock. Also, under the optimal Taylor policy the impact decrease of the nominal and accordingly the real interest rate is stronger than in the Ramsey plan. This reveals the procyclical nature of monetary policy within the context of business cycles attributed to technological improvements. Under the Ramsey plan, the nominal interest rate exhibits lower volatility, because the Ramsey planner maximizes the expected lifetime utility of the representative household by employing all variables of the model. Under the Taylor rule policy, the policymaker has only one available policy instrument, i.e., the nominal interest rate, and as a result it has to undertake higher nominal interest rate changes to obtain the desired optimal dynamic adjustment. The policymaker takes advantage of the productivity increase during the business cycle and reduces the nominal interest rate to boost consumption, aggregate demand, and close the gap between the competitive allocation and the modified golden rule.

The impulse responses under the optimal Taylor rule are not close enough to those associated with the Ramsey optimal plan if the business cycle is driven by government expenditure shock. Although the adjustment of the model is similar qualitatively, there are quantitative differences in terms of amplitude response and persistence as well. The gap between the impulse responses of the optimal Taylor rule and the Ramsey plan to government expenditure shocks was initially observed and explained by Schmitt-Grohé and Uribe (2006): the gap is attributed to the little contribution of the government spending shock to the optimal nature of monetary policy. As described in table 4, the optimal volatility of output and inflation rate is mainly attributed to technology rather than government spending disturbances. Hence, government expenditure shock has a minor role in the design of optimal monetary policy over the business cycle. This provides the rationale behind the gap between the impulse responses under the Ramsey optimal plan and the optimal Taylor rule.

10 Conclusion

The present paper is motivated by the normative discussion made by Croix et al. (2007) and the need for further research towards the implications of the labor market structure on optimal monetary policy, as Rotemberg and Woodford (1997), King and Wolman (1999), Woodford (2002), Levin et al. (2005), Chugh (2006) and Faia (2008a, 2009) point out. The paper provides an extensive analysis for the consequences of the fair wage hypothesis of the efficiency wage theory on the optimal nature of monetary policy.

The results of the paper are in line with those of similar analyses implemented in NK environments with alternative setups of non Walrasian labor market, such as the search and matching frictions theory of Mortensen and Pissarides (1999) (Faia 2008b, 2009), labor turnover costs (Faia et al. 2011), and unionized labor markets (Faia and Rossi 2012). The normative results of the paper deviate from the policy implications of Nakajima (2010), derived within the shirking variety of the NK model á la Alexopoulos (2004) in case where agents are perfectly insured against unemployment: strict inflation targeting is sub-optimal even if there is perfect insurance against unemployment. The intuition behind this result lies on the negative influence of unemployment on the family's total salaries and thus on the average income of each family member. Although the unemployed members of the family are perfectly insured, unemployment reduces the average income of the household, per capita consuption and thus welfare.

We showed that introducing fair wage considerations into the benchmark NK model with monopolistic competition and nominal price stickiness renders the strict inflation targeting a suboptimal monetary policy choice. The divine coincidence property of the baseline NK framework, described by Blanchard and Galí (2007), collapses with fair wages: the natural allocation is always attainable with price stability, but the efficient equilibrium remains infeasible. The fair wage hypothesis generates real wage rigidity in the labor market which is positively related to optimal inflation volatility. In the context of an extensive sensitivity analysis, we observed that deviating from strict price stability remains a robust characteristic of optimal monetary policy under alternative plausible parameterizations of the model.

In sum, the fair wage hypothesis generates a Pareto suboptimal unemployment in the labor market and provides a rationale behind the presence of the so-called cost-push term of the New Keynesian Phillips curve, which accounts for deviations of optimal policy from strict price stability. One might propose that the fair wage hypothesis is based on a reduced form expression pertaining to effort, which undermines the micro-foundations of the New Neoclassical Synthesis. Although the effort function is completely rationalized by an explicit underlying theory, i.e., the gift-exchange set up of efficiency wages (Danthine and Kurmann 2004), we intend to remedy this potential shortcoming of the model and strengthen the normative implications of the fair wage assumption further. Towards this direction, we pursue as a next step of research to implement the present normative analysis within a NK environment where efficiency wages and real wage rigidity are endogenously determined from a utility maximizing framework based on reciprocity motives and founded by Danthine and Kurmann (2007, 2010).

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TABLE 1: DEEP PARAMETERS

Parameter		Baseline Value	Range
A. Demand side			
Discount factor	β	$1.04^{-1/4}$	
(Gross) Inflation rate	π	$1.042^{1/4}$	
Substitutability between effort function arguments	ψ	0.1	[0, 0.1]
Effort sensitivity to labor market tightness	ϕ_2	0.001	(0, 0.06]
Effort sensitivity to aggregate wage	ϕ_3	0.25	(0, 0.25]
Effort sensitivity to lagged aggregate wage	ϕ_4	0.6	(0, 0.6]
Government spending to output	g/y	0.25	
B. Supply side			
Elasticity of intermediate products	ε	6	
Calvo price rigidity	θ	0.75	[0.5, 0.8]
Unemployment rate	u	0.05	
C. Shocks			
Technology shock persistence	ρ_z	0.95	
Technology shock std.dev.	σ_z	0.008	
Government spending persistence	ρ_g	0.9	
Government spending std.dev.	σ_g	0.0074	

TABLE 2

SIMULATED MOMENTS - CYCLICAL TAYLOR RULE

z_t shock	σ_y	σ_n	σ_w	$\frac{\sigma_n}{\sigma_y}$	$\frac{\sigma_w}{\sigma_y}$	$corr(w_t, y_t)$	$corr(n_t, y_t)$	$corr(w_t, n_t)$
Benchmark NK	1.81	0.20	1.61	0.1105	0.8895	1.00	-0.97	-0.96
Fair Wage NK	4.17	2.12	0.89	0.5084	0.2134	0.58	0.96	0.39
g_t shock	σ_y	σ_n	σ_w	$\frac{\sigma_n}{\sigma_y}$	$\frac{\sigma_w}{\sigma_y}$	$corr(w_t, y_t)$	$corr(n_t, y_t)$	$corr(w_t, n_t)$
Benchmark NK	0.21	0.21	0.01	1.00	0.0476	-1.00	1.00	-1.00
Fair Wage NK	0.08	0.08	0.03	1.00	0.375	0.56	1.00	0.53
z_t and g_t shocks	σ_y	σ_n	σ_w	$\frac{\sigma_n}{\sigma_y}$	$\frac{\sigma_w}{\sigma_y}$	$corr(w_t, y_t)$	$corr(n_t, y_t)$	$corr(w_t, n_t)$
Benchmark NK	1.47	0.46	1.52	0.3129	1.034	0.99	-0.82	-0.89
Fair Wage NK	3.95	1.95	0.83	0.4937	0.2101	0.52	0.96	0.32

Note: Simulated moments in response to technology or/and government expenditure shocks are computed with time horizon $T = 100$ quarters and $J = 1000$ number of iterations. The standard deviations of variables are expressed in percentage terms.

TABLE 3

RAMSEY AND COMPETITIVE EQUILIBRIUM STEADY-STATE

Allocation	y	c	n	u	w	e	s	mc	annual π
Ramsey	0.96783	0.73154	0.96673	0.033275	0.83429	1.0011	1.00	0.8333	1.00
Competitive	0.94517	0.70888	0.95	0.05	0.82481	1.00	1.0051	0.82902	1.042

Note: The Ramsey and competitive equilibrium steady-states associated with the baseline calibration.

TABLE 4
STANDARD DEVIATIONS - RAMSEY PLAN

	Benchmark NK		Fair Wage NK	
Shock	σ_y	σ_π	σ_y	σ_π
z_t	1.99	0.00	5.46	1.89
g_t	0.21	0.00	0.02	0.02
z_t and g_t	1.71	0.01	4.52	2.36

Note: Simulated standard deviations under the Ramsey (optimal) plan in response to technology or/and government expenditure shocks. Each model economy is approximated around the Ramsey steady-state using the second order perturbation method. Moments are computed with $T = 100$ quarters time horizon, and $J = 1000$ iterations. The standard deviation of inflation rate is expressed in annualized percentage terms.

TABLE 5
SENSITIVITY ANALYSIS - SECOND MOMENTS

$\psi = 0.1$, $\phi_3 = 0.25$, $\phi_4 = 0.6$							
ϕ_2	Ω_1	Ω_2	$1/\Omega$	Ψ	$\lambda\,\Psi$	std.dev(y_t)	std.dev(π_t)
0.001	0.040208	0.923080	1.913052	0.447082	0.038347	5.7305	2.3885
0.005	0.201040	0.923080	0.382610	1.864858	0.159954	4.0168	0.9557
0.01	0.402080	0.923080	0.191305	3.089543	0.264998	3.5184	0.5900
0.015	0.603110	0.923080	0.127539	3.955367	0.339262	3.3183	0.4373
0.02	0.804150	0.923080	0.095654	4.599962	0.394551	3.2101	0.3509
0.04	1.608300	0.923080	0.047827	6.088202	0.522201	3.0363	0.2004
0.06	2.412500	0.923080	0.031884	6.824182	0.585328	2.9751	0.1406
$\psi = 0.1$, $\phi_2 = 0.001$, $\phi_4 = 0.6$							
ϕ_3	Ω_1	Ω_2	$1/\Omega$	Ψ	$\lambda\,\Psi$	std.dev(y_t)	std.dev(π_t)
0.001	0.029071	0.66741	11.440611	0.077985	0.006689	4.3345	2.7236
0.01	0.029365	0.674160	11.096203	0.080384	0.006895	4.3948	2.7322
0.05	0.030747	0.705880	9.5658113	0.093112	0.007986	4.6868	2.7507
0.1	0.032669	0.750000	7.6525146	0.116091	0.009957	5.0986	2.7227
0.15	0.034847	0.800000	5.739375	0.154126	0.013220	5.5212	2.6318
0.2	0.037336	0.857140	3.8263338	0.229221	0.019661	5.8302	2.4892
0.25	0.040208	0.923080	1.9130521	0.447082	0.038347	5.7305	2.3885
0.3	-0.048722	1.000000	0	9.000000	0.771954	4.7911	2.8103

Note: Steady-state values refer to the competitive equilibrium steady-state. Standard deviations in percentage terms under the Ramsey (optimal) plan are computed when the model is driven by both technology and government spending shocks.

TABLE 6

SENSITIVITY ANALYSIS - SECOND MOMENTS

$\psi = 0.1$, $\phi_2 = 0.001$, $\phi_3 = 0.25$							
ϕ_4	Ω_1	Ω_2	$1/\Omega$	Ψ	$\lambda\,\Psi$	std.dev(y_t)	std.dev(π_t)
0.05	0.040208	0.076923	22.95755	0.039033	0.003348	3.2129	1.8836
0.01	0.040208	0.153875	21.0437	0.042566	0.003651	3.3098	2.0445
0.2	0.040208	0.307690	17.21822	0.051968	0.004457	3.5844	2.3503
0.3	0.040208	0.461540	13.39186	0.066707	0.005722	4.0164	2.5877
0.4	0.040208	0.615380	9.565758	0.093112	0.007986	4.6720	2.6828
0.5	0.040208	0.769230	5.739405	0.154125	0.013220	5.5070	2.5615
0.6	0.040208	0.923080	1.913052	0.447082	0.038347	5.7305	2.3885
0.65	0.000000	1.000000	∞	∞	∞	4.8912	2.9445
$\phi_2 = 0.001$, $\phi_3 = 0.25$, $\phi_4 = 0.60$							
ψ	Ω_1	Ω_2	$1/\Omega$	Ψ	$\lambda\,\Psi$	std.dev(y_t)	std.dev(π_t)
0.001	0.025448	0.80107	7.8171173	0.127780	0.010960	5.0639	3.0286
0.01	0.026507	0.81081	7.1373599	0.138513	0.011881	5.2208	2.9634
0.05	0.031834	0.857140	4.4876547	0.209359	0.017957	5.7361	2.6697
0.1	0.040208	0.923080	1.9130521	0.447082	0.038347	5.7305	2.3885
0.15	0.000000	1.000000	∞	∞	∞	4.7661	2.5831
0.2	0.065362	1.0909	-1.390716	-0.671864	-0.057628	–	–

Note: Steady-state values refer to the competitive equilibrium steady-state. Standard deviations in percentage terms under the Ramsey (optimal) plan are computed when the model is driven by both technology and government spending shocks.

TABLE 7

SENSITIVITY ANALYSIS - SECOND MOMENTS

$\psi = 0.1$, $\phi_2 = 0.001$, $\phi_3 = 0.25$, $\phi_4 = 0.6$

ϵ	μ^p	Ω_1	Ω_2	$1/\Omega$	Ψ	λ	$\lambda\,\Psi$	std.dev(y_t)	std.dev(π_t)
2	2	0.042283	0.923080	1.819171	0.468953	0.085773	0.040223	5.7567	3.6668
3	1.50	0.041091	0.923080	1.871943	0.456403	0.085773	0.039147	5.9074	3.23
4	1.33	0.040617	0.923080	1.893788	0.451402	0.085773	0.038718	5.9223	2.8928
5	1.25	0.040363	0.923080	1.905706	0.448720	0.085773	0.038488	5.855	2.6199
6	1.20	0.040208	0.923080	1.913052	0.447082	0.085773	0.038347	5.7305	2.3885
7	1.167	0.040104	0.923080	1.918013	0.445983	0.085773	0.038253	5.5633	2.185
8	1.143	0.040033	0.923080	1.921415	0.445233	0.085773	0.038189	5.3637	2.0005
9	1.125	0.039982	0.923080	1.923866	0.444694	0.085773	0.038143	5.1395	1.8293
10	1.111	0.039946	0.923080	1.925600	0.444313	0.085773	0.038110	4.8977	1.6673
11	1.10	0.039922	0.923080	1.926757	0.444059	0.085773	0.038088	4.6447	1.5118
12	1.091	0.039908	0.923080	1.927433	0.443911	0.085773	0.038075	4.3869	1.3608
13	1.083	0.039901	0.923080	1.927771	0.443837	0.085773	0.038069	4.1308	1.2133
14	1.077	0.039902	0.923080	1.927723	0.443848	0.085773	0.038070	3.8833	1.0687
15	1.071	0.039911	0.923080	1.927288	0.443943	0.085773	0.038078	3.6513	0.9271
16	1.067	0.039928	0.923080	1.926468	0.444123	0.085773	0.038094	3.4417	0.789
17	1.063	0.039954	0.923080	1.925214	0.444397	0.085773	0.038117	3.2607	0.6557
18	1.059	0.039991	0.923080	1.923433	0.444789	0.085773	0.038151	3.1131	0.5287
19	1.056	0.040041	0.923080	1.921031	0.445317	0.085773	0.038196	3.0013	0.4099
20	1.053	0.040111	0.923080	1.917678	0.446057	0.085773	0.038260	2.9244	0.3014
21	1.05	0.040205	0.923080	1.913195	0.447051	0.085773	0.038345	2.8781	0.2055

Note: Steady-state values refer to the competitive equilibrium steady-state. Standard deviations in percentage terms under the Ramsey (optimal) plan are computed when the model is driven by both technology and government spending shocks.

TABLE 8

SENSITIVITY ANALYSIS - SECOND MOMENTS

$\psi = 0.07$, $\phi_2 = 0.001$, $\phi_3 = 0.20$, $\phi_4 = 0.724$

θ	Quarters	Ω_1	Ω_2	$1/\Omega$	Ψ	λ	$\lambda\,\Psi$	std.dev(y_t)	std.dev(π_t)
0.1	1.11	0.040167	0.923080	1.915005	0.446649	8.108782	3.621780	12.0326	43.9471
0.2	1.25	0.040167	0.923080	1.915005	0.446649	3.207806	1.432763	10.9015	25.0214
0.3	1.43	0.040168	0.923080	1.914957	0.446660	1.640163	0.732595	10.0998	16.5963
0.4	1.67	0.040169	0.923080	1.914910	0.446670	0.905854	0.404618	9.3766	11.5077
0.5	2	0.040172	0.923080	1.914767	0.446702	0.504879	0.225530	8.6239	7.9884
0.6	2.5	0.040178	0.923080	1.914481	0.446765	0.270570	0.120881	7.7367	5.3592
0.7	3.33	0.040191	0.923080	1.913861	0.446903	0.131499	0.058767	6.5408	3.2859
0.75	4	0.040208	0.923080	1.913052	0.447082	0.085773	0.038347	5.7305	2.3885
0.8	5	0.040242	0.923080	1.911436	0.447442	0.051951	0.023245	4.7141	1.5483
0.9	10	0.040803	0.923080	1.885156	0.453365	0.012087	0.005480	2.8301	0.0857

Note: Steady-state values refer to the competitive equilibrium steady-state. Standard deviations in percentage terms under the Ramsey (optimal) plan are computed when the model is driven by both technology and government spending shocks.

TABLE 9

TAYLOR RULES AND MINIMUM WELFARE COSTS (λ^cx100)

Policy Arguments					α_r	α_π	α_y	α_n	α_w	λ^cx100
	π_t				–	1.5	–	–	–	0.6242
	π_t				–	3.0	–	–	–	0.4566
r_{t-1}	π_t				0.32	1.5	–	–	–	0.3649
	π_t	y_t			–	1.5	-0.07	–	–	0.3013
r_{t-1}	π_t	y_t			0.32	1.5	-0.01	–	–	0.3633
r_{t-1}	π_t	y_t			0.5	1.5	0.03	–	–	0.3788
r_{t-1}	π_t	y_t			0.9	1.5	0.11	–	–	0.3387
	π_t		n_t		–	3.0	–	0.19	–	0.3653
r_{t-1}	π_t		n_t		0.9	1.5	–	0.21	–	0.2325
r_{t-1}	π_t		n_t		0.5	1.8	–	0.15	–	0.3137
	π_t			g_t^w	–	2.4	–	–	3.0	0.1972
r_{t-1}	π_t			g_t^w	0.9	1.5	–	–	3.0	0.1086
r_{t-1}	π_t			g_t^w	0.5	1.5	–	–	3.0	0.1081

Note: The conditional social welfare ($W_{0,t}^T$) and welfare cost (λ^c x 100) are computed with the second order perturbation method of Schmitt-Grohé and Uribe (2004b) when the model economy is simulated with both technology (z_t) and government expenditure (g_t) shocks.

TABLE 10

OPTIMIZED INTEREST RATE RULES – z_t and g_t BCs

Arguments					α_r	α_π	α_y	α_n	α_w	$W_{0,t}^T$	λ^cx100
	π_t					2.1687				-30.0174	0.3863
r_{t-1}	π_t				0.3148	1.5000				-29.9955	0.3649
	π_t	y_t				1.5000	-0.0722			-29.9297	0.3007
r_{t-1}	π_t	y_t			1.0000	1.5000	0.1270			-29.9490	0.3196
	π_t		n_t			3.0000		0.1810		-29.9958	0.3653
r_{t-1}	π_t		n_t		1.0000	1.5003		0.2315		-29.8415	0.2147
	π_t			g_t^w		2.4272			3.0000	-29.8235	0.1971
r_{t-1}	π_t			g_t^w	0.6476	1.5000			3.0000	-29.7198	0.0960
	π_t	y_t	n_t			1.5000	-0.3185	0.5000		-29.6751	0.0523
r_{t-1}	π_t	y_t	n_t		0.0000	1.5129	-0.3164	0.5000		-29.6779	0.0550
	π_t	y_t		g_t^w		1.6686	-0.0758		3.0000	-29.7145	0.0908
r_{t-1}	π_t	y_t		g_t^w	1.0000	1.5000	0.0433		2.9831	-29.7187	0.0949
	π_t		n_t	g_t^w		1.6076		-0.1480	3.0000	-29.7424	0.1180
r_{t-1}	π_t		n_t	g_t^w	0.9989	1.5000		0.0926	3.0000	-29.7043	0.0808
	π_t	y_t	n_t	g_t^w		1.5000	-0.3168	0.5000	0.8535	-29.6591	0.0367
r_{t-1}	π_t	y_t	n_t	g_t^w	0.9017	1.5000	-0.2440	0.5000	3.0000	-29.6537	0.0314

Note: The conditional social welfare ($W_{0,t}^T$) and welfare cost (λ^c x 100) are computed with the second order perturbation method of Schmitt-Grohé and Uribe (2004b) when the model economy is simulated with technology (z_t) and government expenditure (g_t) shocks. The search for the optimal response coefficients is made over the following intuitive intervals: $\alpha_\pi \epsilon [1.5, 3]$, $\{\alpha_y, \alpha_n\}$ $\epsilon[-0.5, 0.5]$, $\alpha_w \epsilon [0, 3]$, and $\alpha_r \epsilon [0, 1]$.

TABLE 11

OPTIMIZED INTEREST RATE RULES – z_t BCs

Arguments					α_r	α_π	α_y	α_n	α_w	$W_{0,t}^T$	λ^cx100
	π_t					3.0000				-0.2297	0.0728
r_{t-1}	π_t				0.5678	1.5000				-0.2139	0.0574
	π_t	y_t				1.5175	-0.0747			-0.1972	0.0411
r_{t-1}	π_t	y_t			0.0007	1.5000	-0.0783			-0.1963	0.0402
	π_t		n_t			3.0000		-0.0082		-0.2297	0.0728
r_{t-1}	π_t		n_t		1.0000	1.5000		0.0960		-0.1882	0.0323
	π_t			g_t^w		3.0000			2.6961	-0.2041	0.0479
r_{t-1}	π_t			g_t^w	1.0000	1.5000			2.2743	-0.1636	0.0084
	π_t	y_t	n_t			2.0633	-0.3347	0.5000		-0.1690	0.0136
r_{t-1}	π_t	y_t	n_t		0.9852	1.5000	-0.2587	0.5000		-0.1599	0.0047
	π_t	y_t		g_t^w		2.5491	-0.0879		2.9575	-0.1770	0.0214
r_{t-1}	π_t	y_t		g_t^w	0.9835	1.5068	-0.0152		2.6079	-0.1626	0.0074
	π_t		n_t	g_t^w		2.3231		-0.1564	3.0000	-0.1810	0.0253
r_{t-1}	π_t		n_t	g_t^w	1.0000	1.5001		-0.0093	2.4212	-0.1631	0.0078
	π_t	y_t	n_t	g_t^w		2.0633	-0.3347	0.5000	0.0000	-0.1690	0.0136
r_{t-1}	π_t	y_t	n_t	g_t^w	0.9996	1.5105	-0.1209	0.2169	1.5857	-0.1613	0.0060

Note: The conditional social welfare ($W_{0,t}^T$) and welfare cost (λ^c x 100) are computed with the second order perturbation method of Schmitt-Grohé and Uribe (2004b) when the model economy is simulated with technology (z_t) shocks. The search for the optimal response coefficients is made over the following intuitive intervals: $\alpha_\pi \epsilon [1.5, 3]$, $\{\alpha_y, \alpha_n\} \epsilon [-0.5, 0.5]$, $\alpha_w \epsilon [0, 3]$, and $\alpha_r \epsilon [0, 1]$.

A Market Clearing

In a symmetric equilibrium all households and firms take identical decisions, and all product markets clear. Retailers $i\epsilon[0,1]$ completely satisfy the demand (2.3) for the product varieties $y_t(i)$ by the final good firms, so that we can write,

$$z_t\, e_t(i)\, n_t(i) = y_t(i) \quad \text{or} \quad z_t\, e_t(i)\, n_t(i) = \left[\frac{P_t(i)}{P_t}\right]^{-\varepsilon} y_t$$

Integrating over all retailers $i\epsilon[0,1]$, we take

$$\int_0^1 \left[z_t\, e_t(i)\, n_t(i)\right] di = y_t \int_0^1 \left[\frac{P_t(i)}{P_t}\right]^{-\varepsilon} di \quad \Rightarrow \quad z_t \int_0^1 \left[e_t(i)\, n_t(i)\right] di = y_t \int_0^1 \left[\frac{P_t(i)}{P_t}\right]^{-\varepsilon} di$$

or

$$z_t \int_0^1 \left[e_t(i)\, n_t(i)\right] di = y_t \int_0^1 \left[\frac{P_t(i)}{P_t}\right]^{-\varepsilon} di$$

In equilibrium, the exerted effort of workers is always equal with its fair level, which is independent of $i\epsilon[0,1]$ insofar as $w_t(i) = w_t$ (i.e., there is no wage dispersion). Thus, we obtain

$$z_t\, e_t \int_0^1 n_t(i)\, di = y_t \int_0^1 \left[\frac{P_t(i)}{P_t}\right]^{-\varepsilon} di$$

or

$$y_t = \left(\frac{1}{s_t}\right) z_t\, e_t\, n_t \tag{A.1}$$

where aggregate employment is

$$n_t = \int_0^1 n_t(i)\, di$$

and the price dispersion measure across firms is defined by

$$s_t = \int_0^1 \left[P_t(i)/P_t\right]^{-\varepsilon} di$$

The price dispersion measure can be written in recursive form as

$$\begin{aligned}
s_t &= \int_0^1 \left[\frac{P_t(i)}{P_t}\right]^{-\varepsilon} di \\
&= (1-\theta)\left(\frac{P_t^*}{P_t}\right)^{-\varepsilon} + \theta\left(\frac{P_{t-1}}{P_t}\right)^{-\varepsilon} \\
&= (1-\theta)\left(\frac{P_t^*}{P_t}\right)^{-\varepsilon} + \theta(1-\theta)\left(\frac{P_{t-1}^*}{P_t}\right)^{-\varepsilon} + \theta^2\left(\frac{P_{t-2}}{P_t}\right)^{-\varepsilon} \\
&= \cdots \\
&= (1-\theta)\sum_{k=0}^{\infty}\theta^k\left(\frac{P_{t-k}^*}{P_t}\right)^{-\varepsilon} \\
&= (1-\theta)\left(p_t^*\right)^{-\varepsilon} + \theta\left(\pi_t\right)^{\varepsilon} s_{t-1}
\end{aligned} \tag{A.2}$$

B Complete Set of Equilibrium Conditions

The equilibrium conditions of the competitive allocation in a symmetric equilibrium are the following:

1. Euler equation:

$$c_t^{-1} = \beta\, r_t\, E_t \left[c_{t+1}^{-1} \left(\frac{1}{\pi_{t+1}} \right) \right]$$

2. Effort function:
If $\psi \epsilon (0,1)$:

$$e_t = \phi_1 \frac{(1-\phi_3)\; w_t^{\psi} - \phi_2 \left(\frac{1}{1-n_t}\right)^{\psi} - \phi_4\, w_{t-1}^{\psi} - (\phi_0 - \phi_2 - \phi_3 - \phi_4)}{\psi}$$

If $\psi = 0$:

$$e_t = \phi_1 \left[(1-\phi_3)\; \ln(w_t) - \phi_2\; \ln\left(\frac{1}{1-n_t}\right) - \phi_4\; \ln(w_{t-1}) \right]$$

3. Demand for Labor:

$$w_t = mc_t \frac{y_t}{n_t}$$

4. Solow condition:

$$e_t = \phi_1\, w_t^{\psi}$$

5. Pricing decision condition:

$$x_t^1 = \left(\frac{\varepsilon - 1}{\varepsilon}\right) x_t^2$$

6. Expected discounted future costs:

$$x_t^1 = (p_t^*)^{-\varepsilon-1}\, y_t\, mc_t + \theta\beta E_t \left(\frac{c_{t+1}}{c_t}\right)^{-1} \pi_{t+1}^{\varepsilon+1} \left(\frac{p_t^*}{p_{t+1}^*}\right)^{-\varepsilon-1} x_{t+1}^1$$

7. Expected discounted future revenues:

$$x_t^2 = (p_t^*)^{-\varepsilon}\, y_t + \theta\beta E_t \left(\frac{c_{t+1}}{c_t}\right)^{-1} \pi_{t+1}^{\varepsilon} \left(\frac{p_t^*}{p_{t+1}^*}\right)^{-\varepsilon} x_{t+1}^2$$

8. Aggregate Price Index:

$$1 = \theta\,(\pi_t)^{\varepsilon-1} + (1-\theta)\,(p_t^*)^{1-\varepsilon}$$

9. Price dispersion measure:

$$s_{t+1} = (1-\theta)\;(p_t^*)^{-\varepsilon} + \theta\;(\pi_t)^{\varepsilon}\, s_t$$

10. Production technology:

$$y_t = \frac{1}{s_{t+1}}\, z_t e_t n_t$$

11. Aggregate resource constraint:

$$y_t = c_t + g_t$$

12. Unemployment:

$$u_t = 1 - n_t$$

13. Real Wage Growth:

$$g_t^w = \frac{w_t}{w_{t-1}}$$

14. Real Interest Rate:

$$\rho_t = \frac{c_{t+1}}{c_t}$$

15. (Contemporaneous) Monetary Policy Rule:

$$\frac{r_t}{r} = \left(\frac{r_{t-1}}{r}\right)^{\alpha_r} \left(\frac{\pi_t}{\pi}\right)^{\alpha_\pi} \left(\frac{y_t}{y}\right)^{\alpha_y} \left(\frac{n_t}{n}\right)^{\alpha_n} (g_t^w)^{\alpha_w}$$

Competitive equilibrium is described by the above fifteen conditions along with the exogenous first-order autoregressive processes for the neutral technology (z_t) and the government expenditure (g_t) shocks, given by

$$\ln(z_{t+1}) = \rho_z \ln(z_t) + \varepsilon_{z,t+1} \quad \text{with} \quad \varepsilon_{z,t} \sim N\left(0, \sigma_z^2\right)$$

$$\ln(g_{t+1}) = (1-\rho_g)\ln(\overline{g}) + \rho_g \ln(g_t) + \varepsilon_{g,t+1} \quad \text{with} \quad \varepsilon_{g,t} \sim N\left(0, \sigma_g^2\right)$$

The endogenous variables associated with the above system of equilibrium conditions are given by the set $\{\ y_t$, c_t, n_t, u_t, w_t, e_t, x_t^1, x_t^2, p_t^*, s_{t+1}, mc_t, π_t, ρ_t, g_t^w, $r_t\ \}$.

C Competitive equilibrium steady-state

The steady-state of the competitive equilibrium allocation is derived in the following order:

1. The (gross) nominal interest rate, from the Euler equation:

$$r = \frac{\pi}{\beta}$$

2.The optimal relative price (p^*), from the aggregate price index:

$$p^* = \left[\frac{1-\theta(\pi)^{\varepsilon-1}}{1-\theta}\right]^{\frac{1}{1-\varepsilon}}$$

3. The price dispersion measure (s), from its definition:

$$s = \frac{(1-\theta)(p^*)^{-\varepsilon}}{1-\theta\,\pi^{\varepsilon}}$$

4. The real marginal cost (mc), from the conditions of the pricing decision problem:

$$mc = p^* \left(\frac{\varepsilon-1}{\varepsilon}\right)\left[\frac{1-\theta\,\beta\,\pi^{\varepsilon+1}}{1-\theta\,\beta\,\pi^{\varepsilon}}\right]$$

5. The employment rate (n), from the labor force definition:

$$n = 1-u$$

6. Aggregate Output (y), from the production technology:

$$y = \left(\frac{1}{s}\right) z\, e\, n$$

7. The real wage (w), from the labor demand condition:

$$w = mc\,\frac{y}{n}$$

8. Government spending (g), from its definition:

$$g = s_g\, y$$

9. Private consumption (c), from the aggregate resource constraint:

$$c = y - g$$

10. The lifetime discounted value of future expected revenues (x_2), from their definition:

$$x^2 = \frac{(p^*)^{-\varepsilon}\, y}{1 - \theta\, \beta\, \pi^{\varepsilon}}$$

11. The lifetime discounted value of future expected cost (x_1), from the pricing decision condition:

$$x^1 = \left(\frac{\varepsilon - 1}{\varepsilon}\right) x^2$$

12. Parameters ϕ_1 and ϕ_0 from the Solow condition and the effort function, respectively:

$$\phi_1 = e\, w^{-\psi}$$

$$\phi_0 = (1 - \phi_3 - \phi_4)\, w^{\psi} - \phi_2 \left(\frac{1}{1-n}\right)^{\psi} + (\phi_2 + \phi_3 + \phi_4) - \left(\frac{\psi\, e}{\phi_1}\right)$$

D Efficient Allocation

The social planner maximizes the lifetime utility of the representative household subject to the aggregate resource constraint of the economy, conditionally on the assumption of perfectly flexible prices (no nominal price stickiness) and the equilibrium level of effort. Namely, the problem is defined as follows:

$$\max_{\{c_t, n_t\}} W_t = E_0 \sum_{t=0}^{\infty} \beta^t \left[\ln(c_t) + (1 - n_t)\, (e_t^*)^2\right]$$

subject to the aggregate resource constraint,

$$c_t + g_t \leq z_t\, e_t\, n_t$$

and the constraint

$$0 \leq n_t \leq 1$$

where the exerted effort is equal to its equilibrium value, i.e.,

$$e_t = \xi\, z_t^{\frac{\psi}{1-\psi}} \quad \text{with} \quad \xi = [\mu^p]^{\frac{\psi}{\psi-1}}\, \phi_1^{\frac{1}{1-\psi}}$$

This is a standard inequality constrained optimization problem solved with Karush-Kuhn-Tucker conditions, as follows:

1. First order conditions:

$$\frac{1}{c_t} = \lambda_{1,t}$$

$$-e_t^2 = -\lambda_{1,t}\, z_t\, e_t + \lambda_{2,t} - \lambda_{3,t}$$

2. Complementarity conditions:

$$\lambda_{1,t}\ (c_t + g_t - z_t\, e_t\, n_t) = 0$$

$$\lambda_{2,t}\ (1 - n_t) = 0$$

$$\lambda_{3,t}\, n_t = 0$$

3. Feasibility conditions:

$$c_t + g_t - z_t\, e_t\, n_t \leq 0$$

$$n_t - 1 \leq 0$$

$$n_t \geq 0$$

$$\lambda_{1,t},\ \lambda_{2,t}, \lambda_{3,t}\ \geq 0$$

Insofar as $c_t > 0$, the lagrange multiplier associated with the aggregate resource constraint is positive, because $\lambda_{1,t} = 1/c_t$. The case $\lambda_{1,t} = 0$ is rejected, because it implies $c_t = +\infty$, which is impossible. As $\lambda_{1,t} > 0$, complementarity condition indicates that the aggregate resource constraint binds, i.e., $c_t + g_t = z_t\, e_t\, n_t$.

Accordingly, we assume $\lambda_{2,t} = 0$. From the first order condition with respect to employment, we obtain,

$$\lambda_{3,t} = e_t\, \left(e_t - \frac{z_t}{c_t} \right)$$

which shows that $\lambda_{3,t} < 0$, because under the baseline parameterization the exerted effort is close to unity, technology variable is unity, and $0 < c_t < 1$; namely, $z_t/c_t > 1$ and $e_t - z_t/c_t < 0$. Feasibility conditions indicate however that the lagrangian multiplies are non-negative. Hence, the solution of $\lambda_{3,t} < 0$ is impossible and accordingly the assumption of $\lambda_{2,t} = 0$ is rejected. As a result, $\lambda_{2,t} > 0$ and from the complementarity condition $\lambda_{2,t}\, (1 - n_t) = 0$, we obtain $n_t = 1$.

To verify the above, we assume finally that $\lambda_{3,t} > 0$. This indicates that $n_t = 0$, due to the corresponding complementarity condition $\lambda_{3,t}\, n_t = 0$. For $n_t = 0$, however, the condition $\lambda_{2,t}\, (1 - n_t) = 0$ gives $\lambda_{2,t} = 0$. Substituting this into the first order condition with respect to employment, and dropping out $\lambda_{1,t}$ accordingly, we obtain

$$\lambda_{3,t} = e_t\, \left(e_t - \frac{z_t}{c_t} \right) < 0$$

which is negative, and an impossible solution due to the non-negativity condition $\lambda_{3,t} \geq 0$. Hence, the assumption $\lambda_{3,t} > 0$ is rejected. For $\lambda_{3,t} = 0$, we find after some algebra that $\lambda_{2,t} > 0$, which along with the associated complementarity condition gives $n_t = 1$.

The efficient level of output (y_t^*) is obtained by substituting into production technology the Pareto efficient employment level and the equilibrium level of exerted effort; that is,

$$y_t^* = \xi\, z_t^{\frac{1}{1-\psi}} \quad \text{where} \quad \xi = (\mu^p)^{\frac{\psi}{\psi-1}}\, \phi_1^{\frac{1}{1-\psi}}$$

or, in log-linear terms,

$$\hat{y}_t^* = \left(\frac{1}{1-\psi} \right)\, \hat{z}_t$$

In the constant effort approach, $\psi = 0$ and the efficient level of output becomes,

$$\hat{y}_t^* = \hat{z}_t$$

The solution of the above problem gives a maximum for the objective function, because the latter is negative semi-definite and the constraints are linear (i.e., convex). Figure 1 plots the aggregate resource constraint and the objective function of the problem for period $t > 0$ and shows that the efficient allocation of the model economy is associated with full employment, i.e., $n_t^* = 1$. Hence in the non Walrasian NK model with fair wage considerations, unemployment is Pareto suboptimal. We also point out that this result is also consistent with the case where the momentary utility function of the family is given by $u_t = \ln(c_t)$, i.e., if we ignore the second component of the objective function, as fair wage literature has assumed so far (see figure 1). Omitting the employment component however will end to a misspecified utility function which cannot generate the micro-founded social welfare loss function, as we describe below.

Finally, if we solve the above optimization problem by ignoring the constraint for variable $n_t \epsilon [0, 1]$, we take a global maximum for the lifetime utility function which corresponds to

$$c_t^{*g} = \frac{z_t}{e_t} \quad \text{and} \quad n_t^{*g} = \frac{z_t + e_t\, g_t}{e_t^2\, z_t}$$

where $e_t = \xi\, z_t^{\psi/(1-\psi)}$. The global maximum of the utility function is also associated with the aggregate output

$$y_t^{*g} = \frac{z_t + e_t\, g_t}{e_t}$$

which, in log-linear terms, is given by,

$$\hat{y}_t^{*g} = (1 - s_c)\, \hat{g}_t + \left(\frac{1 - 2\,\psi}{1 - \psi} \right) s_c \hat{z}_t$$

where $s_c = c/y$ is the steady-state fraction of consumption to aggregate output. For the constant effort approach, i.e., for $\psi = 0$, the level of output associated with the global maximum of utility function becomes equal to,

$$\hat{y}_t^{*g} = (1 - s_c)\, \hat{g}_t + s_c \hat{z}_t$$

E Social Loss Function

E.1 Variable Effort ($0 < \psi < 1$)

In symmetric equilibrium, the momentary utility function of the representative family becomes

$$U_t = E_0 \sum_{t=0}^{\infty} \beta^t \left[\ln(c_t) + (1 - n_t)\, e_t^2 \right]$$

because the employed members of the family always exert the fair level of effort ($e_t = e_t^*$). In the natural allocation where prices are completely flexible, the exerted effort of workers is equal with [29]

$$e_t = \xi\, z_t^{\frac{\psi}{1-\psi}} \quad \text{where} \quad \xi = (\mu^p)^{\frac{\psi}{\psi-1}}\, \phi_1^{\frac{1}{1-\psi}}$$

[29]The Solow condition $e_t = \phi_1\, w_t^{\psi}$ along with the Price Setting equation $w_t = (\phi_1/\mu^p)^{1/(1-\psi)}\, z_t^{1/(1-\psi)}$ delivers the equilibrium level of effort in the flexible-price allocation.

where $\mu^p > 1$ is the static markup, $\{\psi, \phi_1\}$ are deep parameters of the effort function (2.2), and z_t is the neutral technology shock. Considering that the social welfare function is computed conditionally on the assumption of complete price flexibility, and the equilibrium level of effort, we write the lifetime utility function as follows:

$$U_t = E_0 \sum_{t=0}^{\infty} \beta^t \left[\ln(c_t) + (1 - n_t)\, e^2(z_t)\right]$$

By dropping out consumption (c_t) with the employment of the aggregate resource constraint $y_t = c_t + g_t$, the momentary utility function becomes

$$u_t = \ln(y_t - g_t) + (1 - n_t)\, e_t^2(z_t)$$

For computational simplicity, we set $f_t = \ln(y_t - g_t)$, and $v_t = (1 - n_t)\, e_t^2$, and take the second order approximation of each component separately. Using the notation $\tilde{x}_t = x_t - x$, the quadratic approximation of the first term f_t becomes:

$$\begin{aligned}
f_t - f &= f_c\, \tilde{y}_t + f_g\, \tilde{g}_t + \frac{1}{2}\, f_{cc}\, \tilde{y}_t^2 + f_{cg}\, \tilde{g}_t\, \tilde{y}_t + \frac{1}{2}\, \tilde{g}_t'\, f_{gg}\, \tilde{g}_t \\
&= \ldots \\
&= f_c\, y\, \hat{y}_t + \frac{1}{2}\, \left[f_c\, y + f_{cc}\, y^2\right]\, \hat{y}_t^2 + y\, f_{cg}\, \tilde{g}_t\, \hat{y}_t + \text{t.i.p}
\end{aligned}$$

Since $f_c = u_c$, $f_{cc} = u_{cc}$, and $f_{cg} = u_{cg}$, we can write

$$f_t - f = y\, u_c \left[\hat{y}_t + \frac{1}{2}\left(1 - \frac{1}{\sigma}\right) \hat{y}_t^2 + \left(\frac{1}{\sigma}\right) \hat{\gamma}_t\, \hat{y}_t\right] + \text{t.i.p} \tag{E.1}$$

where t.i.p. includes the terms independent of policy, and σ, $\hat{\gamma}_t$ are given by,

$$\sigma = -\frac{u_c}{u_{cc}\, y} \qquad \hat{\gamma}_t = -\frac{u_{cg}\, \tilde{g}_t}{y\, u_{cc}}$$

Similarly, the second order approximation of the second term (v_t) is given as follows:

$$\begin{aligned}
v_t - v &= v_n\, \tilde{n}_t + v_e\, \tilde{e}_t + \frac{1}{2}\, v_{nn}\, \tilde{n}_t^2 + v_{ne}\, \tilde{e}_t\, \tilde{n}_t + \frac{1}{2}\, \tilde{e}_t'\, v_{ee}\, \tilde{e}_t \\
&= \ldots \\
&= v_n\, n\, \hat{n}_t + \frac{1}{2}\, \left[v_n\, n + v_{nn}\, n^2\right]\, \hat{n}_t^2 + n\, v_{ne}\, \tilde{e}_t\, \hat{n}_t + \text{t.i.p}
\end{aligned}$$

Since $v_n = u_n$, $v_{nn} = u_{nn}$, and $v_{ne} = u_{ne}$, we can write

$$v_t - v = u_n\, n \left[\hat{n}_t + \frac{1}{2}\, (1 + \varphi)\, \hat{n}_t^2 - \hat{\omega}_t\, \hat{n}_t\right] + \text{t.i.p}$$

where

$$\hat{\omega}_t = -\frac{u_{ne}\, \tilde{e}_t}{u_n} \quad \text{and} \quad \varphi = \frac{u_{nn}\, n}{u_n}$$

Accordingly, by combining the aggregate employment definition, given by $n_t = \int_0^1 n_t(i)di$, with the production technology $y_t(i) = z_t e_t n_t(i)$ (effort is independent of $i\epsilon[0, 1]$ because nominal wages are assumed completely flexible), and the Dixit-Stiglitz demand for $y_t(i)$, given by $y_t(i) = [P_t(i)/P_t]^{-\varepsilon} y_t$, we obtain

$$n_t = \frac{y_t}{z_t\, e_t}\, s_t$$

where $s_t = \int_0^1 [P_t(i)/P_t]^{-\varepsilon} di$ defines the price dispersion measure, which in log-linearized terms is equal to,

$$\hat{s}_t = \frac{\varepsilon}{2}\, \text{var}\, [\hat{p}_t(i)]$$

Dropping out the aggregate employment from the quadratic approximation of the second term (v_t), we take:

$$\begin{aligned} v_t - v &= u_n\, n \left[\hat{y}_t - \left(\frac{1}{1-\psi}\right) \hat{z}_t + \hat{s}_t + \left(\frac{1+\varphi}{2}\right) \left\{ \hat{y}_t - \left(\frac{1}{1-\psi}\right) \hat{z}_t + \hat{s}_t \right\}^2 - \hat{\omega}_t \left\{ \hat{y}_t - \left(\frac{1}{1-\psi}\right) \hat{z}_t + \hat{s}_t \right\} \right] + \text{t.i.p} \\ &= \dots \\ &= u_n\, n \left[\hat{y}_t + \hat{s}_t + \left(\frac{1+\varphi}{2}\right) \hat{y}_t^2 - (1+\varphi) \left(\frac{1}{1-\psi}\right) \hat{y}_t\, \hat{z}_t - \hat{\omega}_t\, \hat{y}_t \right] + \text{t.i.p} \end{aligned} \tag{E.2}$$

Then, we combine (E.1) and (E.2) to obtain the second-order approximation of the momentary utility function as follows:

$$\begin{aligned} u_t - u = y\, u_c & \left[\hat{y}_t + \frac{1}{2} \left(1 - \frac{1}{\sigma}\right) \hat{y}_t^2 + \left(\frac{1}{\sigma}\right) \hat{\gamma}_t\, \hat{y}_t \right] + \\ & + u_n\, n \left[\hat{y}_t + \hat{s}_t + \left(\frac{1+\varphi}{2}\right) \hat{y}_t^2 - (1+\varphi) \left(\frac{1}{1-\psi}\right) \hat{y}_t\, \hat{z}_t - \hat{\omega}_t\, \hat{y}_t \right] + \text{t.i.p} \quad \Rightarrow \dots \end{aligned}$$

$$\begin{aligned} \frac{u_t - u}{u_c\, y} &= \hat{y}_t + \frac{1}{2} \left(\frac{\sigma - 1}{\sigma}\right) \hat{y}_t^2 + \left(\frac{1}{\sigma}\right) \hat{\gamma}_t\, \hat{y}_t + \frac{u_n}{u_c}\, \frac{n}{y} \left[\hat{y}_t + \hat{s}_t + \left(\frac{1+\varphi}{2}\right) \hat{y}_t^2 - (1+\varphi) \left(\frac{1}{1-\psi}\right) \hat{y}_t\, \hat{z}_t - \hat{\omega}_t\, \hat{y}_t \right] + \text{t.i.p} \\ &= \dots \\ &= -\left(\frac{1}{2}\right) \left[\varepsilon\, \text{var}_i\, [\hat{p}_t(i)] + \left(\varphi + \frac{1}{\sigma}\right) \left\{ \hat{y}_t^2 - 2\, \hat{y}_t \left(\frac{\frac{\hat{\gamma}_t}{\sigma} + (1+\varphi) \left(\frac{1}{1-\psi}\right) \hat{z}_t + \hat{\omega}_t}{\varphi + \frac{1}{\sigma}} \right) \right\} \right] + \text{t.i.p.} \\ &= \dots \\ &= -\left(\frac{1}{2}\right) \left[\varepsilon\, \text{var}_i\, [\hat{p}_t(i)] + \frac{1}{s_c} \left(\hat{y}_t - \hat{y}_t^{*g}\right)^2 \right] + \text{t.i.p.} \end{aligned}$$

where $s_c = c/y$ and $\hat{y}_t^{*g} = (1 - s_c)\, \hat{g}_t + s_c\, [(1 - 2\,\psi)/(1-\psi)]\, \hat{z}_t$ denote the steady-state share of consumption to output and the efficient level of output (in log-linear terms) associated with the global maximum of the lifetime utility function, respectively.

After some tedious algebra, we can also prove that[30]

$$\sum_{t=0}^{\infty} \beta^t\, \text{var}_i\, [\hat{p}_t(i)] = \frac{\theta}{(1-\beta\,\theta)(1-\theta)} \sum_{t=0}^{\infty} \beta^t\, \hat{\pi}_t^2$$

and the discounted sum of utility of the representative family, approximated by

$$W_t = E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{u_t - u}{u_c\, y} \right]$$

becomes

$$W_t = -\left(\frac{1}{2}\right) E_0 \sum_{t=0}^{\infty} \beta^t \left[\left(\frac{\varepsilon}{\lambda}\right) \hat{\pi}_t^2 + \frac{1}{s_c} \left\{ \hat{x}_t^{*g} \right\}^2 \right] \tag{E.3}$$

where $\lambda = (1 - \beta\,\theta)(1-\theta)/\theta$, is the parameter pertaining to the NKPC condition (4.2), and $\hat{x}_t^{*g} = \hat{y}_t - \hat{y}_t^{*g}$.

[30]The proof is available by Woodford (2003).

E.2 Constant Effort ($\psi = 0$)

In a symmetric equilibrium, the momentary utility function of household becomes

$$U_t = E_0 \sum_{t=0}^{\infty} \beta^t \left[\ln(c_t) + (1 - n_t)\, e^2\right]$$

because the employed members of the family always exert in equilibrium the fair level of effort. If $\psi = 0$, the Solow condition $e_t = \phi_1\, w_t^{\psi}$ indicates that the exerted effort becomes constant. Hence the second term of the momentary utility function is a linear function of employment. For computational simplicity, we assume $f_t = \ln(c_t)$ and $v_t = (1 - n_t)\, e^2$. We take the second-order approximation of the momentary utility function by adding the quadratic approximations of each component f_t and v_t. For the first part, we obtain:

$$\begin{aligned} f_t - f &= f_c\, \tilde{y}_t + f_g\, \tilde{g}_t + \frac{1}{2}\, f_{cc}\, \tilde{y}_t^2 + f_{cg}\, \tilde{g}_t\, \tilde{y}_t + \frac{1}{2}\, \tilde{g}_t'\, f_{gg}\, \tilde{g}_t \\ &= \dots \\ &= y\, f_c\, \hat{y}_t + \frac{1}{2}\, \left(y\, f_c + f_{cc}\, y^2\right)\, \hat{y}_t^2 + y\, f_{cg}\, \tilde{g}_t\, \hat{y}_t + \text{t.i.p.} \end{aligned}$$

The utility function is log-separable in its arguments, so that we can write $f_c = u_c$, $f_{cc} = u_{cc}$, $f_{cg} = u_{cg}$, and

$$f_t - f = y\, u_c \left[\hat{y}_t + \frac{1}{2}\left(1 - \frac{1}{\sigma}\right) \hat{y}_t^2 + \left(\frac{1}{\sigma}\right)\, \hat{\gamma}_t\, \hat{y}_t\right] + \text{t.i.p.} \tag{E.4}$$

where

$$\sigma = -\frac{u_c}{u_{cc}\, y} \quad \text{and} \quad \hat{\gamma}_t = -\frac{u_{cg}\, \tilde{g}_t}{y\, u_{cc}}$$

Similarly, the second component (v_t) becomes:

$$v_t - v = u_n\, n\, \left[\hat{n}_t + \left(\frac{1 + \varphi}{2}\right)\, \hat{n}_t^2\right] \tag{E.5}$$

where

$$\varphi = \frac{u_{nn}\, n}{u_n}$$

Thus, adding (E.4) and (E.5), and taking into account that $\hat{n}_t = \hat{y}_t - \hat{z}_t + \hat{s}_t$, where $\hat{s}_t = (\varepsilon/2)\, \text{var}_i[\hat{p}_t(i)]$, we obtain the quadratic approximation of the utility function of the representative family, as follows:

$$\begin{aligned} \frac{u_t - u}{u_c\, y} &= \hat{y}_t + \frac{1}{2}\left(1 - \frac{1}{\sigma}\right) \hat{y}_t^2 + \left(\frac{1}{\sigma}\right)\, \hat{\gamma}_t\, \hat{y}_t + \frac{u_n}{u_c}\, \frac{n}{y}\, \left[\left(\frac{1 + \varphi}{2}\right)\, \hat{y}_t^2 + \hat{y}_t - (1 + \varphi)\, \hat{y}_t\, \hat{z}_t + \hat{s}_t\right] + \text{t.i.p} \\ &= \dots \\ &= -\left(\frac{1}{2}\right) \left[\varepsilon\, \text{var}_i\left[\hat{p}_t(i)\right] + \left(1 + \varphi + \frac{1 - \sigma}{\sigma}\right) \left\{\hat{y}_t^2 - 2\, \hat{y}_t\, \left(\frac{\frac{\hat{\gamma}_t}{\sigma} + (1 + \varphi)\, \hat{z}_t}{1 + \varphi + \frac{1 - \sigma}{\sigma}}\right)\right\}\right] + \text{t.i.p} \\ &= \dots \\ &= -\left(\frac{1}{2}\right) \left[\varepsilon\, \text{var}_i\left[\hat{p}_t(i)\right] + \left(\frac{1}{s_c}\right)\, \left(\hat{y}_t - \hat{y}_t^{*g}\right)^2\right] + \text{t.i.p} \\ &= -\left(\frac{1}{2}\right) \left[\varepsilon\, \text{var}_i\left[\hat{p}_t(i)\right] + \left(\frac{1}{s_c}\right)\, \left\{\hat{x}_t^{*g}\right\}^2\right] + \text{t.i.p} \end{aligned}$$

where $s_c = c/y$ is the steady-state fraction of consumption to output, $\hat{y}^{*g} = (1 - s_c)\hat{g}_t + s_c\hat{z}_t$ is the efficient level of output associated with the global maximum of the lifetime utility of family, and $\hat{x}_t^{*g} = \hat{y}_t - \hat{y}_t^{*g}$ is the corresponding welfare-relevant output gap. Following Woodford (2003), we can also show after some algebra that

$$\sum_{t=0}^{\infty} \beta^t \, var_i \left[p_t(i)\right] = \frac{1}{\lambda} \sum_{t=0}^{\infty} \beta^t \pi_t^2$$

where $\lambda = (1-\beta\,\theta)(1-\theta)/\theta$ is the elasticity of current inflation to real marginal cost, according to the NKPC condition (4.2), so that the social loss function becomes

$$W_t = -\left(\frac{1}{2}\right) E_0 \sum_{t=0}^{\infty} \beta^t \left[\left(\frac{\varepsilon}{\lambda}\right) \hat{\pi}_t^2 + \left(\frac{1}{s_c}\right) \left\{\hat{x}_t^{*g}\right\}^2\right] \tag{E.6}$$

F Linear-Quadratic Approach

F.1 Variable Effort ($0 < \psi < 1$)

Optimal monetary policy is obtained by the solution of the following minimization problem:

$$\min_{\{\pi_t,\, \hat{y}_t\}} W_t = -\left(\frac{1}{2}\right) E_0 \sum_{t=0}^{\infty} \beta^t \left[\left(\frac{\varepsilon}{\lambda}\right) \hat{\pi}_t{}^2 + \left(\frac{1}{s_c}\right) \left(\hat{y}_t - \hat{y}_t^{*g}\right)^2\right] \tag{F.1}$$

subject to the New Keynesian Phillips curve condition

$$\hat{\pi}_t = \beta\, E_t\left(\hat{\pi}_{t+1}\right) + \lambda\, \Psi \left(\hat{y}_t - \hat{y}_t^{*g}\right) + \lambda\, \Psi\, v\left(\hat{z}_t, \hat{z}_{t-1}, \hat{g}_t\right) \tag{F.2}$$

where $\lambda = (1-\beta\,\theta)(1-\theta)/\theta$. The cost-push component $v(\hat{z}_t, \hat{z}_{t-1}, \hat{g}_t)$ is given by,

$$v\left(\hat{z}_t, \hat{z}_{t-1}, \hat{g}_t\right) = (1-s_c)\,\hat{g}_t + \left[s_c\left(\frac{1-2\,\psi}{1-\psi}\right) - \frac{1+\Omega_1}{(1-\psi)\,\Omega_1}\right] \hat{z}_t + \frac{\Omega_2}{(1-\psi)\;\Omega_1}\,\hat{z}_{t-1}$$

The elasticities Ψ, Ω_1, and Ω_2 are determined by the following equations:

$$\Psi = \frac{(1-\psi)\,\Omega_1}{1+\psi\,\Omega_1 - \Omega_2\, L} \equiv \frac{(1-\psi)\,\Omega_1}{1+\psi\,\Omega_1 - \Omega_2}$$

$$\Omega_1 = \left(\frac{\phi_2}{1-\psi-\phi_3}\right) \frac{(1-\psi-\phi_3-\phi_4)\; n\; (1-n)^{-1-\psi}}{\phi_2\;(1-n)^{-\psi} + (\phi_0-\phi_2-\phi_3-\phi_4)}$$

$$\Omega_2 = \frac{\phi_4}{1-\psi-\phi_3}$$

The first order conditions of the above problem are given by the following system of difference equations:

$$\hat{\zeta}_t - \hat{\zeta}_{t-1} + 2\left(\frac{\varepsilon}{\lambda}\right) \hat{\pi}_t = 0 \tag{F.3}$$

$$2\left(\frac{1}{s_c}\right) \hat{x}_t^{*g} - \lambda\, \Psi\, \zeta_t = 0 \tag{F.4}$$

$$\hat{\pi}_t = \beta\, E\left(\hat{\pi}_{t+1}\right) + \lambda\, \Psi\, \hat{x}_t^{*g} + \lambda\, \Psi\, (1-s_c)\,\hat{g}_t + \lambda\, \Psi \left[s_c\left(\frac{1-2\,\psi}{1-\psi}\right) - \frac{1+\Omega_1}{(1-\psi)\,\Omega_1}\right] \hat{z}_t + \lambda\, \Psi\, \frac{\Omega_2}{(1-\psi)\,\Omega_1}\,\hat{z}_{t-1} \tag{F.5}$$

where $\hat{x}_t^{*g} = \hat{y}_t - \hat{y}_t^{*g}$. We augment the above system of equilibrium conditions with the definitions of the welfare-relevant output gap $\hat{x}_t^* = \hat{y}_t - \hat{y}_t^*$, the efficient output ($\hat{y}_t^*$), and the exogenous processes pertaining to the driving variables $\hat{z}_t$ and $\hat{g}_t$, i.e.,

$$0 = -\hat{x}_t^{*g} + \hat{x}_t^* + \left[\frac{1-(1-2\,\psi)s_c}{1-\psi}\right] \hat{z}_t - (1-s_c)\,\hat{g}_t \tag{F.6}$$

$$0 = -\hat{x}_t^* + \hat{y}_t - \hat{y}_t^* \tag{F.7}$$

$$0 = -\hat{y}_t^* + \left(\frac{1}{1-\psi}\right) \hat{z}_t \tag{F.8}$$

$$\hat{z}_{t+1} = \rho_z \, \hat{z}_t + \varepsilon_{z,t+1} \tag{F.9}$$

$$\hat{g}_{t+1} = \rho_g \, \hat{g}_t + \varepsilon_{g,t+1} \tag{F.10}$$

The complete system of the above linear expectational difference equations is written in state-space form as follows:

$$0 = A\,x(t) + B\,x(t-1) + C\,y(t) + D\,z(t)$$
$$0 = E_t\left[F\,x(t+1) + G\,x(t) + H\,x(t-1) + J\,y(t+1) + K\,y(t) + L\,z(t+1) + M\,z(t)\right]$$
$$z(t+1) = N\,z(t) + \epsilon(t+1)$$

where the vectors of endogenous predetermined, jump, and exogenous variables, are given by $x(t) = [\hat{\zeta}_t,\, \hat{\omega}_t]'$, $y(t) = [\hat{\pi}_t,\, \hat{x}_t^{*g},\, \hat{x}_t^*,\, \hat{y}_t,\, \hat{y}_t^*]'$, and $z(t) = [\hat{z}_t,\, \hat{g}_t]'$, respectively, and the white noise vector is $\epsilon_{t+1} = [\varepsilon_{z,t+1}, \varepsilon_{g,t+1}]'$. Variable $\hat{\omega}_t$ defines the expected inflation rate, i.e., $\hat{\omega}_t = E_t(\hat{\pi}_{t+1})$, and augments the above system of equilibrium conditions. The state-space system is solved with the method of undetermined coefficients described by Uhlig (2003).

F.2 Constant Effort ($\psi = 0$)

If $\psi = 0$, effort function (2.2) becomes logarithmic and exerted effort is always constant over the business cycle ($e_t = \phi_1$). In this case, the policymaker's problem becomes

$$\min_{\{\hat{\pi}_t,\, \hat{y}_t\}} W_t = -\left(\frac{1}{2}\right) E_0 \sum_{t=0}^{\infty} \beta^t \left[\left(\frac{\varepsilon}{\lambda}\right) \hat{\pi}_t{}^2 + \left(\frac{1}{s_c}\right) \left(\hat{y}_t - \hat{y}_t^{*g}\right)^2\right] \tag{F.11}$$

subject to the NKPC

$$\hat{\pi}_t = \beta\, E_t\left(\hat{\pi}_{t+1}\right) + \lambda\, \Psi\, \left(\hat{y}_t - \hat{y}_t^{*g}\right) + \lambda\, \Psi\, f\left(\hat{z}_t, \hat{z}_{t-1}, \hat{g}_t\right) \tag{F.12}$$

where $\lambda = (1-\beta\,\theta)(1-\theta)/\theta$. The cost-push term $f\left(\hat{z}_t, \hat{z}_{t-1}, \hat{g}_t\right)$ is given by

$$f\left(\hat{z}_t, \hat{z}_{t-1}, \hat{g}_t\right) = (1-s_c)\,\hat{g}_t + \left[s_c - \frac{1+\Omega_1}{\Omega_1}\right] \hat{z}_t + \frac{\Omega_2}{\Omega_1}\,\hat{z}_{t-1}$$

The elasticities Ψ, Ω_1, and Ω_2 are determined by

$$\Psi = \frac{\Omega_1}{1-\Omega_2\,L} \equiv \frac{\Omega_1}{1-\Omega_2}$$

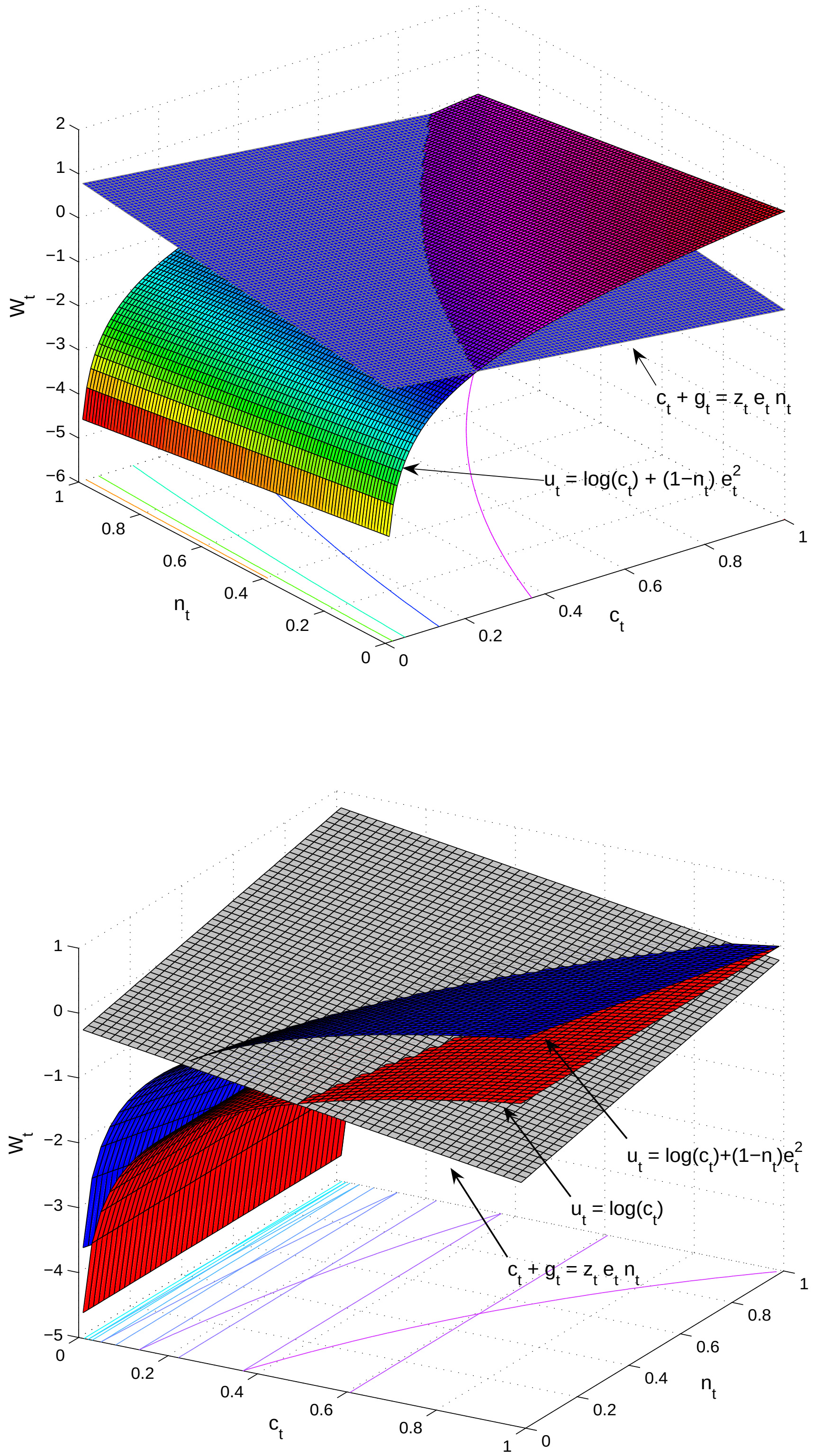
$$\Omega_1 = \frac{\phi_2\, n\, (1-n)^{-1}}{1-\phi_3} \quad \text{and} \quad \Omega_2 = \frac{\phi_4}{1-\phi_3}$$

The above linear quadratic problem is solved similarly to the case where effort varies over the business cycle, i.e., $0 < \psi < 1$, as analytically described above.

The social loss function indicates that the policymaker has an output and inflation stabilization objective. On the one hand, the monetary authority intends to target inflation so as to minimize the inefficient price dispersion. On the other hand, it finds it optimal to target the welfare-relevant output gap, associated with the global maximum of the lifetime utility function of the representative household, to push the economy close to the Pareto efficient allocation. The weight ε/λ assigned on the inflation argument depends on parameters that describe the traditional distortions present in the NNS environment: monopolistic competition, and nominal price stickiness. Similarly, the weight $1/s_c$ assigned on the output gap stabilization is implicitly determined, among other things, by the steady-state level of effort which reflects the efficiency wage considerations.

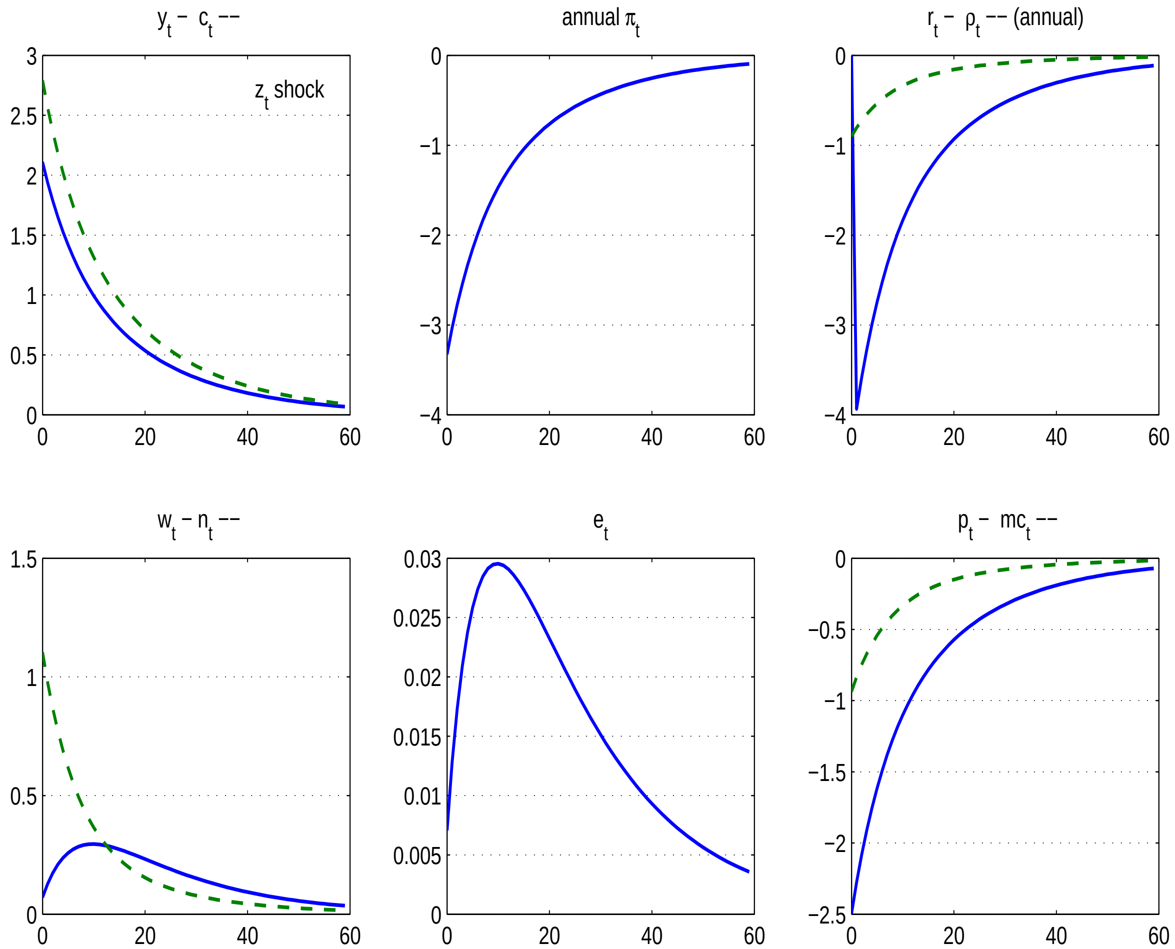
The endogenously derived cost-push component of the NKPC condition reveals that the so-called divine coincidence property (Blanchard and Galí 2007) of the standard New Keynesian model collapses under the fair wage assumption. The real wage rigidity caused by efficiency wage considerations generate in turn labor market wedges that prevent output gap stabilization with strict inflation targeting. Hence, the monetary authority must decide for an optimal trade-off between output and inflation stabilization to minimize the social loss function.

Figure 1: The social welfare, the aggregate resource constraint, and the efficient allocation under the baseline parameterization.



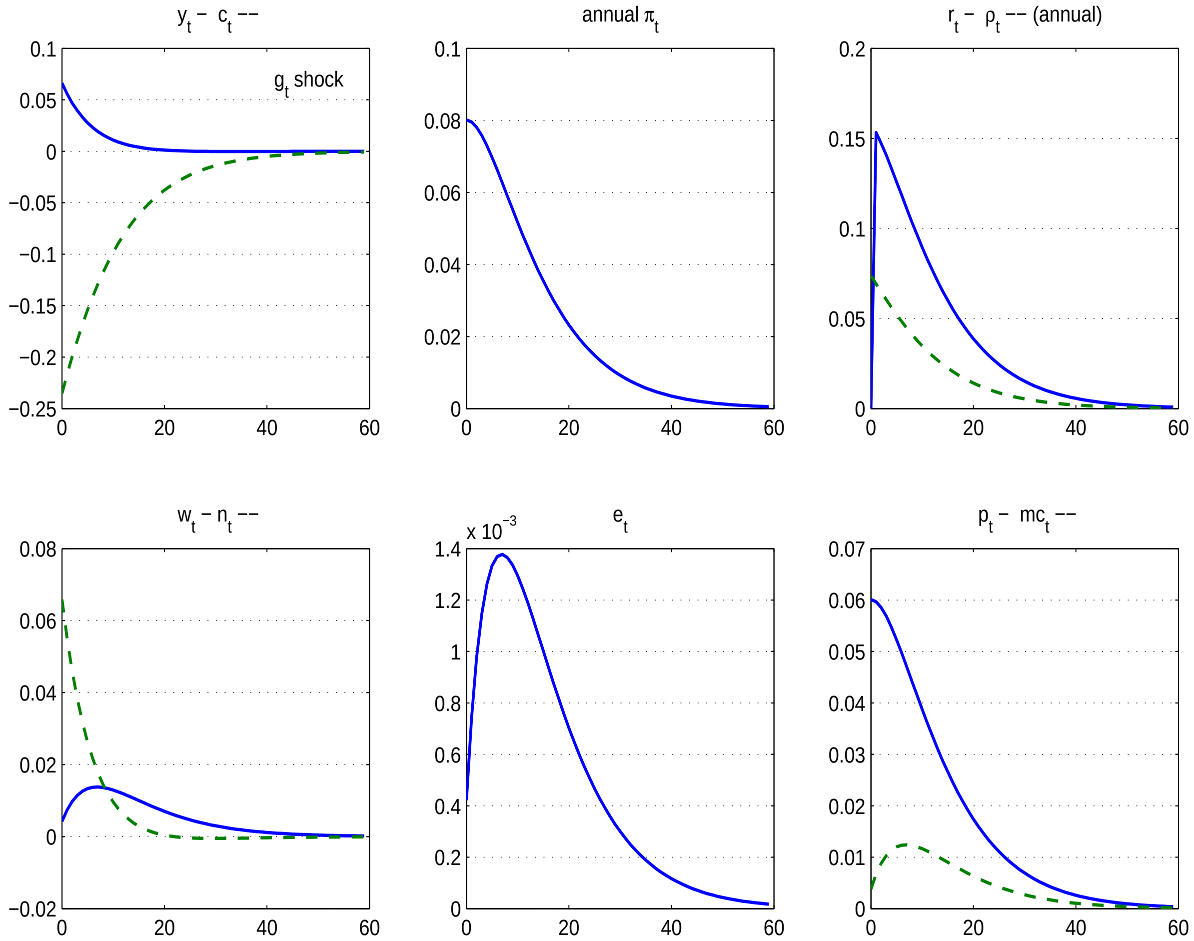
Note: The concave surfaces with respect to employment and consumption give the momentary utility functions $u_t = \ln(c_t) + (1 - n_t)\, e_t^2$ and $u_t = \ln(c_t)$, while the linear surface plots the aggregate resource constraint $c_t + g_t = z_t\, e_t\, n_t$. The maximum of both utility functions is obtained for $n_t = 1$.

Figure 2: Impulse responses under the (non inertial) cyclical Taylor rule ($\hat{r}_t = 1.5\,\hat{\pi}_t + (0.5/4)\,\hat{y}_t$) to 1% productivity shock.



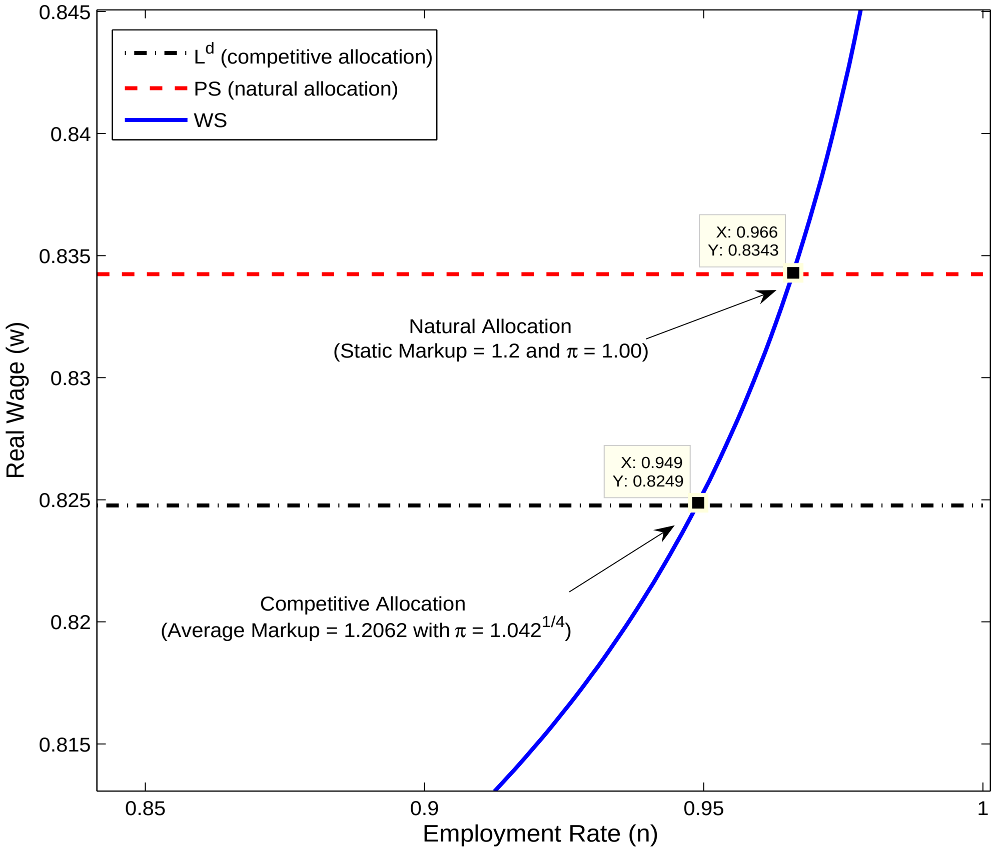
Note: All variables are expressed in percentage deviations from steady-state. y_t = output, c_t = consumption, π_t = (annual) inflation rate, r_t = nominal interest rate, ρ_t = real interest rate ($\rho_t = r_t - E_t(\pi_{t+1})$), n_t = employment, w_t = real wage, e_t = exerted effort, p_t = relative optimal price, mc_t = real marginal cost.

Figure 3: Impulse responses under the (non inertial) cyclical Taylor rule ($\hat{r}_t = 1.5\,\hat{\pi}_t + (0.5/4)\,\hat{y}_t$) to 1% government expenditure shock.



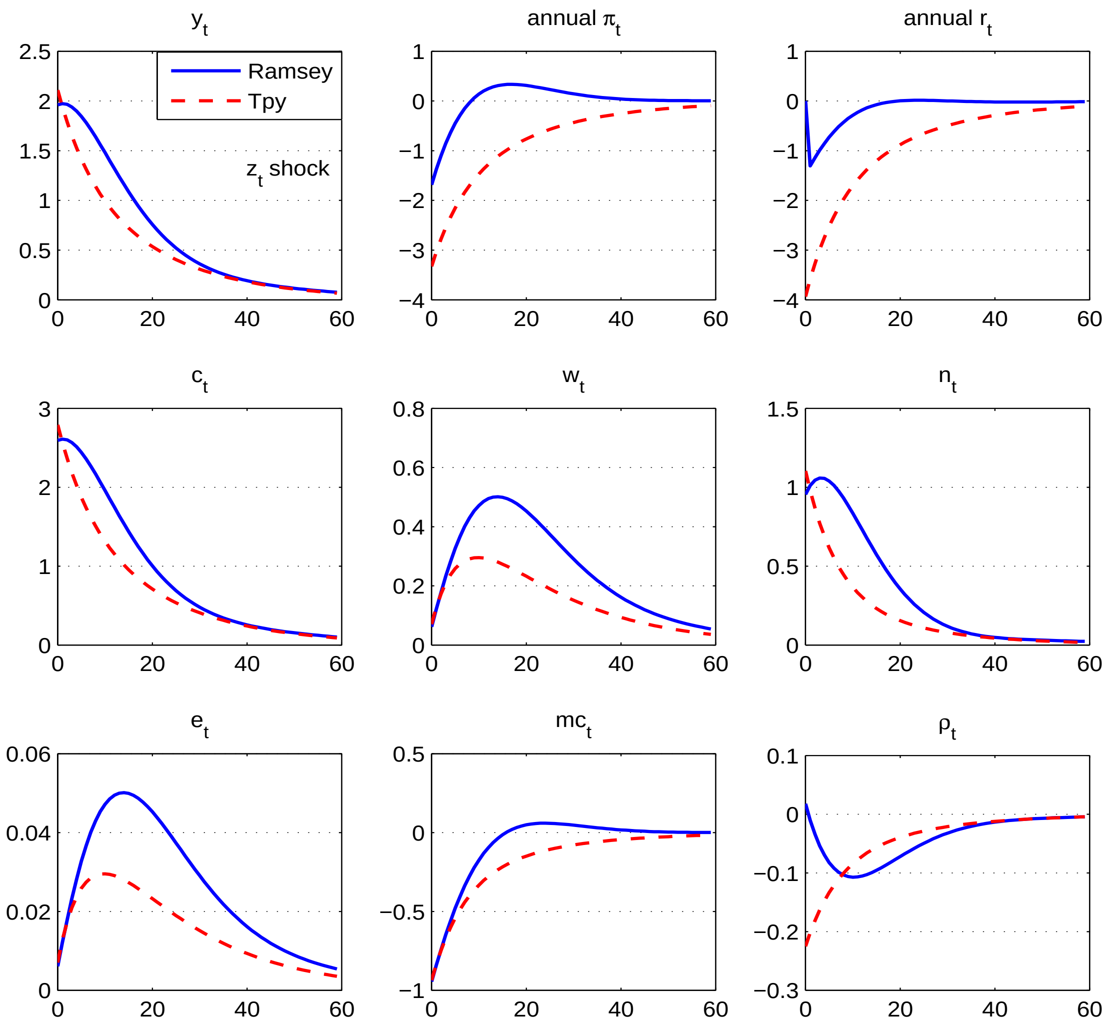
Note: All variables are expressed in percentage deviations from steady-state. y_t = output, c_t = consumption, π_t = (annual) inflation rate, r_t = nominal interest rate, ρ_t = real interest rate ($\rho_t = r_t - E_t(\pi_{t+1})$), n_t = employment, w_t = real wage, e_t = exerted effort, p_t = relative optimal price, mc_t = real marginal cost.

Figure 4: The labor market equilibrium under the competitive and the Ramsey steady-state.



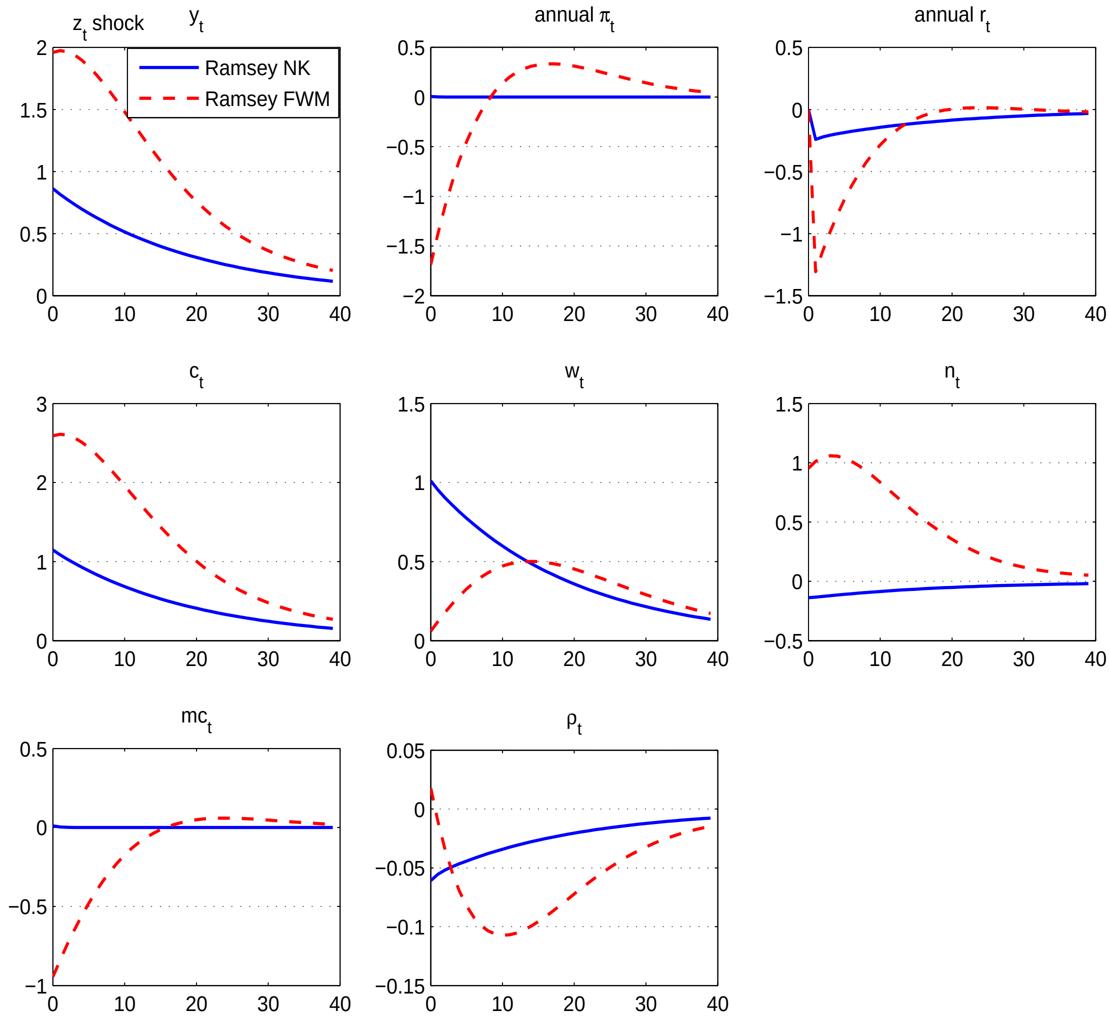
Note: The upward sloping solid line depicts the Wage Setting (WS) curve, which is the labor supply condition in the fair wage approach of the labor market. The dashed-dotted line depicts the labor demand curve ($w_t = mc_t \, mpn_t$) under the competitive equilibrium steady-state where $\pi = 1.042^{1/4}$. The dashed line represents the Price Setting (PS) curve, i.e., the labor demand when prices are completely flexible.

Figure 5: Impulse responses to 1% productivity shock. Comparison between the Ramsey optimal plan and the (non inertial) cyclical Taylor rule ($\hat{r}_t = 1.5\,\hat{\pi}_t + (0.5/4)\,\hat{y}_t$).



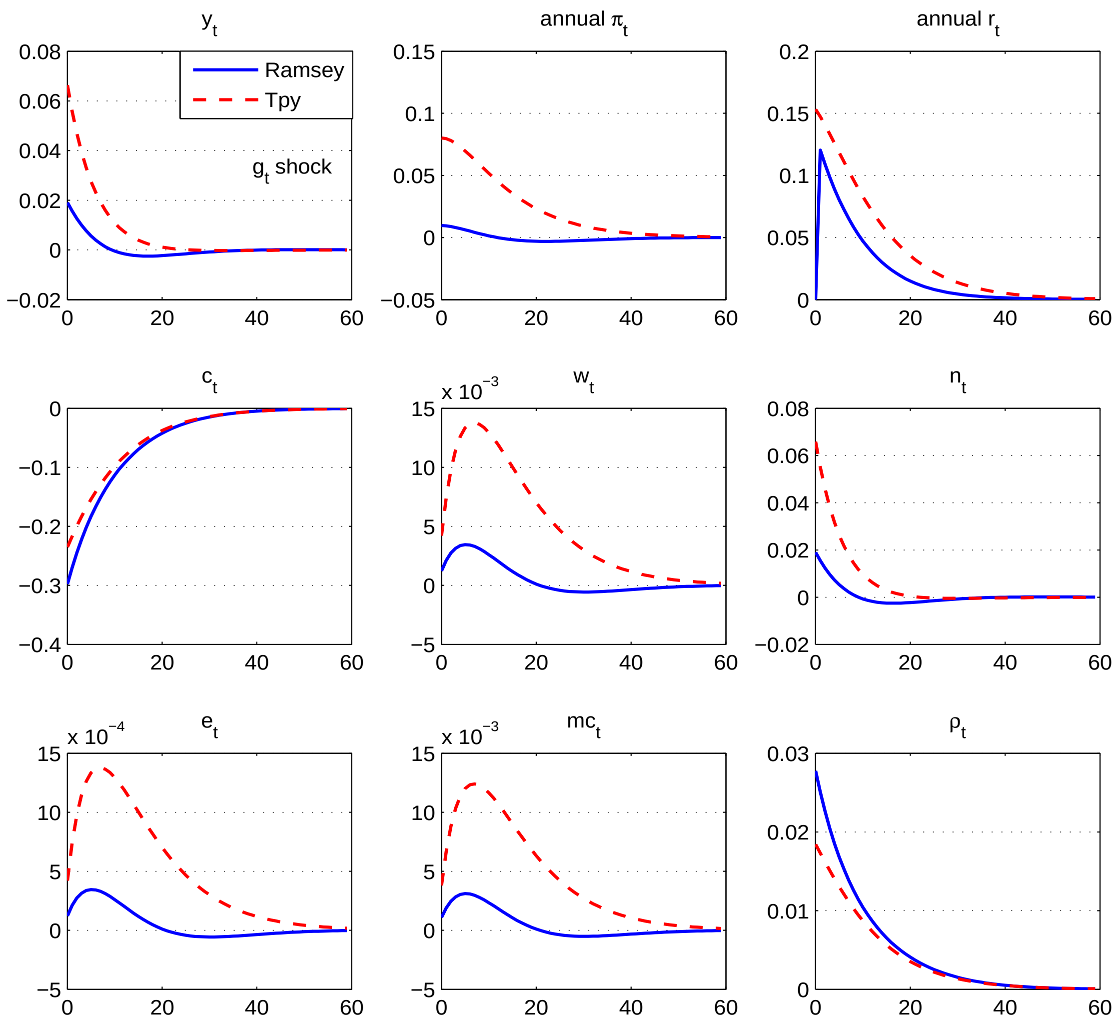
Note: Solid line: Ramsey optimal plan; Dashed line: Cyclical Taylor rule (Tpy). All variables are expressed in percentage deviations from steady-state. y_t = output, π_t = (annual) inflation rate, r_t = (annual) nominal interest rate, c_t = consumption, w_t = real wage, n_t = employment, e_t = exerted effort, mc_t = real marginal cost, ρ_t = real interest rate ($\rho_t = r_t - E_t(\pi_{t+1})$).

Figure 6: Impulse responses under the Ramsey optimal plan to 1% technology shock in the baseline NK model with neoclassical labor market and the NK model with Fair Wages.



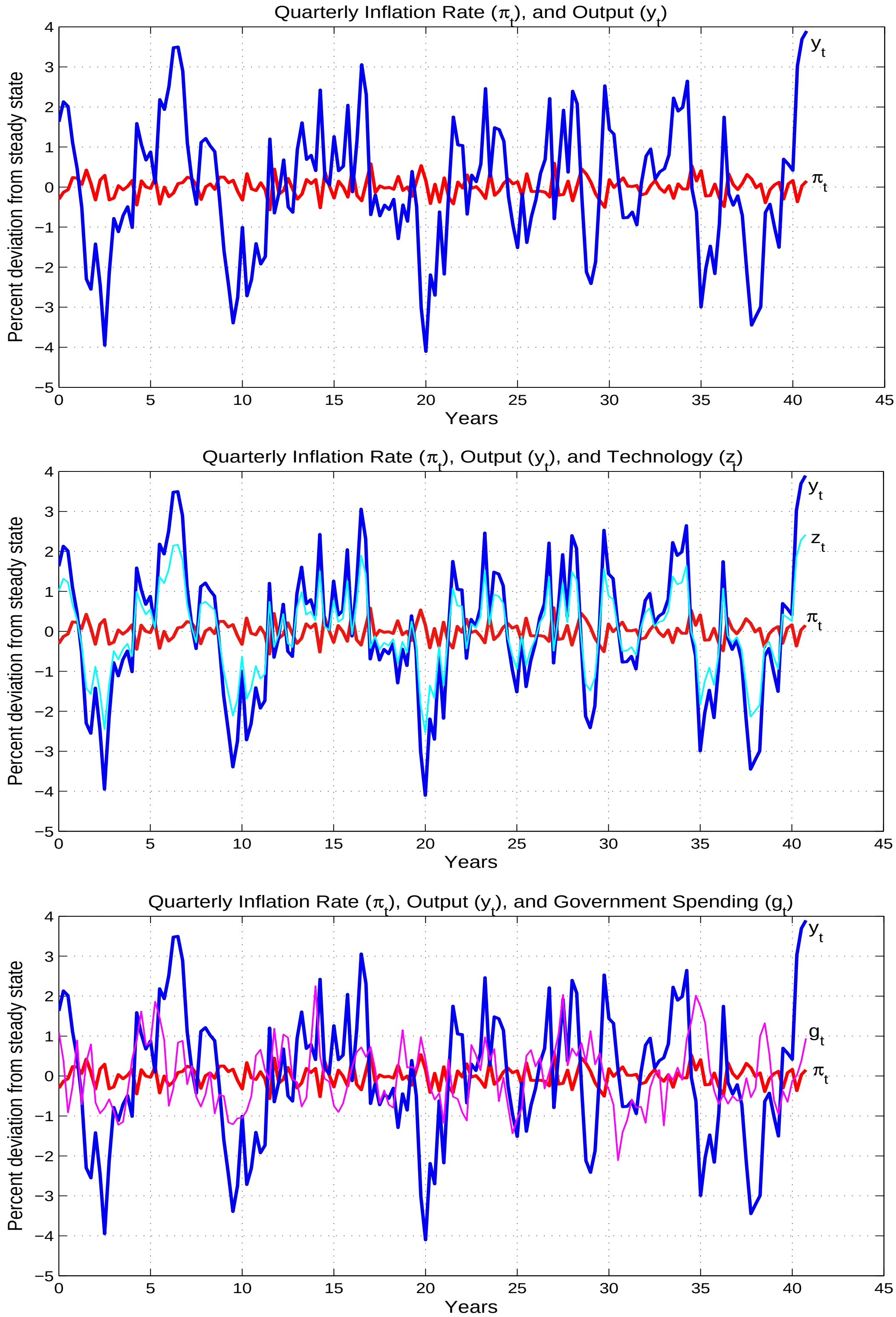
Note: Solid line: Benchmark NK model with neoclassical labor market. Dashed line: Baseline NK model with non Walrasian labor market based on Fair Wage considerations. All variables are expressed in percentage deviations from steady-state. y_t = output, π_t = (annual) inflation rate, r_t = (annual) nominal interest rate, c_t = consumption, w_t = real wage, n_t = employment, mc_t = real marginal cost, ρ_t = real interest rate ($\rho_t = r_t - E_t(\pi_{t+1})$).

Figure 7: Impulse responses to 1% government spending shock. Comparison between the Ramsey optimal plan and the (non inertial) cyclical Taylor rule ($\hat{r}_t = 1.5\,\hat{\pi}_t + (0.5/4)\,\hat{y}_t$).



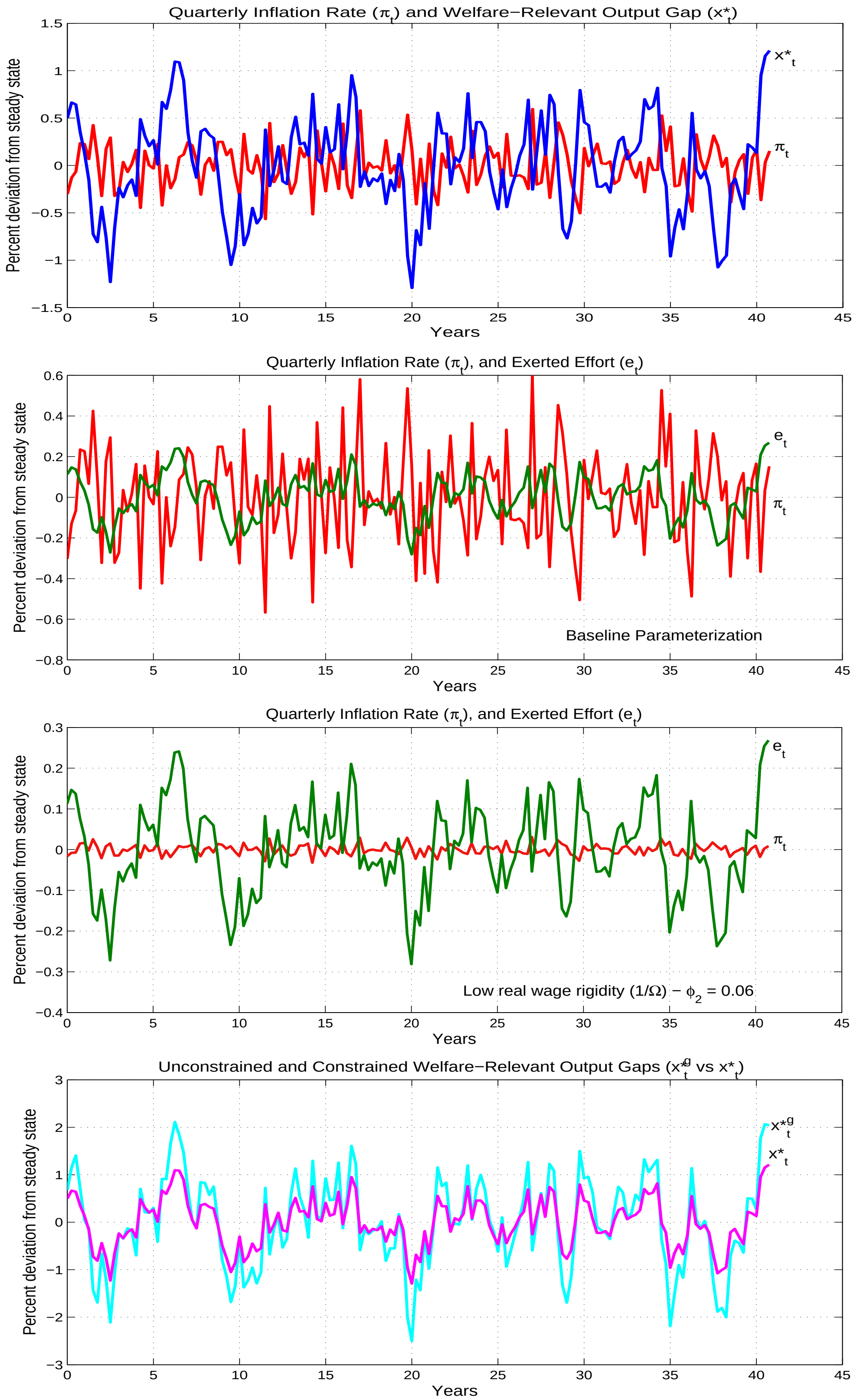
Note: Solid line: Ramsey optimal plan; Dashed line: Cyclical Taylor rule (Tpy). All variables are expressed in percentage deviations from steady-state. y_t = output, π_t = (annual) inflation rate, r_t = (annual) nominal interest rate, c_t = consumption, w_t = real wage, n_t = employment, e_t = exerted effort, mc_t = real marginal cost, ρ_t = real interest rate ($\rho_t = r_t - E_t(\pi_{t+1})$).

Figure 8: Simulated Series (HP-filtered) for selected macro-variables under the Optimal Monetary Policy.



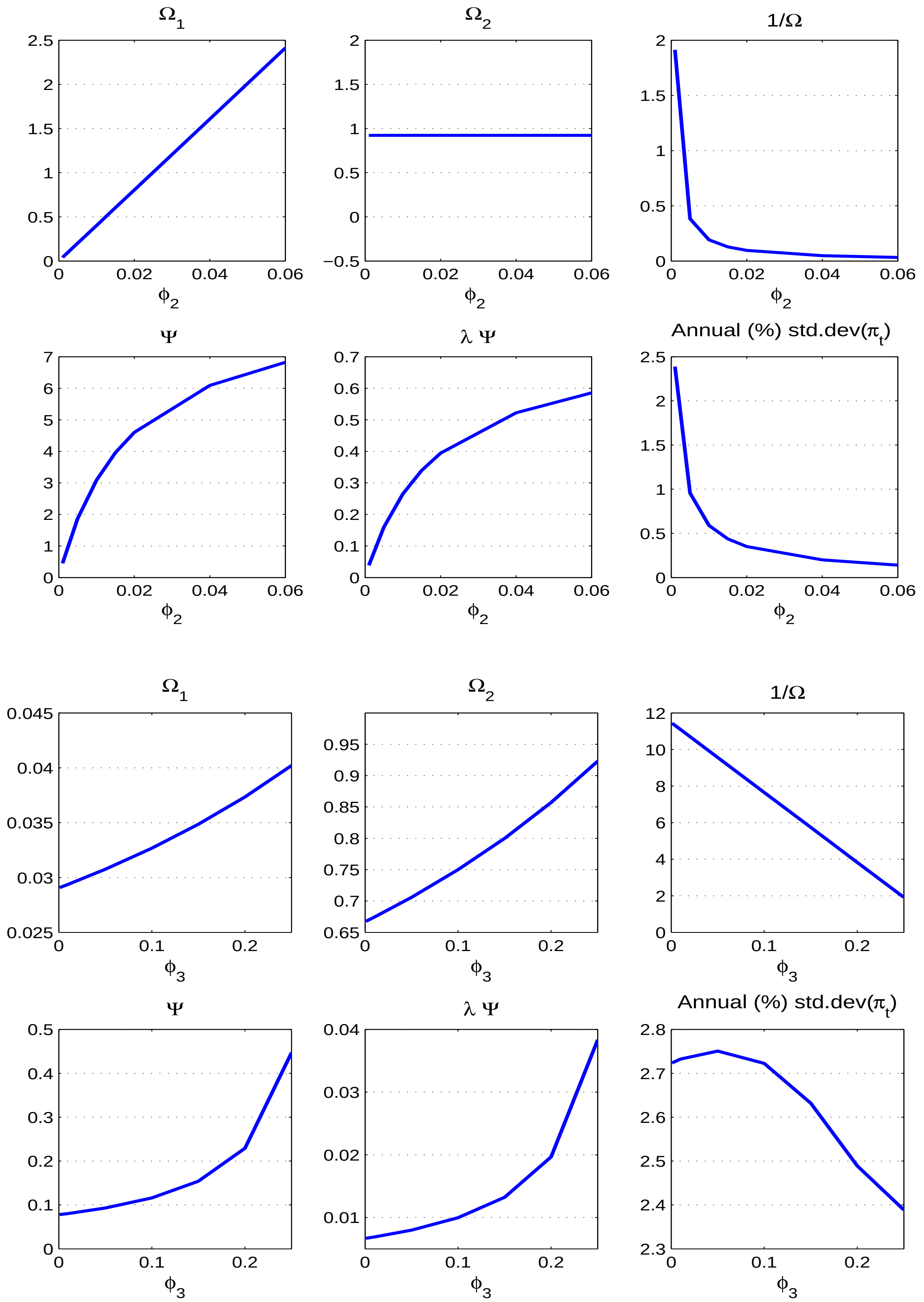
Note: The simulated time series were generated in response to both z_t and g_t shock, and detrended with the H-P filter with $\lambda = 1600$.

Figure 9: Simulated Series (HP-filtered) for selected macro-variables under the Optimal Monetary Policy.



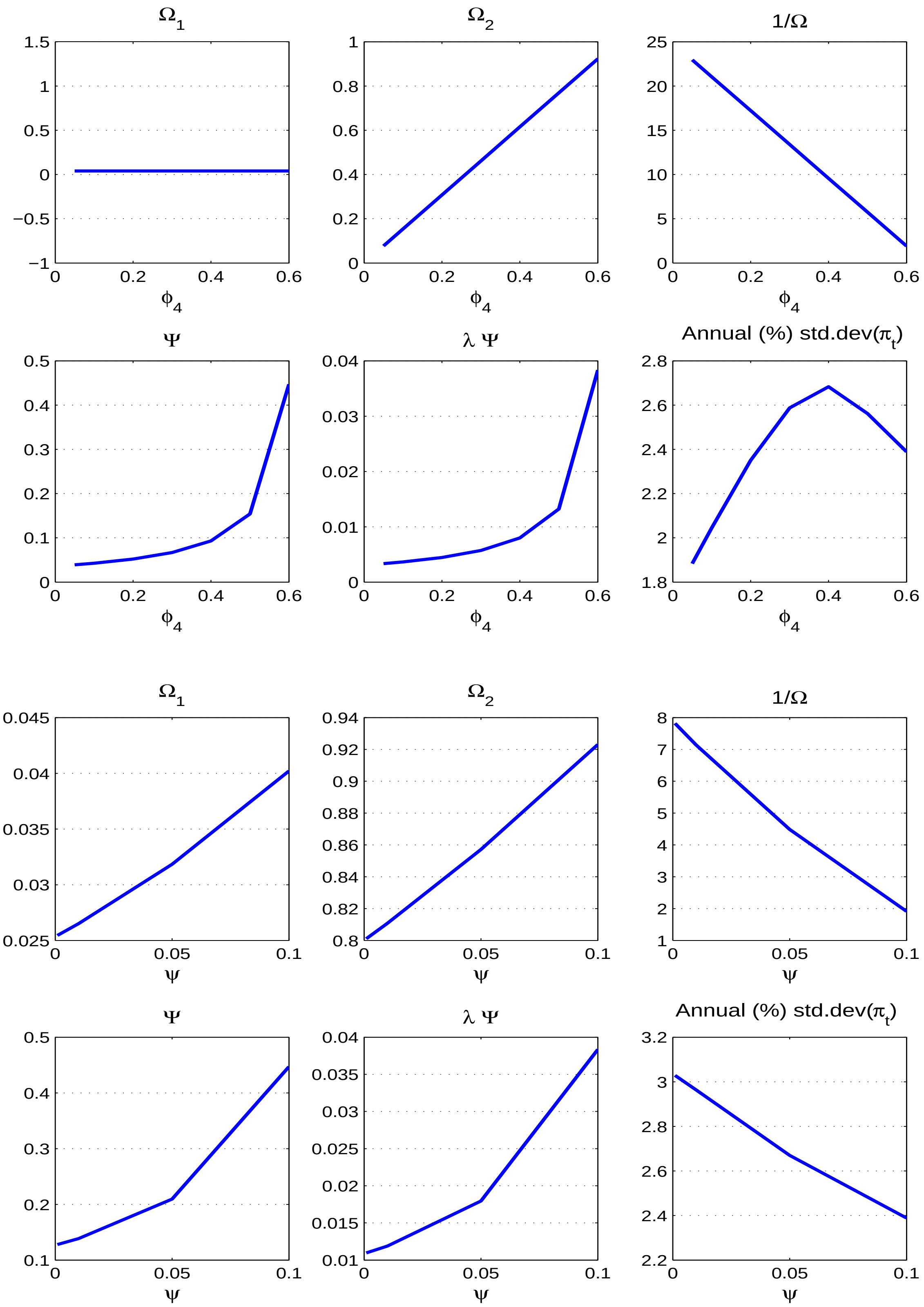
Note: The simulated time series were generated in response to both z_t and g_t shock, and detrended with the H-P filter with $\lambda = 1600$.

Figure 10: Optimal Inflation Volatility and Real Wage Rigidity Measures for alternative values of effort sensitivity to labor market tightness (ϕ_2) and current real wage (ϕ_3).



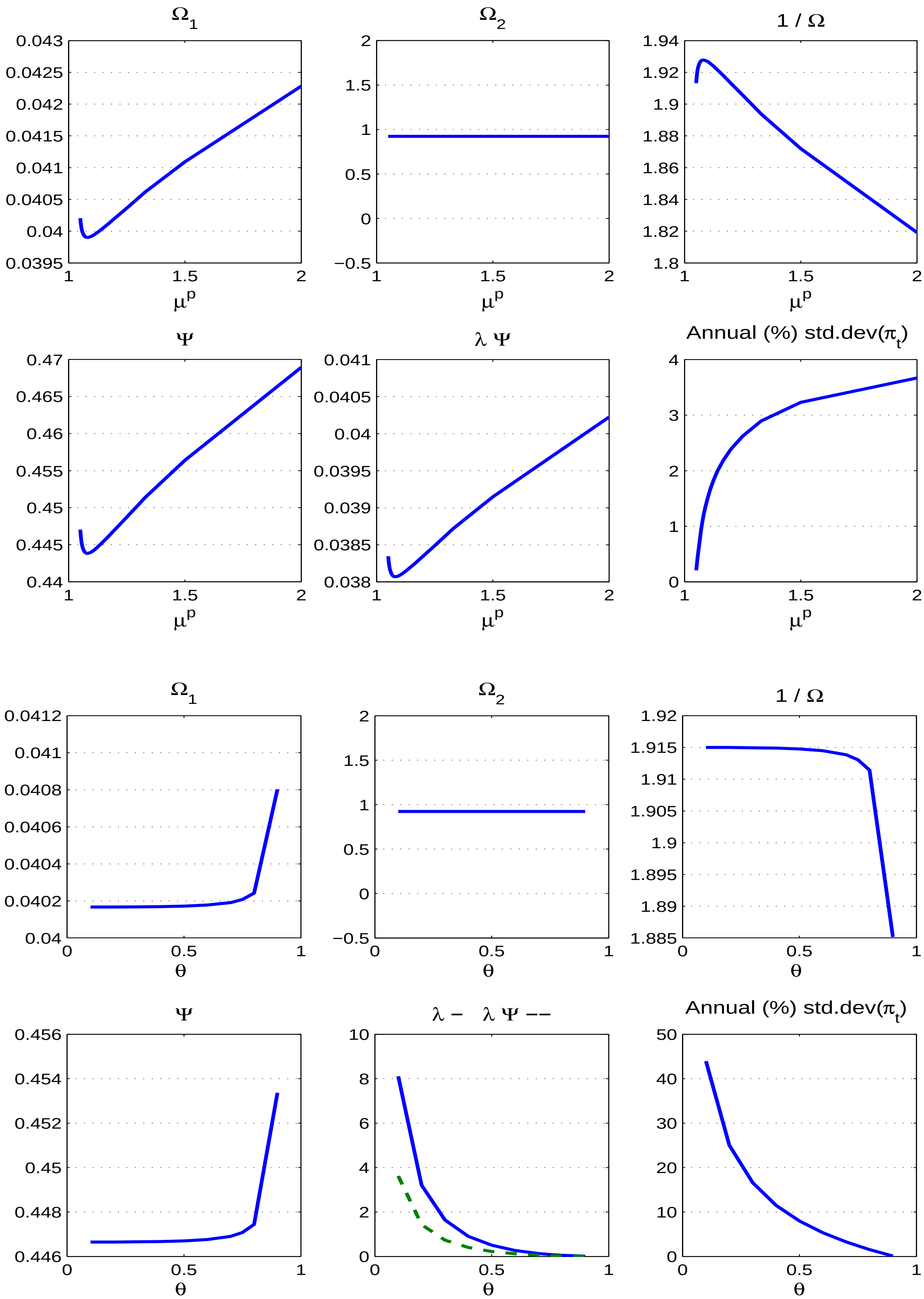
Note: Ω_1: wage elasticity to employment; Ω_2: wage elasticity to past wage (w_t sluggishness); $1/\Omega$: Real wage rigidity measure; Ψ: mc_t sensitivity to output gap; $\lambda\,\Psi$: NKPC coefficient on output gap; std.dev(π_t): annualized standard deviation of inflation rate under the Ramsey (optimal) plan.

Figure 11: Optimal Inflation Volatility and Real Wage Rigidity Measures for alternative values of effort sensitivity to lagged aggregate wage (ϕ_4) and the substitutability between effort function arguments (ψ).



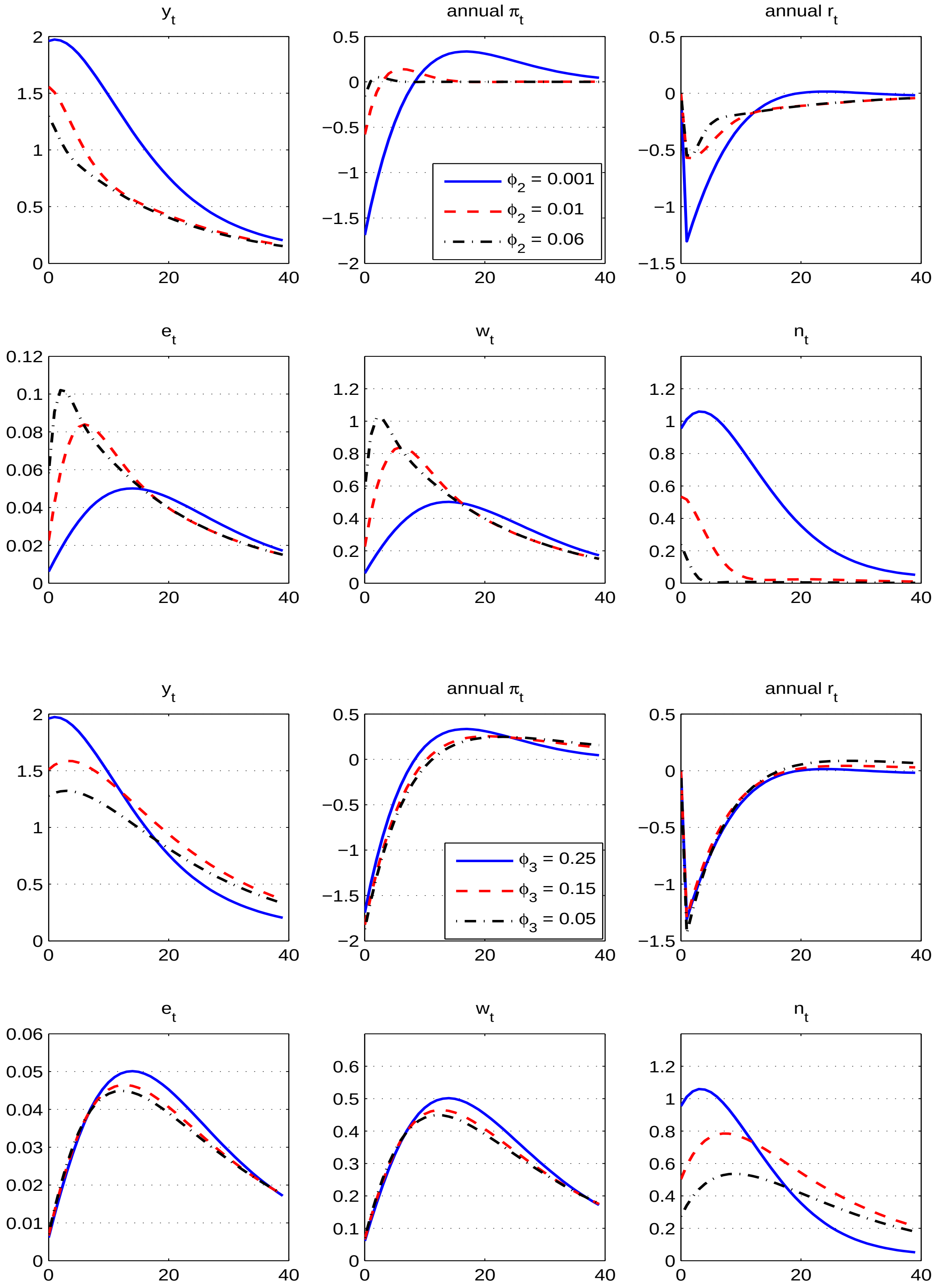
Note: Ω_1: wage elasticity to employment; Ω_2: wage elasticity to past wage (w_t sluggishness); $1/\Omega$: Real wage rigidity measure; Ψ: mc_t sensitivity to output gap; $\lambda\,\Psi$: NKPC coefficient on output gap; std.dev(π_t): annualized standard deviation of inflation rate under the Ramsey (optimal) plan.

Figure 12: Optimal Inflation Volatility and Real Wage Rigidity Measures for alternative values of static markup (μ^p) and Calvo price stickiness (θ).



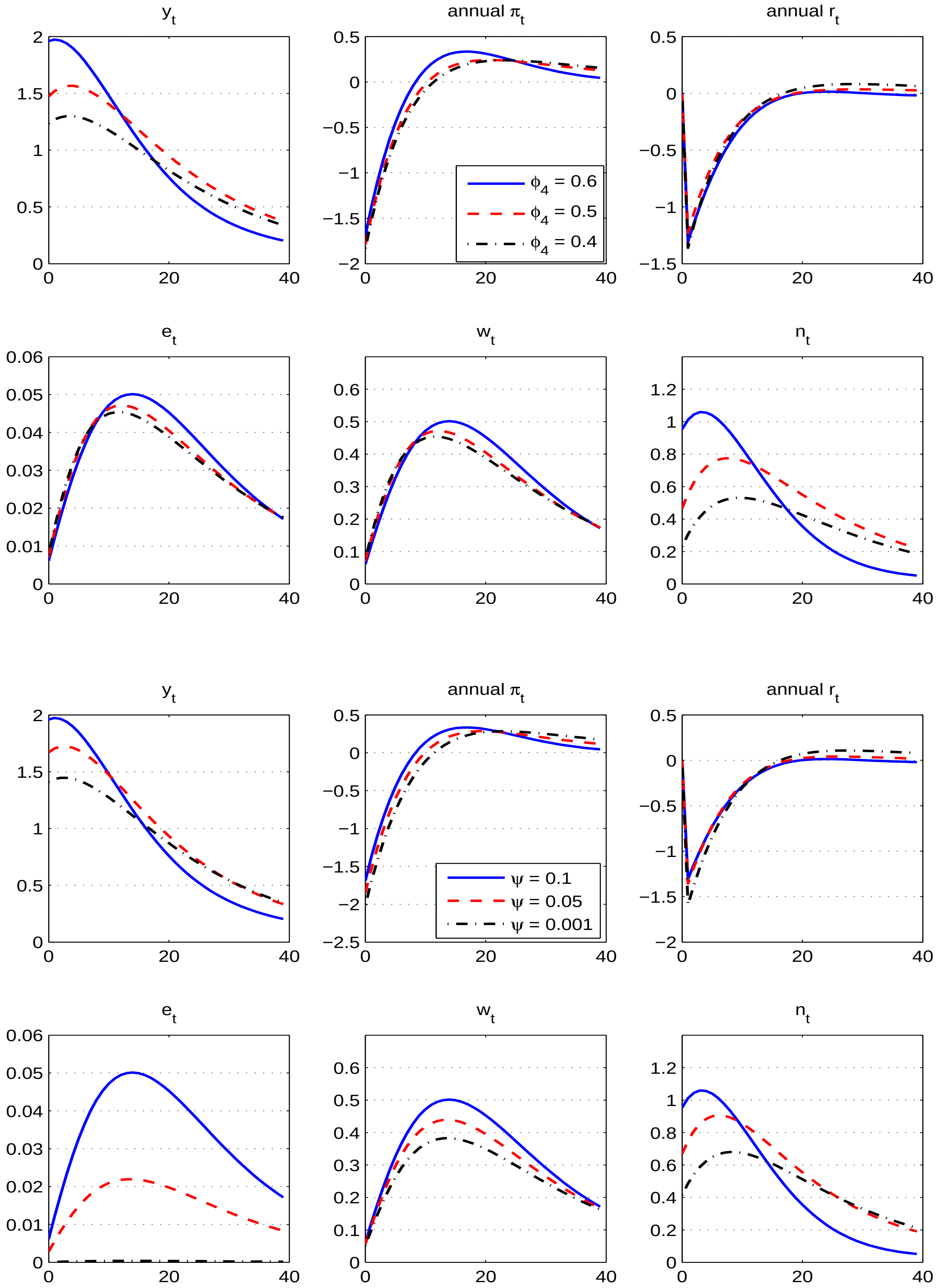
Note: Ω_1: wage elasticity to employment; Ω_2: wage elasticity to past wage (w_t sluggishness); $1/\Omega$: Real wage rigidity measure; Ψ: mc_t sensitivity to output gap; $\lambda\,\Psi$: NKPC coefficient on output gap; std.dev(π_t): annualized standard deviation of inflation rate under the Ramsey (optimal) plan.

Figure 13: Impulse responses under the Ramsey optimal plan to 1% productivity shock for alternative values of the effort sensitivity to labor market tightness (ϕ_2) and real wage (ϕ_3).



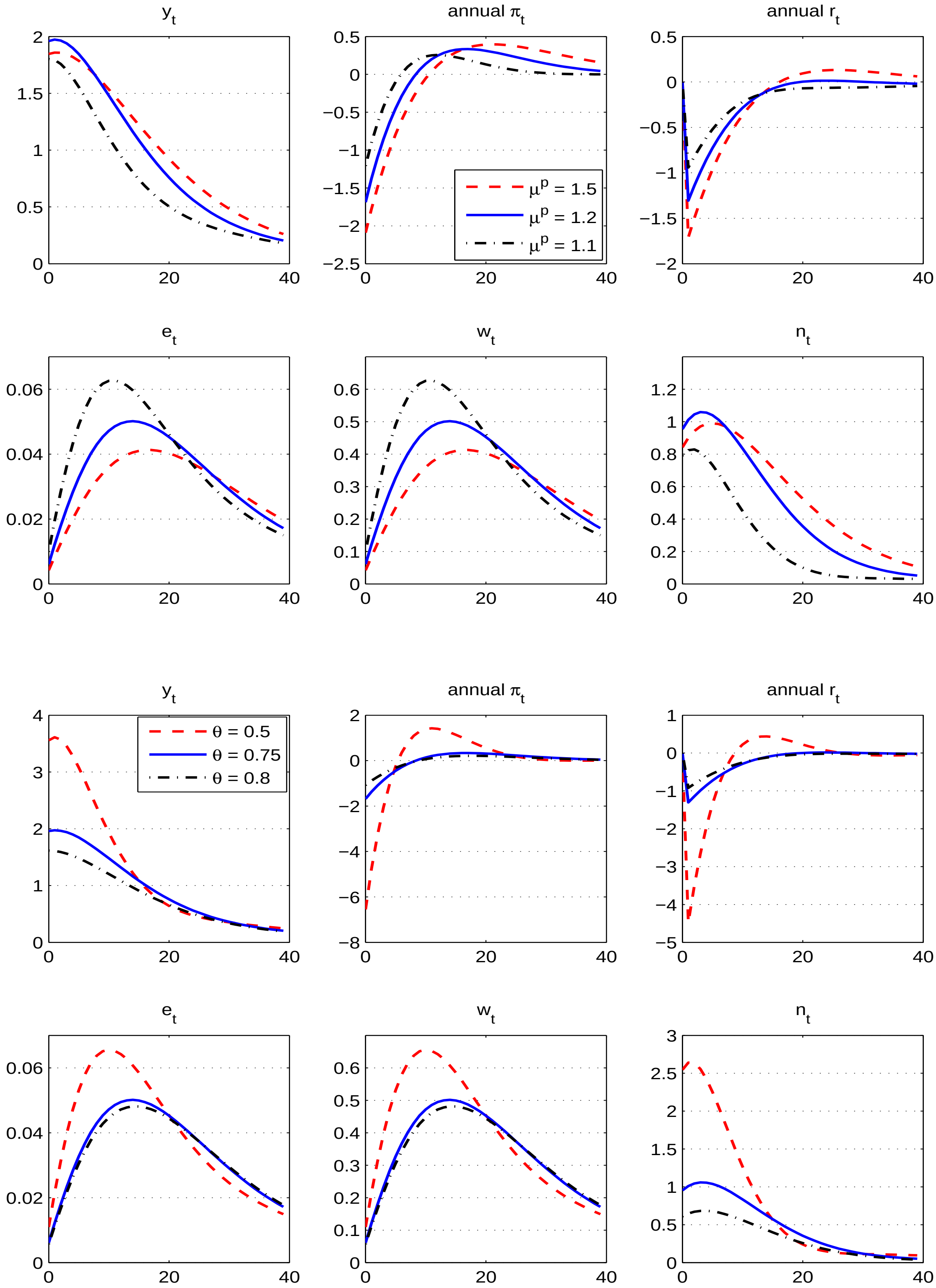
Note: All variables are expressed in percentage deviations from steady-state. y_t = output, π_t = annual inflation rate, r_t = nominal interest rate, w_t = real wage, e_t = exerted effort of workers, n_t = employment.

Figure 14: Impulse responses under the Ramsey optimal plan to 1% productivity shock for alternative values of the substitutability between effort arguments (ψ) and effort sensitivity to lagged wage (ϕ_4).



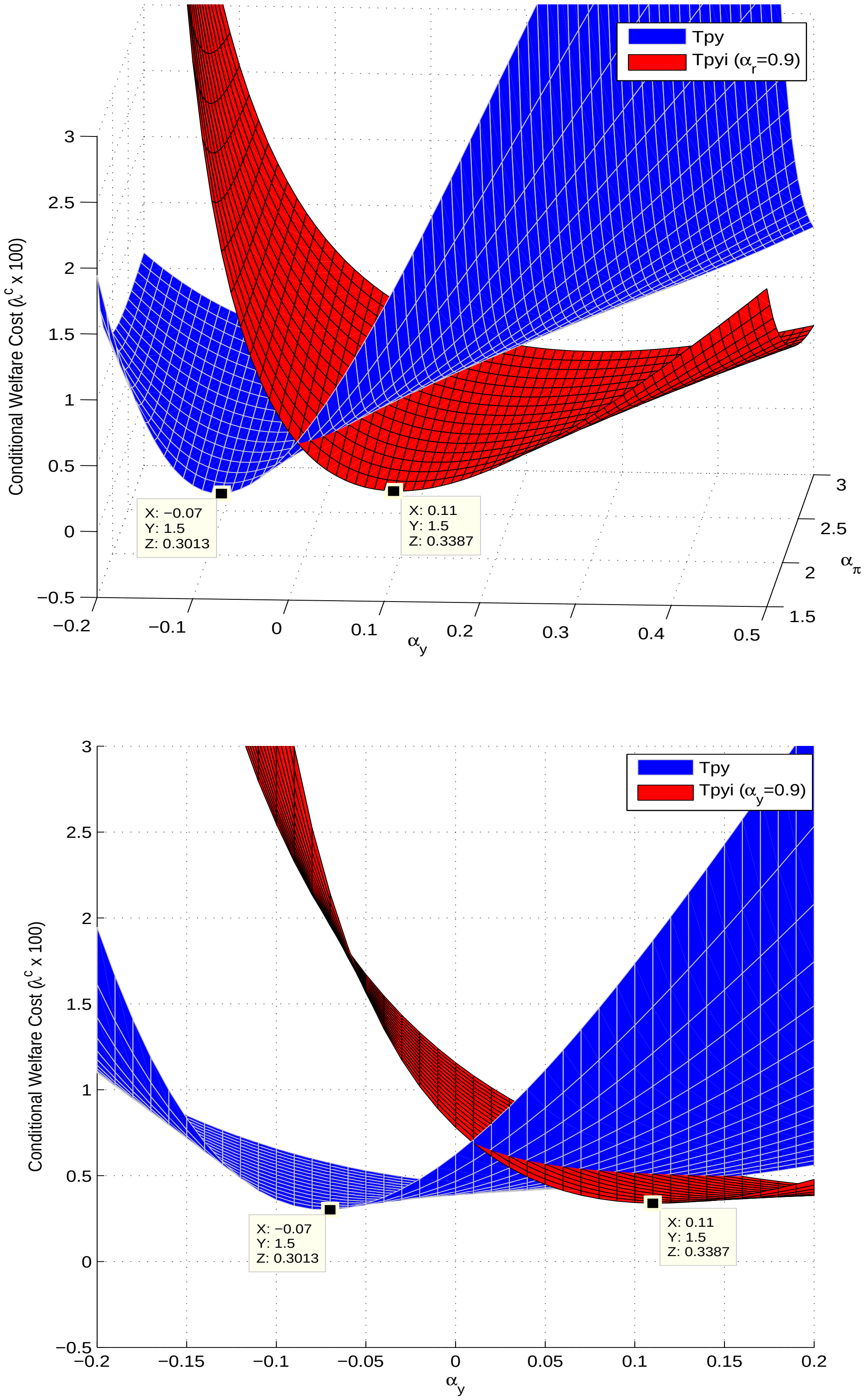
Note: All variables are expressed in percentage deviations from steady-state. y_t = output, π_t = annual inflation rate, r_t = nominal interest rate, w_t = real wage, e_t = exerted effort of workers, n_t = employment.

Figure 15: Impulse responses under the Ramsey optimal plan to 1% productivity shock for alternative values of static markup (μ_p) and Calvo price stickiness (θ).



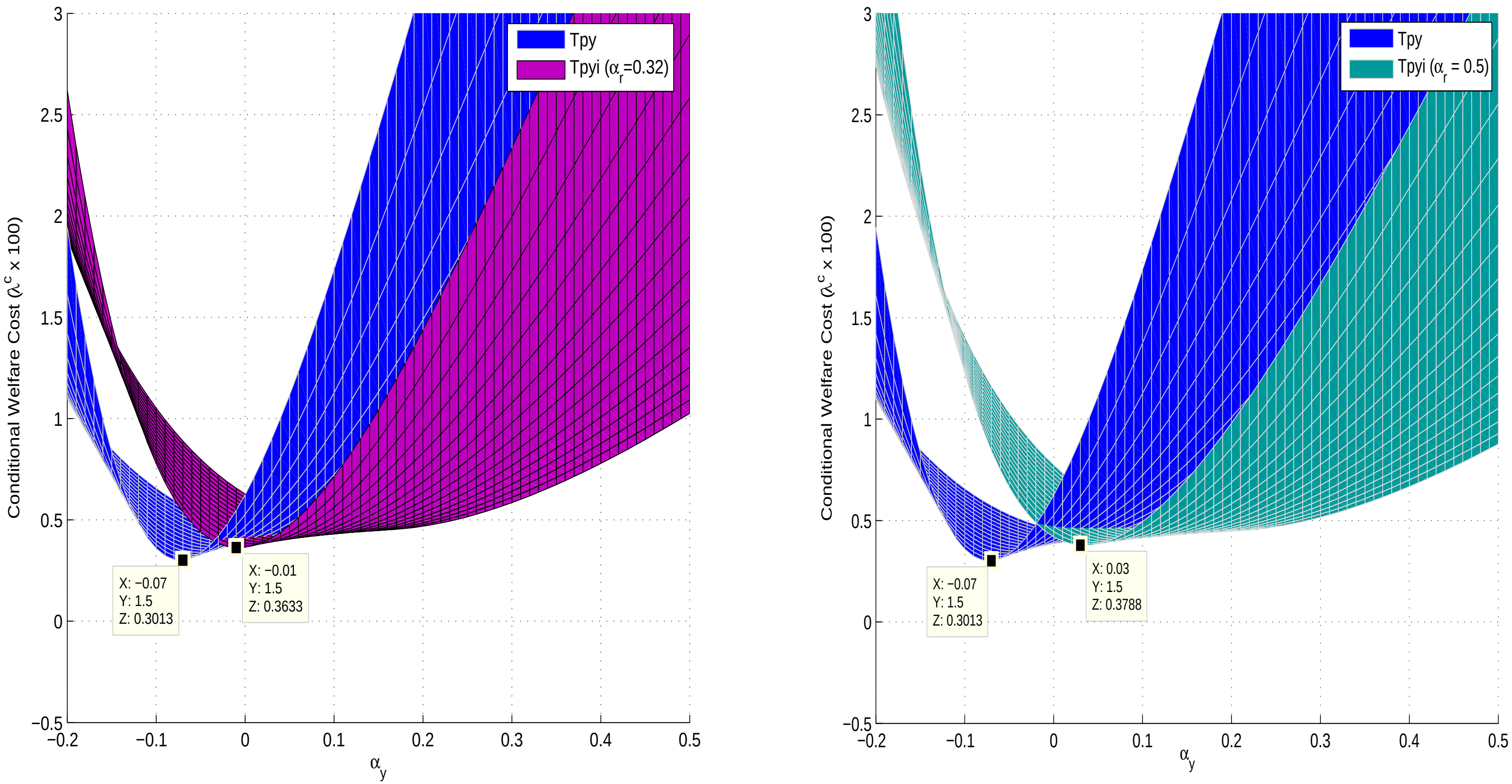
Note: All variables are expressed in percentage deviations from steady-state. y_t = output, π_t = annual inflation rate, r_t = nominal interest rate, w_t = real wage, e_t = exerted effort of workers, n_t = employment.

Figure 16: Welfare Evaluation of Cyclical Taylor Rules $\hat{r}_t = \alpha_r\,\hat{r}_{t-1} + \alpha_\pi\,\hat{\pi}_t + \alpha_y\,\hat{y}_t$.



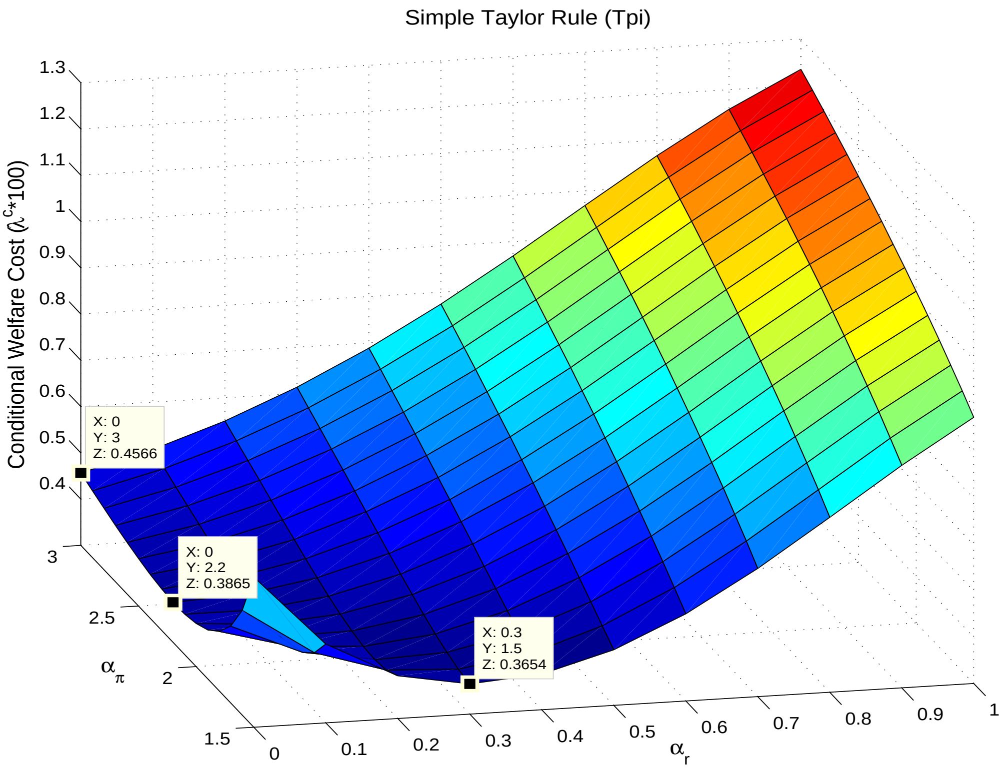
Note: Conditional welfare costs λ^cx100 are computed with second order perturbation method when the model economy is perturbed by both neutral technology and government expenditure shocks.

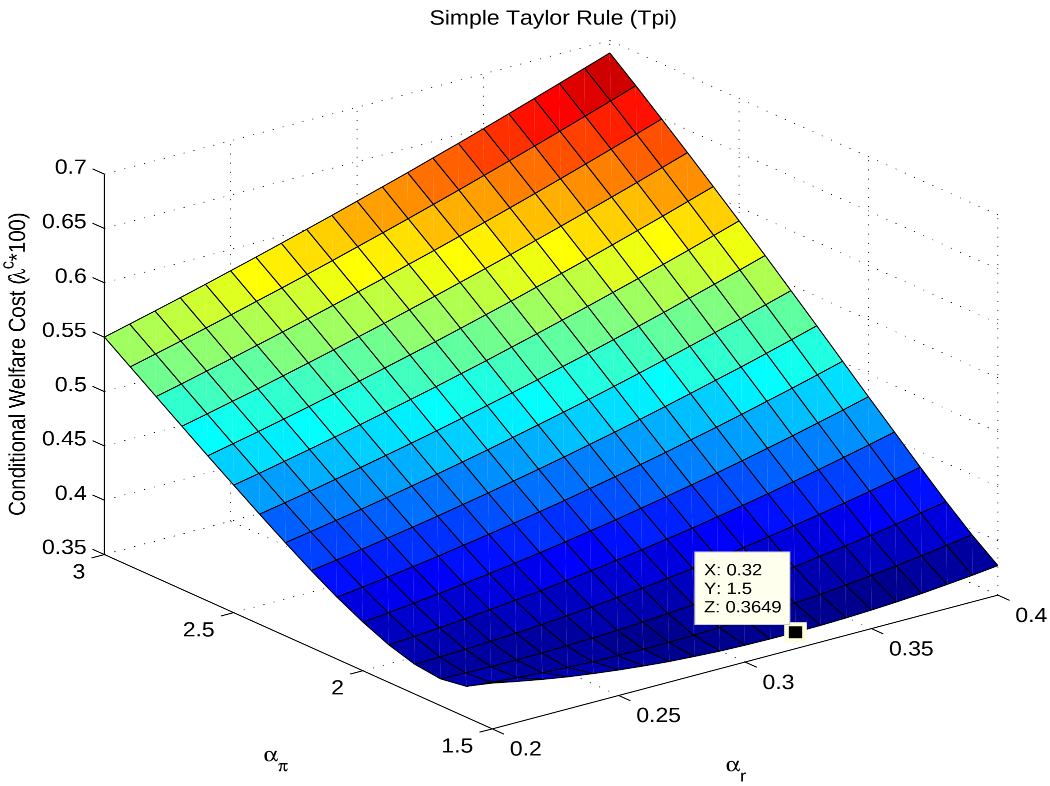
Figure 17: Welfare Evaluation of Cyclical Taylor Rules ($\hat{r}_t = \alpha_r \, \hat{r}_{t-1} + \alpha_\pi \, \hat{\pi}_t + \alpha_y \, \hat{y}_t$) for alternative degrees of interest rate inertia.



Note: Conditional welfare costs λ^cx100 are computed with second order perturbation method when the model economy is perturbed by both neutral technology and government expenditure shocks.

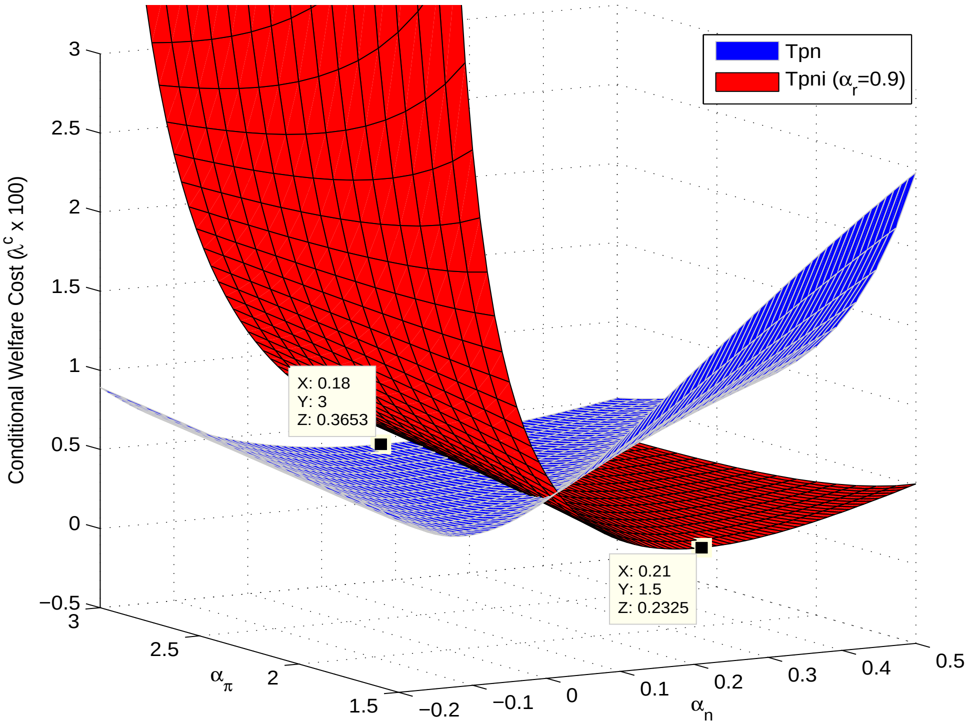
Figure 18: Welfare Evaluation of (Acyclical) Simple Taylor Rule $\hat{r}_t = \alpha_r\, \hat{r}_{t-1} + \alpha_\pi\, \hat{\pi}_t$.

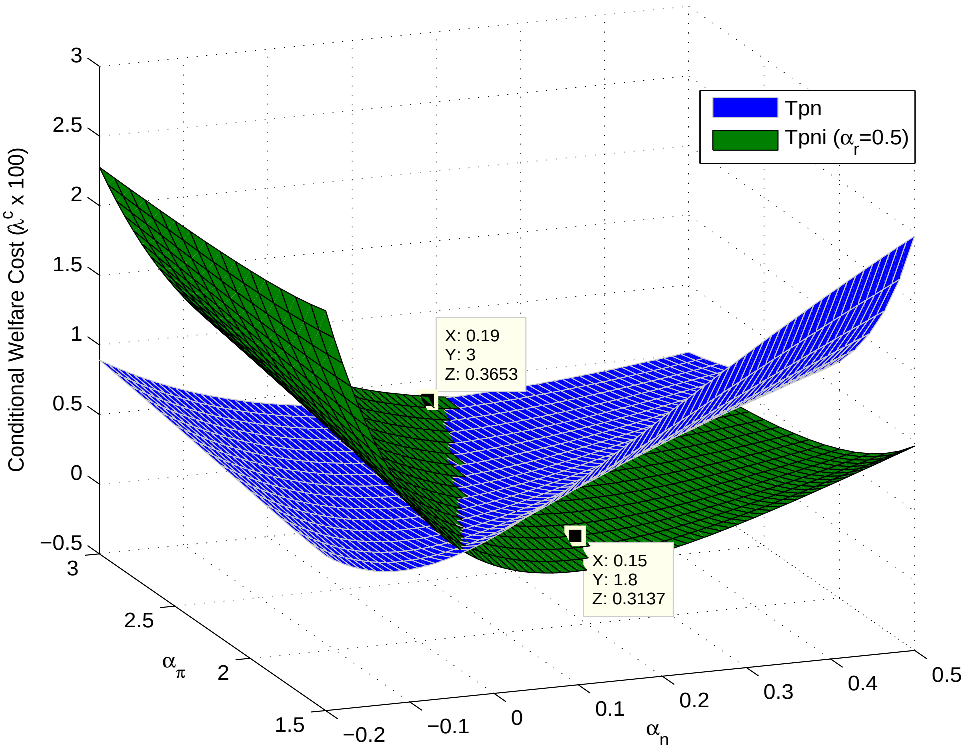




Note: Conditional welfare costs λ^cx100 are computed with second order perturbation method when the model economy is perturbed by both neutral technology and government expenditure shocks.

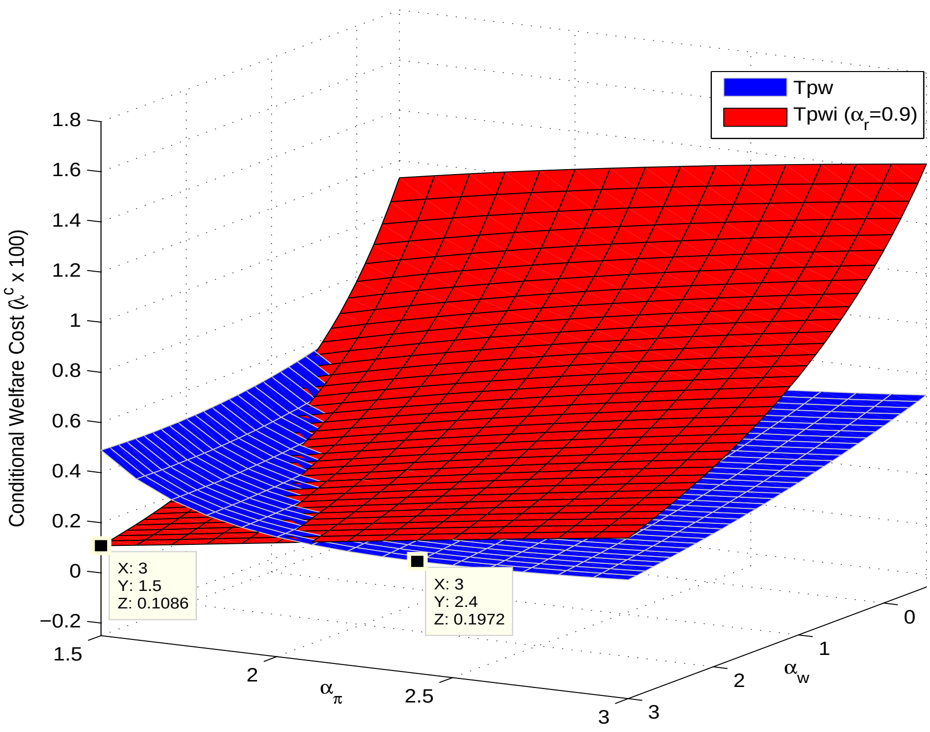
Figure 19: Welfare Evaluation of Employment Taylor Rules $\hat{r}_t = \alpha_r\, \hat{r}_{t-1} + \alpha_\pi\, \hat{\pi}_t + \alpha_n\, \hat{n}_t$.

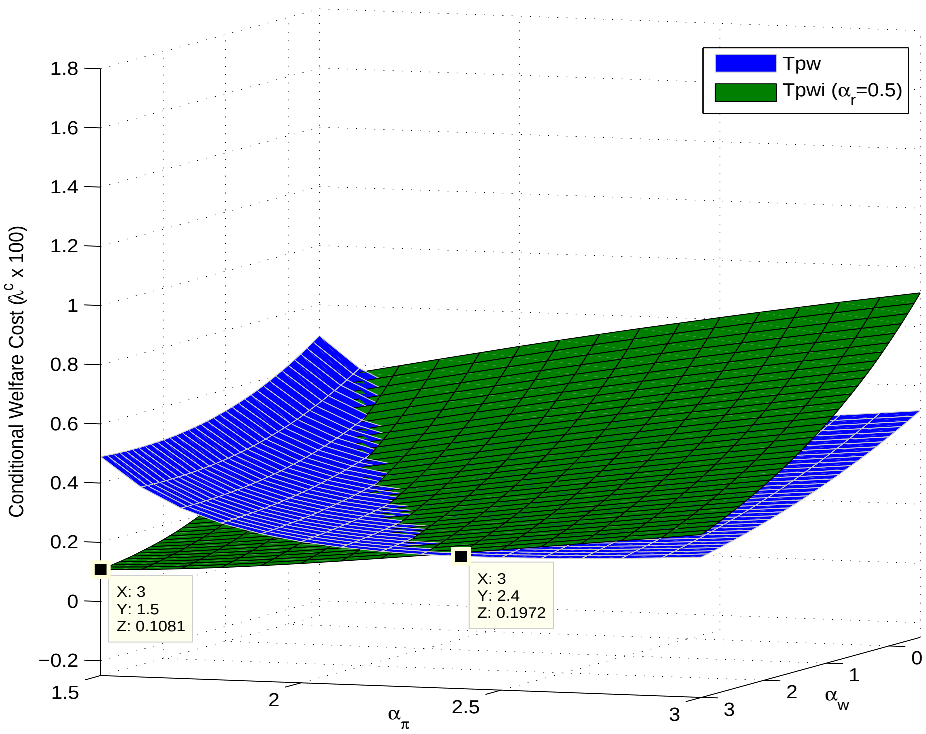




Note: Conditional welfare costs λ^cx100 are computed with second order perturbation method when the model economy is perturbed by both neutral technology and government expenditure shocks.

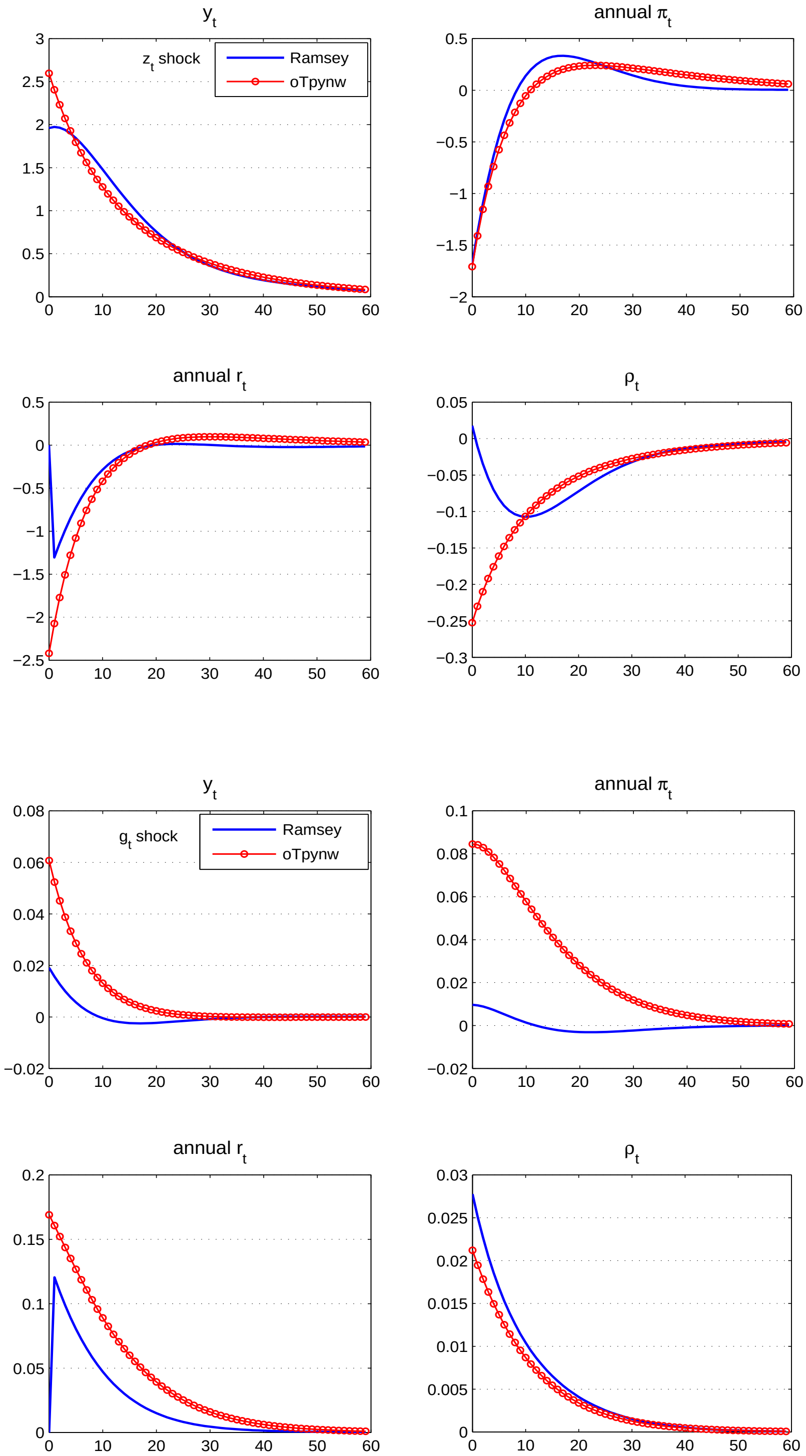
Figure 20: Welfare Evaluation of Wage Taylor Rules $\hat{r}_t = \alpha_r \, \hat{r}_{t-1} + \alpha_\pi \, \hat{\pi}_t + \alpha_w \, \hat{g}_t^w$.





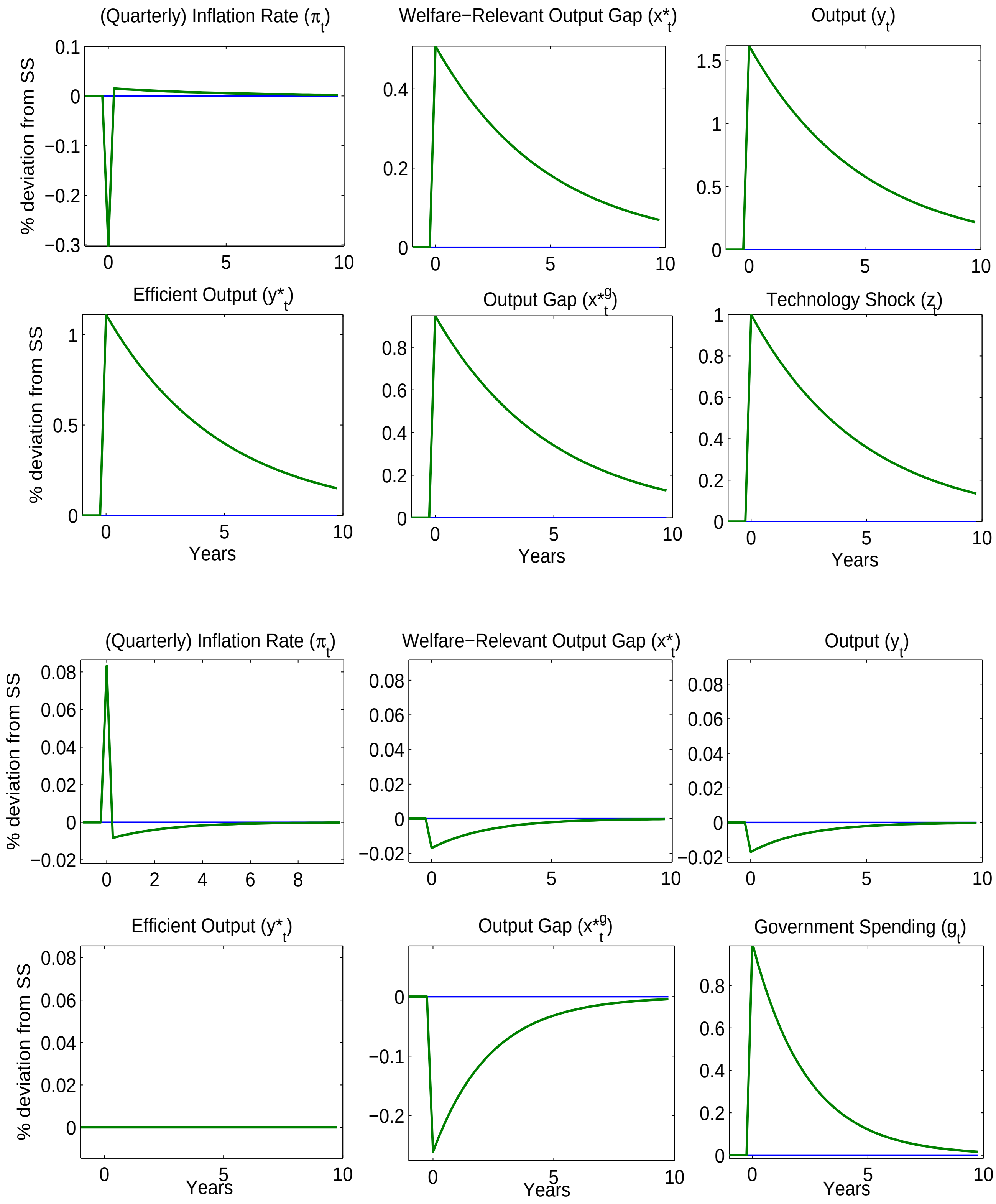
Note: Conditional welfare costs λ^cx100 are computed with second order perturbation method when the model economy is perturbed by both neutral technology and government expenditure shocks.

Figure 21: Impulse responses of selected variables to 1% increase of productivity (upper subplot) and government expenditure (bottom subplot) shocks. Comparison between the Ramsey plan and the generalized optimal non inertial Taylor rule.



Note: All variables are expressed in percentage deviations from steady-state. y_t = output, π_t = (annual) inflation rate, r_t = (annual) nominal interest rate, ρ_t = real interest rate. Solid line: Ramsey plan. Circled line: Optimal generalized (contemporaneous) Taylor rule without inertia (oTpynw: $\hat{r}_t = 0.9017\,\hat{r}_{t-1} + 1.5\,\hat{\pi}_t - 0.244\,\hat{y}_t + 0.5\,\hat{n}_t + 3.0\,\hat{g}_t^w$).

Figure 22: Linear Quadratic Approach: Impulse responses under the optimal monetary policy to 1% increase of technology (upper subplot) and government expenditure (bottom subplot) shock.



Note: All variables are expressed in percentage deviations from the constrained efficient allocation (Ramsey steady-state). π_t: quarterly inflation rate. x_t^*: welfare-relevant output gap. y_t: output. y_t^*: efficient output. $\hat{x}_t^{*g}$: output gap associated with the global maximum of the lifetime utility function. z_t: neutral technology. g_t: government spending.

Figure 23: Determinacy Regions of Simple (Contemporaneous) Taylor Rules.