Macroeconomic Dynamics, **17**, 2013, 464–475. Printed in the United States of America.
doi:10.1017/S1365100511000083

NOTES

QUADRATIC LABOR ADJUSTMENT COSTS, BUSINESS CYCLE DYNAMICS, AND OPTIMAL MONETARY POLICY

WOLFGANG LECHTHALER
Kiel Institute for the World Economy

DENNIS J. SNOWER
Kiel Institute for the World Economy
and
University Kiel

We build quadratic labor adjustment costs into an otherwise standard New Keynesian model of the business cycle and show that this increases output persistence in a vein similar to that of other models of labor market frictions. Furthermore, we demonstrate the implication of quadratic labor adjustment costs for monetary policy. We show that there is a simple rule determining whether quadratic labor adjustment costs imply a trade-off between stabilizing inflation and output.

Keywords: Monetary Persistence, Labor Adjustment Costs, Optimal Monetary Policy

1. INTRODUCTION

Recently, many attempts have been undertaken to incorporate labor market frictions into otherwise standard New Keynesian models to improve the performance of the latter, e.g., to increase the persistence of output in response to monetary shocks. The approaches used range from linear labor turnover costs[1] over fair wages[2] to search and matching frictions.[3] Recent attempts to use quadratic labor adjustment costs are those of Dib (2003) and Janko (2008), who show that this improves the performance of the model. Quadratic labor adjustment costs are also popular in large-scale DSGE-models.[4]

Although models of quadratic labor adjustment costs have been widely used in the literature, their empirical validity is still heavily debated. Although Caballero et al. (1997) and Caballero and Engel (2004) argue against quadratic adjustment costs, their approach has been criticized by Cooper and Willis (2004) for mismeasurement. Hamermesh (1989) finds evidence against quadratic adjustment costs at the firm level but not at the aggregate level. In a more recent study, Ejarque

Address correspondence to: Wolfgang Lechthaler, Hindenburgufer 66, 24105 Kiel, Germany; e-mail: wolfgang.lechthaler@ifw-kiel.de.

 1365-1005/12

and Portugal (2007) find that quadratic adjustment costs are much more important than fixed adjustment costs.

In this paper we demonstrate that a model with simple quadratic labor adjustment costs yields results very similar to those for more complicated models of labor market frictions. Of course, a model with quadratic labor adjustment costs cannot be used to analyze the dynamics of unemployment, but we demonstrate that they can be a useful and simple short cut if one is more interested in the aggregate behavior of other variables.

As the main contribution of this paper, we demonstrate the consequences of quadratic labor adjustment costs for optimal monetary policy. In the standard New Keynesian model, the central bank does not face a trade-off between stabilizing inflation and stabilizing output. If the central bank stabilizes one, it automatically stabilizes the other. Therefore it is optimal for the central bank to keep prices stable at any time. In this way it avoids price distortions and can replicate an economy with flexible prices.

Thomas (2008) and Blanchard and Galí (2010) show that this can still be the case if search and matching frictions are included and wages are flexible. However, they assume that employment is at the efficient level by using the Hosios (1990) condition. Faia (2008, 2009) demonstrates that relaxing this assumption implies a trade-off between stabilizing output and inflation. It is no longer optimal to keep prices constant. Instead, a Ramsey planner allows inflation in response to temporary shocks. Faia et al. (2009) demonstrate that the same is true in a model of linear hiring and firing costs. Furthermore, they demonstrate that the optimal level of inflation depends on the magnitude of hiring and firing costs—the higher these costs are, the higher is the optimal volatility of inflation.

In this paper we contribute to this literature by showing that similar conclusions can be derived in a much simpler framework, namely by incorporating quadratic labor adjustment costs. We demonstrate that, similarly to the search and matching framework, there is a simple rule determining whether quadratic labor adjustment costs imply a trade-off between stabilizing inflation and output. If labor adjustment costs depend on aggregate variables (e.g., aggregate output), there is an externality calling for positive inflation after business-cycle shocks.

The paper proceeds as follows. First, we describe the underlying model. In Section 3 we demonstrate some business cycle statistics and compare them to other models and the data. Section 4 analyzes optimal monetary policy; Section 5 concludes.

2. THE MODEL

The model we use is closely related to that of Krause and Lubik (2007), but the search and matching labor market is replaced by quadratic labor adjustment costs as, e.g., in Dib (2003).

2.1. Households

Households have a standard utility function of the form

$$U_t = E_t \sum_{j=t} \beta^{j-t} \left(\frac{C_j^{1-\sigma}}{1-\sigma} + \log\left(\frac{M_j}{P_j}\right) - \frac{L_j^{1+\varphi}}{1+\varphi} \right). \tag{1}$$

Utility depends positively on consumption C and real money balances M/P (where P is the price index) and negatively on labor input L. The parameters σ and φ denote the elasticity of intertemporal substitution and the inverse of the Frisch elasticity of labor supply, respectively. Households maximize utility with respect to the budget constraint

$$B_t + C_t P_t = W_t L_t + (1 + r_{t-1}) B_{t-1} - \tau_t + \Pi_t, \tag{2}$$

where B are bond holdings, W is the wage, r is the interest rate, τ are lump-sum taxes, and Π are nominal profits. Utility maximization yields the standard consumption Euler equation, labor supply, and money demand:

$$C_t = E_t C_{t+1} \left((1 + r_t) \beta \frac{P_t}{E_t P_{t+1}} \right)^{-1/\sigma} \tag{3}$$

$$L_t^{\varphi} = C_t^{-\sigma} \frac{W_t}{P_t} \tag{4}$$

$$C_t^{\sigma} = \frac{r_t}{1 + r_t} \frac{M_t}{P_t}. \tag{5}$$

2.2. Production

We follow the recent literature in separating the markup pricing decision from the labor demand decision. This implies that there are three types of firms. Intermediate good–producing firms employ labor to produce the intermediate good. Firms in the wholesale sector take the intermediate goods as input, and differentiate those. Subject to quadratic price adjustment costs, they sell to a final retail sector under monopolistic competition. Retailers bundle the differentiated goods into a consumption basket C, which is sold to households under perfect competition at the aggregate price level P.

Intermediate-good firms. Intermediate-good firms hire labor to produce the intermediate good Z. Their production function is $Z = A \times L$, where A is aggregate productivity. However, the labor input is subject to quadratic adjustment costs. Thus, profits in real terms are given by

$$E_t \sum_{j=t} \Delta_{j,t} \left[\frac{P_{z,j}}{P_j} A_j L_j - \frac{W_j}{P_j} L_j - \frac{\Psi}{2} \left(\frac{L_j}{L_{j-1}} - 1 \right)^2 Y_j \right],$$

https://doi.org/10.1017/S1365100511000083 Published online by Cambridge University Press

where P_z is the price of the intermediate good, $\Delta_{j,t} = \beta C_j^{-\sigma}/C_t^{-\sigma}$ is the stochastic discount factor from period j to period t, and the last term inside the brackets is the real adjustment cost, expressed in units of the final good. It depends on Ψ, a parameter measuring the extent of adjustment costs, and on aggregate output Y.[5]

Maximizing profits with respect to L_t, we obtain the optimal labor input, which depends on the labor input of the previous period and the expected labor input of the following period:

$$\frac{P_{z,t}}{P_t}A_t = \frac{W_t}{P_t} + \Psi\left(\frac{L_t}{L_{t-1}} - 1\right)Y_t - \Delta_{t+1,t}\Psi\left(\frac{E_t L_{t+1}}{L_t} - 1\right)\frac{E_t L_{t+1}}{L_t^2}Y_t. \quad \textbf{(6)}$$

In this equation we have marginal returns on the left-hand side and marginal costs on the right-hand side. The marginal costs are no longer just made up by the wage, as in the standard model, but include the costs of adjusting the workforce. Importantly, these costs depend on lagged and expected future levels of employment. Because of these costs, firms try to smooth movements in labor and keep adjustments low.

Wholesale sector. Firms in the wholesale sector are distributed on the unit interval and indexed by i. The homogenous intermediate good is the only input into wholesale production, being traded in a competitive market for price P_z per unit. Wholesale firms produce a differentiated good Y_i according to the production function $Y_i = Z_i$, where Z_i is their demand for intermediate goods. They sell the good to the final retail sector under monopolistic competition. Demand is given by

$$Y_{i,t} = Y_t\left(\frac{P_{i,t}}{P_t}\right)^{-\varepsilon}, \quad \textbf{(7)}$$

where ε is the elasticity of substitution between varieties.

The firms can change their price at any period, but face quadratic price adjustment costs.[6] Noting that the production cost of a wholesale firm is the price of its input (P_z), the problem of a price-resetting firm can be formulated as

$$\max_{P_{i,t}} \quad E_t\sum_{j=t}^{\infty}\Delta_{j,t}\left[\frac{P_{i,j}}{P_j}Y_{i,j} - \frac{P_{z,j}}{P_j}Y_{i,j} - \frac{\Phi}{2}\left(\frac{P_{i,j}}{P_{i,j-1}} - 1\right)^2 Y_j\right]$$

$$\text{s.t.} \quad Y_{i,j} = \left(\frac{P_{i,j}}{P_j}\right)^{-\varepsilon}Y_j,$$

where $P_{i,t}$ denotes the new optimal price of producer i in period t and Φ is a parameter measuring the extent of price adjustment costs. Taking the derivative with respect to the price yields, after some manipulations, the following expectational Phillips curve:

$$0 = (1-\varepsilon) + \varepsilon\frac{P_{z,t}}{P_t} - \Phi(\pi_t - 1)\pi_t + E_t\left\{\Delta_{t,t+1}\Phi(\pi_{t+1} - 1)\frac{Y_{t+1}}{Y_t}\pi_{t+1}\right\}. \quad \textbf{(8)}$$

Final retail sector. The final retailer operates in a competitive market and buys differentiated wholesale goods to arrange them into a representative basket, producing the final consumption bundle Y, according to

$$Y_t = \left(\int Y_{i,t}^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}}, \tag{9}$$

which delivers the standard price index $P_t = (\int P_{i,t}^{1-\varepsilon} di)^{1/(1-\varepsilon)}$ from the cost-minimization problem of the firm.

Monetary and fiscal policy. The policy instrument of the central bank is the money growth rate, which is defined by

$$\mu_t = \frac{M_t}{M_{t-1}} = \frac{M_t}{P_t}\frac{P_t}{P_{t-1}}\frac{P_{t-1}}{M_{t-1}} = \frac{m_t \pi_t}{m_{t-1}} \tag{10}$$

and follows an $AR(1)$ process. Government consumption G is financed by the lump-sum tax and also follows an $AR(1)$ process.

Aggregation. Aggregate production is given by

$$Y_t = \int Y_{i,t} di = \int Z_{i,t} di = \int A_t L_{i,t} di = A_t L_t. \tag{11}$$

Assuming that all profits are distributed to the households, aggregation of households' income yields

$$C_t = Y_t - \frac{\Psi}{2}\left(\frac{L_t}{L_{t-1}-1}\right)^2 Y_t - \frac{\Phi}{2}(\pi_t - 1)^2 Y_t - G_t. \tag{12}$$

Thus, the model consists of eight unknown variables: $w, C, L, p_z, \pi, Y, i, m$. The eight equations are the households' optimality conditions, (3), (4), and (5); the labor demand of intermediate-good firms (6); the price set by a wholesale firm (8); the aggregation of output (11); the aggregation of income (12); and the definition of money growth (10).

3. BUSINESS CYCLE STATISTICS

The model is calibrated in close accord with Krause and Lubik (2007), because we want to compare our model to this benchmark. Thus the elasticity of substitution between intermediate products is set to $\varepsilon = 11$, whereas the elasticity of intertemporal substitution is set to $\sigma = 2$. The subjective discount rate is set to $\beta = 0.99$ and the parameter governing the cost of price adjustment is set to $\phi = 40$. The parameter governing the disutility of labor is set to the standard value 1. Dib (2003) estimates the parameter for the labor adjustment costs to be $\Psi = 1.85$.

In this section we compare the business cycle statistics of the model with quadratic labor adjustment costs with the results for search and matching frictions

https://doi.org/10.1017/S1365100511000083 Published online by Cambridge University Press

TABLE 1. Business cycle statistics

	U.S. data	Productivity shock			Money supply shock			Joint shock		
		LMS	KL	QAC	LMS	KL	QAC	LMS	KL	QAC
Relative SD										
Inflation	1.11	0.53	0.38	0.31	1	0.73	2.7	0.93	0.43	0.84
Correlations										
Y, inflation	0.39	−0.11	−0.11	−0.15	0.63	0.97	0.95	0.01	0.12	0.2
Autocorrelations										
Output	0.87	0.96	0.98	0.95	0.81	0.78	0.72	0.96	0.95	0.94
Inflation	0.56	0.25	0.60	0.01	0.11	0.60	0.47	0.19	0.61	0.41

Notes: LMS: Lechthaler et al. (2010); KL: Krause and Lubik (2007); QAC: Quadratic labor adjustment costs.

reported in Krause and Lubik (2007) and the results for linear labor turnover costs reported in Lechthaler et al. (2010). To this end, we use the exact same numbers for the shocks; i.e., the standard deviation of the money-supply shock is set to 0.00623, whereas the standard deviation of the productivity shock is set to 0.0049. The parameters of autocorrelation are set to 0.95 for the productivity and to 0.49 for the money shock.

The results of our simulations are reported in Table 1. It can be seen that all three models report relatively similar numbers. The model of Krause and Lubik (2007) fares a bit better than the other two models with respect to the autocorrelation of inflation. The model with linear labor adjustment costs is better in covering the volatility of inflation, whereas the model with quadratic labor adjustment costs yields better numbers with respect to the correlation between output and inflation. The important thing to note is that the model with quadratic labor adjustment costs does not perform worse—with respect to output and inflation—than the more complex models. But of course the simple model cannot say anything about fluctuations in unemployment and the flow rates of workers between unemployment and employment.

4. OPTIMAL MONETARY POLICY

4.1. Flexible Price Allocation

Before describing the optimal policy plan, we ask the question whether it is feasible to implement the flexible price allocation. The answer is: it depends. For the specification of quadratic labor adjustment costs used in this paper, where the adjustment costs depend on the level of aggregate output, as in, e.g., Dib (2003), the flexible price allocation is not feasible. If adjustment costs do not depend on aggregate output, as in, e.g., Pesenti (2008), the flexible price allocation is indeed feasible.

The central planner seeks to maximize utility subject to the resource constraint[7]

$$U_t = E_t \sum_{j=t} \beta^{j-t} \left(\frac{C_j^{1-\sigma}}{1-\sigma} - \frac{L_j^{1+\varphi}}{1+\varphi} \right)$$

$$\text{s.t.} \quad C_j = A_j L_j - \frac{\Psi}{2} \left(\frac{L_j}{L_{j-1}} - 1 \right)^2 Y_j. \tag{13}$$

After some manipulations, the first-order condition reads

$$A_t = \frac{L_t^{\varphi}}{C_t^{-\sigma}} + \Psi \left(\frac{L_t}{L_{t-1}} - 1 \right) \frac{Y_t}{L_{t-1}} - \beta \frac{C_{t+1}^{-\sigma}}{C_t^{-\sigma}} \Psi \left(\frac{E_t L_{t+1}}{L_t} - 1 \right) \frac{E_t L_{t+1}}{L_t^2} Y_t$$
$$- C_t^{-\sigma} \frac{\Psi}{2} \left(\frac{L_t}{L_{t-1}} - 1 \right)^2 A_t. \tag{14}$$

This outcome has to be compared with the solution for the competitive economy. Under flexible prices, the price distortion through Rotemberg adjustment costs vanishes. Furthermore, the distortion through monopolistic competition can be tackled through the appropriate choice of a subsidy $(1/\varepsilon)$ on the marginal costs of monopolistic firms, i.e., on the price P_z of the intermediate firm.[8] The optimal price of the intermediate good is still to be described by equation (6). Plugging in equation (4) for the wage and substituting the stochastic discount factor yields

$$A_t = \frac{L_t^{\varphi}}{C_t^{-\sigma}} + \Psi \left(\frac{L_t}{L_{t-1}} - 1 \right) \frac{Y_t}{L_{t-1}} - \beta \frac{C_{t+1}^{-\sigma}}{C_t^{-\sigma}} \Psi \left(\frac{E_t L_{t+1}}{L_t} - 1 \right) \frac{E_t L_{t+1}}{L_t^2} Y_t. \tag{15}$$

It is immediately clear that this equation does not coincide with the solution of the central planner given in equation 14. The equation of the central planner exhibits an additional term, driving a wedge Γ between the two equations:

$$\Gamma_t = -C_t^{-\sigma} \frac{\Psi}{2} \left(\frac{L_t}{L_{t-1}} - 1 \right)^2 A_t. \tag{16}$$

Basically, through the dependence of adjustment costs on aggregate output, an individual firm imposes an externality on other firms. In other words, it ignores socially relevant costs that the central planner (of course) includes. This implies that the central planner wants to further smooth employment adjustments over the business cycle, or put differently, the competitive economy exhibits fluctuations that are too large. In a world with sticky prices, the planner would want to use inflation to smooth fluctuations in employment and output.

However, from the analysis above, it is also clear that this externality depends crucially on the exact specification of labor adjustment costs. If labor adjustment costs took the form $\Psi/2(L_t/L_{t-1} - 1)^2$ (i.e., just ignoring the dependence on aggregate output), it would make the flexible price allocation feasible. In such a case, no trade-off between stabilizing inflation and output would arise.

4.2. The Ramsey Planner

The optimal policy plan is determined by a monetary authority that maximizes the discounted sum of utilities of all agents, given the constraints of the competitive economy.[9] Of course, the money growth rule given in equation (10) is no longer valid. To be able to concentrate on the distortions through price and labor adjustment costs, we assume that the distortion through monopolistic competition is offset by an appropriate subsidy. The solution algorithm used is the one of the Dynare package.[10]

As in Faia (2008, 2009), we determine optimal monetary policy in an economy that is hit by shocks to aggregate productivity and shocks to aggregate demand (government spending).[11] We parameterize the shock processes in line with these papers and the evidence for industrialized countries. Productivity shocks follow an $AR(1)$ process. The autocorrelation is set to $\rho_a = 0.95$ and the standard error of the shock is $\sigma_a = 0.008$, whereas government consumption follows an $AR(1)$ with $\sigma_g = 0.0074$ and $\rho_g = 0.9$ [see, e.g., Perotti (2004)].

Figure 1 shows impulse response functions of the Ramsey plan after positive productivity shocks, comparing different values of adjustment costs. As is standard, in the model without any adjustment costs, the Ramsey plan stabilizes prices at any time, setting the interest rate in such a way that agents have no desire to change the price.[12] In this way the price distortion can be avoided and the economy replicates an economy with flexible prices.

However, in line with Faia (2008, 2009) and Faia et al. (2009), this is no longer the case, once there are labor market frictions. These frictions make output adjustments costly, and thus the Ramsey planner tries to smoothen employment fluctuations. This can only be achieved by allowing fluctuations in the price level. Thus, under quadratic labor adjustment costs, the Ramsey planner can no longer achieve the first-best outcome but has to trade off the effects of the nominal distortion (price rigidities) against the effects of the real distortion (labor adjustment costs).

After a positive productivity shock, labor supply and therefore labor input is reduced immediately (because the increase in productivity increases consumption and therefore decreases marginal utility of consumption). In the presence of labor adjustment costs, it is costly to reduce labor input, and therefore the Ramsey planner tries to smooth adjustments and counteracts by stimulating demand even further. It can do so by reducing prices, resulting in deflation on impact of the shock. The reduction in labor input is not avoided completely, but only smoothed, and therefore inflation becomes positive in later periods. As in Faia et al. (2009), the fluctuations in the price level increase with the level of labor adjustment costs.

The effects of government spending shocks are illustrated in Figure 2. As is common in these kinds of models, government spending increases output but

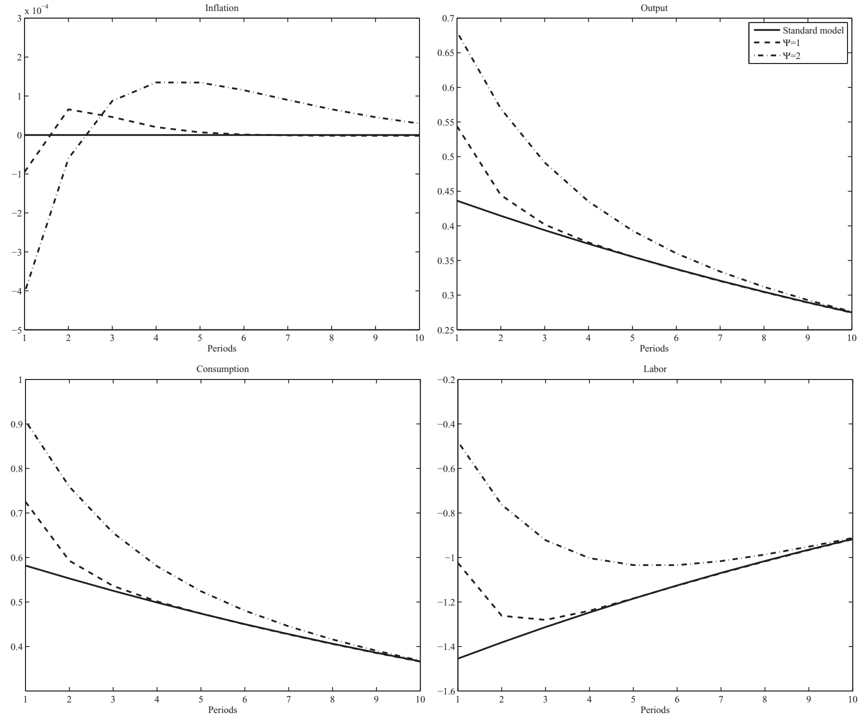

FIGURE 1. Ramsey policy after productivity shock.

partially crowds out private consumption. Because productivity is constant, the increase in output can only be accomplished by increasing labor input. Again, in the presence of labor adjustment costs, the Ramsey planner tries to smooth labor adjustments. In this case, this means counteracting the increase in output by lowering consumption even further. This is accomplished by increasing prices on impact of the shock. In later periods the planner tries to push back consumption and therefore causes deflation.

The important conclusion so far is that the inclusion of quadratic labor adjustment costs is sufficient to introduce a trade-off for monetary policy. It is no longer optimal for the Ramsey planner to keep prices absolutely stable. In that sense we can replicate the results in Faia (2008, 2009) and Faia et al. (2009), but in a much simpler framework. Similarly to models with matching frictions, however, the trade-off is quantitatively not very large.

In a last exercise we demonstrate the dependence of optimal inflation volatility on the size of labor-adjustment costs in Figure 3. It can be seen that optimal inflation volatility increases with the level of labor-adjustment costs. But the relationship is not linear, so the effects become smaller with higher labor-adjustment costs.

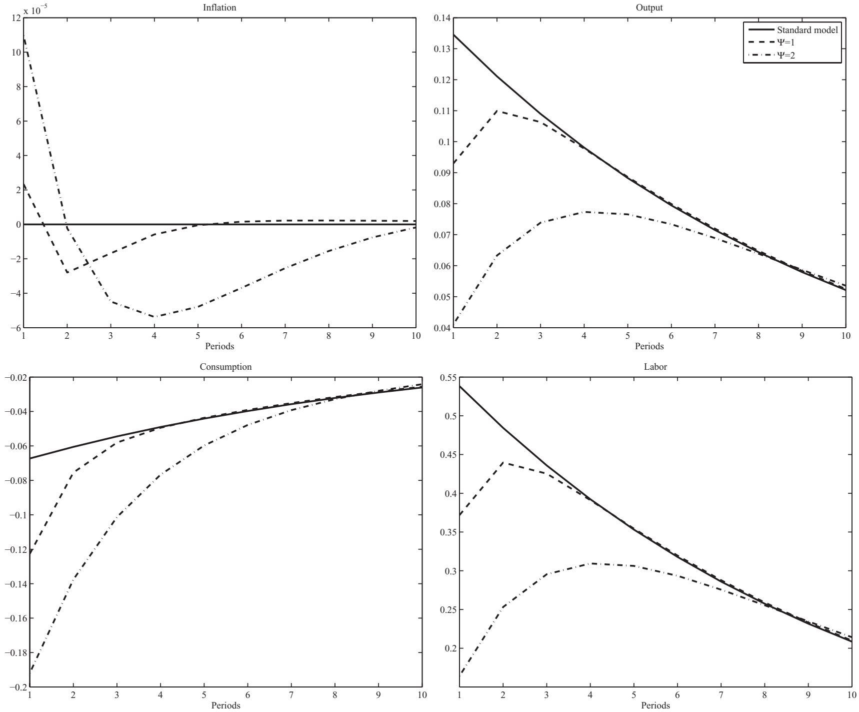

FIGURE 2. Ramsey policy after demand shock.

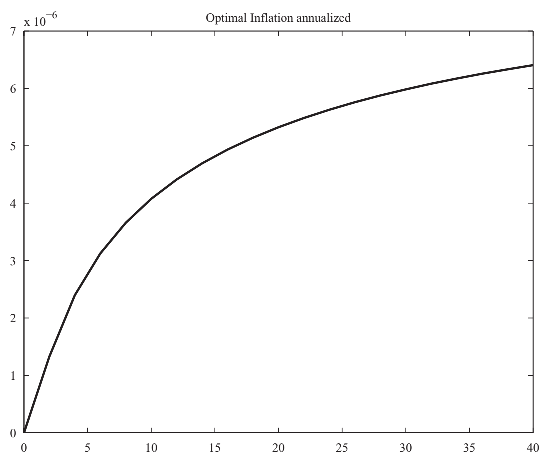

FIGURE 3. Optimal inflation volatility.

https://doi.org/10.1017/S1365100511000083 Published online by Cambridge University Press

5. CONCLUSION

Labor market frictions have been at the heart of recent developments in the New Keynesian literature. Incorporating labor market frictions can increase the persistence of a model's reaction in response to temporary shocks and can lead to trade-offs between output and inflation stabilization.

In this paper we demonstrate that these goals can be achieved with a simpler framework than the search and matching approach dominant in the literature. A model with quadratic labor adjustment costs yields business cycle statistics similar to those for a model with search and matching frictions, thus suggesting quadratic labor adjustment costs as a simple and useful shortcut. Furthermore, quadratic labor adjustment costs are sufficient to break down the divine coincidence, the result that stable prices imply a stable output gap in the standard New Keynesian model. However, this last result depends heavily on the exact specification of labor adjustment costs.

NOTES

1. See, e.g., Lechthaler et al. (2010).
2. See, e.g., Danthine and Kurmann (2004).
3. See, e.g., Walsh (2005) and Krause and Lubik (2007).
4. See, e.g., Juillard et al. (2006) and Pesenti (2008).
5. It will depend crucially on the assumption that labor adjustment costs depend on aggregate output whether full price-stabilization is optimal or not.
6. We stick to quadratic price adjustment costs to be comparable to Krause and Lubik (2007), but Calvo staggering would yield similar results.
7. Because we are looking at a flexible price economy, we ignore money in the utility function.
8. See, e.g., Gali (2008) for more details.
9. See Lucas and Stokey (1983) for a setup with flexible prices. Khan et al. (2003) adopt a similar structure to analyze optimal monetary policy in a closed economy with market power, price stickiness, and monetary frictions, whereas Schmitt-Grohe and Uribe (2004) analyze a problem of joint determination of optimal monetary and fiscal policy.
10. See Juillard (1996).
11. Because we analyze optimal monetary policy here, we can no longer use monetary shocks.
12. See, e.g., Gali (2008).

REFERENCES

Blanchard, O.J. and J. Galí (2010) Labor markets and monetary policy: A New Keynesian model with unemployment. *American Economic Journal—Macroeconomics* 2 (2), 1–30.

Caballero, R. and E. Engel (2004) A comment on the economics of labor adjustment: Mind the gap: Reply. *American Economic Review* 94 (4), 1238–1244.

Caballero, R., E. Engel, and J. Haltiwanger (1997) Aggregate employment dynamics: Building from microeconomic evidence. *American Economic Review* 87 (1), 115–137.

Cooper, R. and J.L. Willis (2004) A comment on the economics of labor adjustment: Mind the gap: Rejoinder. *American Economic Review* 94 (4), 1245–1247.

Danthine, J.-P. and A. Kurmann (2004) Fair wages in a New Keynesian model of the business cycle. *Review of Economic Dynamics* 7, 107–142.

Dib, A. (2003) An estimated Canadian DSGE model with nominal and real rigidities. *Canadian Journal of Economics* 36 (4), 949–972.

Ejarque, J.M. and P. Portugal (2007) Labor Adjustment Costs in a Panel of Establishments: A Structural Approach. Working paper 3091, IZA.

Faia, E. (2008) Optimal monetary policy rules with labor market frictions. *Journal of Economic Dynamics and Control* 32 (5), 1357–1720.

Faia, E. (2009) Ramsey monetary policy with labour market frictions. *Journal of Monetary Economics* 56 (4), 570–581.

Faia, E., W. Lechthaler, and C. Merkl (2009) Labor Turnover Costs, Workers' Heterogeneity, and Optimal Monetary Policy. Working paper 1534, Kiel Institute for the World Economy.

Gali, J. (2008) *Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework*. Princeton, NJ: Princeton University Press.

Hamermesh, D. (1989) Labor demand and the structure of adjustment costs. *American Economic Review* 79 (4), 674–689.

Hosios, A. (1990) On the efficiency of matching and related models of search and unemployment. *Review of Economic Studies* 57, 279–298.

Janko, Z. (2008) Nominal wage contracts, labor adjustment costs and the business cycle. *Review of Economic Dynamics* 11, 434–448.

Juillard, M. (1996) Dynare: A Program for the Resolution and Simulation of Dynamic Models with Forward Variables. CEPREMAP working paper 9602.

Juillard, M., P. Karam, D. Laxton, and P. Pesenti (2006) Welfare-based Monetary Policy Rules in an Estimated DSGE Model of the US Economy. ECB working paper 613.

Khan, A., R.G. King, and A. L. Wolman (2003) Optimal monetary policy. *Review of Economic Studies* 70 (4), 825–860.

Krause, M. and T. Lubik (2007) The (ir)relevance of real wage rigidity in the New Keynesian model with search frictions. *Journal of Monetary Economics* 54 (3), 706–727.

Lechthaler, W., C. Merkl and D. Snower (2010) Monetary persistence and the labor market: A new perspective. *Journal of Economic Dynamics and Control* 34 (5), 968–983.

Lucas, R.E. and N.L. Stokey (1983) Optimal fiscal and monetary policy in an economy without capital. *Journal of Monetary Economics* 12 (1), 55–93.

Perotti, R. (2004) Estimating the Effects of Fiscal Policy in OECD Countries. IGIER working paper 276.

Pesenti, P. (2008) The Global Economy Model: Theoretical Framework. IMF staff paper 55-2.

Schmitt-Grohé, S. and M.M. Uribe (2004) Optimal fiscal and monetary policy under sticky prices. *Journal of Economic Theory* 114 (2), 198–230.

Thomas, C. (2008) Search and matching frictions and optimal monetary policy. *Journal of Monetary Economics* 55 (5), 936–956.

Walsh, C.E. (2005) Labor market search, sticky prices, and interest rate policies. *Review of Economic Dynamics* 8 (4), 829–849.