Gains from Wage Flexibility and the Zero Lower Bound*

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Abstract

We analyze the welfare impact of greater wage flexibility while taking into account explicitly the existence of the zero lower bound (ZLB) constraint on the nominal interest rate. We show that the ZLB constraint generally *amplifies* the adverse effects of greater wage flexibility on welfare when the central bank follows a conventional Taylor rule. When demand shocks are the driving force, the presence of the ZLB implies that an increase in wage flexibility reduces welfare even under the optimal monetary policy with commitment.

Keywords: labor market flexibility, nominal rigidities, optimal monetary policy with commitment, Taylor rule, ZLB

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1 Introduction

Most mainstream economists view wage rigidity as an undesirable feature for an economy, one that is likely to hamper macroeconomic stability and cause a higher and volatile unemployment rate. The perceived costs of wage rigidity rely on a logic based on the familiar labor market diagram found in introductory textbooks: a decrease in wages should offset, at least partly, the negative effects on employment (and output) of any adverse aggregate shock that reduces labor demand. If wages are rigid and that adjustment doesn't take place (or it is slow) the negative employment and output effects of adverse shocks are likely to be amplified and unemployment will rise, at least temporarily.[1]

Eighty years ago Keynes (1936) called into question the previous logic, which he associated with "classical" economics, and deemed it irrelevant to understand the workings of modern economies. In his view, the wage level did not have a direct role in the determination of employment. The latter was instead determined by aggregate demand *for goods*. Aggregate demand management, rather than wage flexibility, was the key to employment stability. More recently, Galí (2013) has revisited Keynes' argument through the lens of the New Keynesian model. Two results are worth stressing from that analysis. First, the extent to which greater wage flexibility contributes to employment and output gap stability hinges critically on the monetary policy rule in place and, in particular, on the strength of the central bank's systematic response to inflation, which in turn determines the response of aggregate demand to changes in wages, through their induced effects on marginal costs and inflation. Secondly, an increase in wage flexibility tends to raise the volatility of price and wage inflation, both of which are costly since they generate an inefficient allocation of resources in the presence of staggered price and wage setting. Thus, if the central bank follows a Taylor rule that calls for a relatively weak response to inflation, the benefits of increased wage flexibility in the form of more stable output gap and employment are generally small, and likely more than offset by the welfare losses brought about by the more volatile price and wage inflation. On the other hand, when the Taylor rule calls for a sufficiently aggressive response to inflation, or when the central bank follows the optimal policy (with commitment) an increase in wage flexibility tends to improve welfare, at least for reasonable calibrations of the economy's parameters.

In the present paper we extend the analysis in Galí (2013) to take explicitly into account the zero

[1] See e.g. Hall (2005) and Shimer (2005, 2012) for a discussion of the role of wage rigidities in accounting for labor market fluctuations in the context of the search and matching model. Blanchard and Galí (2007, 2010) emphasize the policy tradeoffs generated by the presence of wage rigidities in a New Keynesian model.

lower bound (ZLB) constraint on the nominal interest rate, and study the role of that constraint in determining the gains from greater wage flexibility. The reason for focusing on the interaction between wage flexibility and the ZLB is that the presence of the latter may limit the ability of central banks to respond to downward pressures on inflation resulting from wage reductions in the face of an adverse shock Accordingly, any potential gains from greater wage flexibility may be hampered by that constraint. Our analysis seeks to assess the extent to which the presence of the ZLB may affect the gains (or losses) from an increase in wage flexibility, under alternative monetary policy regimes (Taylor rule vs optimal policy) and sources of fluctuations (demand vs. technology shocks).

1.1 Related Literature

The present paper is related to several branches of the literature. At a more general level, our paper is related to the recent literature that seeks to understand the implications of the ZLB constraint along different dimensions: the design of optimal monetary policy (e.g. Adam and Billi (2006, 2007), Nakov (2008), Jung et al. (2005)), the role of forward guidance (e.g. Eggertsson and Woodford (2003)), the emergence of multiple equilibria under a Taylor rule (e.g. Benhabib et al. (2001, 2002), Mertens and Ravn (2014), Benigno and Fornaro (2017)), and the effectiveness of fiscal policy (Eggertsson (2011), Christiano et al. (2011)), among other issues.

Our paper is more closely connected to a smaller literature that studies the impact of (changes in) nominal rigidities on macroeconomic stability. Thus, De Long and Summers (1986) use a model with staggered Taylor contracts to show that an increase in wage flexibility may be destabilizing due to the contractionary impact of *falling* prices, working through the expected real rate. More recently, and using a New Keynesian model, Bhattarai et al. (2018) study the conditions under which an increase in price flexibility may have destabilizing effects on output and employment. They show that this will be the case if demand shocks are prevailing and interest rates do not respond strongly to inflation. By contrast, when supply shocks are dominant, greater price flexibility is destabilizing only if interest rates respond strongly to inflation. Galí (2013) addresses the same question with a focus on wage flexibility and its impact on welfare. He shows that an increase in wage flexibility may be welfare reducing if the interest rate is not too responsive to inflation. Galí and Monacelli (2016) revisit the impact of wage flexibility on macro stability and welfare in the context of an open economy, focusing on the role of the exchange rate regime. They show that a strong concern for exchange rate stability or, in the limit, the adoption of a foreign currency or the membership in a large currency union, make it more likely that welfare is reduced in response to greater wage flexibility.

The constraints on monetary policy imposed by a credible exchange rate peg are similar to those implied by a binding zero lower bound on the nominal interest rate.[2] In that context, Eggertsson et al. (2014) raise a warning on the possible contractionary effects of structural reforms (modelled as favorable supply shocks), due to the increase in real interest rates resulting from the combination of deflationary pressures and an unresponsive nominal rate.

Our paper proceeds as follows. Section 2 contains a description our baseline model. Section 3 analyzes the effects of an exogenous adjustment in labor costs. Section 4 studies the effect of wage flexibility on macro stability and welfare. Section 5 looks at the implications of simultaneous changes in price and wage flexibility. Section 6 concludes.

2 Our Baseline Model

We carry out our analysis using a version of the New Keynesian model with staggered price and wage setting à la Calvo, originally developed by Erceg et al. (2000), augmented with a ZLB constraint on the short-term nominal interest rate. In some of the scenarios considered, monetary policy is described by a (truncated) Taylor rule, while in others the central bank is assumed to follow the optimal policy under commitment. We rely on a standard calibration of the model as a baseline for our analysis. Next we introduce briefly the key equations describing the model's equilibrium. The reader can find detailed derivations of those equations as well as a complete analysis of the model in the absence of the ZLB constraint in Galí (2015).[3]

2.1 Private Sector

The behavior of the private sector is described by the equilibrium conditions introduced in this section, which correspond to a closed economy version of the New Keynesian model with staggered price and wage setting, without capital accumulation or a fiscal sector. We augment the standard model with a payroll tax. All the equations have been log-linearized around a steady state with zero price and wage inflation.

[2] Similar, *but not identical*, as made clear by Erceg and Lindé (2012).

[3] For convenience we use identical notation to Galí (2015). The only difference with that model lies in the introduction of a wage subsidy. See Galí and Monacelli (2016) for details.

The demand side of the economy is described by the consumer's Euler equation, which combined with the goods market clearing condition yields:

$$y_t = E_t\{y_{t+1}\} - \frac{1}{\sigma}\left(i_t - E_t\{\pi^p_{t+1}\} - \rho - (1-\rho_z)z_t\right) \tag{1}$$

where y_t denotes (log) output, i_t is the nominal interest rate, π^p_t is price inflation, and z_t is a preference shifter (or demand shock) which follows an exogenous $AR(1)$ process with autoregressive coefficient ρ_z. Parameters σ and ρ denote the household's coefficient of relative risk aversion and discount rate, respectively.

The supply side of the economy is described by the following three equations representing the dynamics of price and wage inflation, π^p_t and π^w_t :

$$\pi^p_t = \beta E_t\{\pi^p_{t+1}\} + \varkappa_p \tilde{y}_t + \lambda_p \tilde{\omega}_t + \lambda_p \tau_t \tag{2}$$

$$\pi^w_t = \beta E_t\{\pi^w_{t+1}\} + \varkappa_w \tilde{y}_t - \lambda_w \tilde{\omega}_t \tag{3}$$

$$\widetilde{\omega}_t \equiv \widetilde{\omega}_{t-1} + \pi^w_t - \pi^p_t - \Delta\omega^n_t \tag{4}$$

where $\tilde{y}_t \equiv y_t - y^n_t$ and $\tilde{\omega}_t \equiv \omega_t - \omega^n_t$ denote, respectively the output and wage gaps, with y^n_t and ω^n_t representing the (log) *natural* output and (log) *natural* wage (i.e. their corresponding equilibrium values in the absence of nominal rigidities). Variable τ_t denotes a payroll tax, proportional to the wage, and which adds to the labor cost incurred by firms. In addition, we note that $\varkappa_p \equiv \frac{\alpha\lambda_p}{1-\alpha}$, $\varkappa_w \equiv \lambda_w\left(\sigma + \frac{\varphi}{1-\alpha}\right)$, $\lambda_p \equiv \frac{(1-\theta_p)(1-\beta\theta_p)}{\theta_p}\frac{1-\alpha}{1-\alpha+\alpha\epsilon_p}$, and $\lambda_w \equiv \frac{(1-\theta_w)(1-\beta\theta_w)}{\theta_w(1+\epsilon_w\varphi)}$, where $\theta_p \in [0,1)$ and $\theta_w \in [0,1)$ are the Calvo parameters indexes of price and wage rigidities, and with $\epsilon_p > 1$ and $\epsilon_w > 1$ denoting the elasticities of substitution among varieties of goods and labor services, respectively. The *natural* output and wage are given by

$$y^n_t = \psi_{ya} a_t + \psi_{y\tau}\tau_t$$

$$\omega^n_t \equiv \psi_{\omega a} a_t + \psi_{\omega\tau}\tau_t$$

where a_t is an exogenous technology shifter which follows an exogenous $AR(1)$ process with autoregressive coefficient ρ_a. In addition $\psi_{ya} \equiv \frac{1+\varphi}{\sigma(1-\alpha)+\varphi+\alpha}$, $\psi_{y\tau} \equiv -\frac{1-\alpha}{\sigma(1-\alpha)+\varphi+\alpha}$, $\psi_{\omega a} \equiv \frac{1-\alpha\psi_{ya}}{1-\alpha}$ and $\psi_{\omega\tau} \equiv -\frac{\sigma(1-\alpha)+\varphi}{\sigma(1-\alpha)+\varphi+\alpha}$, with φ and α denoting, respectively, the curvature of labor disutility and the degree of decreasing returns to labor in production. As shown in Galí (2015), (2) and (3) can be derived from the aggregation of the price and wage setting decisions of workers and firms, in an environment in which such re-optimization takes place with probabilities $1 - \theta_p$ and $1 - \theta_w$, respectively.

Much of the focus of our analysis below is on the consequences of changes in the wage rigidity parameter θ_w.

2.2 Monetary Policy

In our analysis we consider two alternative monetary policy regimes. The first regime is described by a "truncated" Taylor rule given by:

$$i_t = \max\left[0, i_t^*\right] \tag{5}$$

where

$$i_t^* = \phi_i i_{t-1}^* + (1 - \phi_i)\left(\rho + \phi_p \pi_t^p + \phi_y \tilde{y}_t\right), \tag{6}$$

The previous rule, which incorporates explicitly the ZLB constraint, can be viewed as capturing in a parsimonious way the behavior of central banks in many advanced economies. Note that i_t^* can be interpreted as a *shadow* interest rate in that context.[4]

The second regime we consider corresponds to the optimal policy under commitment and subject to a ZLB constraint. That policy is a state contingent plan that maximizes the representative household's welfare, subject to an infinite sequence of private sector constraints given by (1) through (4), for $t = 0, 1, 2, ...$ That optimal policy problem is described formally in Appendix 1 and gives rise to a set of difference equations which, together, with equations (1) through (4) describe the equilibrium under the optimal policy with commitment.

2.3 Calibration

Our baseline calibration is quite conventional and largely follows Galí (2015). We set the discount factor β to 0.995, to imply a (annualized) steady-state real interest rate of 2 percent. We set $\sigma = 1$, $\varphi = 5$ and $\alpha = 0.25$. Elasticity of substitution parameters ϵ_p and ϵ_w are set to 9 and 4.5, respectively. We set $\theta_p = \theta_w = 0.75$, consistent with an average duration of price and wage spells of one year. We

[4] Our specification of the rule for the shadow rate, which makes the latter a function of its own lag (as opposed to the lag of the actual policy rate) implies a kind of "forward guidance" that may compensate partly for the lost monetary stimulus due to the presence of a ZLB constraint.

adopt the interest rate rule coefficients proposed in Taylor (1993), i.e. $\phi_p = 1.5$ and $\phi_y = 0.125$. The smoothing coefficient in the Taylor rule is set to 0.8, close to the estimates in Clarida et al. (2000) and others. The autoregressive coefficient of the driving variables is set to 0.8 to generate sufficient persistence, and with the standard deviation of their respective innovation chosen in order to have a ZLB incidence of 5 percent under the Taylor rule, and conditional on each of the shocks (demand or technology) being the only source of fluctuations in the economy. Our baseline calibration is summarized in Table 1.

Next we turn to the analysis of some the model's predictions regarding the interaction of wage flexibility and the ZLB.[5] We start by studying the impact of the latter on the effectiveness of labor cost reductions.

3 The Effects of Labor Cost Reductions in the Presence of the ZLB

The eventual stabilizing role of wage flexibility hinges critically on the influence that adjustments in wages (or other components of labor) may have on output and employment. As argued in Galí (2013), in an economy described by the New Keynesian model, the amount of labor hired is determined, in the short run and for a given technology, not by the prevailing wage but by the quantity of output that firms want to produce which, in turn, is determined by aggregate demand. Thus, the effect of a change in labor costs on employment is transmitted through the impact of the former on marginal costs, inflation and –through the monetary policy rule– on nominal and real interest rates, which finally affect consumption. If the ZLB is binding and, as a result, the change in inflation does not elicit a change in the nominal rate, the previous causal chain in the transmission of labor cost adjustments to employment breaks down. Furthermore, in the face of a constant nominal rate, any reduction in expected inflation caused by a downward adjustment in labor costs will lead to a rise in the real interest rate, and may thus end up having a "perverse" effect on output and employment.

In order to illustrate the role played by the ZLB in determining the effects of labor cost adjustments, we use the model above to analyze the impact of a large, unanticipated, negative demand shock and its interaction with a payroll tax cut, where the latter is presumably enacted in order to counteract the adverse effects of the shock on output and employment. The shock is assumed to last for 20 quarters and its size is normalized so that the drop of output on impact is 4 percent, under a

[5] The model outcomes are obtained with Dynare using an extended-path method. Replication files are available from the authors upon request.

constant payroll tax.

Figure 1 displays the responses of output, inflation, and the nominal and real interest rates to the shock just described, with and without a simultaneous payroll tax cut. We assume that the payroll tax cut lasts for as long as the shock (i.e. 20 quarters) and has a size of 0, 1 or 3 percent. As shown in the Figure, the size of the shock is large enough to make the ZLB binding for many periods, independently of the response of the payroll tax. The latter, however, has a significant impact on the response of output and inflation. Thus, we see that the larger is the cut in the payroll tax the more the short run output decline, which is presumably the opposite effect of what was intended. Similarly, the deflationary effects of the adverse demand shock can be seen to be enhanced by the cut in payroll taxes. The fourth panel of Figure 1 displays the response of the real interest rate under the three scenarios considered, and points to the mechanism responsible for the adverse impact of the payroll tax rate: the deflationary effects of the latter combined with the binding ZLB lead to a higher real rate, thus amplifying the initial negative effects of the shock on aggregate demand and output.

The previous exercise provides an illustration of the potentially perverse effects that labor cost adjustments may have in combination with a binding ZLB. Needless to say, actual economies are not always against a binding ZLB constraint. But to the extent that ZLB episodes are recurrent, the associated recessions may be deeper and more persistent if they bring about large downward wage adjustments. In that case the presence of the ZLB may reduce or even reverse the sign of the the welfare gains that the conventional wisdom associates with greater wage flexibility. The analysis below seeks to evaluate the plausibility of that hypothesis.

4 Gains from Wage Flexibility and the Zero Lower Bound

A key objective of our analysis is the evaluation of the impact of changes in the degree of wage rigidity on welfare, under the ZLB and in its absence. For that purpose, we use as a welfare metric the second order approximation to the average welfare losses experienced by the representative household as a result of fluctuations around an efficient steady state, expressed as a fraction of steady state consumption. Such welfare losses can be written as:[6]

[6] See Galí (2015) for a derivation.

$$\mathbb{L} = \frac{1}{2}\left[\left(\sigma + \frac{\varphi+\alpha}{1-\alpha}\right) var\left(\tilde{y}_t\right) + \frac{\epsilon_p}{\lambda_p} var\left(\pi_t^p\right) + \frac{\epsilon_w(1-\alpha)}{\lambda_w} var\left(\pi_t^w\right)\right].$$

Note that the welfare loss has three distinct components, respectively associated with the volatilities in the output gap, price inflation, and wage inflation. Parameter θ_w enters the welfare loss function through λ_w, to which it is inversely related. Thus, an increase in wage flexibility (i.e. a smaller θ_w) reduces welfare losses, for any *given* volatility of wage inflation. The reason is that, given $var\left(\pi_t^w\right)$, more flexible wages are associated with less wage dispersion, and a smaller inefficiency resulting from misallocation of labor. In equilibrium, however, the volatility of wage inflation, price inflation and the output gap is not invariant to a change in θ_w. In particular, we expect that greater wage flexibility will be associated with higher volatility of wage inflation and, ceteris paribus, of price inflation as well. On the other hand, more flexible wages should make employment (and, thus, output) deviate less from their natural counterparts, thus reducing $var\left(\tilde{y}_t\right)$. As a result, the net effect on welfare from a reduction in θ_w is generally ambiguous ex ante. As emphasized in Galí (2013) (and Galí and Monacelli (2016) in the context of a small open economy), which factor ends up dominating depends to a large extent on the monetary policy regime in place. The latter is, in turn, affected by the presence of a ZLB constraint. Next we describe such effects through a number of simulations.

Figure 2 shows the welfare losses as a function of the index of nominal wage rigidities, θ_w, with the latter's baseline value (0.75) represented by a vertical line. Each of the four panels corresponds to a particular combination of monetary policy regime (Taylor rule vs optimal policy) and source of fluctuations (demand vs technology shocks), and displays the welfare losses with and without a ZLB constraint as lines with red diamonds and blue circles, respectively. Not surprisingly, welfare losses appear to be generally larger with the ZLB constraint. But this is not the focus of our inquiry, which pertains instead to the effect of *changes* in θ_w on welfare, i.e. on the *slope* of the welfare loss function, rather than on its relative position.

Our results for the case of no ZLB, represented by the lines with blue circles in Figure 1, replicate the main qualitative findings in Galí (2013). First, and under the calibrated Taylor rule, an increase in wage flexibility leads to higher welfare losses for a large range of initial θ_w values (one that includes the baseline setting of 0.75). This is true for both technology and demand shocks. Under the optimal policy, on the other hand, welfare losses are either zero independently of wage rigidity (in the case of demand shocks, which are fully offset by the central bank), or they are decreasing as wages become more flexible (in the case of technology shocks).[7] The previous simulations thus make clear that the existence of welfare gains from greater wage flexibility is not generally true. On the contrary, the sign and extent of the resulting welfare effects depend critically on the monetary policy in place (and the nature of the shock in the case of the optimal policy).

The introduction of a ZLB constraint alters those findings in two ways, as a comparison of the two lines in each panel makes clear. Firstly, under the Taylor rule, the presence of the ZLB *amplifies* the adverse effects of greater wage flexibility on welfare, both for demand and technology shocks, as reflected in a steeper welfare loss function for a broad range of θ_w values. Secondly, under the optimal policy and demand shocks, an increase in wage flexibility raises welfare losses when the ZLB is in place, for a very large range of initial θ_w values. Under technology shocks, on the other hand, the introduction of the ZLB raises welfare losses, without affecting significantly the sensitivity of welfare to wage rigidity (though the gains from greater wage flexibility appear to be slightly smaller in the ZLB case).

Next we show that the finding that the presence of a ZLB amplifies the adverse effects of greater wage flexibility on welfare under the Taylor rule is robust to alternative calibrations of the parameters in that rule (ϕ_p, ϕ_y, ϕ_i, ρ). Figure 3 shows the *ratio* of welfare losses with and without the ZLB constraint, as a function of θ_w, and for alternative values of the coefficients in the rule. For concreteness, the figure assumes demand shocks as a source of fluctuations. Several results are worth pointing out. First, we see that the loss ratio is larger than one in all cases, i.e. the introduction of the ZLB constraint always reduces welfare for any given calibration. Secondly, we see that in response to greater wage flexibility (i.e. a reduction in θ_w), welfare losses increase in a greater proportion when the ZLB constraint is present, as reflected by the negative slope of the loss ratio curves. That impact of the ZLB on the welfare effect of enhanced wage flexibility holds for all the rule coefficients considered, but is particularly strong for large values of ϕ_p and ϕ_y, small values of ϕ_i and ρ, since in all of those cases the incidence of a binding ZLB is higher. Similar findings to those in Figure 3 obtain when technology shocks are the source of fluctuations (not shown).

We show next how the presence of the ZLB constraint affects the three components of the welfare loss function, associated respectively to the volatility of the output gap, price inflation, and wage in-

[7] As discussed in Galí (2013), the finding that welfare losses are an inverse monotonic function of wage rigidity under the optimal policy is not completely general and may be overturned for some extreme calibrations (e.g. extreme price stickiness).

flation. Figures 4 to 7 display welfare losses and its components as a function of θ_w, with and without the ZLB. Each figure corresponds to a different monetary policy regime and source of fluctuations.[8]

Figure 4 shows the welfare loss and its components under a Taylor rule with demand shocks as the source of fluctuations. Absent a ZLB, an increase in wage flexibility from its baseline value stabilizes the output gap (which reduces welfare losses), but on the other hand increases the volatility in price and wage inflation (which increases welfare losses). The latter effect appears to dominate, except when the initial degree of wage rigidities is very low. Note in particular that the (local) increase in the losses from higher volatility of wage inflation occurs despite the fact that the cost of any given level of such volatility is smaller when wages are more flexible. The presence of the ZLB constraint raises the volatility in the output gap, price inflation, and wage inflation for any given level of θ_w, and thus the corresponding welfare losses. More interestingly, we see that the three components play a role in the amplification of the adverse welfare effects of greater wage flexibility that results from the presence of the ZLB constraint. The previous results are qualitatively similar if instead technology shocks are the source of fluctuations, as Figure 5 shows.

Figure 6 shows the welfare loss function and its components under the optimal policy with commitment, with and without the ZLB, when demand shocks are the only source of fluctuations. As discussed above, absent a ZLB, the optimal policy fully stabilizes the output gap, price inflation and wage inflation, so no losses emerge from any of those components, as captured by the flat lines at zero. The presence of the ZLB makes it impossible for monetary policy to fully offset large adverse demand shocks. As a result, the output gap and price and wage inflation deviate from their first-best values and welfare losses arise. An increase in wage flexibility, starting from the baseline value, partly offsets the larger costs resulting from the ZLB by reducing the volatility of the output gap (see top-right panel). But that beneficial impact of greater wage flexibility is more than offset by the increase in the costs resulting from greater volatility in price and wage inflation, as shown in the two bottom panels, accounting for the net increase in welfare losses.

In the case of an optimal policy under technology shocks our findings are somewhat different, as shown in Figure 7. In this case, and as discussed above, an increase in wage flexibility reduces welfare losses both with and without the ZLB constraint. The main difference with respect to demand

[8] In these figures, there is a non-monotonic effect of wage flexibility on the component of welfare connected to wage inflation (bottom-right panel). The reason for this non-monotonicity is that, as explained earlier, if wages become more flexible, the volatility in wage inflation increases; however, the weight attached to such volatility in the social welfare function decreases. Thus, if wages are very flexible, a further increase in wage flexibility leads to a reduction in the component of welfare connected to wage inflation.

shocks is that with technology shocks and increase in wage flexibility reduces the volatility of *price* inflation. In response to a positive technology shock, prices tend to go down, due to a fall in marginal costs, and wages tend to increase. Greater wage flexibility allows for larger wage raises and hence a smaller decline in marginal costs and prices, thus accounting for the smaller price inflation volatility associated with lower θ_w values. This effect contributes to the positive relation between wage rigidity and welfare losses. Note also that the slope of the two curves is similar with and without the ZLB constraint, suggesting that in this case, and in contrast with the cases considered previously, the presence of the ZLB constrain doesn't alter significantly the welfare impact of a *change* in wage flexibility.

5 Price Rigidities, Wage Rigidities, Welfare and the Zero Lower Bound

Next we study the welfare effect of simultaneous changes in price and wage flexibility on welfare, and how those effects depend on the monetary policy regime and the presence or not of a ZLB constraint.

Figure 8 shows the welfare loss from fluctuations in the economy, as a function of θ_w (line with blue circles) and as a function of θ (line with red diamonds). We use θ to denote a common value for θ_w and θ_p. The other parameters are kept at their baseline value.[9] The figure shows outcomes *without* a ZLB constraint in the model. The top panels show the outcome under a Taylor rule, conditional on demand shocks or technology shocks being the source of fluctuations. As discussed above, in both cases, an increase in wage flexibility leads to a deterioration in welfare for a large range of initial θ_w values. On the other hand, and starting from the baseline setting of 0.75 for θ, a similar deterioration of welfare obtains *locally* in response to a simultaneous increase in price and wage flexibility (i.e. a decrease in θ). However, as the same plot reveals, the relation between welfare losses and nominal rigidities changes sign at relatively large values of θ, implying that a nontrivial *joint* increase in price and wage flexibility from their baseline value would generate a welfare improvement. The bottom-right panel shows the corresponding outcome under the optimal policy when technology shocks are the source of fluctuations. In this case, and as discussed above, an increase in wage flexibility (while keeping θ_p constant) is welfare improving. Interestingly, as shown in Figure 8, that improvement vanishes (and becomes a welfare deterioration) when both prices and wages become more flexible

[9] As θ_w and θ_p share the same value in our baseline calibration, the vertical line in the figure indicates the baseline value of both these parameters.

(locally) starting from the baseline value for θ. The reason for this is that both price and wage inflation become more volatile in that case (with and without the ZLB), offsetting the smaller losses due to a more stable output gap.

Next we show how the presence of a ZLB constraint affects the relation between welfare and nominal rigidities (i.e. price and wage rigidities, jointly). Figure 9 shows the welfare loss as a function of θ, with and without a ZLB constraint in the model. As shown in the top two panels, under a Taylor rule and conditional on either demand or technology shocks, the introduction of the ZLB constraint amplifies the increase in welfare losses from a (local) reduction in nominal rigidities. The ZLB constraint is also seen to increase the range of θ values for which welfare is reduced in response to a decrease in nominal rigidities, relative to the case without a ZLB constraint. The bottom-left panel shows the outcome under the optimal policy conditional on demand shocks. In contrast with the case of a change in wage flexibility *only*, discussed above in the context of Figure 2, now a welfare gain can be attained with a relatively small increase in *both* price and wage flexibility, starting from their baseline value. This is not the case when we condition on technology shocks (bottom-right panel): in that case, under the optimal policy, a small parallel increase in both wage and price flexibility from the baseline leads to a welfare deterioration, with and without a ZLB constraint.

Note finally that in the limit, if both prices and wages are fully flexible, the first-best is attained with the resulting welfare losses being zero in all the scenarios considered. Accordingly, a *sufficiently large joint increase* in price and wage flexibility generates a welfare gain, independently of the monetary regime in place and the presence or not of the ZLB constraint (since both become irrelevant for real allocations and welfare in the absence of nominal rigidities).

6 Concluding Remarks

We have revisited the analysis in Galí (2013) on the welfare consequences of greater wage flexibility by explicitly taking into account the existence of a ZLB constraint on the nominal interest rate. In a first exercise, we have shown how a downward adjustment in labor costs in the face of a recession and with a binding ZLB may (unintendedly) deepen the downturn, due to the implied procyclical response of the real interest rate.

We then have studied the impact of an occasionally binding ZLB constraint on the relationship between wage flexibility and the welfare costs of recurrent fluctuations. Several findings have emerged from our analysis. Firstly, and perhaps not surprisingly, the presence of the ZLB increases welfare losses for any calibration of nominal rigidities and/or policy regime. Secondly, the main finding in Galí (2013), namely, that under a (realistic) Taylor rule an increase in wage flexibility is welfare reducing, is robust to the presence of the ZLB constraint. Furthermore, we show that the ZLB constraint generally *amplifies* the adverse effects of greater wage flexibility on welfare. Thirdly, when demand shocks are the driving force, an increase in wage flexibility is associated with larger welfare losses even when the central bank follows an optimal monetary policy. This is not true however for technology shocks. Finally, we have shown that under a Taylor rule and conditional on either demand or technology shocks, the introduction of the ZLB constraint (i) amplifies the increase in welfare losses from a (local) simultaneous reduction in both price and wage rigidities and (ii) increases the range of those rigidities for which welfare losses are decreasing in the degree of nominal rigidities, relative to the case without a ZLB constraint.

To summarize: through the lens of the New Keynesian model the case for greater wage flexibility appears to be weaker than commonly held, and it is only weakened further by the introduction of an explicit ZLB constraint on the nominal interest rate.

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APPENDIX: Optimal Policy under Commitment with a ZLB Constraint

The problem of optimal policy with commitment is given by

$$\min \frac{1}{2} E_0 \sum_{t=0}^{\infty} \beta^t \left[\left(\sigma + \frac{\varphi + \alpha}{1-\alpha} \right) \tilde{y}_t^2 + \frac{\epsilon_p}{\lambda_p} \left(\pi_t^p \right)^2 + \frac{\epsilon_w (1-\alpha)}{\lambda_w} \left(\pi_t^w \right)^2 \right]$$

subject to (1)-(4) and $i_t \geq 0$.

Write the period Lagrangian

$$\begin{aligned} L_t = & \frac{1}{2} \left[\left(\sigma + \frac{\varphi + \alpha}{1-\alpha} \right) \tilde{y}_t^2 + \frac{\epsilon_p}{\lambda_p} \left(\pi_t^p \right)^2 + \frac{\epsilon_w (1-\alpha)}{\lambda_w} \left(\pi_t^w \right)^2 \right] + \beta E_t V_{t+1} \\ & + m_{1t} \left[y_t + \frac{1}{\sigma} \left(i_t - \rho - (1-\rho_z) z_t \right) \right] - \frac{1}{\beta} m_{1t-1} \left(y_t + \frac{1}{\sigma} \pi_t^p \right) \\ & + m_{2t} \left(\pi_t^p - \varkappa_p \tilde{y}_t - \lambda_p \tilde{\omega}_t \right) - m_{2t-1} \pi_t^p \\ & + m_{3t} \left(\pi_t^w - \varkappa_w \tilde{y}_t + \lambda_w \tilde{\omega}_t \right) - m_{3t-1} \pi_t^w \\ & + m_{4t} \left(\omega_t - \omega_{t-1} - \pi_t^w + \pi_t^p \right). \end{aligned}$$

The Kuhn-Tucker conditions are

$$0 = \frac{\partial L_t}{\partial y_t} = \left(\sigma + \frac{\varphi + \alpha}{1-\alpha} \right) \tilde{y}_t + m_{1t} - \frac{1}{\beta} m_{1t-1} - \varkappa_p m_{2t} - \varkappa_w m_{3t} \tag{7}$$

$$0 = \frac{\partial L_t}{\partial \pi_t^p} = \frac{\epsilon_p}{\lambda_p} \pi_t^p - \frac{1}{\beta \sigma} m_{1t-1} + m_{2t} - m_{2t-1} + m_{4t} \tag{8}$$

$$0 = \frac{\partial L_t}{\partial \pi_t^w} = \frac{\epsilon_w (1-\alpha)}{\lambda_w} \pi_t^w + m_{3t} - m_{3t-1} - m_{4t} \tag{9}$$

$$0 = \frac{\partial L_t}{\partial \omega_t} = \frac{\partial \beta E_t V_{t+1}}{\partial \omega_t} - \lambda_p m_{2t} + \lambda_w m_{3t} + m_{4t} \tag{10}$$

$$0 = \frac{\partial L_t}{\partial i_t} i_t = \frac{1}{\sigma} m_{1t} i_t, \quad m_{1t} \geq 0 \text{ and } i_t \geq 0, \tag{11}$$

whereas the envelope condition gives

$$\frac{\partial \beta E_t V_{t+1}}{\partial \omega_t} = -\beta E_t m_{4t+1}.$$

The equilibrium conditions are then (1)-(4) and (7)-(11).

Table 1: Baseline calibration

Parameter	Description	Value
β	Discount factor	0.995
σ	Curvature of consumption utility	1
φ	Curvature of labor disutility	5
α	Index of decreasing returns to labor	0.25
ϵ_p	Elasticity of substitution of goods	9
ϵ_w	Elasticity of substitution of labor	4.5
θ_p	Calvo index of price rigidities	0.75
θ_w	Calvo index of wage rigidities	0.75
ϕ_i	Smoothing coefficient in the Taylor rule	0.8
ϕ_p	Rule coefficient on price inflation	1.5
ϕ_y	Rule coefficient on output gap	0.125
$\rho_{a,z}$	Persistence of shocks	0.8
σ_a	Std. deviation of technology shock	0.033
σ_z	Std. deviation of demand shock	0.044

Note: Values are shown in quarterly rates.

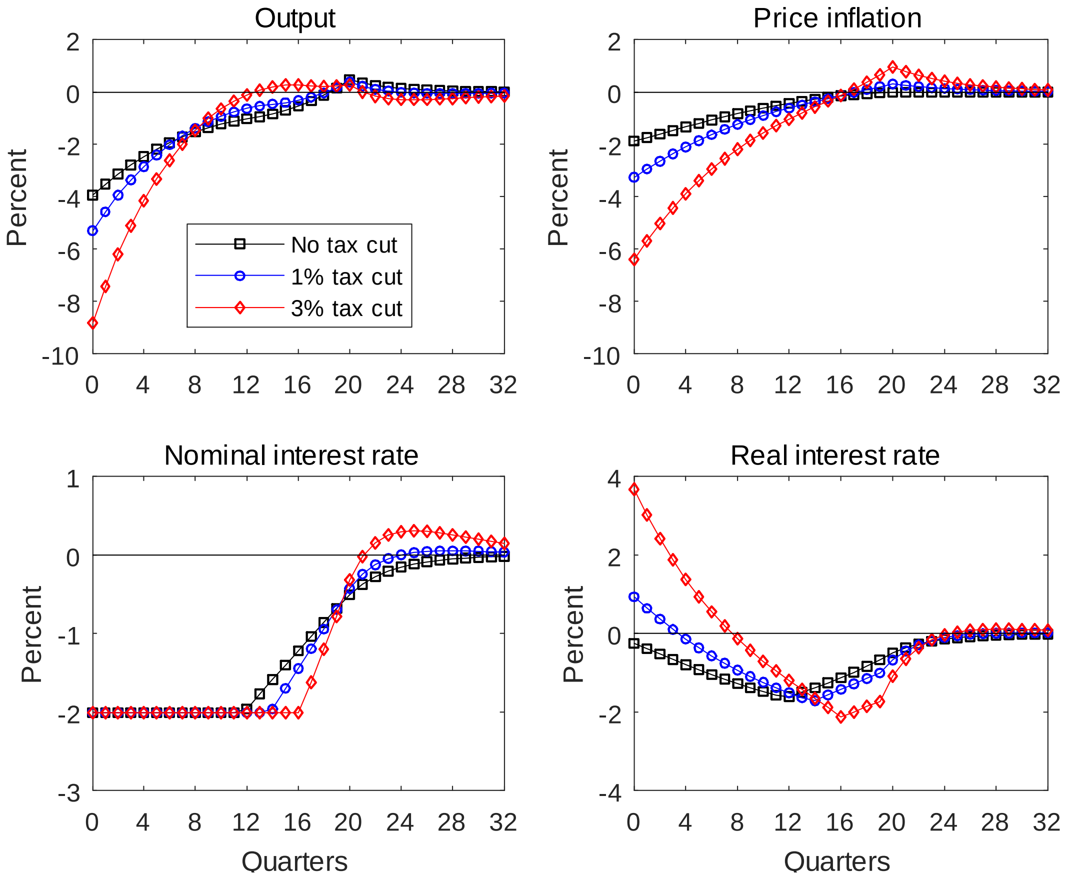

Figure 1: Dynamic responses to a payroll tax cut during a ZLB episode.

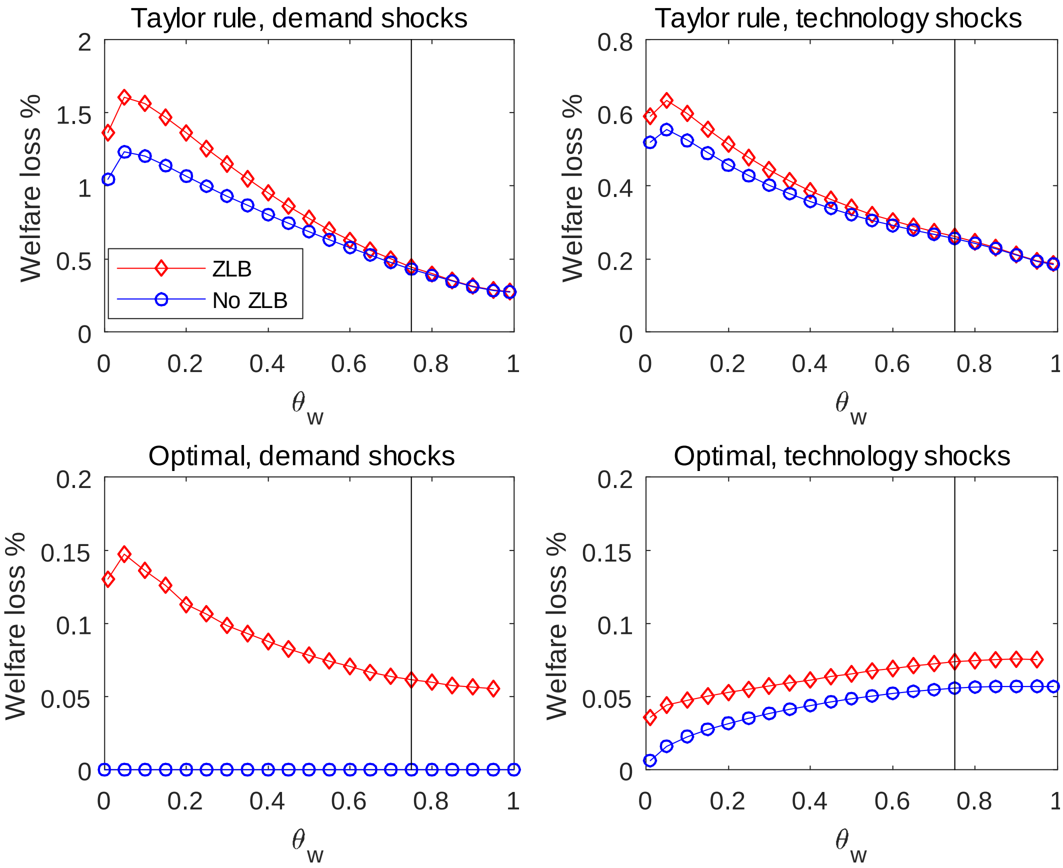

Figure 2: Wage rigidities and welfare: effect of ZLB.

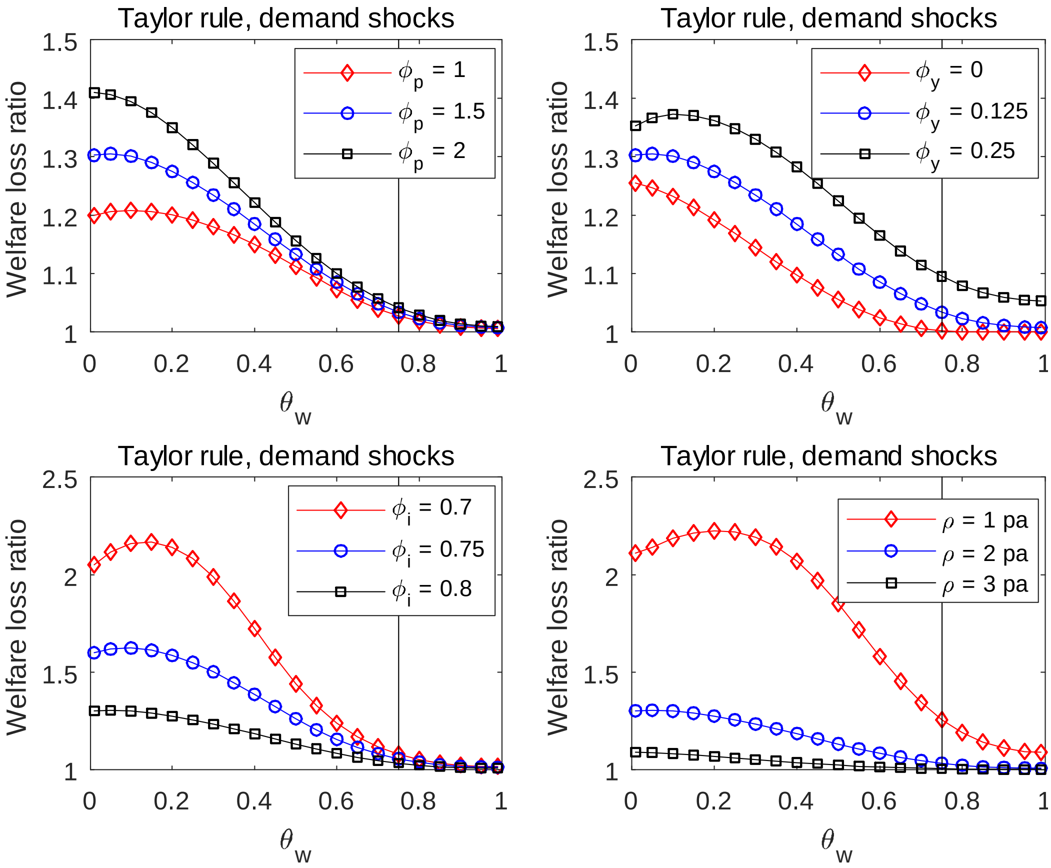

Figure 3: Wage rigidities and welfare loss from ZLB: role of policy responsiveness.

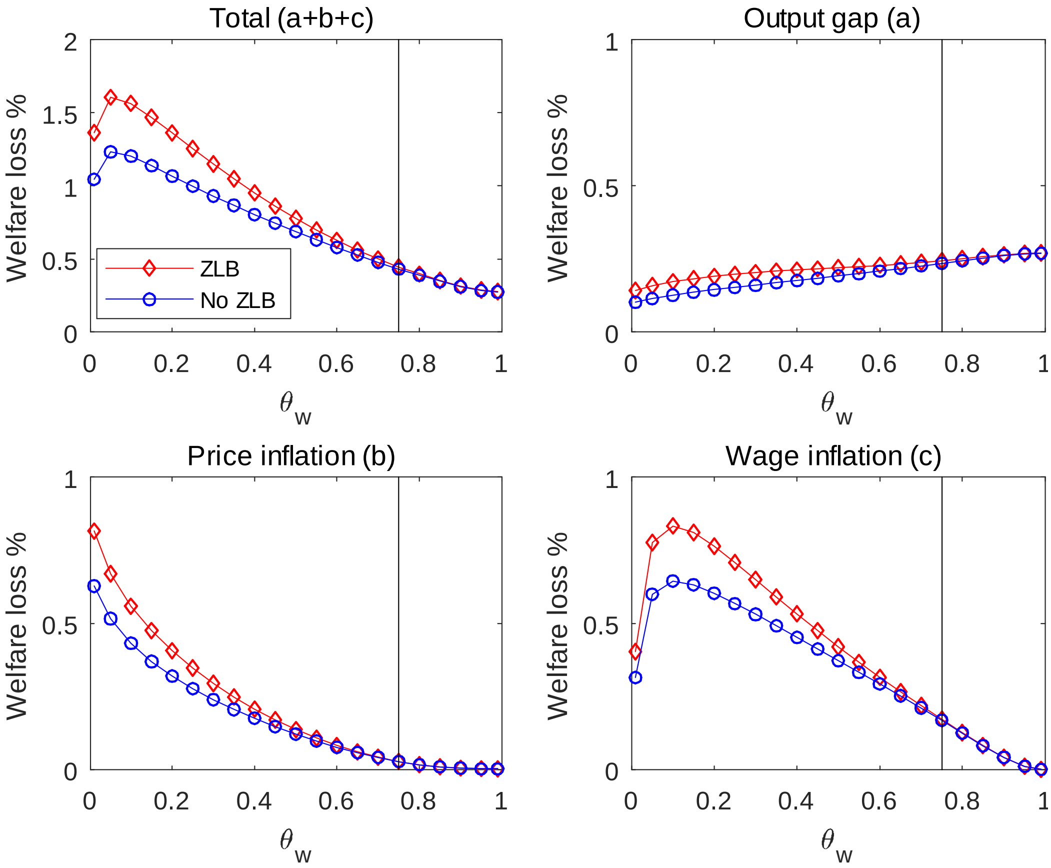

Figure 4: Wage rigidities and welfare components: Taylor rule and demand shocks.

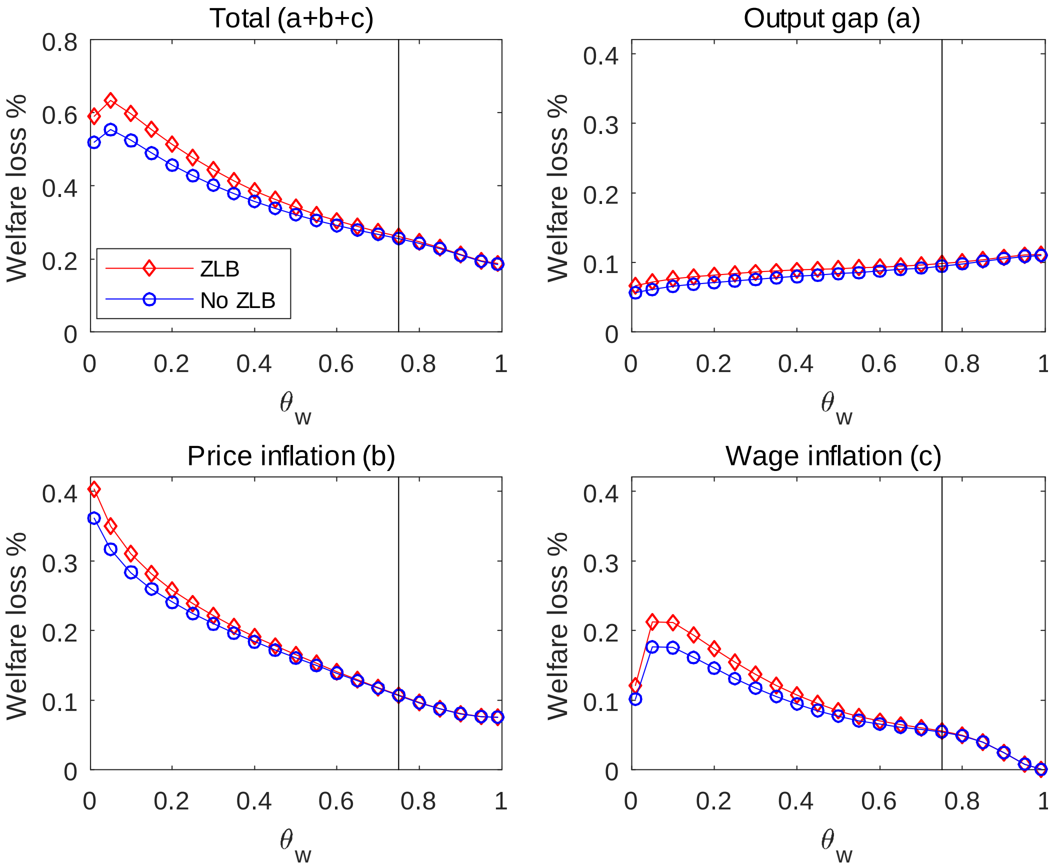

Figure 5: Wage rigidities and welfare components: Taylor rule and technology shocks.

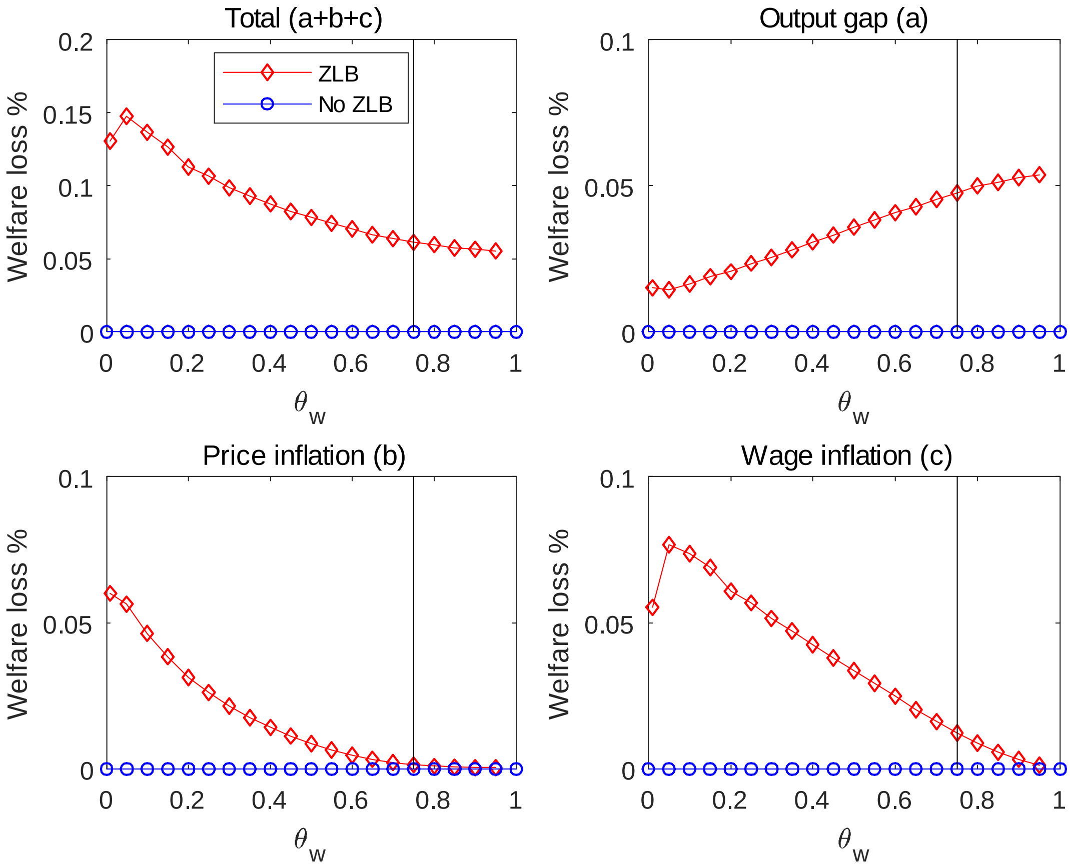

Figure 6: Wage rigidities and welfare components: optimal policy and demand shocks.

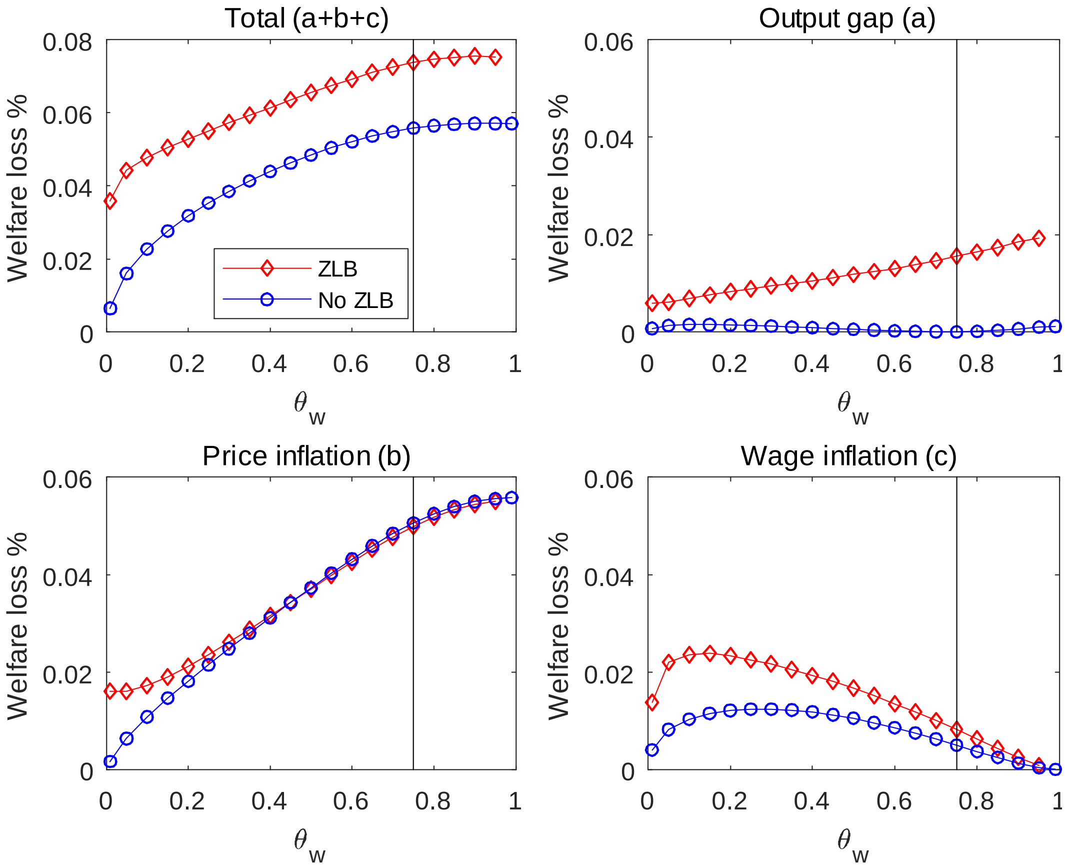

Figure 7: Wage rigidities and welfare components: optimal policy and technology shocks.

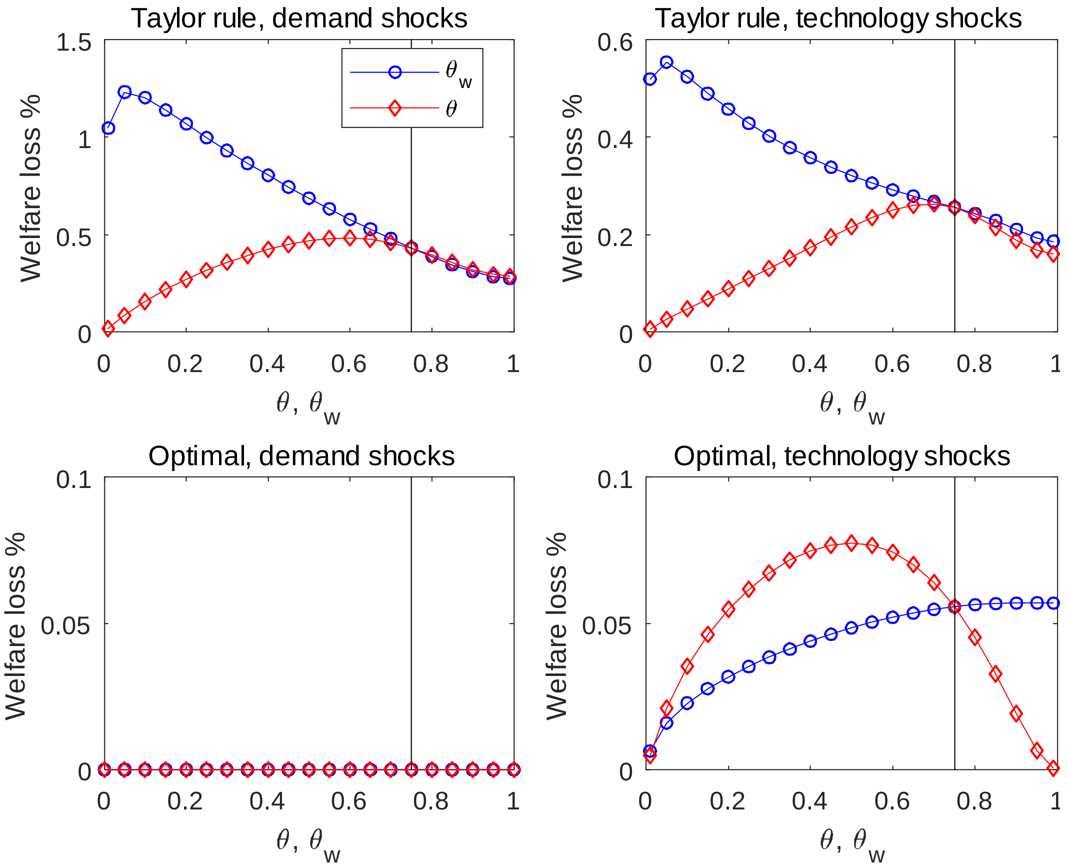

Figure 8: Nominal rigidities and welfare if ZLB absent.

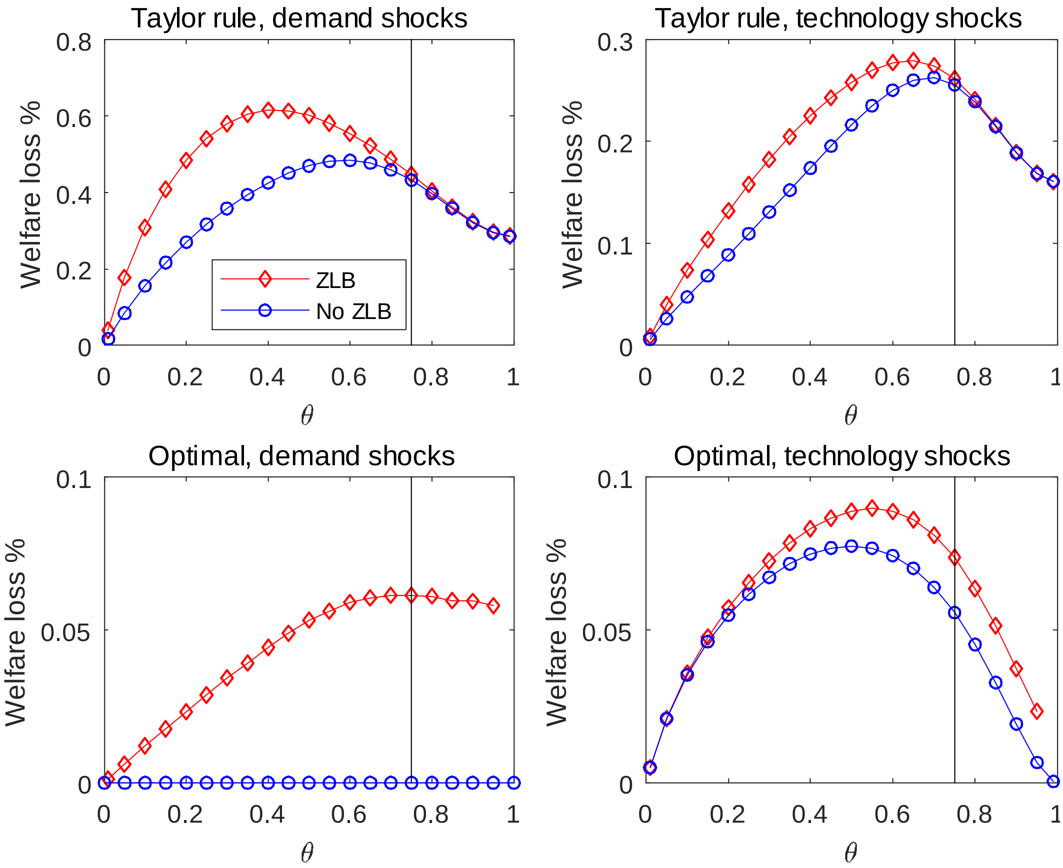

Figure 9: Nominal rigidities and welfare: effect of ZLB.