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Abstract

In this paper, we propose a matching and search model with adjustment costs in the form of labor disruption charges that can generate counter-cyclical real wages. Empirically, we use a measure of wage cyclicality based on the generalized impulse response function of real wages to a shock in a cycle measure. We provide evidence that wages in the United States are counter-cyclical during the first few quarters. The calibration and simulated results of the model match remarkably well the counter-cyclicality obtained from our empirical model.

JEL Classification: E24, E32, J32, J63
Keywords: Labor disruption costs, real wages, matching frictions, wage cyclicality

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1 Introduction

The study of the cyclicality of real wages is at the heart of macroeconomic theory for many reasons. Indeed, not only wage cyclicality has important implications for understanding the function of labour markets (see, for example, Pissarides (2009)) but also it is crucial for the validity of competing business cycle theories in opposition to a keynessian functioning of the labour market (Abraham and Haltiwanger (1995)). According the the theoretical assumptions retained, real wages are found to be counter-cyclical under sticky wages but procyclical under sticky prices.

More precisely, Keynesian models with sticky nominal wages that predict counter-cyclical real wages have been criticized and rejected in favor of Real Business Cycle (RBC) or New Keynesian (NK) models that, based on price stickiness and imperfect competition, yield pro-cyclical wages.[1] However, given the inability of the previous models to be plausibly reconciled with observed data in many cases, a common view is that having both pricing and wage decisions staggered can generate procyclical, acyclical, or countercyclical real wages (e.g., Barro and Grossman (1971), Blanchard (1986) and Huang, et al. (2004)).

In this paper, we contribute to this wide debate by studying the impact of adjustment costs on real wages cyclicality. In particular, we develop a model with matching and search frictions and adjustment costs generated by labor disruption. These costs represent the forgone output due to the interruption in the production process while hiring and firing workers. More in detail, incumbent employees spend part of their working time training new hired workers and it takes some time before the new hired workers start to produce an become fully productive. Additionally, incumbent workers need to be reallocated to the job positions of the workers who are separated from the firm.[2]

From an empirical point we provide a description of the cyclical behaviour of quarterly real wages in the United States for the 1960-2011 period. To this end, we adopt a dynamic approach and propose a precise measure of wage cyclicality based on the generalized impulse response function (GIRF) derived from a VAR model. Note that the GIRF, suggested by Koop et al., has the enviable advantage of not requiring the orthogonalization of the innovations. As such, it does not depend of the ordering of the variables in the model.

We calibrate and simulate the model for the USA. We consider the incidence of linear and quadratic adjustment costs as well as the possibility that labor disruption costs operate immediately or with one period lag, capturing the idea that reorganizing the production process takes some time. We show that in the presence of labor disruption costs, firms translate part of them to the workers' wage, reducing their implicit bargaining power and, depending on the structure of these costs, generating a reduction in wages in response to a positive shock in the output-gap.

[1] See Abraham and Haltiwanger (1995) for a discussion of alternative hypotheses concerning the cyclicality of real wages.

[2] Along this line, Russell Cooper (2009) estimated that plants lose 3% of their revenues as consequence of the presence of labor disruption costs.

The presence of a countercyclical behavior in the worker's bargaining power with matching frictions is also present in Rotemberg (2008) and Abbritti and Fahr (2011). In the first case, fluctuations in market power are due to fluctuations in the elasticity of demand facing the typical firm. In turn, Abbritti and Fahr (2011) introduce wage adjustment costs in a New-Keynesian DSGE model. These costs are present in the intermediate goods sector and are modeled by a convex function with lower costs for adjusting wages upwards than downward. The need to bargain wages leads to a situation where the adjustment cost is partly transferred to the employee through wage negotiations, generating a countercyclical response in the worker's bargaining power.

Both the GIRF for the USA and the simulated impulse-response functions from our model provide similar results: real wages fall immediately after a positive shock in the output gap. After a few quarters, they display an inverted hump-shaped pattern. The model also shows the presence of wage rigidity when these costs are linear and there is no lag adjustment. In this case, the positive effect of the increase in the output gap is canceled out by the negative effect that operates throughout the reduction in the implicity worker's bargaining power. Summing-up, adjustment costs in the form of labor disruption charges can generate counter-cyclical real wages -when these costs are quadratic- or acyclicality- when they are linear-.

The rest of the paper is organized as follows. In section 2 we present a matching and search model with labor disruption costs. Section 3 describes the empirical methodology and the data set. Section 4 and we provide the empirical results and the calibration for the US economy. Finally, we conclude in section 5.

2 Theoretical model

In this section we present a model that has the main objective to analyze the impact of output shocks on the cyclical behavior of wages under the presence of labor disruption costs and matching frictions. The labor market consists of a continuum of risk-neutral, infinitely-lived workers and large firms.[3] Workers and firms discount future payoffs at a common rate β. Furthermore, capital markets are perfect and time is discrete.

Workers may be either unemployed or employed. Unemployed individuals enjoy an instantaneous utility b each period. Those who are employed earn a wage w_t. Each period a constant proportion λ of workers are exogenously separated from the firm. Thus, when an employment relationship is broken, the worker becomes unemployed. Search frictions in the labor market are captured by a constant-returns-to-scale matching function $m(u_t, v_t)$, where u_t denotes the unemployment rate and v_t is the vacancy rate in period t. We follow den Haan, Ramey, and Watson (2000) and assume the following matching function:

$$m(u_t, v_t) = \frac{u_t v_t}{(u_t^{\varphi} + v_t^{\varphi})^{1/\varphi}}, \qquad \varphi > 0. \tag{1}$$

This matching function implies that the higher the number of vacancies with respect to the

[3]We normalize the measure of workers to 1.

number of unemployed workers, the easier to find a job and the more difficult to fill up vacancies. Unemployed workers find jobs at the rate $f(\theta_t) = m(u_t, v_t)/u_t$, and vacancies are filled at the rate $q(\theta_t) = m(u_t, v_t)/v_t$,where $\theta_t = v_t/u_t$ denotes labor market tightness. Employment, n_t evolves according to the following dynamics:

$$n_t = (1 - \lambda)n_{t-1} + q(\theta_t)v_t. \tag{2}$$

Then, by the normalization of the labor force, unemployment is equal to $u_t = 1 - n_t$.

2.1 The representative firm

Each firm consists of a number of jobs which are either filled or vacant. Labor is the only factor of production and firms' technologies exhibit constant returns to scale. The output in each firm is given by $y_t = A_t n_t$ where A_t is the productivity level common to all firms. The production costs consist of the wage cost, w_t, the constant cost of posting vacancies, c, and the labor adjustment costs ξ_t. These last costs capture the forgone output due to the interruption in the production process while hiring and firing workers. For example, incumbent employees spend time training new hired workers and it takes some time before the new hired workers become fully productive. Moreover, some incumbent workers must be reallocated to the job positions of the workers who are separated from the firm. As in Henry, Karanassou, and Snower (2000), the adjustment costs represent an extra cost paid by the firm in terms of each worker's wage. Accordingly, we set:

$$\xi_t = \phi(\lambda A_t n_{t-1} + v_t q(\theta_t) A_t)^{\chi}, \tag{3}$$

where ϕ and χ are non negative parameters. The first term inside the parenthesis of the right hand side equation represents the production lost when firing workers, λn_{t-1}, while the second term captures the disruption costs when hiring workers, $v_t q(\theta_t)$. Given the wage and the labor adjustment costs, the firm post the number of vacancies from the following profit maximization problem[4]:

$$F_t = \max_{v_t}\{A_t n_t - w_t \xi_t n_t - c v_t + \beta E_t F_{t+1}\}, \qquad s.t.(2). \tag{4}$$

The first order condition is given by:

$$\frac{\partial F_t}{\partial v_t} = A_t q_t - w_t \xi_t q_t - c + \beta E_t \frac{\partial F_{t+1}}{\partial v_t} = 0. \tag{5}$$

Using the envelope condition we obtain the job creation condition:

$$A_t - w_t \xi_t + \beta(1 - \lambda)E_t \frac{c}{q_{t+1}} = \frac{c}{q_t}. \tag{6}$$

The presence of labor adjustment costs, ξ_t, reduces the net productivity, $A_t - w_t \xi_t$, and, therefore, contracts job creation.

[4]For exposition reasons, we omit writing the aggregate state variables A_t and θ_t as arguments of all value functions.

2.2 Wages bargaining

Wages are determined through Nash bargaining between the firm and each individual worker where they split the total surplus generated by that specific employment relationship. That implies that the relevant surplus depends on the marginal value of a job, J_t. Therefore, the expression for J_t is

$$J_t = A_t - w_t\xi_t + \beta(1-\lambda)E_tJ_{t+1}. \tag{7}$$

In turn, the values of employment, W_t and unemployment, U_t for the marginal worker are

$$U_t = b + \beta E_t\{f(\theta_t)W_{t+1} + (1 - f(\theta_t))U_{t+1}\}, \tag{8}$$

$$W_t = w_t + \beta E_t\{\lambda U_{t+1} + (1-\lambda)W_{t+1}\}. \tag{9}$$

Thus, the Nash bargaining solution is a wage rate w_t that solves

$$\max_{w_t}(W_t - U_t)^{\eta}(J_t)^{1-\eta}, \tag{10}$$

where η is the worker bargaining power. This yields the following first order condition for wages

$$\eta J_t = (1-\eta)\xi_t(W_t - U_t). \tag{11}$$

Using (7) -(9) and (11) , we can now solve for the equilibrium wage as a function of the aggregate state A_t and θ_t,

$$w_t = \widehat{\eta}_t A_t + (1-\eta)b + \widehat{\eta}_t(1-\lambda)\beta E_t\theta_{t+1}c, \tag{12}$$

where $\widehat{\eta}_t = \frac{\eta}{\xi_t}$ is the worker bargaining power corrected by the adjustment in labor costs. It tell us that during the wage negotiation, firms translate part of the disruption costs to the worker, reducing their implicit bargaining power. Notice that an economy without labor adjustment costs takes place when $\xi_t = 1$ for every aggregate state. Also notice that the higher the adjustment cost per worker ξ_t the lower is the implicit worker bargaining power, $\widehat{\eta}_t$, implying the possibility of a reduction in wages when output increases after an aggregate labor productivity shock, A_t.

3 Empirical strategy and data description

3.1 The empirical measure of wage cyclicality

The general concept of wage cyclicality refers to the relationship between real wages and a measure of the economic cycle, such as the output gap. Traditionally, estimates based on aggregate data rely on the unconditional, contemporaneous correlation between de-trended or growth real manufacturing wages and the indicator of the cycle or the coefficient of an static OLS regressions of real wage on the business cycle series (e.g. Otani (1978), Chirinko (1980), Sumner and Silver (1989), etc). Alternatively, econometric studies based on dynamic specifications usually rely on structural VAR models (e.g. Abraham and Haltiwanger (1995), Fleischman (1999), Spencer (2007), etc). Whereas these literature explicitly account for alternative causes of the business cycles, it imposes identifying restrictions from a theoretical framework which are usually controversial and not tested in advanced.[5] Under these important restrictions, Abraham and Haltiwanger (1995) suggest that it is possible to reconcile the overall comovement and specific episodes of comovement in real wages and employment with different combinations of shocks and elasticities. They also insists that correcting for all of the measurement problems estimation problems and composition problems does not lead to a finding of systematically procyclical or countercyclical real wages.

More recently, Messina et al. (2009) relies on both the degree of co-movement between VAR forecast errors at different horizons and a frequency domain approach to analyse real wage behavior in some OECD countries. Their results suggest that country differences remain important even after controlling for differences in data and methods. In addition, they provide evidence that more open economies and countries with stronger unions tend to have less pro-cyclical (or more counter-cyclical) wages.

In this paper, we also adopt a dynamic approach to give account of possible lagged effects and persistence of the data over time. Indeed, the horizon is important since, as argued in the theoretical model, it is possible that due to the presence of labour adjustment cost, wages take time to adjust to changes in business cycle conditions.

In particular, we propose a precise measure of wage cyclicality based on the generalized impulse response function (GIRF) of growth real wages to a shock in the cycle measure -the output gap or the growth rate of the GDP and the industrial production. An important improvement of the GIRF is that it does not require identifying assumptions that are usually needed for VAR decompositions.

Briefly, the idea is to obtain a media of the future shocks in a way that the response is an average of what could happened given the present and the past. Given an actual arbitrary shock, δ_k, in the k variable, the GIRF is defined as:

$$GIRF[n, \delta_k, \Omega_{t-1}] = E[y_{t+n} \mid \varepsilon_{kt}, \Omega_{t-1}] - E[y_{t+n} \mid \bar{\Omega}_{t-1}] \tag{13}$$

Where n is the number of periods ahead, $\delta_k = (\sigma_{kk})^{1/2}$ denotes one standard error shock, Ω_{t-1} is all the information available in the moment of the shock (*i.e.* the known history of the economy up to the moment $t-1$), $E[\cdot|\cdot]$ is the conditional mathematical expectation taken with respect to the VAR model and ε_{kt} are the original innovations in the VAR. In opposition to the standard impulse response function, in the GIRF all contemporaneous and future shocks are integrated out. Thus, the generalized impulse response function for the y vector n periods ahead is the difference between the expected value of y_{t+n} when the δ_k shock is taken into account and the expected value without the shock. Assuming Gaussian errors, Koop, Pesaran, and Potter (1996)

[5]For instance, Abraham and Haltiwanger (1995) assume that labor demand disturbances shift the labor demand schedule and generate positive comovements between real wages and employment. Labor supply disturbances, in turn, shift the labor supply schedule and generate negative comovements between real wages and employment. Additionally, another identifying assumption is that the demand and supply shocks are uncorrelated.

show that the conditional expectation of the shock is equal to:

$$E[\varepsilon_t|\varepsilon_{kt} = \delta_k] = (\sigma_{1k}, \sigma_{2k}, ..., \sigma_{mk})' - \sigma_{kk}^{-1}\delta_k = \Sigma e_j {\sigma_{jj}}^{-1}\delta_j \qquad (14)$$

where e_k is the selected vector with the k-th element equal to one and all other elements equal to zero and $\Sigma = E(\varepsilon_t \varepsilon_t^{'})$. Then, the GIRF for a one standard deviation shock, $\delta_k = 1$, to the k variable is:

$$\gamma_k(n) = \psi_n \Sigma e_k \sigma_{kk}^{-1} \qquad (15)$$

Thus, given the historic distribution in the residuals, it is important to notice that a one shock in the k-th equation implies shocks in the other equations as well. In this way, the generalized impulse response does not pretend to answer what would happened if there is one shock with "all other thing remaining equal". It is rather the historical distribution of residuals (as expressed in the variance and covariance matrix) which determines the effects of the impact of other variables.

3.2 Data description

We consider quarterly data on nominal hourly earnings in the manufacturing sector, Consumer Price Index (CPI) deflator, Producer Price Index (PPI) deflator, real GDP, the industrial production index and the employment rate for the USA in the 1960Q1-2011Q4 period. All the data is provided by the OECD main economic statistics.

We computed consumer and producer real wages as hourly wages divided by the consumer price index or the producer price index, respectively. We worked with the year-on-year growth rate of real wages.

Given that there are a number of issues that may affect the sensitivity of the estimated cyclicality, we consider different indicators for the cycle (the output gap, the annual growth rate of the industrial production and the GDP) and real wages (consumption and production). In addition, instead of considering the relationship between filtered series for a series of reasons regarding the properties of filtered data, we estimate the VAR models with annualized growth rates.[6]

4 Real wage cyclicality in the USA

In this section we present first the graphical representation of the generalized impulse response functions derived from our VAR models for the United States between the 1960-2011 period. We then calibrate and simulate the model presented in section 2.

4.1 The Generalized Impulse Response Function

To investigate the cyclical character of real wages, we first analyze the response of wages to a shock in the cycle measure (the output gap, GDP growth and industrial production growth).

[6] The only exception is the output gap which corresponds to the difference, in percentage points, between the real GDP and the potential GDP computed with the HP filter.

Figure 1 displays the results of the generalized impulse response function together with their 5% error bands for forty different forecasting horizon obtained from the different VAR models.[7]

[INSERT figure 1]

Two main comments can be drawn from these figures. First, as expected, the GIRF show that production wages display a relatively more pronounced but less prolonged response to a shock in the output gap. In turn, the shock last considerably longer for consumption wages. This small difference between consumption and producer wages can be explained by the fact that, compared to the PPI, the CPI is likely to be most influenced by the cyclical evolution of mark-ups at later stages of the production and distribution chains (e.g. Messina (2009)). Second, the confidence intervals are larger in the cases of the two other business cycle indicators (growth GDP and growth industrial production index). In both cases wages seem to be anti-cyclical after about 8 periods or acyclical in the case of production wages.

Summing up, at the aggregate level and, at least in the short-run, real wages in the USA react negatively to a shock in the business cycle. In other words, real wages display an anti-cyclic behavior.

4.2 Calibration and simulated results

We calibrate the model presented in Section 2 at quarterly frequency in order to match several empirical facts of the USA economy between 1985 and 2009. We set the discount factor $\beta = 0.99$, which implies a reasonable quarterly interest rate of nearly 1 percent. Following Blanchard and Diamond (1994), we target an average unemployment rate u^* of 11%. This value is consistent with the fraction of unmatched workers in the USA when consider not only the officially unemployed but also those not in the labor force who want a job. Similar to Shimer (2005), we fix a steady-state job separation probability λ equal to 0.10 per quarter and set the value of leisure to b to match an unemployment replacement rate of 40%. The worker's bargaining power, η, is set to one half.

We normalize the average aggregate labor productivity A^* to 1 and assume that $log(A_t)$ follows a first-order autoregressive process of the following form:

$$log(A_t) = \rho log(A_{t-1}) + \epsilon_t, \tag{16}$$

where ϵ_t is an i.d.d. normal distributed random variable $N(0, \sigma_\epsilon)$. The parameters ρ and σ_ϵ are set to match the persistence and standard deviation of the output gap between 1985 and 2009.

As in Silva and Toledo (2009), we set the vacancy costs parameter c such that vacancy costs represent 4.3 percent of wages in the steady state. With respect to the labor adjustment costs, we evaluate the model's results considering the presence of both linear and quadratic disruption

[7] We retained the Schwarz information as criterium for the lag length.

costs. Using USA plant level data, Russell Cooper (2009) estimate that plant loses 3% of its revenues during the adjustment. Thus, the parameter ξ^* is calibrated to approximate this target in the steady sate. Finally, the matching technology parameter φ, the adjustment costs parameter, δ, the labor market tightness, θ^*, and the wage, w^*, are calibrated by solving the equations (1), (2), (6) and (12) in the steady-state.

We simulate the model considering linear, $\chi = 1$, and quadratic, $\chi = 2$, labor adjustment costs as well as the possibility that the disruption costs operate immediately or with one period lag, capturing the idea that reorganizing the production process after labor adjustment takes time. Given the wage and the labor adjustment costs. We also consider an scenario without labor adjustment costs by fixing $\xi_t = 1$ for every aggregate state. In all these simulations we adjust the parameters of the model in order to maintain our calibration target values. We simulate the economy for 500 periods and discard the first 385 of them in order to obtain the USA period between 1985 and 2009 (116 quarters). We generate the output gap, y_{gap_t} using an HP filter with 1600 smoothing parameter and we log-differentiate the wage to obtain the annualized growth rate of wages, Δw_t. Finally, we estimate a set of VAR models with these two simulated variables. Finally, we calculate the generalized impulse response of wages with respect to a positive shock in the output gap.

Figure 2 shows the generalized impulse-response functions of the annualized growth rate of real wage with respect to a positive shock of one standard deviation in the output gap.[8] When there are not labor adjustment costs (Figure 1.a), wages growth during the first three quarters. After that quarter, the impact of the shock is negative. In contrast, under the presence of quadratic disruption costs with no lag adjustment (Figure 2.b), the wages show an negative behavior, decreasing during the first three quarters. Then, Δw_t becomes positive.

[INSERT figure 2]

In Figures 1.c and 1.e, wages show an inverted hump-shaped patterns when reorganizing employment lags one period and generates quadratic and linear adjustment costs, respectively. In the case of quadratic costs (Figure 1.c), Δw_t falls rapidly during the first three quarters and then decreases but at a much lower rate. Instead, with the presence of linear costs, Δw_t increases in the first quarter and then, as in the case of the presence of quadratic costs, decreases during the next quarters.

[INSERT figure 2]

Finally, Figure 1.d shows that under the presence of linear labor disruption costs with no lag adjustment, the response of wages is near zero. In this case, the positive effect of the increase in the output gap is canceled out by the negative effect that operates throughout the reduction in the implicity worker's bargaining power, so wages are rigid under this scenario.

[8]Similar results are obtained with a positive shock in the annual growth rate of wages. For simplicity, we don't show the impulse-response functions but they are available upon request.

[INSERT figure 2]

Summarizing, when labor disruption costs are present, firms translate part of them to the workers' wages, reducing their implicit bargaining power and, depending on the structure of these costs, generating a reduction in wages in response to a positive shock in the output gap. To illustrate this behavior, Figure 3 shows the impulse response functions of the implicit bargaining power, $\Delta\widehat{\eta}_t$, after a positive shock in the output gap under the presence of quadratic and linear labor disruption costs with different lag adjustments. The workers bargaining power decreases as a consequence of the adjustment in the disruption costs, implying that these costs are partially translated to workers throughout a reduction in real wages.

[INSERT figure 3]

A key labor market variable of the model is the relative number of vacancies to unemployment, θ_t, also known as labor market tightness. Figure 4 shows the generalized impulse-response functions of $\Delta\theta_t$ to a positive y_{gap_t} under different scenarios of labor adjustment costs. In all of these scenarios, labor market tightness increases during the first two or three quarters of the shock and then decreases. However, in most of the cases, the response becomes not significant after the four quarter. With respect to the rest of variables, and according to the response of θ_t, the model generates a procyclical behavior in vacancies and employment and a countercyclical response in unemployment during the first three or four quarters of a positive shock in y_{gap_t}.

[INSERT figure 4]

5 Conclusions

How real wages react to business cycle conditions has been a subject of important debates for a very long time. Indeed, theoretically, real wages are found to be counter-cyclical under sticky wages (i.e the keynesian point of view) but procyclical under sticky prices (real business cycle and new keynesian propositions). Furthermore, the empirical evidence is no less controversial and inconclusive, with results depending on the wage measure adopted, the price index, the detrending technique, the frequency of the data or even the period analyzed.

In order to contribute to this debate, we propose a model with search and matching frictions and labor disruption costs. In addition, we estimate a generalized impulse response function derived from a bi-variate VAR model with real wages and different measures of the business cycle for quarterly data for the United States between 1960 and 2011.

We provide evidence that manufacturing real wages are counter-cyclic in the United States. In effect, the impulse-response functions show that real wages fall after a positive shock in the output gap and display an inverted hump-shaped pattern after a few quarters. Moreover, the simulated results of our model match remarkably well the counter-cyclicality obtained from our empirical model. According to our theoretical model, wages behave counter-cyclically because, with a positive shock in the output gap and in the presence of labor disruption costs, firms translate part of these costs to the workers' wage, reducing their implicit bargaining power and, therefore, generating a decrease in wages in response to a positive shock in the output-gap.

In addition, the calibration and simulation of the model show that different types of disruption cost (i.e quadratic, linear, etc) tend to generate a countercyclical or even an acyclical responses of wages. In contrast, in the absence of disruption costs wages are highly procyclic. Therefore, our model allows to explain the different pattern found in the empirical literature. For instance, according to our findings, the USA behaves as an economy with quadratic labor adjustment costs with one period lag. Summing-up, we propose that, other things equal, in an economy in which labor disruption costs are present, real wages may react in a countercyclical way in response to an aggregate labour productivity shock.

Figure 1: **Generalized impulse response function: Consumer and producer real wages and output gap/unemployment as cyclical indicators**

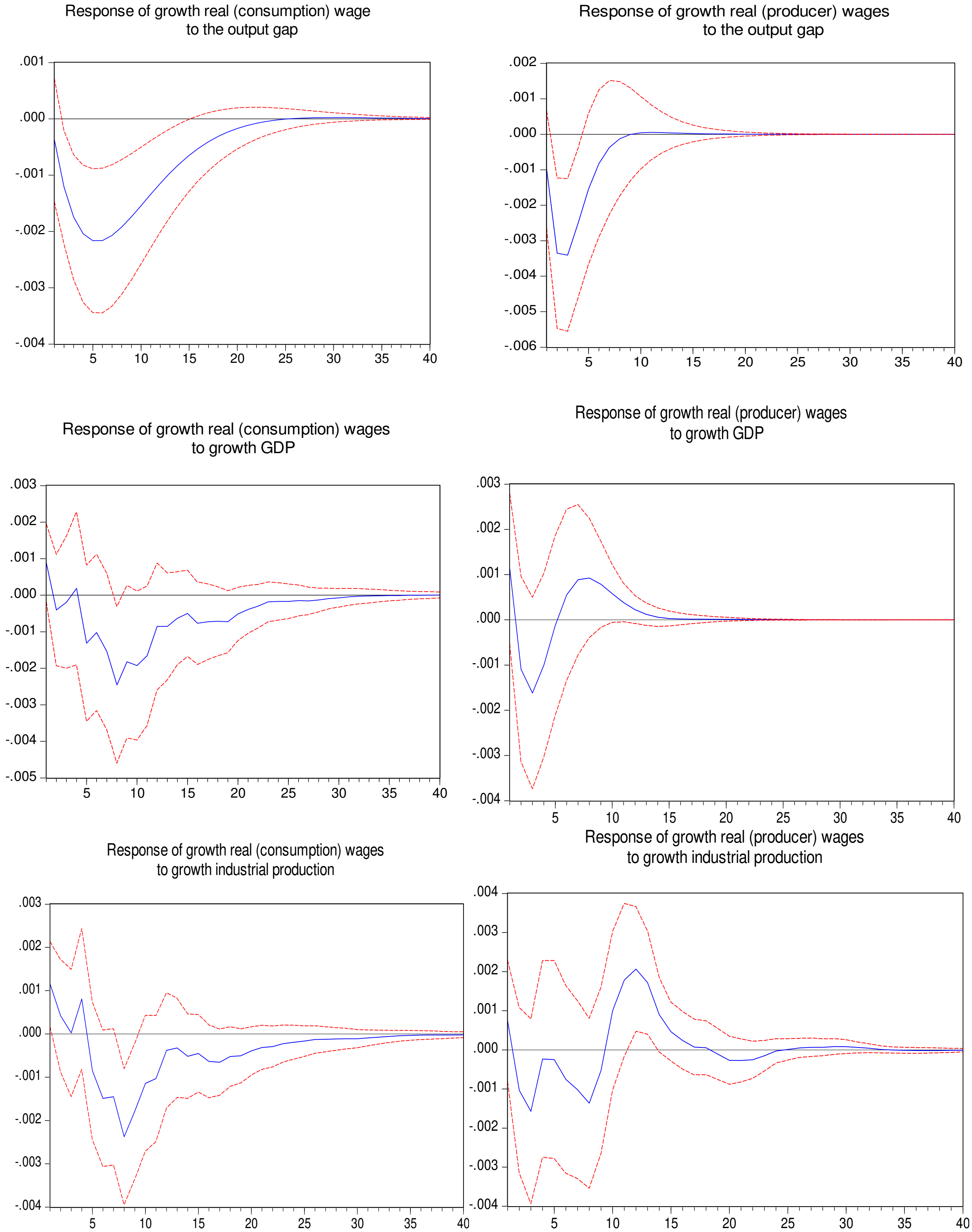


Figure 2: Generalized impulse-response functions of Δw_t to a positive y_{gap_t} shock

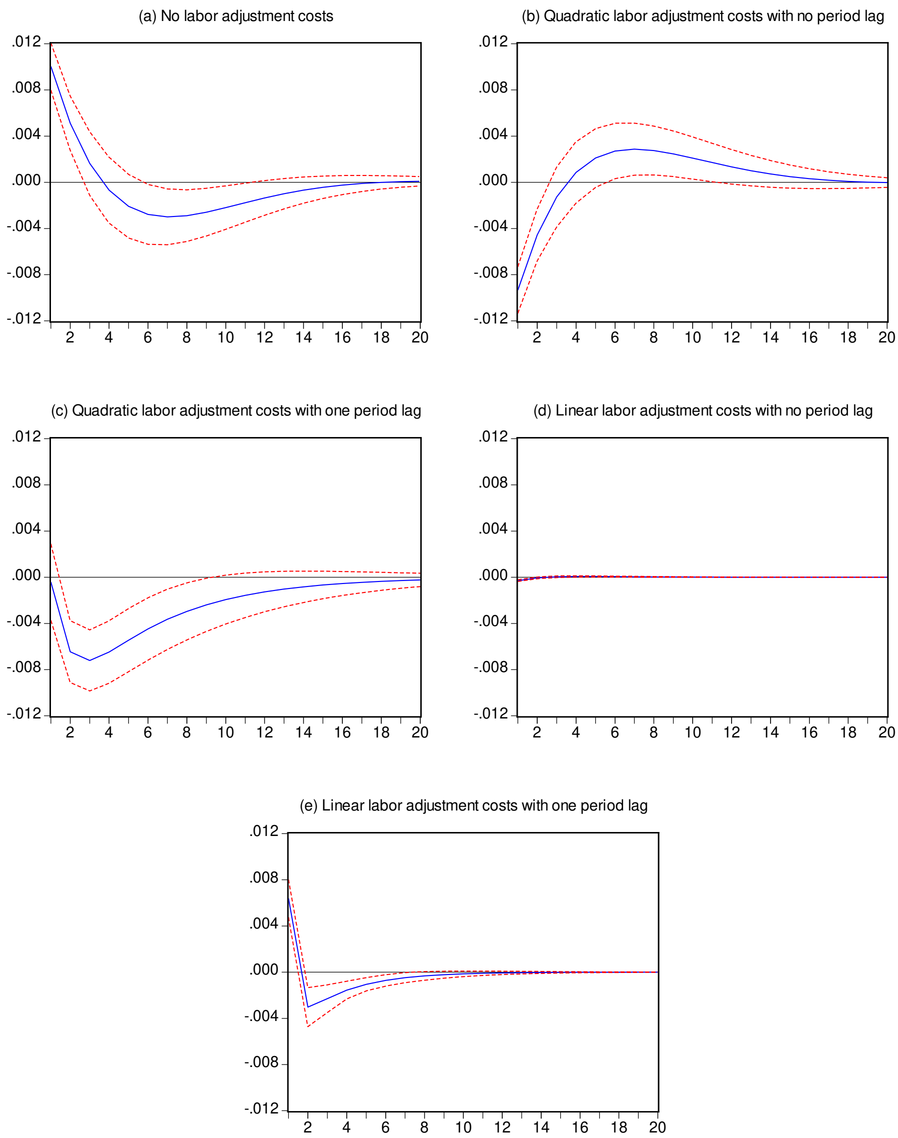


Figure 3: Generalized impulse-response function of $\Delta\widehat{\eta}_t$ to a positive y_{gap_t} shock

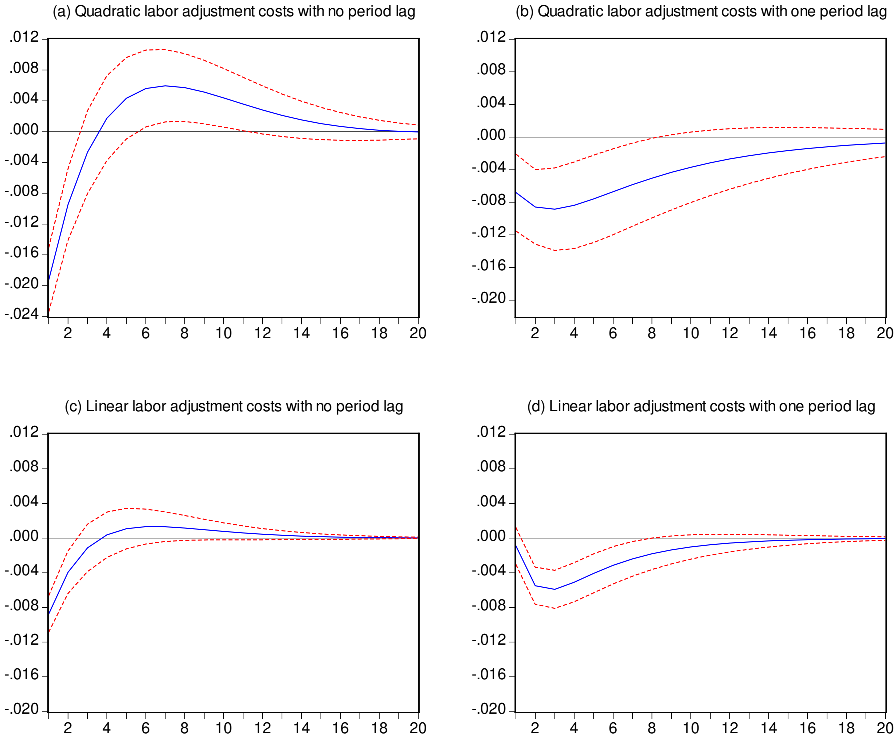
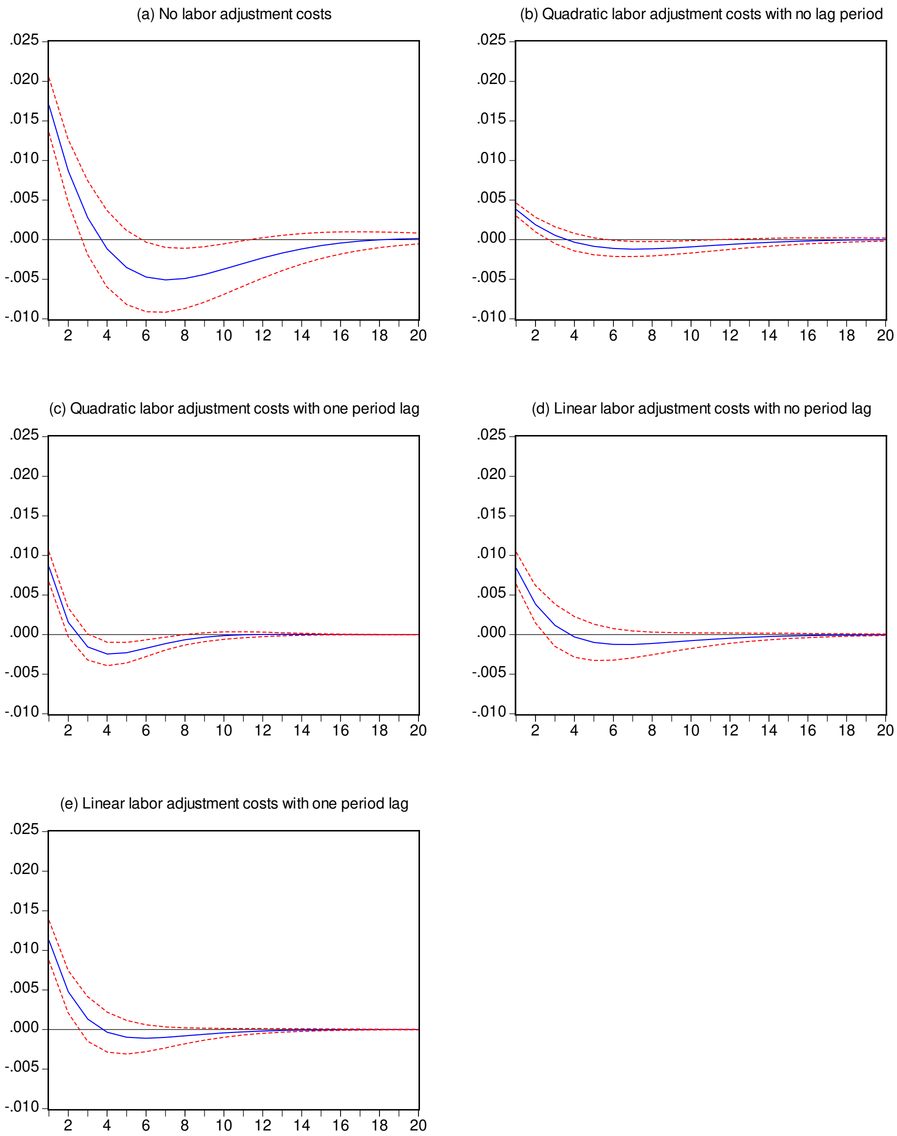


Figure 4: Generalized impulse-response function of $\Delta\theta_t$ to a positive y_{gap_t} shock



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