Immigration and the Macroeconomy: Some New Empirical Evidence. ONLINE APPENDIX*

Francesco Furlanetto† Ørjan Robstad‡
Norges Bank Norges Bank

October 2018

Abstract

We propose a stylized New Keynesian model driven by immigration shocks. The model is used to check the theoretical foundations of the identification assumptions imposed in the SVAR model and to shed light on the economic mechanisms that may explain a decrease in unemployment in response to a positive immigration shock. We present also additional impulse responses from the SVAR model and we describe an extension in which we disentangle the business cycle shock into a demand and a productivity shock.

1 Model

In this Online Appendix we extend the New Keynesian model with endogenous labor force participation and search and matching frictions presented in Foroni, Furlanetto and Lepetit (2018). We include an immigration shock which is modeled as an exogenous increase in population as in Kiguchi and Mountford (2017), Smith and Thoenissen (2018) and Weiske (2017). We consider two scenarios: in the first, immigrants enter the labor market as searchers; in the second, immigrants enter directly into the employment pool. Although very stylized, the model is useful for a theoretical cross-check of our identification

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†Corresponding author. Norges Bank, P.O. Box 1179 Sentrum, 0107 Oslo, Norway. E-mail: francesco.furlanetto@norges-bank.no

‡Norges Bank, Bankplassen 2, P.O. Box 1179 Sentrum, 0107 Oslo, Norway. E-mail: orjan.robstad@norges-bank.no

assumptions and to shed light on the economic mechanisms that may explain a decrease in the unemployment rate in response to a positive immigration shock.

The model departs from the standard New Keynesian model in three ways. First, the labor market is not perfectly competitive but is characterized by search and matching frictions. Second, the labor force participation decision is modeled explicitly. Individual workers can be in three different labor-market states: employment, unemployment, and outside the labor force (which we also refer to as non-participation). Third, we include an immigration shock modeled as a shock to population. The core of the model is taken from Foroni, Furlanetto and Lepetit (2018) where all the parts of model not related to the immigration extension are described in detail.

Labor market. Following Kiguchi and Mountford (2017), Smith and Thoenissen (2018) and Weiske (2017), population (POP_t) is subject to exogenous immigration shocks (IMM_t) and evolves accordingly to the following law of motion: $POP_t = POP_{t-1} + IMM_t$. The new citizens enter directly into the labor force upon arrival, in keeping with our interest in job-related immigration in the empirical model.

The total population is given by

$$POP_t = L_t + IMM_t + O_t$$

where L_t represents the number of domestic participants and O_t the number of citizens who are outside the labor force, or equivalently:

$$1 = l_t + imm_t + o_t$$

where lower case variables indicate proportions in the total population. The process for immigration over population evolves as follows:

$$\log imm_t = \rho_{imm} \log imm_{t-1} + \varepsilon_{imm,t}$$

where $\varepsilon_{imm,t}$ is an independently and identically distributed $N(0,\ \sigma^2_{imm})$ immigration shock.

In our baseline model immigrants enter the labor market as searchers. Workers and firms need to match in the labor market in order to become productive. The number of matches in period t is given by a Cobb-Douglas matching function $M_t = \Gamma S_t^{\alpha} V_t^{1-\alpha}$, S_t being the number of job seekers and V_t the number of vacancies posted by firms. The parameter Γ reflects the efficiency of the matching process. $\alpha \in [0,1]$ is the elasticity of the matching function with respect to the number of job seekers. Define $\theta_t = \frac{V_t}{S_t}$ as labor market tightness. The probability q_t for a firm of filling a vacancy and the probability p_t for a worker of finding a job are respectively $q_t = \frac{M_t}{V_t} = \Gamma\theta_t^{-\alpha}$ and $p_t = \frac{M_t}{S_t} = \Gamma\theta_t^{1-\alpha}$.

At the end of each period, a fraction ρ of existing employment relationships is exogenously destroyed. We follow Christiano, Eichenbaum and Trabandt (2015) and assume that both those ρN separated workers and the unemployed workers face an exogenous probability of exiting the labor force $1-\omega$, ω being the "staying rate"[1] and N the number of employed workers. At the beginning of the following period, the representative household chooses the number of non-participants $\digamma$ it transfers to the labor force. The size of the domestic labor force in period t is thus given by $L_t = \omega(L_{t-1} + IMM_{t-1} - N_{t-1} + \rho N_{t-1}) + (1-\rho)N_{t-1} + \digamma_t$ and the number of job seekers by $S_t = \omega(L_{t-1} + IMM_{t-1} - (1-\rho)N_{t-1}) + IMM_t + \digamma_t = L_t + IMM_t - (1-\rho)N_{t-1}$. Note that immigrants become part of the domestic labor force after one period.

Employment evolves according to the following law of motion

$$N_t = (1-\rho)N_{t-1} + M_t \tag{1}$$

New hires become productive in the period and separated workers can find a job immediately with a probability given by the job finding rate, in keeping with the timing proposed by Ravenna and Walsh (2008). The unemployment rate in period t is $u_t = \frac{L_t + IMM_t - N_t}{L_t + IMM_t}$.

We consider also an alternative scenario in which immigrants arrive already with a job

[1] As in Christiano, Eichenbaum and Trabandt (2015), we introduce this staying rate to account for the fact that workers move in both directions between unemployment, employment and participation. However, the introduction of ω has no impact on the equilibrium conditions of the model. The household adjusts the number of non-participants that enter the labor force ($\digamma_t$) according to the value of ω in order to reach its desired value of L_t.

(a similar case is also considered by Kiguchi and Mountford, 2017, in their appendix). In that case the law of motion for employment reads

$$N_t = (1-\rho)N_{t-1} + IMM_t + M_t$$

and the definition of searchers is changed accordingly.

Households. The household utility is expressed as

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{c_t^{1-\sigma}}{1-\sigma} - \chi \frac{l_t^{1+\varphi}}{1+\varphi} \right] POP_t \tag{2}$$

where c_t is the consumption level of each member of the household, l_t the proportion of domestic participants in the total population, β the household discount factor, σ the coefficient of risk aversion. Full risk sharing implies the same level of consumption for all family members. These preferences are akin to those used by Arseneau and Chugh (2012) and Galí (2011) when the disutility of participating in the labor force is identical for employed and unemployed workers. Shocks to the parameter χ are interpreted as domestic labor supply shocks, as discussed in Foroni, Furlanetto and Lepetit (2018). The household chooses consumption and the number of participants so as to maximize (2) subject to its budget constraint and its perceived law of motion of employment

$$P_t C_t + (1+R_t)^{-1} B_{t+1} = P_t \left[w_t N_t + b^u U_t \right] + B_t + P_t \Pi_t^r - P_t T_t \tag{3}$$

$$N_t = (1-\rho)N_{t-1} + p_t \left[L_t + IMM_t - (1-\rho)N_{t-1} \right] \tag{4}$$

Total labor income is given by $w_t N_t$ and unemployed household members (U_t) receive unemployment benefits b^u where $U_t = L_t + IMM_t - N_t$. Households receive profits Π_t^r from the monopolistic sector and invest in risk-free bonds that promise a unit of currency tomorrow and cost $(1+R_t)^{-1}$. They also have to pay lump-sum taxes T_t in order to finance the unemployment insurance system. The final consumption good $C_t \equiv \int_0^1 \left[C_t(z)^{\frac{\varepsilon-1}{\varepsilon}} dz \right]^{\frac{\varepsilon}{\varepsilon-1}}$ is a Dixit-Stiglitz aggregator of the different varieties of goods produced by the retail sector and ε is the elasticity of substitution between the different varieties. The optimal allocation of income on each variety is given by $C_t(z) = \left[\frac{P_t(z)}{P_t}\right]^{-\varepsilon} C_t$, where $P_t = \left[\int_0^1 P_t(z)^{\varepsilon-1} dj\right]^{1/(1-\varepsilon)}$ is the price index.

Firms. The economy consists of two sectors of production. Firms in the wholesale sector produce an intermediate homogeneous good in competitive markets using labor. Their output is sold to final good sector firms (retailers), which are monopolistically competitive and transform the homogeneous goods into differentiated goods at no extra cost and apply a mark-up. Firms in the retail sector are subject to nominal price staggering.

Wholesale firms produce according to the following technology

$$Y_{jt}^w = ZN_{jt} \tag{5}$$

where Z is a common technology parameter. Posting a vacancy comes at cost κ. Firm j chooses its level of employment N_{jt} and the number of vacancies V_{jt} in order to maximize the expected sum of its discounted profits

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{\lambda_t}{\lambda_0} \left[\frac{P_t^w}{P_t} Y_{jt}^w - \kappa V_{jt} - w_t N_{jt} \right] \tag{6}$$

subject to its perceived law of motion of employment $N_{jt} = (1-\rho)N_{jt-1} + V_{jt}q_t$ and taking the wage schedule as given. λ_t represents the marginal utility of consumption. Wholesale firms sell their output in a competitive market at a price P_t^w. We define $\mu_t = \frac{P_t}{P_t^w}$ as the mark-up of retail over wholesale prices. The second and third terms in equation (6) are, respectively, the cost of posting vacancies and the wage bill.

Wages. In order to characterize the outcome of wage negotiations, we must first define the value of the marginal worker for the firm and the value of the marginal employed individual for the household. The value of the marginal worker for the firm is

$$J_t = \frac{Z}{\mu_t} - w_t + E_t \beta_{t+1} (1-\rho) J_{t+1}$$

The value to the household of the marginal employed individual is

$$W_t - U_t^V = w_t - b^u + E_t\beta_{t+1}(1-\rho)(1-p_{t+1})(W_{t+1} - U_{t+1}^V)$$

Wages are then determined through a Nash bargaining scheme between workers and employers who maximize the joint surplus arising from the employment relationship by choosing real wages

$$argmax_{\{w_t\}} \left[(J_t)^{1-\eta}\left(W_t - U_t^V\right)^{\eta}\right] \tag{7}$$

where η is the worker's bargaining power. Shocks to the parameter η are interpreted as wage bargaining shocks as in Foroni, Furlanetto and Lepetit (2018).

Retail firms. A measure one of monopolistic retailers produces differentiated goods with identical technology transforming one unit of intermediate good into one unit of differentiated retail good. The demand function for the retailer's products is

$$Y_t(z) = (P_t(z)/P_t)^{-\varepsilon} Y_t^d \tag{8}$$

where Y_t^d is aggregate demand for the final consumption good. Each retailer can reset its price with a fixed probability $1-\delta$ that is independent of the time elapsed since the last price adjustment. The Calvo pricing assumption implies that prices are fixed on average for $\frac{1}{1-\delta}$ periods. Retailers optimally choose their price $P_t^o(z)$ to maximize expected future discounted profits given the demand for the good they produce and under the hypothesis that the price they set at date t applies at date $t+s$ with probability δ^s.

$$Max_{P_t^o(z)} E_t \sum_{s=0}^{\infty} (\delta^s \beta_{t,t+s} \left[\frac{P_t^o(z) - P_{t,t+s}^w}{P_{t,t+s}}\right] Y_{t,t+s}(z))$$

All firms resetting prices in any given period choose the same price. The aggregate price dynamics are then given by

$$P_t = \left[\delta P_{t-1}^{\varepsilon} + (1-\delta)\left(P_t^o\right)^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}$$

Resource constraint and monetary policy. Aggregating equation (8) across firms, we obtain

$$Y_t = ZN_t = \int_0^1 \left(\frac{P_t(z)}{P_t}\right)^{-\varepsilon} [C_t + \kappa V_t]\, dz \tag{9}$$

where $\int_0^1 \left(\frac{P_t(z)}{P_t}\right)^{-\varepsilon}$ measures relative price dispersion across retail firms. Monetary policy is assumed to be conducted according to an interest rate reaction function responding to inflation (Π_t) and real economic activity

$$log\left(\frac{1+R_t}{1+R}\right) = \phi_r log\left(\frac{1+R_{t-1}}{1+R}\right) + (1-\phi_r)\left(\phi_\pi log\left(\frac{\Pi_t}{\Pi}\right) + \phi_y log\left(\frac{Y_t}{Y}\right)\right) \tag{10}$$

where ϕ_r represents the degree of interest rate smoothing.

2 Results

We use the theoretical model to derive sign restrictions that are robust to parameter uncertainty. In order to do so, we assume that the values of key parameters are uniformly and independently distributed over a selected range. This range for each structural parameter is chosen by conducting a survey of the empirical literature following Canova and Paustian (2011). We then draw a random value for each parameter, obtain a full set of parameters, and compute the impact response to a given shock for each variable of interest. This exercise is repeated for 10,000 simulations. We concentrate our attention on the immigration shock since the effects of all the other shocks are discussed in detail in Foroni, Furlanetto and Lepetit (2018) in the context of the same model.

The model period is one quarter. Some parameters and steady-state ratios are fixed to a particular value. The discount factor is set to 0.99, so that the annual interest rate equals 4%. The steady-state labor force participation rate is set to 0.66, its pre-crisis level. The growth rate of population is set at 0.01 in steady state. We set the steady state levels of tightness and unemployment to their mean values over the period 1985-2014. Our targets will thus be 6% for the unemployment rate and 0.5 for labor market tightness while the steady state job finding rate is fixed at 0.7. These targets imply, through the Beveridge Curve, a job destruction rate of approximately 0.15. The staying rate ω is set to 0.22, its mean in the data over the period 1990-2013.

The intervals for the other parameters are chosen according to the results of empirical studies. The coefficient of risk-aversion σ is allowed to vary in the interval $[1, 3]$, the preference parameter φ driving the disutility of labor supply in the interval $[1, 5]$, and the degree of price stickiness δ in the interval $[0.4, 0.8]$. The elasticity of substitution between goods ε is assumed to vary in the interval $[6, 11]$, which corresponds to a steady-state mark-up between 10 and 20 percent. The elasticity of matches with respect to the number of job seekers α is allowed to vary in the standard interval $[0.5, 0.7]$. The replacement ratio b/w is assumed to lie in the interval $[0.2, 0.6]$, which is centered around the value used by Shimer (2005) and comprises the ratio of benefits paid to previous earnings of 0.25 used by Hall and Milgrom (2008). Following evidence in Silva and Toledo (2009), the vacancy posting cost κ is fixed such that hiring costs are comprised between 4 and 14 percent of quarterly compensation. The steady state values of the matching efficiency parameter Γ, the bargaining power η and the parameter scaling the disutility of participating χ are then determined through steady-state relationships.

For the monetary policy rule, we choose ranges that include parameter values generally discussed in the literature. We restrict the inflation response to the range $[1.5, 3]$, the output response to the range $[0, 1]$, and the degree of interest rate smoothing to the range $[0, 0.9]$. The persistence of the immigration shock is allowed to vary between 0.1 and 0.8. The following table summarizes the ranges for all the parameters:

Parameter	Description	Range
σ	Coefficient of risk aversion	[1,3]
φ	Inverse of the Frisch labor supply elasticity	[1,5]
δ	Degree of price stickiness	[0.4,0.8]
ε	Elasticity of substitution between goods	[6,11]
α	Elasticity of matches with respect to s	[0.5,0.7]
$\frac{b}{w}$	Replacement ratio	[0.2,0.6]
$\frac{\kappa}{q}$	Hiring costs (as a percentage of quarterly wages)	[4,14]
ϕ_r	Interest rate inertia	[0,0.9]
ϕ_π	Interest rate reaction to inflation	[1.5,3]
ϕ_y	Interest rate reaction to output	[0,1]
ρ_{imm}	Autoregressive coefficient, immigration shock	[0.1,0.8]

We now proceed to the simulation exercise. Impulse responses to wage bargaining and domestic labor supply shocks are discussed in Foroni, Furlanetto and Lepetit (2018) and are consistent with the sign restrictions imposed in the SVAR model proposed in the main text. We focus here on the dynamics generated by a positive immigration shock. In Figure 1 we plot impulse responses for the variables used in our baseline SVAR. The solid line represents at each horizon the median across the 10000 impulse responses corresponding to each parameterization while the dashed lines represent the 10th and the 90th percentiles.

All sign restrictions imposed in the SVAR to identify an immigration shock are satisfied also in the DSGE model. In particular, real wages decrease and the aggregate participation rate (including domestic participants and immigrants) increases. This not surprising given that the restrictions are intuitive and tailored to the kind of immigration (i.e. job-related immigration) studied in our empirical model for Norway. Unemployment increases in response to an immigration shock. Immigrants enter as searchers in our model and some of them find a job within the quarter whereas some become unemployed. In contrast, unemployment decreases in our SVAR model in response to an exogenous increase in population.

Note, however, that a decline in unemployment can be obtained also in the DSGE model if immigrants enter the labor market already with a job (directly into the employment pool) and not as searchers. This case is considered in Figure 2 where we see that unemployment decreases in the short-run in response to an exogenous increase in immigration. For many parameterizations the decline in unemployment materializes already on impact. We emphasize that this exercise is purely illustrative to show how a fast integration of immigrants in the labor market can on its own generate expansionary effects in response to an exogenous increase in population. Complementarities in production between natives and immigrants are certainly another plausible mechanism able to generate expansionary effects.

3 Additional impulse responses from the SVAR model

In Figures 3 to 5 we present impulse responses to business cycle shocks, wage bargaining shocks and residual shocks from our baseline SVAR model presented in the main text.

In Figures 6 to 10 we show impulse responses to the five identified shocks in the baseline model extended to include one narrative restriction of Type 2 on immigration shocks and one narrative restriction of Type 1 on domestic labor supply shocks, as described in detail in the main text.

In Figures 11 to 16 we propose impulse responses to all shocks in an extension of our baseline model in which we disentangle the business cycle shock into two components: a demand shock and a supply (productivity) shock. Such a specification captures a more complete description of the Norwegian business cycle but does not allow us to leave the price index unrestricted in response to immigration shocks, arguably a benefit of our baseline specification. We disentangle the demand shock from the other shocks by assuming that prices increase in response to a positive demand shock (while unemployment decreases). A residual shock captures the dynamics not accounted for by the remaining five shocks, as in the baseline model. Note that the medium-run response of prices to an immigration shock is positive as in our baseline set-up. Unemployment still decreases in response to a positive immigration shock.

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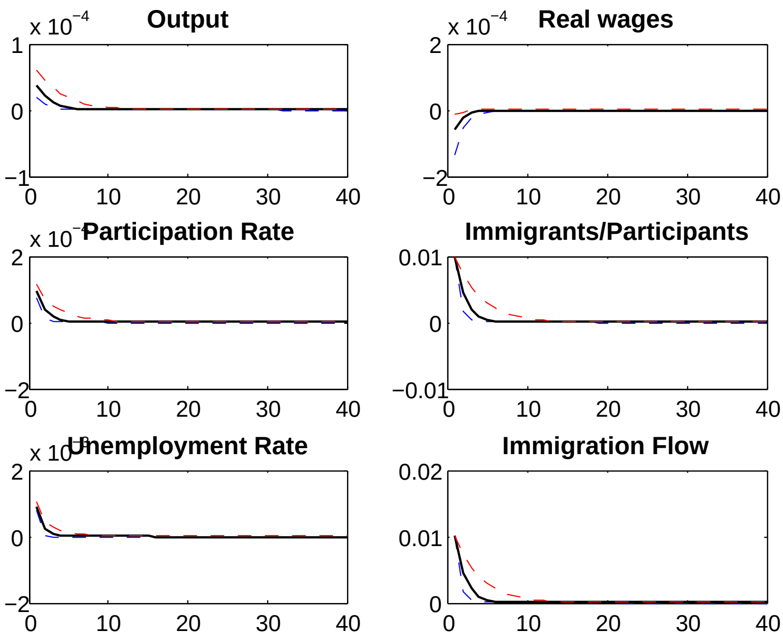

Figure 1: Impulse responses to an immigration shock from the theoretical model where immigrants enter as searchers. The solid line represent the median impulse response from the 10,000 parameter draws. The dashed lines represent the 10th and 90th percentile impulse response from the different parameter draws.

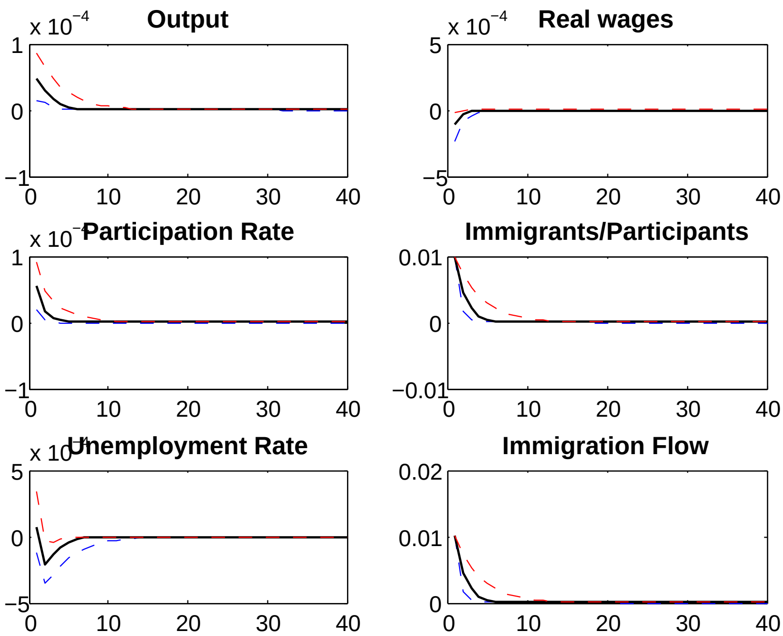

Figure 2: Impulse responses to an immigration shock from the theoretical model where immigrants enter as employed. The solid line represent the median impulse response from the 10,000 parameter draws. The dashed lines represent the 10th and 90th percentile impulse response from the different parameter draws.

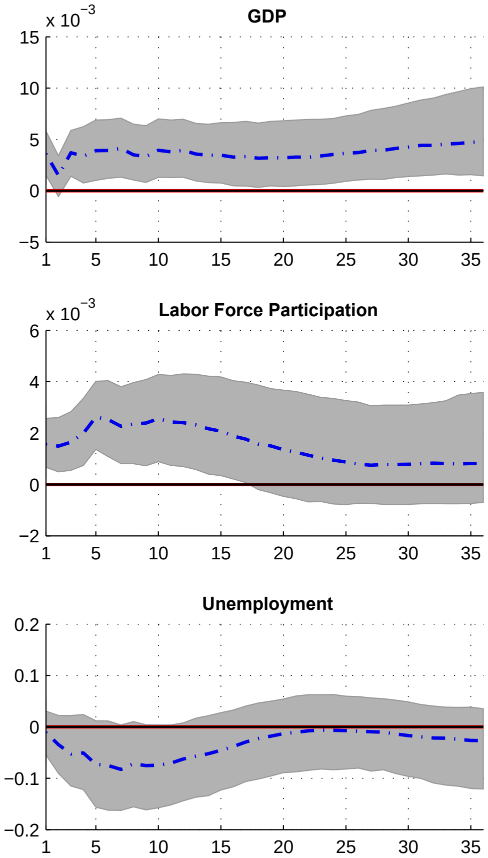

Figure 3: Impulse responses to an one-standard-deviation business cycle shock in the baseline model. The dashed-dotted line represent the posterior median at each horizon and the shaded area indicates the 68th posterior probability region of the estimated impulse responses

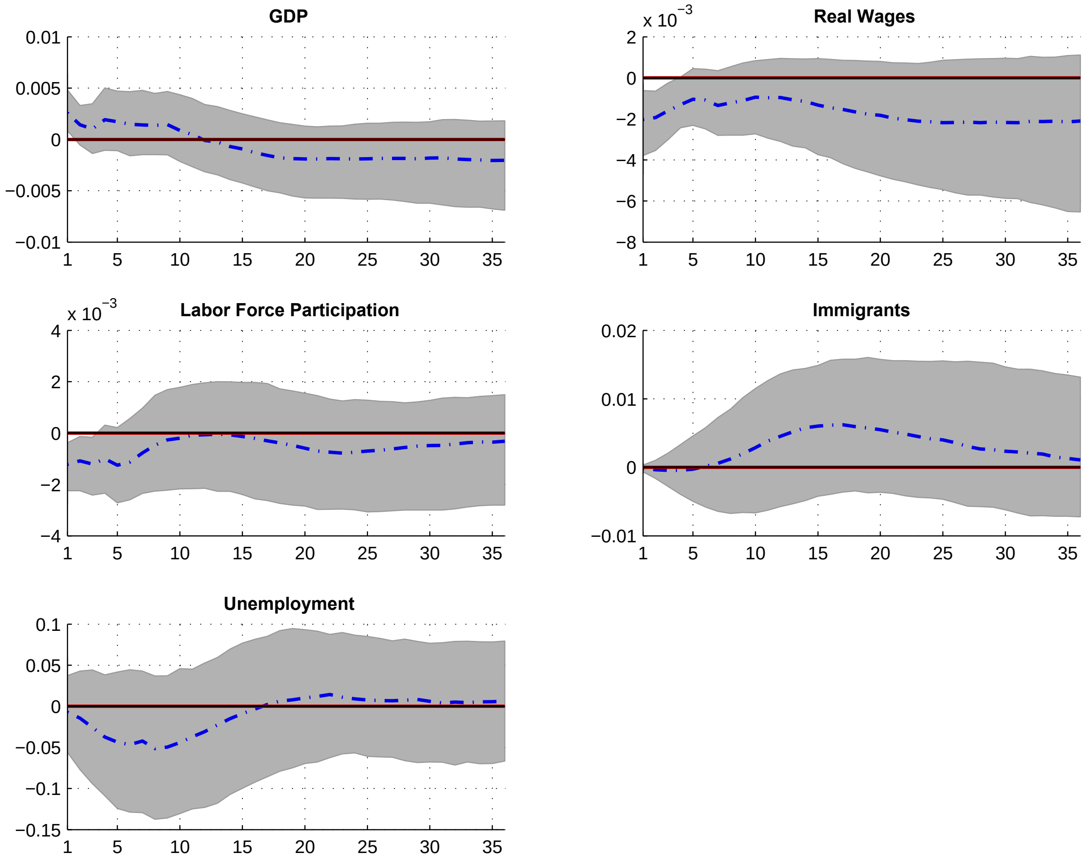

Figure 4: Impulse responses to an one-standard-deviation wage bargaining shock in the baseline model. The dashed-dotted line represent the posterior median at each horizon and the shaded area indicates the 68th posterior probability region of the estimated impulse responses

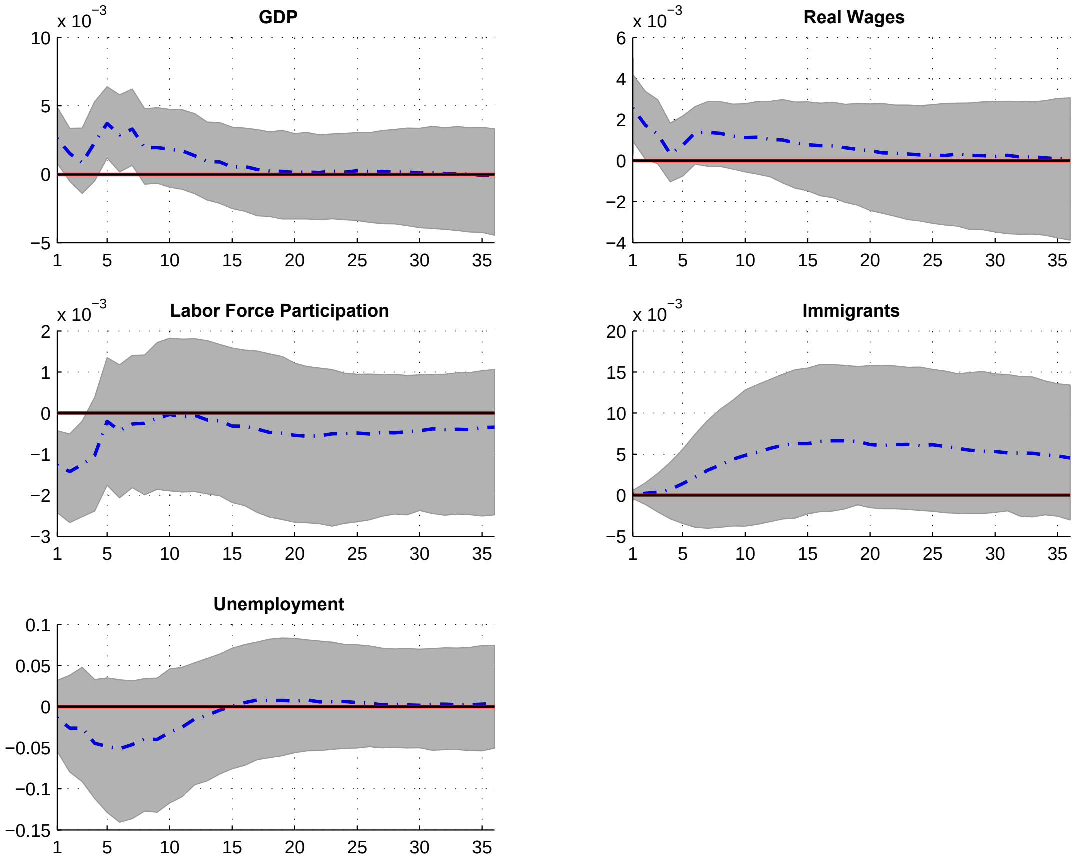

Figure 5: Impulse responses to an one-standard-deviation residual shock in the baseline model. The dashed-dotted line represent the posterior median at each horizon and the shaded area indicates the 68th posterior probability region of the estimated impulse responses

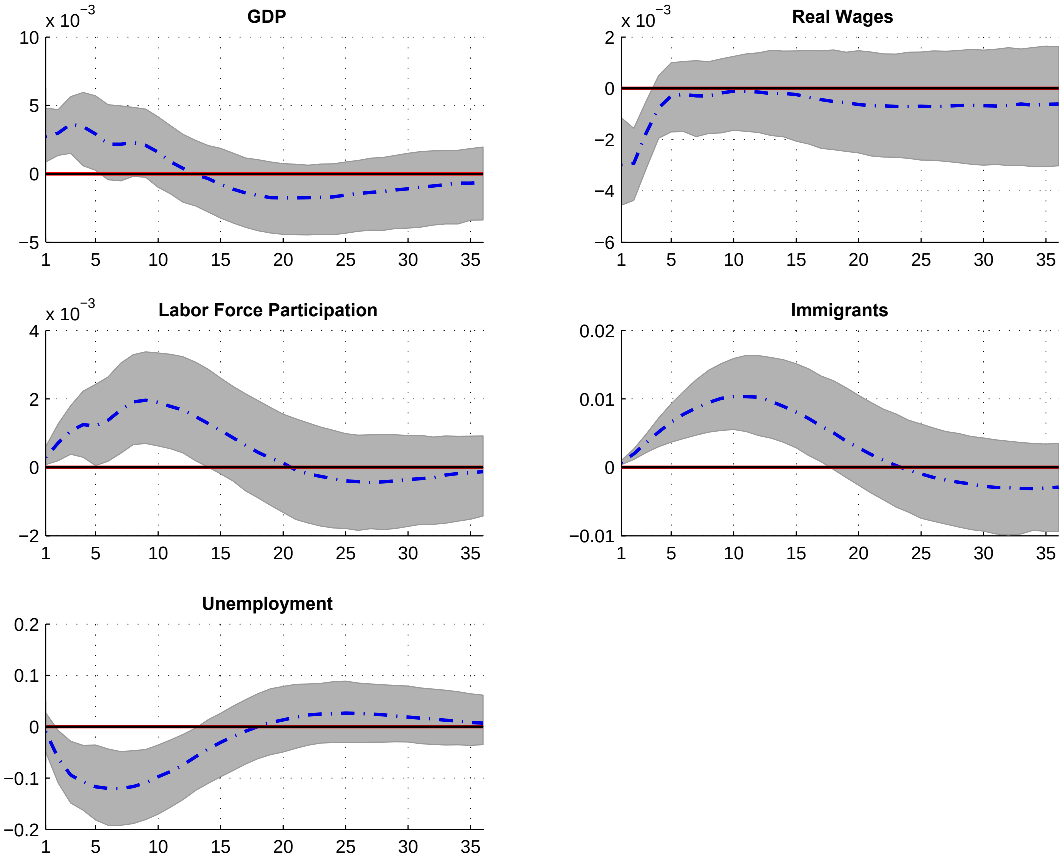

Figure 6: Impulse responses to an one-standard-deviation immigration shock in the model with narrative restrictions. The dashed-dotted line represent the posterior median at each horizon and the shaded area indicates the 68th posterior probability region of the estimated impulse responses

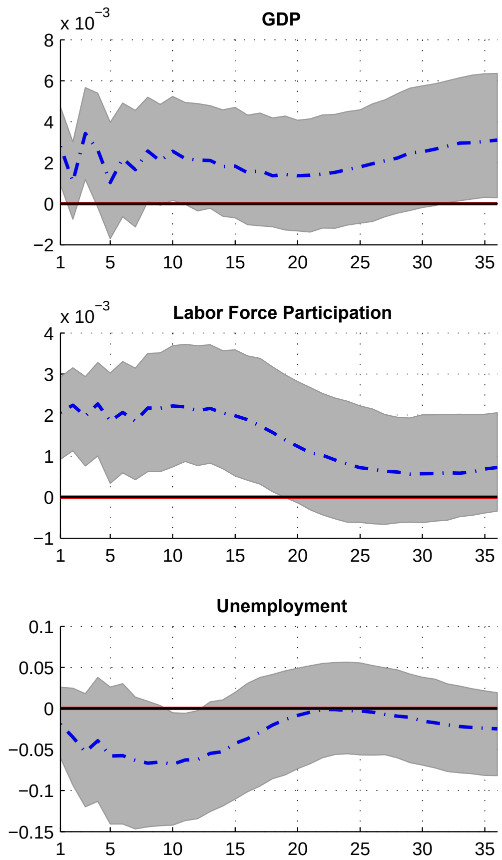

Figure 7: Impulse responses to an one-standard-deviation domestic labor supply shock in the model with narrative restrictions. The dashed-dotted line represent the posterior median at each horizon and the shaded area indicates the 68th posterior probability region of the estimated impulse responses

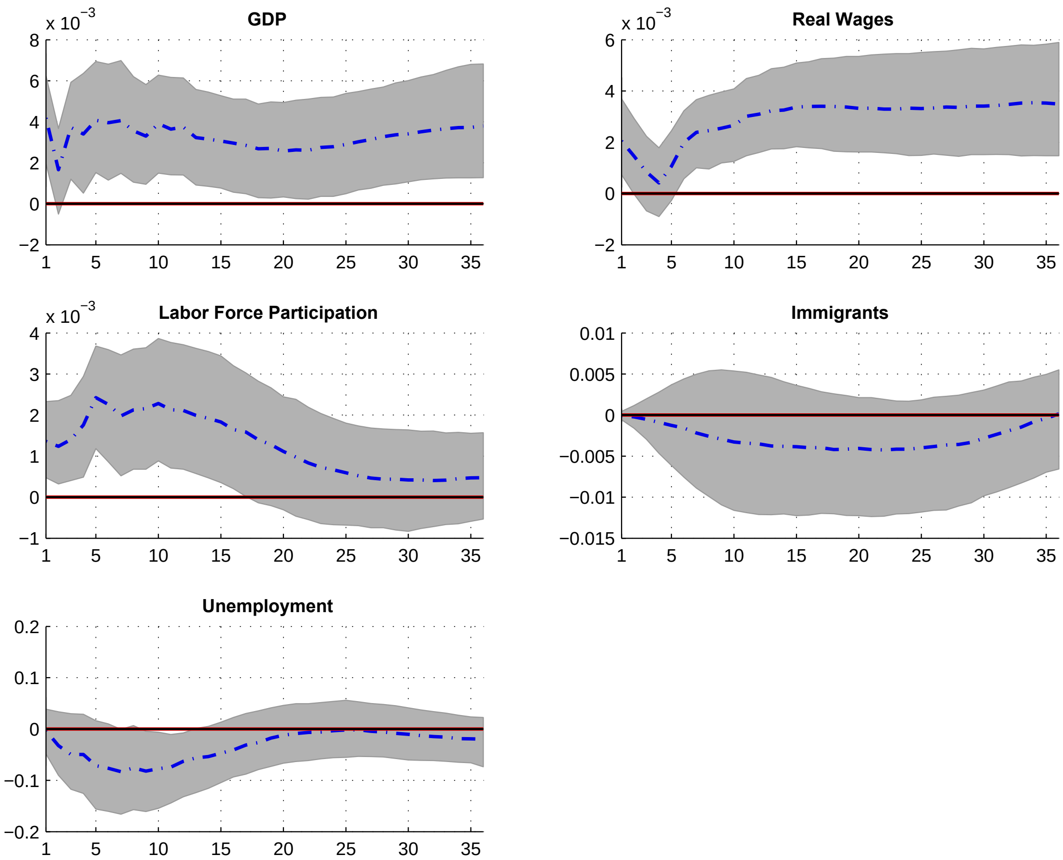

Figure 8: Impulse responses to an one-standard-deviation business cycle shock in the model with narrative restrictions. The dashed-dotted line represent the posterior median at each horizon and the shaded area indicates the 68th posterior probability region of the estimated impulse responses

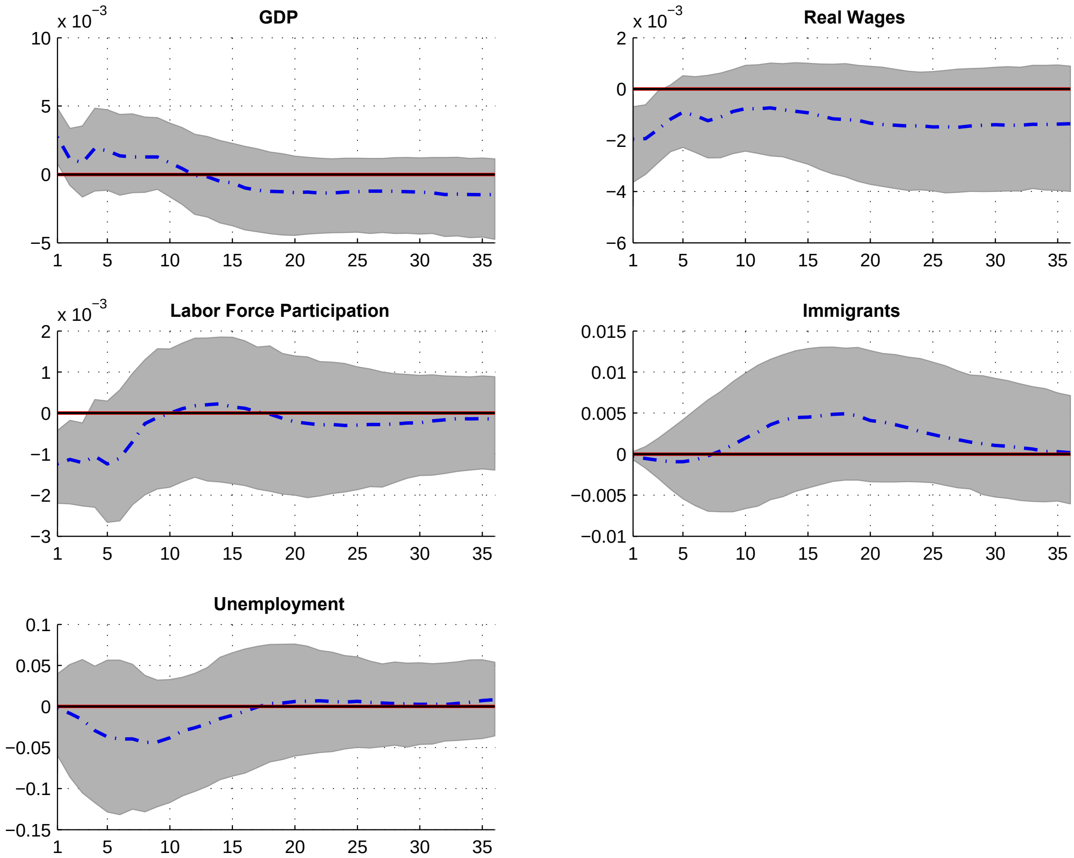

Figure 9: Impulse responses to an one-standard-deviation wage bargaining shock in the model with narrative restrictions. The dashed-dotted line represent the posterior median at each horizon and the shaded area indicates the 68th posterior probability region of the estimated impulse responses

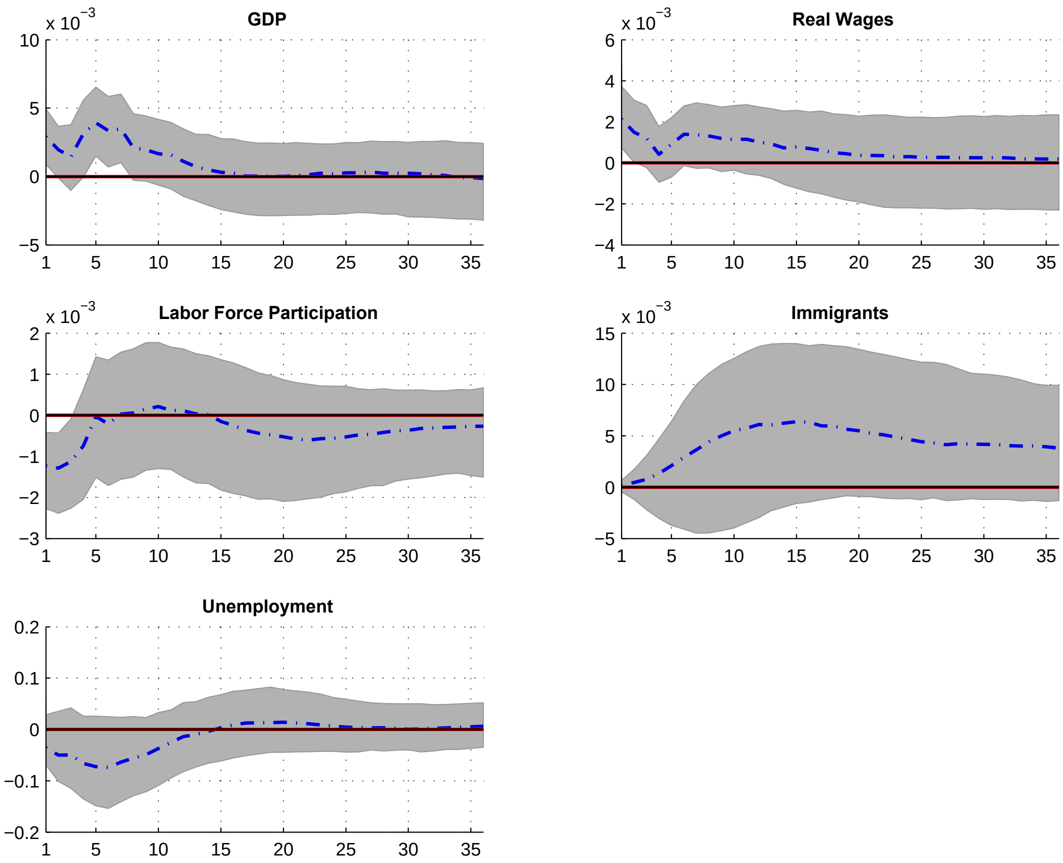

Figure 10: Impulse responses to an one-standard-deviation residual shock in the model with narrative restrictions. The dashed-dotted line represent the posterior median at each horizon and the shaded area indicates the 68th posterior probability region of the estimated impulse responses

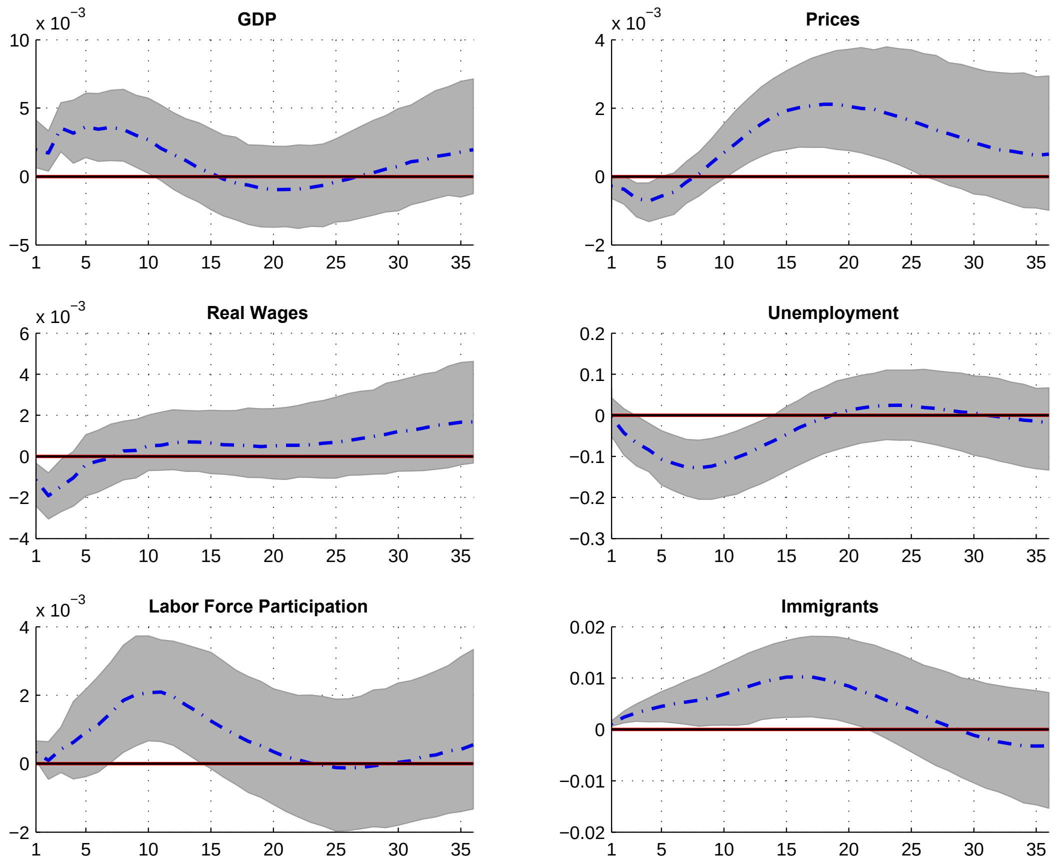

Figure 11: Impulse responses to an one-standard-deviation immigration shock in the extended model. The dashed-dotted line represent the posterior median at each horizon and the shaded area indicates the 68th posterior probability region of the estimated impulse responses

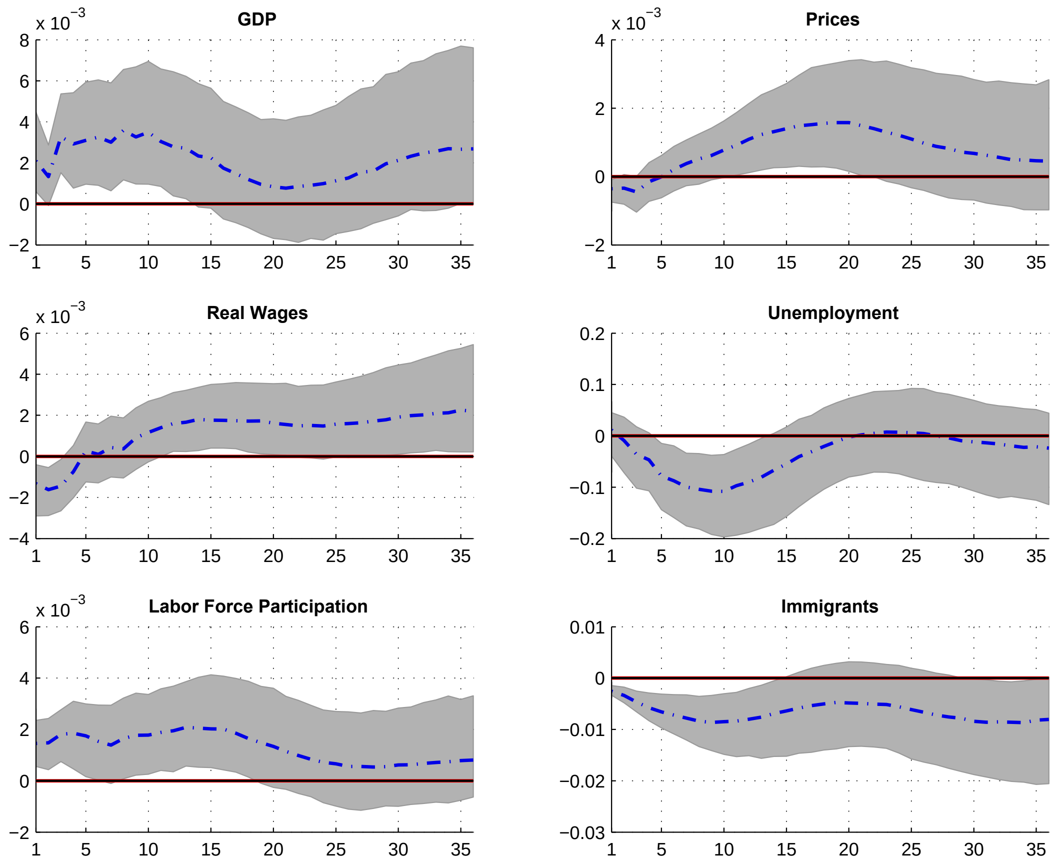

Figure 12: Impulse responses to an one-standard-deviation domestic labor supply shock in the extended model. The dashed-dotted line represent the posterior median at each horizon and the shaded area indicates the 68th posterior probability region of the estimated impulse responses

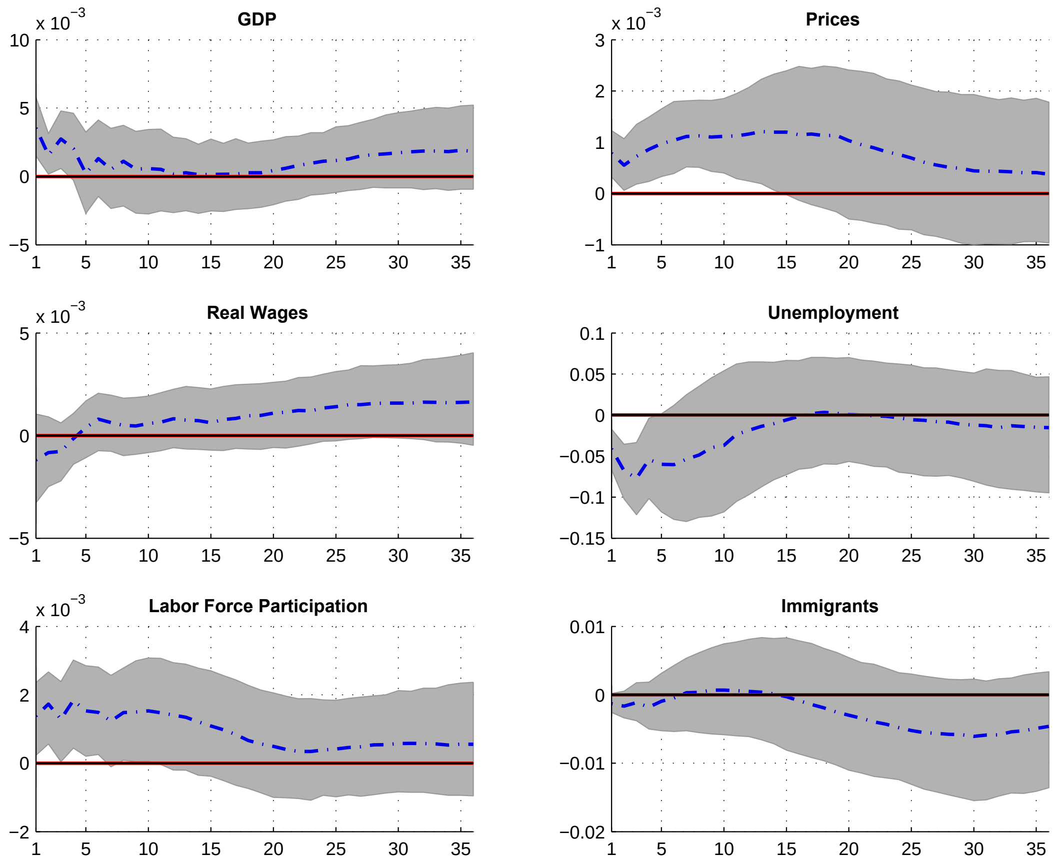

Figure 13: Impulse responses to an one-standard-deviation demand shock in the extended model. The dashed-dotted line represent the posterior median at each horizon and the shaded area indicates the 68th posterior probability region of the estimated impulse responses

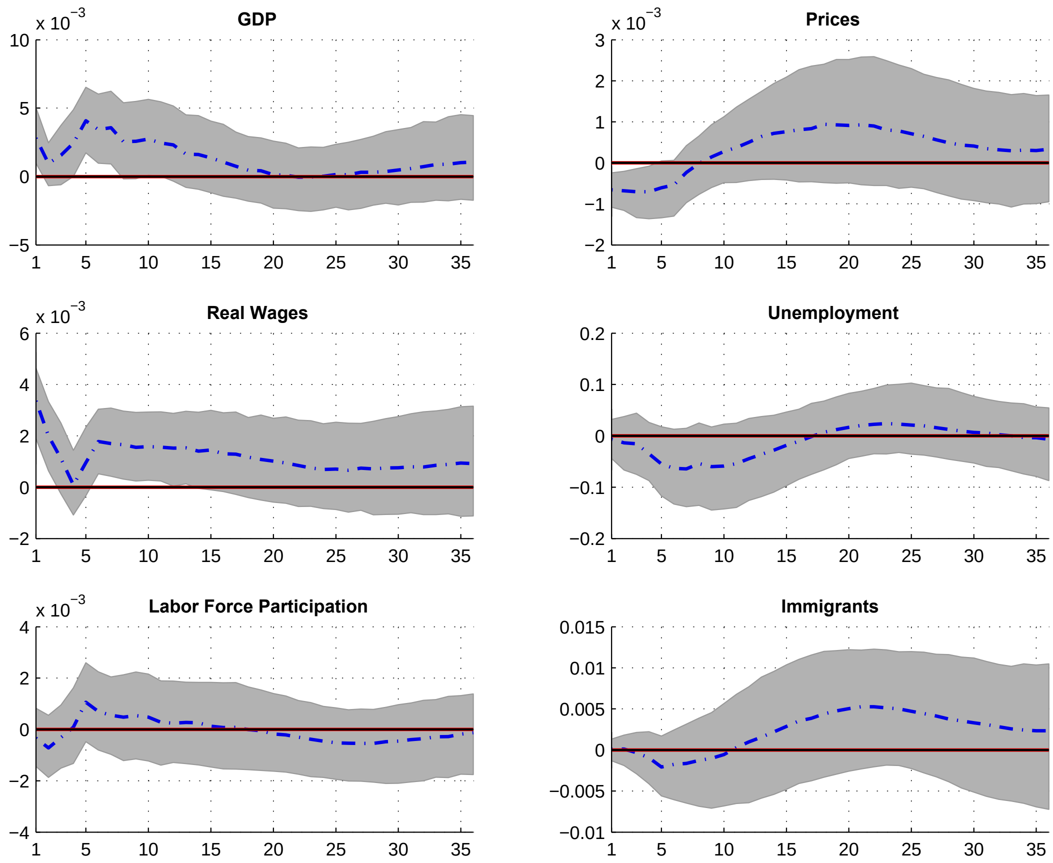

Figure 14: Impulse responses to an one-standard-deviation technology shock in the extended model. The dashed-dotted line represent the posterior median at each horizon and the shaded area indicates the 68th posterior probability region of the estimated impulse responses

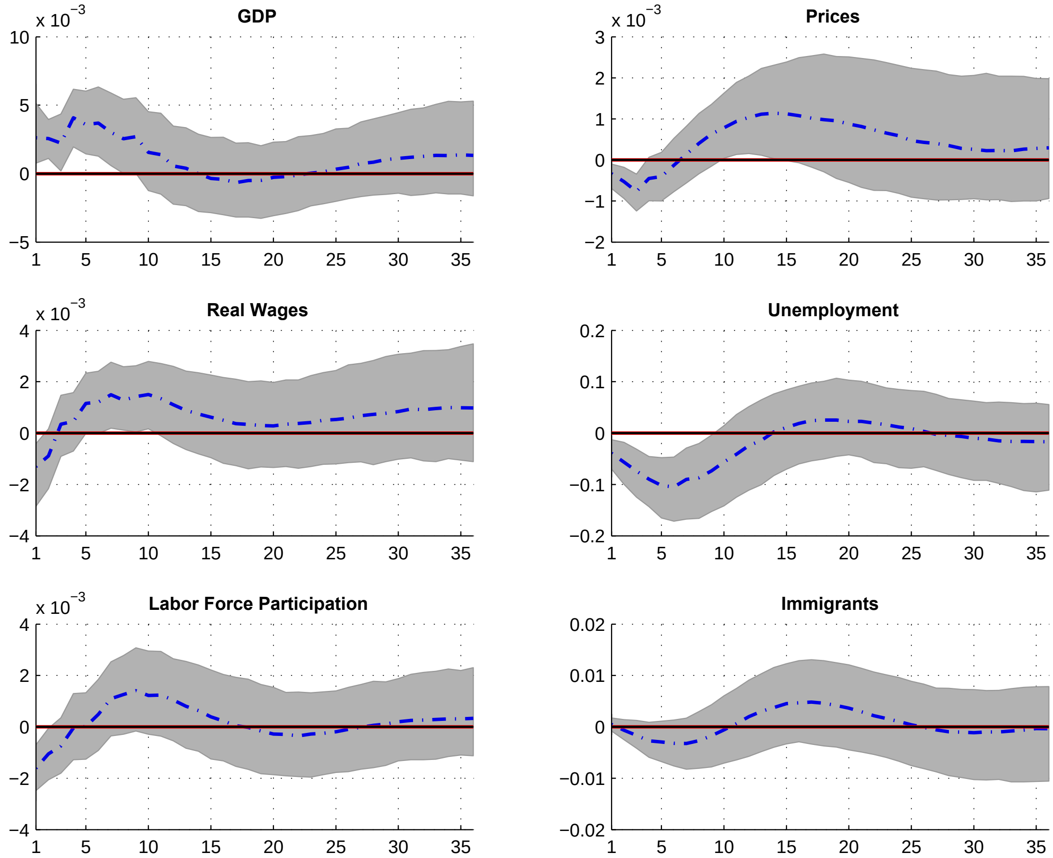

Figure 15: Impulse responses to an one-standard-deviation wage bargaining shock in the extended model. The dashed-dotted line represent the posterior median at each horizon and the shaded area indicates the 68th posterior probability region of the estimated impulse responses

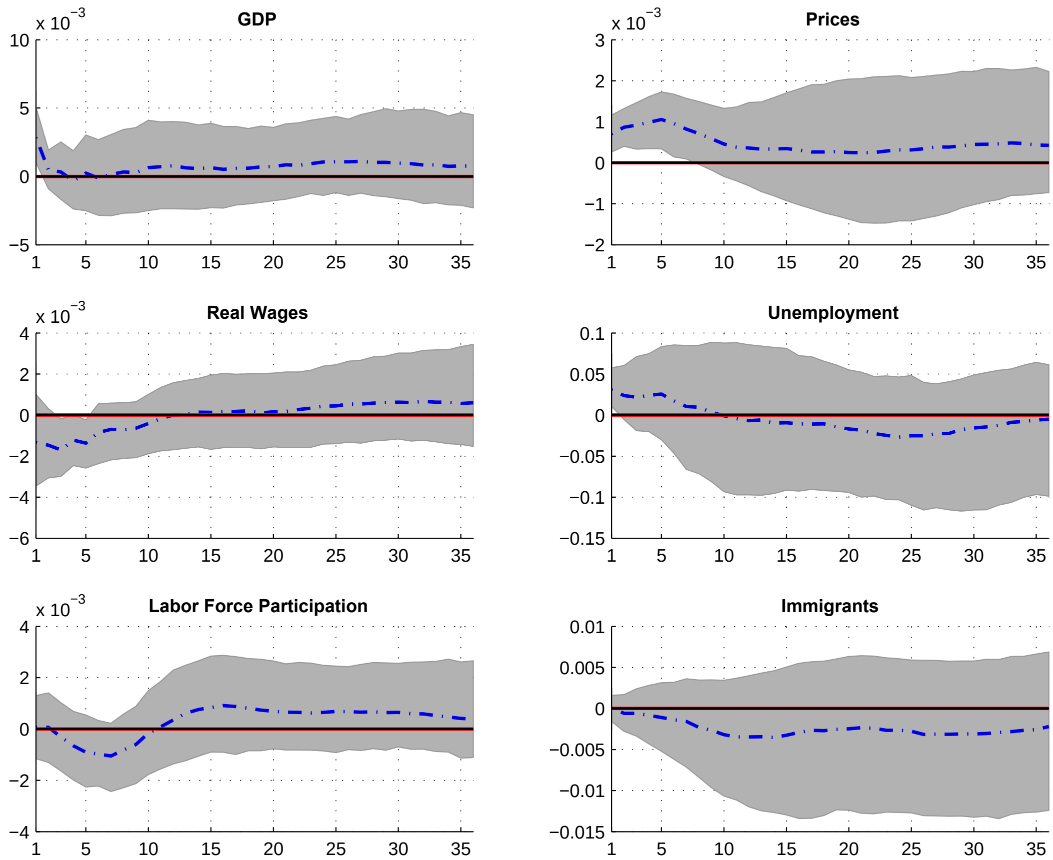

Figure 16: Impulse responses to an one-standard-deviation residual shock in the extended model. The dashed-dotted line represent the posterior median at each horizon and the shaded area indicates the 68th posterior probability region of the estimated impulse responses