Labor Markets, Fiscal Policy and Inflation Dynamics: a Pandemic Perspective*

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Abstract

The Covid-19 pandemic initially caused inflation to fall, but it has since risen sharply to a 40-year high. Vacancies and labor market tightness strongly correlate with inflation rates in the United States and major European countries. A labor search and matching model augmented with demand-side shocks and labor market matching frictions effectively explains these inflation dynamics. The extended model, which considers endogenous search intensity and recruiting intensity, captures the significant correlations between inflation and labor market variables. Downward nominal wage rigidity plays a role in wage and price inflation. Fiscal policy alone cannot replicate inflation behavior as well as matching frictions do, but coupling it with changes in matching efficiency generates faster reversal in inflation.

JEL classification: E24; E31; E32; E37; E62

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1 Introduction

The COVID-19 pandemic has spurred research into its impact on inflation rates. Despite a brief period of negative inflation at the outset of the pandemic in 2020, inflation in the United States has since exceeded its historical values since the Great Inflation period (1965-1982). Understanding the nature of the shock, how it propagates through the economy, and its implications for inflation remains a crucial area of study for policymakers and economists alike.

In response to the COVID-19 pandemic, the U.S. Congress passed multiple stimulus packages, including the Coronavirus Aid, Relief, and Economic Security (CARES) Act, which authorized over 2 trillion dollars in spending, and the American Rescue Plan Act, which allowed for nearly 2 trillion dollars in spending. The massive stimulus has been speculated as a key driver of the current inflation episode. Studies have estimated that these fiscal measures may have raised inflation by approximately 3 percentage points by the end of 2021 (Jordà et al., 2022). Models constructed with funded and unfunded fiscal shocks suggest that unfunded spending has played a critical role in explaining inflation dynamics, including the post-pandemic period (Bianchi et al., 2022).

Our analysis of U.S. data shows a strong positive correlation between the inflation rate and labor market tightness, as measured by the vacancies-unemployment ratio. During the early stages of the pandemic, vacancies decreased while unemployment rose, reducing labor market tightness and placing downward pressure on prices. The sudden drop in demand further impacted prices. As the labor market began to recover, vacancies surpassed pre-pandemic levels and unemployment declined, resulting in higher labor market tightness and upward pressure on nominal wages. This increase in wages was due to firms competing for job searchers to fill vacancies. The probability of finding a job for searchers returned to pre-shock levels, while the probability of a firm filling a vacancy remains significantly lower than pre-pandemic levels. Potentially reflecting these developments in the labor market, inflation started to rise beyond pre-pandemic levels. We observe a similarly strong correlation between labor market tightness and inflation in a group of European OECD countries.

The paper proposes a labor search and matching model with downward nominal wage rigidity to study the implications of a shock that has both demand-side and supply-side effects on inflation. The shock reduces households' willingness to spend and creates a friction in the matching process between job seekers and firms. The model is estimated using *pre*-COVID data, and its ability to explain the recent inflation episode is assessed in an out-of-sample exercise.

The model successfully replicates the dynamics of inflation and other empirical regularities. The negative demand shock helps to explain the initial stage of the pandemic, while the friction in the matching process enables the model to account for the dynamics of inflation in the second stage. Ignoring the effect of the shock on match formation in the labor market limits the model's ability to replicate the inflation dynamics since the start of the pandemic. Moreover, wage rigidity allows the model to justify the behavior of nominal wages that continued to rise throughout the pandemic. Without wage rigidity, nominal wages initially fall and thus act as a "shock absorber" that limits the fall in labor and vacancies. Furthermore, without wage rigidity, the rise in inflation in the second stage is muted.

The analyses indicate that fiscal policy alone cannot explain the observed dynamics of the inflation rate or other macroeconomic aggregates. In a version of the model where the impact on the matching process is shut off, and government spending or transfers rise in response to the shock, the model fails to replicate the empirical regularities and inflation is not persistent. Therefore, the impact of the shock on the matching process is crucial. However, introducing fiscal policy makes the impact of the shock on economic activity muted, short-lived, and leads to a faster reversal of economic activity and inflation.

We further extend the model to include a labor force participation margin, which rationalizes the effect of changes in the labor force participation rate on inflation. The extended model also allows for the efficiency of the matching process to depend on the search and recruiting intensities. The empirical analysis shows that both search and recruiting intensities fell in the early stages of the pandemic. Recruiting intensity quickly recovered and exceeded its pre-pandemic level after nearly two quarters while search intensity continued to be below pre-Covid levels. The model is able to capture these dynamics and we find that both intensities are important for the model's ability to replicate the inflation dynamics since the beginning of the pandemic. Our model also better explains the co-movement of the inflation rate with various labor market variables since the spring of 2020.

Related to our study, Ball et al. (2023) decompose headline inflation into core inflation and deviations from core, and explain core inflation with long-term expected inflation and the level of tightness in the labor market. Our model confirms their findings by showing that the relationship between inflation and labor market tightness is consistent with their analysis. However, we extend their analysis by demonstrating, quantitatively, that the state of the labor market can explain inflation dynamics even in the absence of other potentially important factors that drive inflation, such as supply chain disruptions, geopolitical tensions, and fiscal policy. The latter may generate a faster rise in inflation, but our results suggest that inflation was likely to rise anyway due to the tightness of the labor market. Furthermore, as we enter the fourth year since the start of the pandemic, core inflation has not yet returned to normal, despite fiscal policy and supply chains largely normalizing. However, the labor market remains significantly tighter than usual, indicating that the state of the labor market may be contributing to persistent inflation.

Our theoretical model is motivated by the empirical literature on the impact of the COVID-19 pandemic. Initially, firms and professional forecasters perceived it as a demand shock, leading to lowered inflation expectations (Meyer et al., 2022). However, as the crisis persisted, views shifted due to supply chain disruptions and labor constraints, resulting in higher inflation expectations (An et al., 2023; Meyer et al., 2023). Household and firm perceptions indicated that the pandemic caused simultaneous shocks to both demand and supply (Hassan et al., 2023; Candia et al., 2020). Supply-driven inflation surged in early 2022, potentially due to economic disruptions associated with the Russian invasion of Ukraine (Shapiro, 2022). Generous fiscal support during the pandemic increased the demand for consumption goods and contributed to rising inflation (de Soyres et al., 2023). These studies highlight the complex impact of the pandemic on inflation, encompassing demand and supply shocks, labor market frictions, and fiscal support.

The remainder of the paper proceeds as follows. Section 2 describes the behavior of inflation and labor market variables for the U.S. and a group of OECD countries. Section 3 outlines the benchmark model. Section 4 describes the calibration of the model and presents numerical results. Section 5 presents an expanded model with an endogenous labor force participation margin, search intensity and recruiting intensity. Section 6 concludes. Additional details on model estimation and extensions are relegated to the appendix.

2 Inflation and the Labor Market During the Pandemic

In this section, we briefly provide evidence regarding the relationship between the inflation rate and key labor market data. The behavior of inflation of course reflects other factors, such as the increase in energy prices following the Russian invasion of Ukraine in February 2022, but our study focuses on the relationship between these key labor market variables and the inflation rate. In addition, while we show here only the CPI (including food and energy prices), in what follows we discuss other measures, such as the Personal Consumption Expenditure index. We also discuss the "core" inflation rate, which excludes food and energy prices. More analysis about these measures and their correlations with the labor market variables can be found in Section 4.

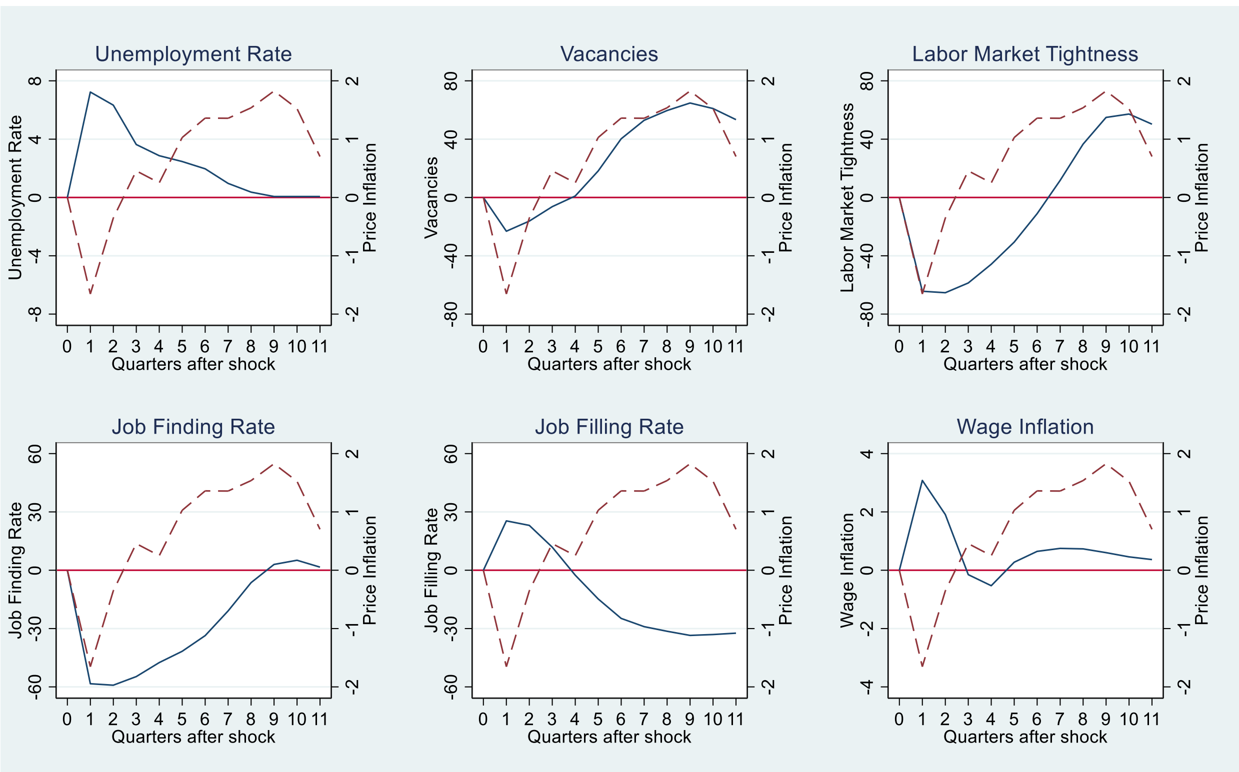

Figure 1: Price Inflation, Wage Inflation and Labor Market Variables

Note: Percentage deviations from the average level between December 2019-February 2020. Time zero indicates the last quarter before the shock. Price Inflation- the percentage change in the consumer price index for all urban consumers- all items in U.S., as plotted in the dashed line and measured in the right axis. Unemployment- Unemployment Level. Unemployment Rate- unemployment-labor force ratio. Vacancies- total unfilled job vacancies for the United States. Labor Market Tightness- the ratio of vacancies to unemployment. Job Finding Rate- ratio of hires (Total Nonfarm) to unemployment. Job Filling Rate- the job finding rate times the inverse of labor market tightness. Wage Inflation- the percentage change in the average hourly earnings of production and nonsupervisory employees, total private. The data are updated as of November 2022.

Figure 1 shows the behavior of the quarterly inflation rate, unemployment rate, vacancies, the labor market tightness (which is the vacancies-unemployment ratio), the job finding rate, the job filling rate and the wage inflation rate. At the time of this writing, there have been a total of 11 quarters since the onset of Covid-19. All variables are expressed as percentage deviations from their average values in the final three months before the Covid-19 (December 2019-February 2020).

The inflation rate is positively correlated with vacancies and labor market tightness throughout the entire period. On the other hand, its correlation with the unemployment rate is negative. Furthermore, early in the pandemic, the job finding rate by job searchers declined, and then it started to gradually rebound. The job filling rate by firms, on the other hand, increased on impact, but declined significantly below its pre-shock level and continued to be lower than its initial level by roughly 33%. Its correlation with the inflation rate is clearly negative.

The nominal wage continued to rise throughout the pandemic. One explanation for the initial uptick is that, with the rising unemployment, particularly among lower wage earners, the average nominal wage jumped. As the labor market began to recover, the growth in the nominal wage moderated. Then, with the rise in vacancies and labor market tightness, the nominal wage continued to rise; the tightness in the labor market may have caused an increase in wage growth.[1]

In Figure 2, we provide a similar analysis for a group of European OECD countries for which data have been readily available at the time of this writing. The positive correlation between the inflation rate and vacancies or labor market tightness seems to hold for all countries in our sample, most noticeably for Austria, Finland, Sweden, France, Poland and the U.K. On this basis, the observations for the U.S. hold for other advanced nations. Interestingly, Poland and Portugal saw the biggest normalization in vacancies and labor market tightness, and they also experienced a clear drop in the inflation rates from their respective peaks.

[1] Using Job Openings- Total Private for vacancies and Average Hourly Earnings of All Employees- Total Private for the nominal wage gives the same results. In addition, using Hires: Total Private to calculate the job finding rate gives the same results.

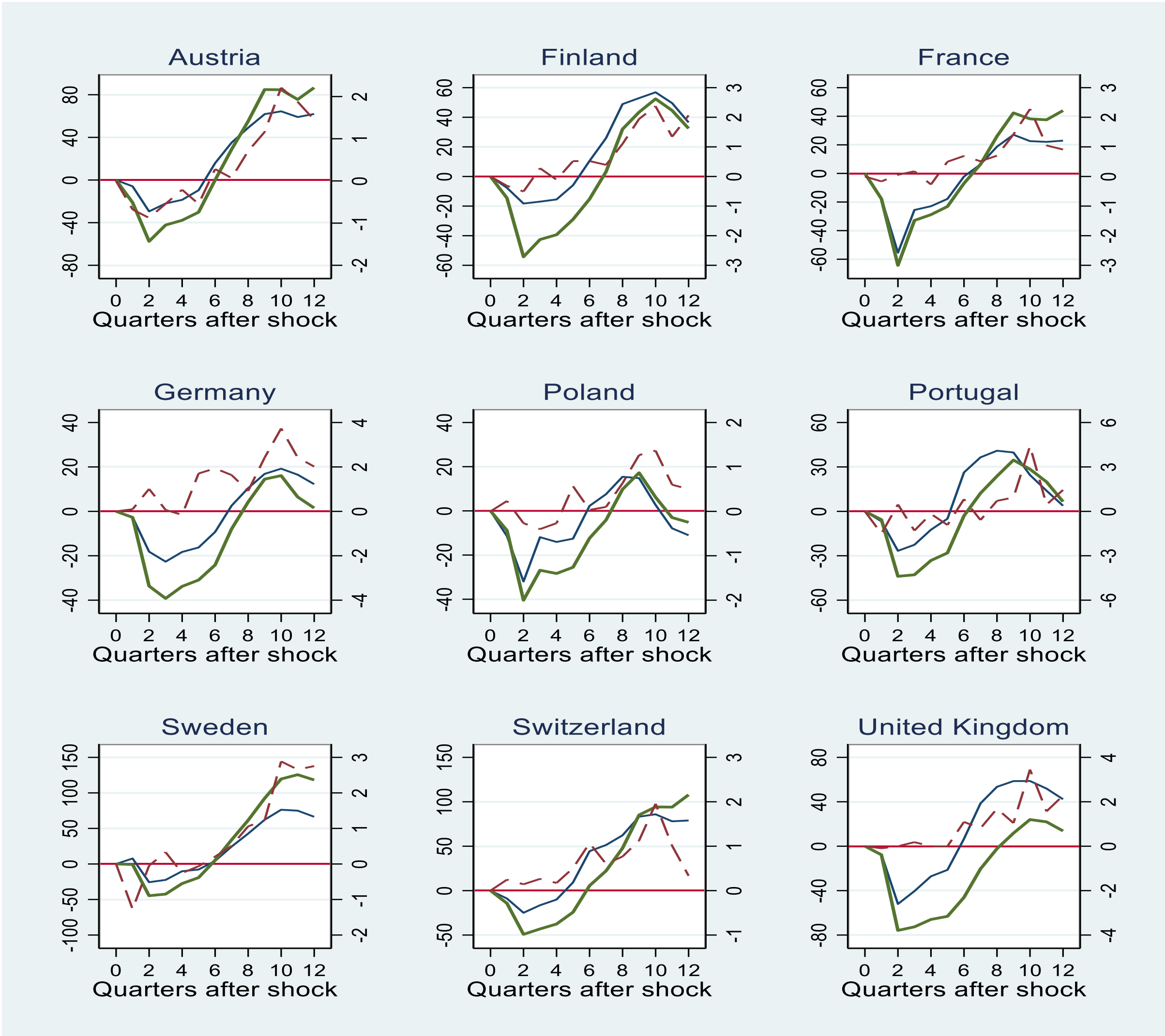

Figure 2: Price Inflation, Vacancies and Labor Market Tightness: OECD Countreis

Note: Percentage deviations from pre-Covid levels. Solid blue line: vacancies (left axis). Solid green thick line: labor market tightness (left axis). Dashed maroon line: price inflation (right axis). Data source: OECD.

In what follows we propose a model that can account for the empirical regularities. Given the relatively rapid decline in the unemployment rate, our focus shifts to vacancies and labor market tightness, as the higher-than-usual tightness solely reflects an elevated number of vacancies. To fix ideas, the benchmark model in Section 3 assumes that the fall in the efficiency of the matching process and labor force participation rate are exogenous. We then present an extended version of the model that allows for endogenous participation in the labor force as well as endogenous changes in the efficiency of matching.

3 The Model

The economy is populated by households, monopolistically-competitive firms that produce differentiated products and a monetary authority. Hiring labor by firms is subject to search and matching frictions as in Pissarides (2000). Each firm faces an asymmetric adjustment cost function for nominal wages, which implies that the costs of reducing nominal wages are higher compared to increasing them by the same magnitude. Changing prices by each firm is subject to a direct resource cost.

3.1 Households

The economy is populated by a representative household which consists of family members of measure one. Each period t, a household member can be either employed or unemployed and searching for a job. Employed individuals are of measure n_t and the unemployed individuals are of measure u_t, where $u_t = 1 - n_t$. As in Merz (1995) and Andolfatto (1996), all household members have the same consumption due to the assumptions of consumption insurance. The disutility of work is the same for all employed individuals and the value of non-work is the same for all unemployed individuals. Then, the household's problem is to maximize:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[e_t u(c_t) - n_t v(h_t) \right], \tag{1}$$

with $\beta < 1$ being the standard subjective discount factor, $\mathbb{E}_0$ is the expectation operator, c_t is consumption, h_t denotes hours per worker, $u(c_t)$ is the period utility function of consumption and $v(h_t)$ is the period disutility from supplying labor. These functions satisfy the usual properties: $\frac{\partial u(\cdot)}{\partial c} > 0, \frac{\partial^2 u(\cdot)}{\partial c^2} < 0$, $\frac{\partial v(\cdot)}{\partial h} > 0$ and $\frac{\partial^2 v(\cdot)}{\partial h^2} > 0$. The variable e_t is a preference shifter, which we discuss in details later.

As standard in New Keynesian models, consumption (c_t) is a Dixit-Stiglitz aggregator of differentiated products $(c_{j,t})$ produced by monopolistically-competitive firms:

$$c_t = \left(\int_0^1 c_{j,t}^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}}, \tag{2}$$

where $\varepsilon > 1$ is the elasticity of substitution between two varieties of final goods. In line with standard Dixit-Stiglitz based New Keynesian models, the optimal allocation of expenditures on each variety is given by:

$$c_{j,t} = \left(\frac{P_{j,t}}{P_t}\right)^{-\varepsilon} c_t, \tag{3}$$

where $P_t = \left(\int_0^1 {P_{j,t}}^{1-\varepsilon} dj\right)^{\frac{1}{1-\varepsilon}}$ is the Dixit-Stiglitz price index that results from cost minimization.

Maximization is subject to the sequence of budget constraints of the form:

$$c_t + \frac{B_t}{P_t} = \frac{n_t h_t W_t}{P_t} + (1-n_t)s + \frac{R_{t-1}B_{t-1}}{P_t} + \frac{T_t}{P_t} + \frac{\Theta_t}{P_t}, \tag{4}$$

where s stands for the outside option (e.g. unemployment benefits), W_t is the nominal wage, B_t denotes nominal bonds, R_t is the nominal gross interest rate on bonds, P_t is the aggregate price level, T_t is net nominal transfers and Θ_t denotes nominal profits from the ownership of firms.

Household's choices of c_t and B_t give the standard Euler equation:

$$e_t u_{c,t} = \beta R_t E_t \left(\frac{e_{t+1} u_{c,t+1}}{\pi^p_{t+1}}\right), \tag{5}$$

where $\pi^p_t = \frac{P_t}{P_{t-1}}$ is the gross price inflation rate and $e_t u_{c,t}$ is the marginal utility of consumption.

3.2 The Production Sector

There is a continuum of measure one of monopolistically-competitive firms. Each firm j hires labor as the only input and produces a differentiated product $y_{j,t}$ using the following technology:

$$y_{j,t} = z_t n_{j,t} f(h_{j,t}), \tag{6}$$

with z_t denoting aggregate productivity (which is common to all firms), $n_{j,t}$ is employment at firm j and $h_{j,t}$ denotes hours per worker at the firm. The pricing of a firm is subject to a quadratic adjustment cost as in Rotemberg (1982), expressed in units of the final good.

Hiring workers by each firm is subject to search and matching frictions. Each period, firms post vacancies and meet unemployed workers searching for jobs. The cost of posting a vacancy v is γ. Matches between unemployed individuals, u_t, and vacancies, v_t, are determined by the following constant return-to-scale matching function:

$$m(u_t, v_t) = \mu d_t u_t^{\zeta} v_t^{1-\zeta}, \tag{7}$$

where ζ is the elasticity of matches with respect to unemployment, μ is a scaling parameter and d_t measures the efficiency of the matching process. The shock acts as a friction and reduces the efficiency of the matching process. In what follows, we assume that d_t responds to this shock.

Labor market tightness is defined as the ratio of vacancies to unemployment:

$$\theta_t = \frac{v_t}{u_t}. \tag{8}$$

The probability of the firm to fill a job is $q(\theta_t) = \frac{m(v_t,u_t)}{v_t}$, and the job finding rate is $p(\theta_t) = \frac{m(v_t,u_t)}{u_t}$. Other thing being equal, the job filling rate decreases in labor market tightness, while the job finding rate increases in labor market tightness. Changes in the efficiency of the matching process, however, break the direct link between labor market tightness, on one hand, and the job filling and finding rates, on the other.

Nominal wages and hours per worker are determined by Nash bargaining between workers and firms. Adjusting nominal wages is costly, and the cost of adjusting the nominal wage of one worker by firm j is given by the following Linear-Exponential (*Linex*) function:

$$\Phi^W_{j,t} = \frac{\phi^w}{\psi^2}\left(\exp[-\psi(\frac{W_{j,t}}{W_{j,t-1}} - \overline{\pi}^w)] + \psi(\frac{W_{j,t}}{W_{j,t-1}} - \overline{\pi}^w) - 1\right) \tag{9}$$

with ϕ^w being the adjustment cost parameter of nominal wages, ψ the degree of asymmetry in wage adjustment and $\overline{\pi}^w$ the steady-state wage inflation rate. For positive values of ψ, the cost of cutting the nominal wage by a certain magnitude is higher than the cost of increasing the nominal wage by the same magnitude. Also, as ψ approaches zero, this function approaches the quadratic adjustment cost function and hence it enables comparison with the case of symmetric adjustment cost function. In the other extreme, as ψ approaches infinity, this adjustment cost function becomes L-shaped, and therefore, nominal wages cannot fall.

Since the nominal wage is determined through bargaining between firms and workers, and not by one side of the labor market, it is unclear who should pay the costs of adjusting wages. We following Arseneau and Chugh (2008) by assuming that firms bear these costs.

Finally, employment at each firm evolves according to the following law of motion:

$$n_{j,t+1} = (1-\rho)\left(n_{j,t} + m(v_{j,t}, u_t)\right), \tag{10}$$

with ρ denoting the separation rate from a match. This formulation assumes that a match formed at time t starts to produce at time $t+1$ if it survives exogenous separation.

The adjustment cost of prices is given by:

$$\Phi_{j,t}^{P} = \frac{\phi^p}{2}\left(\frac{P_{j,t}}{P_{j,t-1}} - \overline{\pi}^p\right)^2 \tag{11}$$

with ϕ^p being the adjustment cost parameter and $\overline{\pi}^p$ the steady-state price inflation rate.

A firm j chooses its price, vacancies and next-period employment to maximize the expected present discounted stream of profits:

$$E_0 \sum_{t=0}^{\infty} \frac{\beta^t e_t u_{c,t}}{e_0 u_{c,0}} \left\{ \frac{P_{j,t}}{P_t} y_{j,t} - n_{j,t} w_{j,t} h_{j,t} - \gamma v_{j,t} - \Phi_{j,t}^{W} n_{j,t} - \Phi_{j,t}^{P} y_t \right\}, \tag{12}$$

subject to the sequence of laws of motion of employment:

$$n_{j,t+1} = (1-\rho)(n_{j,t} + v_{j,t} q(\theta_t)), \tag{13}$$

and the downward-sloping demand function for its product:

$$z_t n_{j,t} f(h_{j,t}) = \left[\frac{P_{j,t}}{P_t}\right]^{-\varepsilon} y_t. \tag{14}$$

Since households own the firms, future profits of the firms are discounted by the stochastic discount factor of households. We assume symmetry across workers (they supply the same number of hours) and firms (they choose the same amount of employment and vacancies), and hence we suppress the index j in what follows. Then, combining the first-order conditions with respect to n_{t+1} and v_t yields:

$$\frac{\gamma}{q(\theta_t)} = \beta(1-\rho) E_t \left\{ \left(\frac{e_{t+1} u_{c,t+1}}{e_t u_{c,t}}\right) \left[mc_{t+1} z_{t+1} f(h_{t+1}) - w_{t+1} h_{t+1} - \Phi_{t+1}^{W} + \frac{\gamma}{q(\theta_{t+1})} \right] \right\}, \tag{15}$$

where $w_t (= \frac{W_t}{P_t})$ is the real wage and mc_t is the Lagrange multiplier on the output constraint (14). This multiplier measures the contribution of one additional unit of output to the revenue of the firm, and, in equilibrium, it equals the real marginal cost of the firm.

Equation (15) is the Job Creation (JC) condition (or Free-Entry condition), and it states that, in equilibrium, the firm equates the vacancy-creation cost to the expected present discounted value of profits from the match. As the term in brackets makes clear, the flow profit to a firm from a match equals output net of wage payments and the costs of adjusting wages.

In a symmetric equilibrium, in which all firms set the same price, Rotemberg pricing gives the standard forward-looking price Phillips curve:

$$1 - \phi^p(\pi_t^p - \overline{\pi}^p)\pi_t^p + \beta\phi^p E_t\left[\left(\frac{e_{t+1}u_{c,t+1}}{e_t u_{c,t}}\right)(\pi_{t+1}^p - \overline{\pi}^p)\pi_{t+1}^p \frac{y_{t+1}}{y_t}\right] = \varepsilon(1 - mc_t). \tag{16}$$

This equation suggests that the current price inflation rate is a function of expected price inflation rate and current real marginal cost. The role of downward nominal wage rigidity in driving inflation is better seen by substituting, using the time (*t-1*) version of equation (15), for the real marginal cost mc_t in equation (16). The adjustment cost of nominal wages increases the marginal cost of the firm and in turn, leads to an increase in inflation. In this context, wage rigidity acts as an endogenous cost-push shock.

3.3 Nash Bargaining

As is typical in the literature, wage payments and hours per employed individual are determined by a Nash bargaining between firms and individuals. Firms and workers then split the surplus of a match according to their bargaining powers. Because of the monetary nature of our model and nominal wage rigidity, we follow Gertler et al. (2009), Arseneau and Chugh (2008) and Thomas (2008) by assuming that bargaining is over nominal wages W_t rather than real wages w_t.

Bargaining over nominal wages gives the following condition that characterizes the real wage setting:

$$\frac{\omega_t}{1-\omega_t}\left[mc_t z_t f(h_t) - w_t h_t - \Phi_t^W + \frac{\gamma}{q(\theta_t)}\right] = w_t h_t - \frac{v(h_t)}{u_{c,t}} - s + E_t\left[\frac{\omega_{t+1}}{1-\omega_{t+1}}\left(\frac{\gamma}{q(\theta_t)} - \gamma\theta_t\right)\right], \tag{17}$$

where η denotes the share of workers in the match surplus (which is also their deterministic steady state bargaining power), $\omega_t = \frac{\eta}{\eta + (1-\eta)\frac{\Delta_t^F}{\Delta_t^W}}$ is the *effective* bargaining power of workers, Δ_t^F is the marginal change in the value of a filled job and Δ_t^W is the marginal change in the value of being employed as the nominal wage varies. The wage adjustment cost thus drives a wedge between the effective bargaining power and the ex-ante bargaining power of workers.

Similarly, bargaining over hours per employed individual gives the following condition:

$$\frac{\Gamma_t}{1-\Gamma_t}\left[mc_t z_t f(h_t) - w_t h_t - \Phi_t^W + \frac{\gamma}{q(\theta_t)}\right] = w_t h_t - \frac{v(h_t)}{u_{c,t}} - s + E_t\left[\frac{\Gamma_{t+1}}{1-\Gamma_{t+1}}\left(\frac{\gamma}{q(\theta_t)} - \gamma\theta_t\right)\right], \quad (18)$$

where $\Gamma_t = \frac{\eta}{\eta+(1-\eta)\frac{\delta_t^F}{\delta_t^W}}$ is the effective bargaining power of workers in hours determination, δ_t^F and δ_t^W are, respectively, the marginal changes in the values of a filled job and being employed as hours per employed individual vary.

Conditions (17) and (18) suggest that the current real wage is affected by the outside option of workers (unemployment benefits), the disutility of work, the cost of adjusting nominal wages and the continuation value of being employed. As standard in this class of models, the real wage is increasing in the value of the outside option and disutility of work, as workers need higher real wages to compensate them for the disutility of work and the forgone outside option. Finally, when nominal wages are fully flexible (or fully stabilized), we have $\omega_t = \eta$.[2]

3.4 The Shocks

The demand (preference) shifter evolves according to the following rule:

$$\ln\left(\frac{e_t}{\overline{e}}\right) = \rho_s \ln\left(\frac{e_{t-1}}{\overline{e}}\right) + q_e \iota_t \quad (19)$$

where ρ_s is the persistence of the shock, $\iota_{H,t} \sim \mathcal{N}(0, \sigma_H^2)$, $q_e > 0$ and $\overline{e} = 1$.

The efficiency of the matching process is given by:

$$\ln\left(\frac{d_t}{\overline{d}}\right) = \rho_s \ln\left(\frac{d_{t-1}}{\overline{d}}\right) + q_d \iota_{t-1} \quad (20)$$

with $q_d > 0$ and $\overline{d} = 1$. At this stage, it is assumed that the effect on matching happens with a lag of one period (a quarter), but we show that this assumption is unimportant for the main findings of the study (particularly with respect to the dynamics of the inflation rate).

The literature has extensively assumed exogenous preference shocks (and shocks on the side of the labor market, such as the bargaining power of workers, etc.) In this paper, we assume that the

[2]The use of the term "effective bargaining power" in a model with wage stickiness follows Gertler et al. (2009) who assume staggered multi-period wage contracting in a labor search and matching model.

same event affects the demand side of the economy and the labor market, but its impacts on the demand side and on matching in the labor market, as measured by q_d and q_e, could be different.

3.5 Market Clearing and Monetary Policy

Bonds are in zero net supply ($b_t = 0$). In addition, in equilibrium, the resource constraint of the economy holds:

$$n_t z_t h_t^{\alpha} = c_t + \gamma v_t + \frac{\phi^w}{\psi^2}\left(\exp[-\psi(\pi_t^w - \overline{\pi}^w)] + \psi(\pi_t^w - \overline{\pi}^w) - 1\right) n_t + \frac{\phi^p}{2}\left(\pi_t - \overline{\pi}^p\right)^2 n_t z_t h_t^{\alpha}, \quad (21)$$

and the labor market clears:

$$u_t = 1 - n_t. \quad (22)$$

In addition, the real wage growth evolves according to:

$$\frac{w_t}{w_{t-1}} = \frac{\pi_t^w}{\pi_t^p}. \quad (23)$$

Condition (23) is typically introduced in models with sticky price and sticky nominal wages. This identity does not hold trivially under sticky nominal wages and sticky prices, and hence it should be added to the equilibrium conditions of the private sector in order to tie the path of real wages to the paths of nominal wages and prices.[3]

Finally, monetary policy is governed by a Taylor-type rule whereby the nominal interest rate responds to deviations of inflation and output from their steady-state values:

$$\ln\left(\frac{R_t}{\overline{R}}\right) = \rho_\pi \ln\left(\frac{\pi_t^p}{\overline{\pi}^p}\right) + \rho_y \ln\left(\frac{y_t}{\overline{y}}\right) \quad (24)$$

with $\overline{y}$ being the steady-state value of output, and $\rho_\pi > 1$ and $\rho_y > 0$ being the coefficients of inflation and output.

3.6 The Private-Sector Equilibrium

Definition 1: given the exogenous process $\{z_t\}$, the private-sector equilibrium is a sequence of allocations $\{c_t, d_t, e_t, h_t, n_t, u_t, v_t, \theta_t, mc_t, w_t, \pi_t^p, \pi_t^w, R_t\}$ that satisfy the equilibrium conditions (5), (8), (13) and (15)-(18) and (19)-(24).

[3] This constraint also appears in the studies of Erceg et al. (2000) and Chugh (2006), among others.

4 Numerical Analysis

We first describe the functional form and the parameterization of the model and then present the model-based numerical results.

4.1 Calibration

We assume the following period utility functions of consumption and disutility of hours:

$$u(c_t) = \frac{c_t^{1-\sigma}}{1-\sigma} \tag{25}$$

$$v(h_t) = \chi \frac{h_t^{1+\vartheta}}{1+\vartheta}, \tag{26}$$

where σ is the curvature parameter of the period utility function of consumption, τ is the curvature parameter of the period utility function of real money, χ is scaling parameter and ϑ is the inverse of the intertemporal elasticity of substitution of labor.

Output per worker has diminishing returns in hours per worker, as follows:

$$f(h_t) = h_t^{\alpha}, \tag{27}$$

with α being the elasticity of output with respect to hours per worker.

4.2 Parameterization

The time unit is a quarter. Table 1 presents a summary of the parameter values. We divide the parameters of the model into two groups. The first group includes parameters for which we use standard values. To this end, we set α based on National Income and Product Accounts (NIPA) data. The exogenous separation rate ρ is in line with the literature, as in Davis et al. (1996). The value of ε implies a net steady state markup of 10 percent. The steady state value of inflation ($\overline{\pi}^p$) is set so that the annual inflation rate is 2%, which is consistent with the pre-shock inflation rates. For condition (23) to be satisfied at the steady state, we set $\overline{\pi}^w = \overline{\pi}^p$. The parameter χ is calibrated so that the deterministic steady state value of h is 0.3.

As is standard in the literature, the benchmark calibration of the model assumes that the Hosios (1990) condition holds, and hence the Nash bargaining power of workers equals the contribution of an unemployed individual to the match (i.e. $\eta = \zeta$). As shown in Hosios (1990), this condition guarantees the efficiency of the matching process. Furthermore, the persistence of the shocks ρ_s is consistent with the effects of the Covid-19 shock being in place for 20 quarters. Productivity is set to its steady state value ($z_t = 1$) for all t.

Table 1: Values of the Parameters- Model with Exogenous Labor Force Participation

Parameter	Description	No FP	With FP
β	Households' utility discount factor	0.99	0.99
σ	Consumption curvature parameter	2.13	2.19
ϑ	Inverse labor supply elasticity	2.25	2.26
α	Elasticity of output with respect to hours per worker	2/3	2/3
ε	Elasticity of substitution between products	11.00	11.00
$\overline{\pi}^p$	Steady-state gross price inflation rate	1.005	1.005
ρ_π	Response of the interest rate to inflation	1.50	1.50
ρ_y	Response of the interest rate to output	0.49	0.50
q_e	Demand shock	0.93	0.90
q_d	Shock to efficiency of matching	7.27	7.40
ρ_s	Persistence of the shock	0.95	0.95
ζ	Contribution of an unemployed individual to a match	0.40	0.40
ϕ^p	Price rigidity	29.73	30.26
ϕ^w	Wage rigidity	79.35	78.75
ψ	Asymmetry parameter of wage rigidity	2362.51	2427.23
ρ_g	Persistence of government spending		0.90
ρ_{gy}	Response of government spending to output		1.19

Note: This table summarizes the values of the parameters in the benchmark analyses. $\overline{\pi}^w = \overline{\pi}^p$ and $\eta = \zeta$. Productivity: $z_t = 1$ for all t. See Appendix A for more details.

For the second group of parameters, we use Bayesian estimation. The details of the estimation procedure, prior values and posterior values can be found in Appendix A. The main parameters in this group include $\phi^p, \phi^w, \psi, q_d$ and q_e, for which we do not have previous estimates. We also estimate the Taylor-rule parameters using this procedure and they tend to be consistent with previous estimates.

Our estimation makes use of U.S. data for the period 1983:Q1-2019:Q4. Therefore, we do not include the pandemic episode in the estimation. The rationale behind this choice is to show that a model that is estimated using pre-shock data can predict the dynamics of inflation and labor market variables once a shock, such as the one that we describe in this paper, hits the economy. We then set the standard deviation of the shock to match the rise in the unemployment rate during the first quarter of the pandemic. That would be the only target that we match since March 2020. We also acknowledge that the sample period since the start of the Covid-19 pandemic is relatively short, which limits our ability to rely solely on this period for estimation. At the time of this writing, we have only 11 quarters of data available for certain variables.

4.3 Impulse Responses- Benchmark Results

We now discuss the impulse response functions that are obtained from solving the full non-linear model. For downward nominal wage rigidity to remain operative, we solve the model using a second-order approximation (as linearization eliminates the asymmetry in wage adjustment). Figure 3 shows the responses of key macroeconomic aggregates to a shock that reduces demand and the efficiency in the matching process.

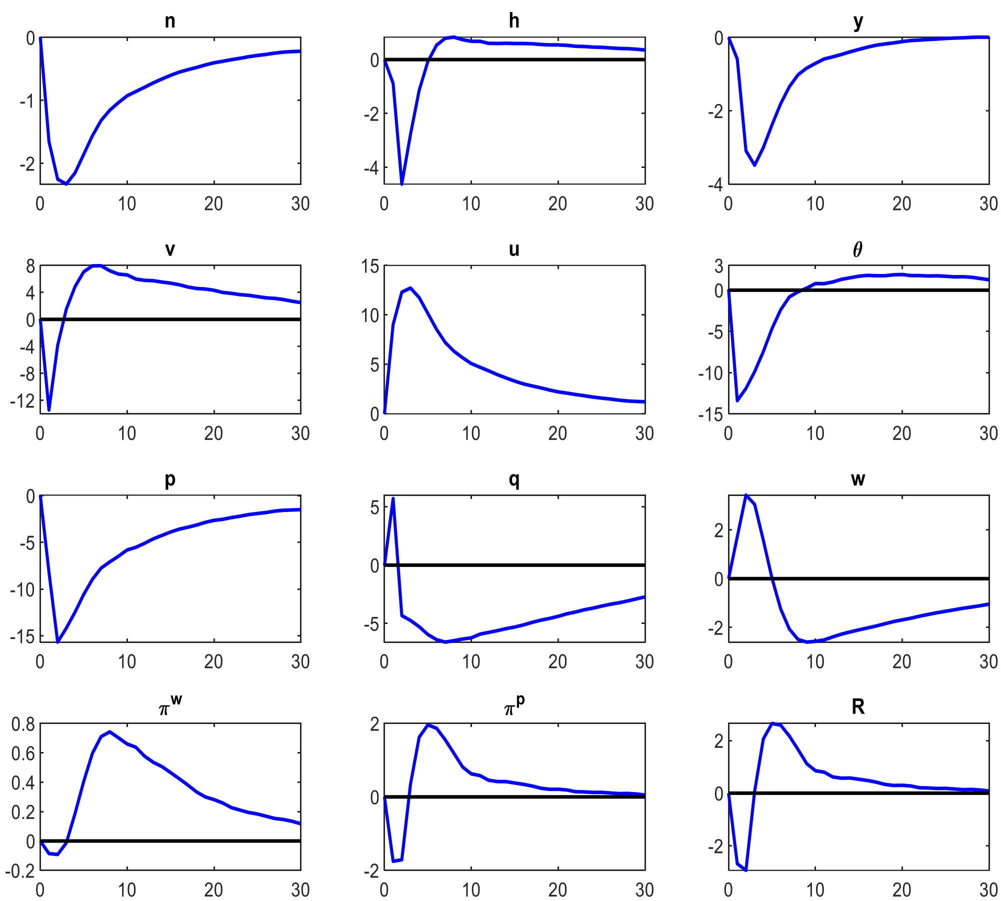

Figure 3: Impulse responses- Benchmark Analysis

Note: Model-based impulse responses. Percentage deviations from the deterministic steady state. These results are obtained from solving the benchmark model with both supply-side and demand-side effects using a second-order approximation. n: employment, h: hours per employed individual, y: output, v: vacancies, u: unemployment, θ: labor market tightness, p: job finding rate, q: job filling rate, w: real wage, π^w: wage inflation, π^p: price inflation, R: nominal interest rate.

Immediately following the shock, employment, vacancies and output drop, while unemployment rises. The combination of a fall in vacancies and a rise in unemployment triggers a fall in labor market tightness. Initially, the job finding rate falls while job filling rate rises. This occurs because the job finding rate is positively related to the tightness of the labor market while the job filling rate is inversely related to it. The fall in the efficiency of the matching process later reduces both rates. The nominal wage continues to be above steady-state and the inflation rate falls below its steady-state level. As a result of the fall in inflation and output, the nominal interest rate falls too. Reflecting the dynamics of wage and price inflation rates, the real wage rises on impact.

After three quarters, the labor market starts to recover and vacancies turn higher than their pre-shock levels. The same pattern applies to the labor market tightness and the inflation rate. The job finding rate recovers, but remains under per-shock levels. The job filling rate, on the other hand, drops below per-shock levels before starting to gradually rebound. The nominal interest rate rises in response to the inflation rate, and it largely follows the path of the latter. Furthermore, as wage inflation starts to moderate and inflation rises, the real wage drops below its initial value.[4]

The results implied by our model are mostly consistent with the data that are presented in Figure 1. The rise in inflation happens while the labor market has not fully recovered, which is also consistent with U.S. data. As such, the model with labor search and matching, augmented with shocks to demand and the efficiency of the matching process, can successfully replicate the observed dynamics of the inflation rate in the United States since Spring 2020. Note also that, in the early stages of the recovery from the pandemic-induced recession, labor and output recovered quickly, and then the recovery slowed. Our model-based result accounts for this observation too.[5]

4.4 Demand Shock vs. Shock to the Efficiency of Matching

In what follows, we present results with the demand-side shock only and the shock to the efficiency of matching only (Figure 4). With a demand shock only, the behavior of all variables is monotonic (after the initial impact). Vacancies fall, unemployment rises and, as a result, labor market tightness falls. The inflation rate falls too. All variables start revering back to the steady state after one

[4]The behavior of the time-varying effective bargaining power of workers ω_t following the shock is highly similar to that of the real wage: it rises on impact and then falls. In addition, in the model simulations, the correlation coefficient between the real wage and the bargaining power exceeds 90%.

[5]In Appendix B, we show the results when the supply-side effect is introduced with no lag. The results are not materially different from what we present in this section.

period. Importantly, neither vacancies nor inflation exceed their steady-state values at any point in time, and the overall impact on the economy is small and short-lived.

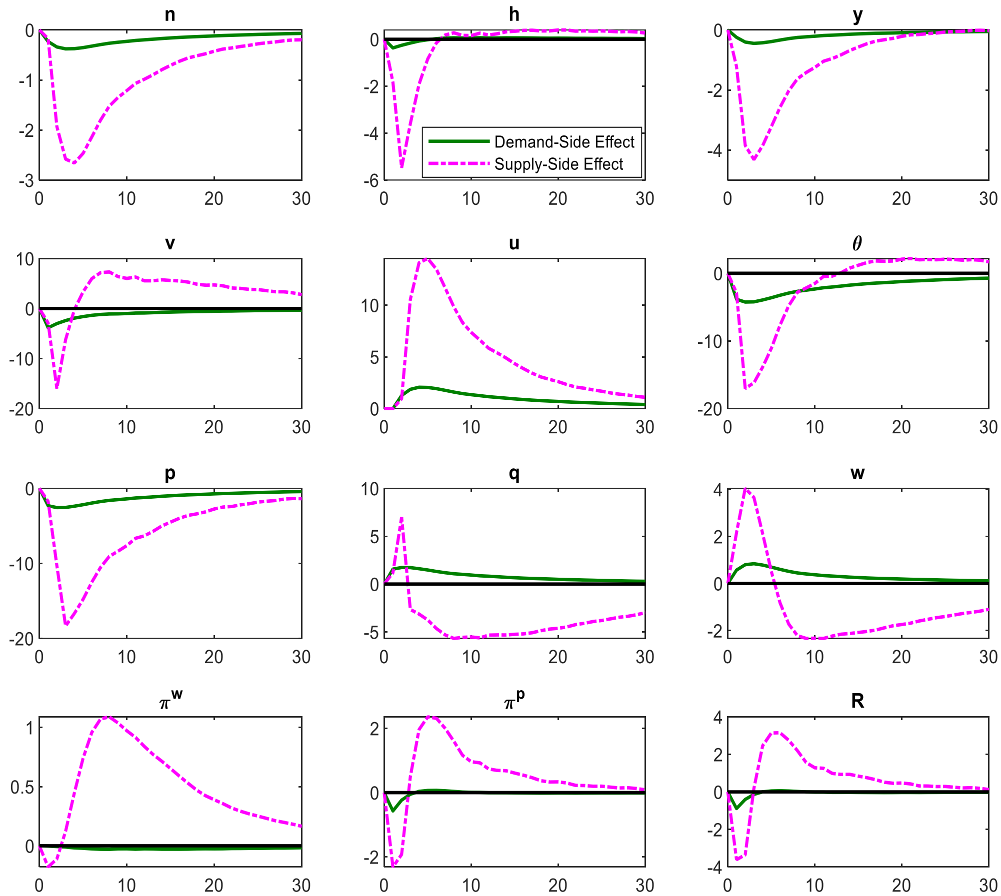

Figure 4: Impulse Responses- Demand Shock vs. Shock to the Matching Process

Note: Model-based impulse responses. Percentage deviations from the deterministic steady state. "Demand-Side Effect": the model with a demand-side effect only ($q_d = 0$). "Supply-Side Effect": the model with a supply-side effect only ($q_e = 0$). n: employment, h: hours per employed individual, y: output, v: vacancies, u: unemployment, θ: labor market tightness, p: job finding rate, q: job filling rate, w: real wage, π^w: wage inflation, π^p: price inflation, R: nominal interest rate.

On the other hand, with only a supply-side effect (i.e. a shock to the matching process), the dynamics of the key variables, including the inflation rate, are mostly consistent with what we observe in the data. In fact, this shock alone goes a long way in accounting for the dynamics of almost all variables, including the inflation rate. Essentially, the model with a shock to the matching process, by reducing matches and labor initially, reduces demand and inflation too.

A noticeable difference between the benchmark results and those with a shock to the matching process only is the delayed response of unemployment. On this basis, while the model with only a supply-side effect performs considerably better than the alternative model with only a demand-side effect, both effects are important: the demand effect improves the initial behavior of the variables while the supply effect better captures the behavior of these variables after reaching the trough.

4.5 The Role of Wage Rigidity

This subsection discusses the importance of wage rigidity in the model. When the nominal wage is fully flexible, the nominal wage initially falls (Figure 5), which is in contrast with its observed behavior since the start of the pandemic. The fall in the nominal wage allows for a muted fall in vacancies and labor than in the benchmark model (as part of the adjustment in the labor market occurs along this margin). Vacancies barely fall and they reverse their initial behavior after one quarter. Labor market tightness continues to be below its initial level, which also contradicts the empirical findings. The job filling by firms and the job finding rate by job searchers both fall before starting to slowly revert back to their initial values. The initial behavior of the filling rate is inconsistent with the data and also at odds with what the benchmark model suggests.

The dynamics of inflation is mostly similar to what we observe in the benchmark model, but the reversal happens sooner. Furthermore, the increase in inflation in the second stage is considerably muted relative to the model with nominal wage rigidity. This finding is consistent with the literature that identified downward nominal wage rigidity as an important driver of inflation; see, for example, Kim and Ruge-Murcia (2009) and Abo-Zaid (2013). Broadly speaking, higher downward nominal wage rigidity leads to higher inflation so that the real wage can adjust following adverse shocks. Therefore, when wage rigidity is eliminated, the response of the inflation rate is weaker.

Abstracting from wage rigidity limits the ability of the model to replicate the observations that are presented in Section 2 and has implications for the dynamics of inflation. One lesson that can be drawn from this exercise is that the rise in wage inflation since the beginning of 2020 was significant for the path of inflation.[6].

[6]To address this, in a recent study conducted by Kiley (2023), an estimate of trend inflation is derived using a time-varying distributed lag model of prices and wages. The study reveals that wages play an informative role in estimating trend inflation, and notably, by 2022, the weight placed on wages had returned to its level observed in the 1980s.

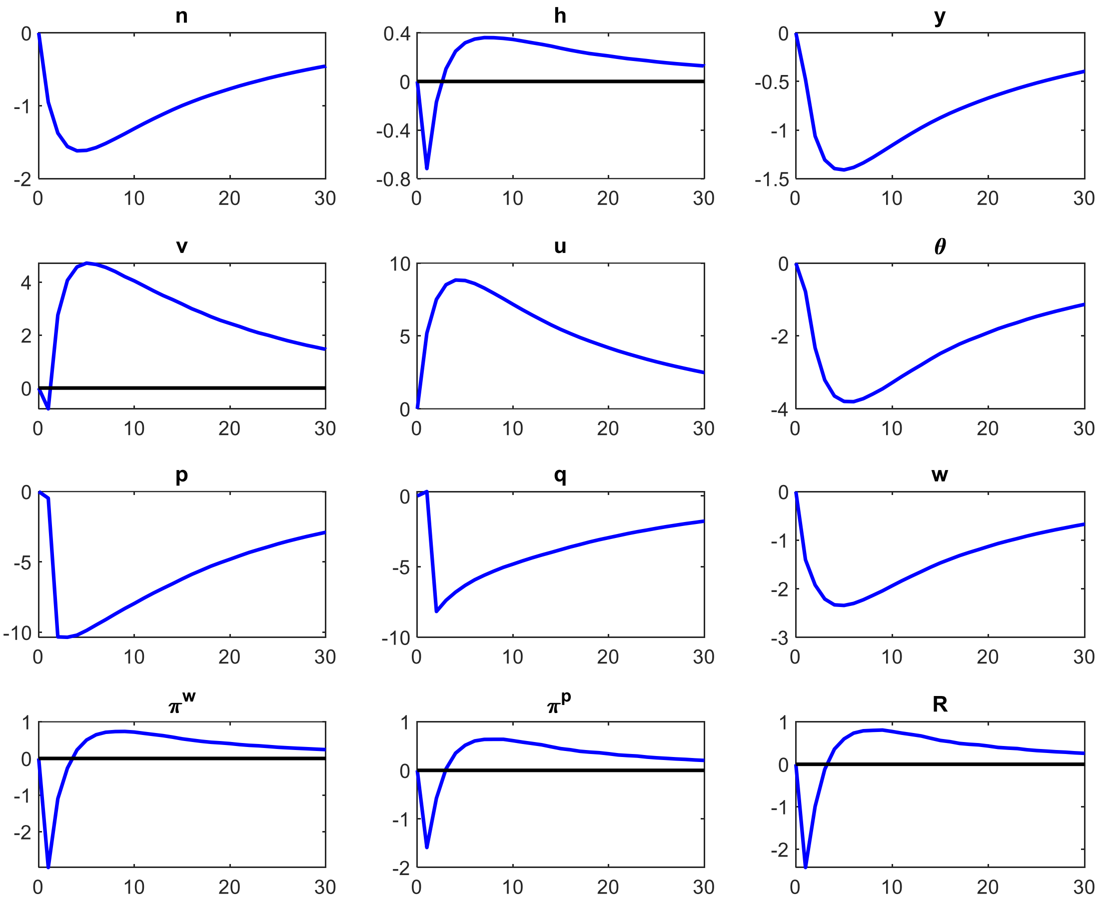

Figure 5: Impulse Responses- The Model With Flexible Wages

Note: Model-based impulse responses. Percentage deviations from the deterministic steady state. The results of the model with a demand-side effect, supply-side effect and flexible wages ($\phi^w = 0$). n: employment, h: hours per employed individual, y: output, v: vacancies, u: unemployment, θ: labor market tightness, p: job finding rate, q: job filling rate, w: real wage, π^w: wage inflation, π^p: price inflation, R: nominal interest rate.

4.6 The Role of Fiscal Policy

In this subsection, we introduce government spending in the model. Specifically, we let government spending (g_t) respond to changes to output, acting as an "automatic stabilizer":

$$\ln\left(\frac{g_t}{\overline{g}}\right) = \rho_g \ln\left(\frac{g_{t-1}}{\overline{g}}\right) - (1-\rho_g)\rho_{gy} \ln\left(\frac{y_t}{\overline{y}}\right), \tag{28}$$

with $\overline{g}$ being the steady-state value of government spending, $\rho_{gy} > 0$ and $\rho_g > 0$ being the coefficient of output and the persistence of government spending, respectively. The government budget constraint is given by:

$$g_t + \frac{R_{t-1}b_{t-1}}{\pi_t^p} = b_t + T_t \tag{29}$$

where we assume that the additional spending is financed via borrowing only (i.e. net transfers T_t are kept fixed). In addition, the resource constraint is modified as follows:

$$y_t = c_t + \gamma v_t + \frac{\phi^w}{\psi^2}\left(\exp[-\psi(\pi_t^w - 1)] + \psi(\pi_t^w - 1) - 1\right) n_t + \frac{\phi^p}{2}\left(\pi_t - 1\right)^2 y_t + g_t. \tag{30}$$

In Figure 6, we show the results with government spending. Without supply-side effect (labelled "FP, Constant d"), the model is unable to replicate the behavior of inflation after the initial fall; the inflation rate barely exceeds its initial value and reverts quickly to its initial level. In addition, the paths of key labor market variables (such as vacancies and labor market tightness) differ from what we observe in the data. Therefore, the supply-side effect remains crucial for replicating the dynamics of the inflation rate and other variables.

Fiscal policy, however, matters for the dynamics of the economy. Figure 6 compares the benchmark model without government spending (labeled "Benchmark, No FP") to the model with government spending (labeled "FP, Variable d"). The rise in government spending following the shock makes the fall in output and labor more muted and short-lived. It also leads to a quicker reversal in the inflation rate and a slightly higher rate of inflation than in the benchmark model that does not allow for fiscal policy. In addition, while the benchmark model without fiscal policy better accounts for the dynamics of key economic variables in the initial stage, the model with fiscal policy seems to well explain the behavior of other variables in the later stage of the pandemic. For example, the return of unemployment, labor and the job finding rate all happen within roughly 10 quarters, which is consistent with the data that we discuss in Section 2.

With fiscal policy, the elevated inflation rate lasts for a shorter period of time and returns to its initial value after approximately 12 quarters. The latter could indicate a return to pre-shock levels of government spending. In other words, since inflation in this model is influenced by the trajectory of fiscal policy, the decline in government spending (following the initial increase) would lead to a faster decrease in inflation.

In Appendix C, we consider an alternative fiscal policy whereby the government provides transfers, as opposed to increasing spending. The results that we obtain are similar. We conclude that fiscal policy alone fails to explain the dynamics of inflation rate at the early stage of the pandemic, but helps reconcile the relationship between inflation and labor market (e.g. unemployment and

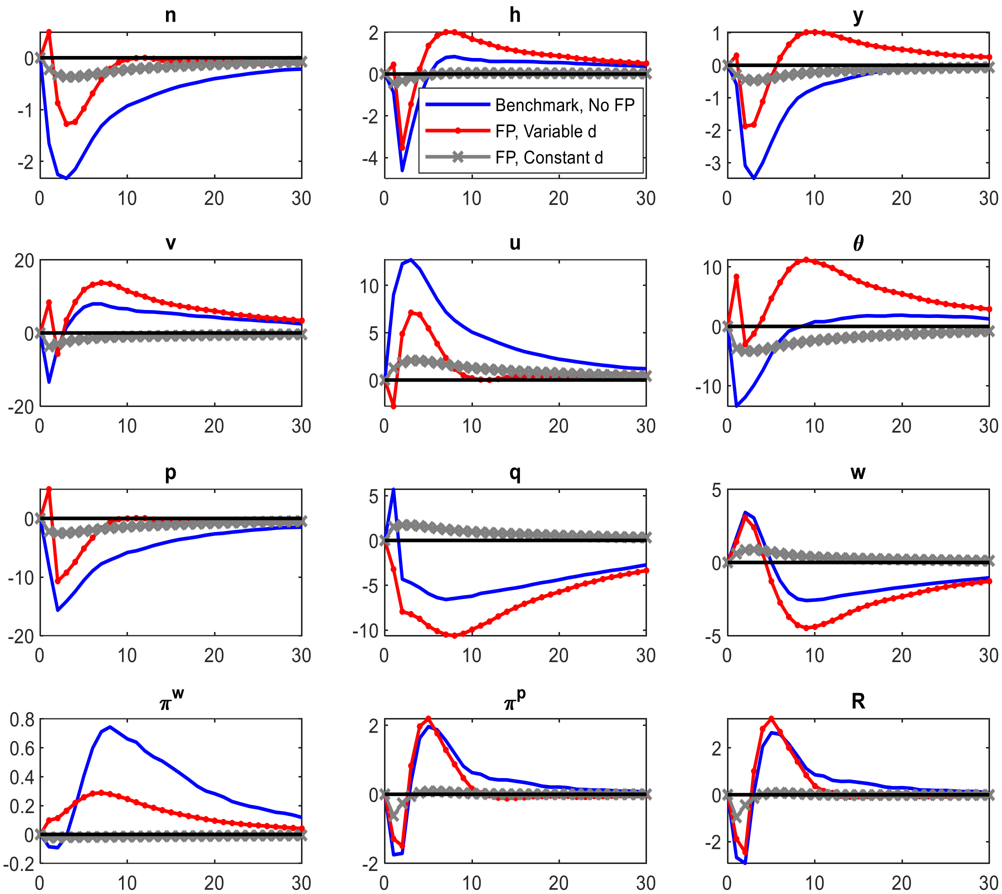

Figure 6: Impulse Responses- The Benchmark vs. the Model With Government Spending

Note: Model-based impulse responses. Percentage deviations from the deterministic steady state. The results of the model with government spending compared to the benchmark model. "Benchmark, No FP": the model with a demand-side effect, supply-side effect, but no fiscal policy. "FP, Variable d": the model with a demand-side effect, supply-side effect and fiscal policy. "FP, Constant d": the model with fiscal policy and demand side effect, but no supply-side effect. n: employment, h: hours per employed individual, y: output, v: vacancies, u: unemployment, θ: labor market tightness, p: job finding rate, q: job filling rate, w: real wage, π^w: wage inflation, π^p: price inflation, R: nominal interest rate.

job finding rate) in the later stage.

5 Labor Force Participation, Search Intensity and Hiring Intensity

In this section, we allow for endogenous participation in the labor force and expand our analysis of the reasons behind the fall in the efficiency of the matching process (d_t). Specifically, the efficiency of the matching process depends on the search intensity by job seekers and the recruiting intensity of firms. In what follows, both intensities are chosen by agents, suggesting that the supply-side effect is a result of agents' choices.

In the labor market, firms recruit with an intensity $s_{v,t}$ and unemployed individuals search with intensity $s_{u,t}$. Therefore, the matching function is now given by:

$$m(u_t, v_t, s_{u,t}, s_{v,t}) = \mu(u_t s_{u,t})^{\zeta}.(v_t s_{v,t})^{1-\zeta}. \tag{31}$$

The efficiency of the matching process can then be written as a function of the search intensity and the recruiting intensity, $d_t = s_{u,t}^{\zeta} s_{v,t}^{1-\zeta}$. Decomposing the efficiency of matching into search and recruiting intensities allows us to disentangle the distinct roles of firm and household choices in generating the observed dynamics of vacancies, labor market tightness, inflation and other macroeconomic aggregates.[7]

5.1 U.S. Data

We provide a brief description of the dynamics of the labor force participation rate, search and recruiting intensities and the efficiency of the matching process in Figure 7. Our approach to calculating the efficiency of the matching process is to consider it as a residual: $d_t = m_t/\mu u_t^{\zeta} v_t^{1-\zeta}$. As such, d_t accounts for variations in matches that do not result from changes in unemployment or vacancies. For the recruiting intensity, we use the data of Davis et al. (2023). Then, to calculate the search intensity, we use $d_t = s_{u,t}^{\zeta} s_{v,t}^{1-\zeta}$.

The participation rate declined by nearly 2% at the beginning of the Covid-19 crisis before gradually recovering. At the end of 2022, it stood at nearly 1% below its pre-shock level. The search and the recruiting intensities as well as the efficiency of the matching process declined on impact. However, while the recruiting intensity quickly recovered and exceeded its pre-shock level, the search intensity and the efficiency of the matching process continued to linger behind, remaining clearly below pre-Covid levels at the end of 2022. As such, the gap between the intensity at which firms try to hire and the intensity at which individuals try to search for jobs has widened since the start of 2020. Note also the strong correlation between the recruiting intensity and the inflation rate since the beginning of the Covid-19 crisis and that, for the most part, inflation follows the path of the recruiting intensity.[8]

[7] Possible variations in search intensity and/or recruiting intensity have been considered in the literature. For example, Leduc and Liu (2020) show that fluctuations in these intensities, that are driven by shocks to productivity and the discount factor, can help with bridging the gap between the actual and model-predicted job-filling rate.

[8] Davis (2011) constructs a measure of search intensity where the latter depends negatively on the mean duration of

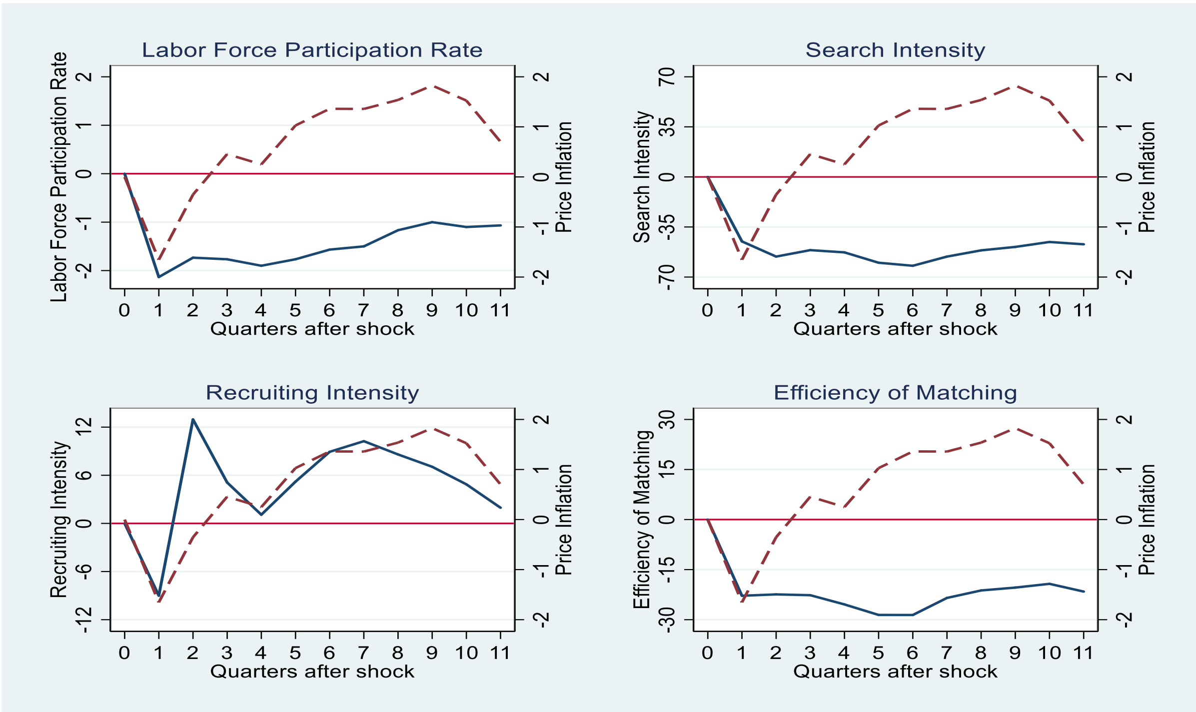

Figure 7: Price Inflation, Labor Force Participation, Search Intensity and Recruiting Intensity

Note: Percentage deviations from the average level between December 2019-February 2020. Time zero indicates the last quarter before the shock. Price Inflation- the percentage change in the consumer price index for all urban consumers- all items in U.S., as plotted in the dashed line and measured in the right axis. Labor Force Participation Rate: Percent, Seasonally Adjusted. Efficiency of the Matching Process: obtained as a residual from the matching function. Recruiting Intensity: obtained from Davis et al. (2023). Search Intensity: obtained from the definition of the efficiency of the matching process and the recruiting intensity.

5.2 Households and Firms

Each period t, an individual can be employed, unemployed or out of the labor force, so that $lf_t = n_t + u_t$, with lf_t being the labor force. The household chooses employment (n_t), unemployment (u_t) and search intensity for work ($s_{u,t}$). Leisure (non-labor market activity) time of the household is then given by $l_t = 1 - n_t h_t - u_t s_{u,t}$. All labor market activities, working or searching for a job, reduce the leisure time of household and cause disutility. The household's problem is to maximize:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[e_t u(c_t) - a_t [n_t v(h_t) + u_t k(s_{u,t})] \right], \tag{32}$$

unemployment. Leduc and Liu (2020) follow a similar approach but use the median duration of unemployment. In Appendix D, we show the search intensity using this approach. Generally, the search intensity initially rises, as the mean and median duration of unemployment falls, which reflects a massive rise in newly unemployed individuals-from roughly 6 million to 23 million. Then, the search intensity falls below its pre-shock level for nearly 2 years.

where $k(s_{u,t})$ is the period disutility from the effort of searching for a job, and it satisfies $\frac{\partial k(\cdot)}{\partial s_u} > 0$ and $\frac{\partial^2 k(\cdot)}{\partial s_u^2} > 0$. As before, e_t is the demand shock while a_t is a shock to the desire of households to be engaged in the labor market (akin to a labor supply shock). The pandemic reduced the desire of individuals to participate in labor market activities (working or searching for employment) and caused a fall in the labor force participation rate and search intensity. Maximization is subject to the sequence of budget constraints and the perceived law of motion of employment.

In the production sector, firm j incurs a cost for adjusting its recruiting intensity $(s_{v,j,t})$ given by $\Phi^S_{j,t}$. The firm chooses its price, vacancies, recruiting intensity and next-period employment to maximize:

$$E_0 \sum_{t=0}^{\infty} \frac{\beta^t e_t u_{c,t}}{e_0 u_{c,0}} \frac{r_t}{r_0} \left\{ \frac{P_{j,t}}{P_t} y_{j,t} - n_{j,t} w_{j,t} h_{j,t} - \gamma v_{j,t} - \Phi^S_{j,t} v_{j,t} - \Phi^W_{j,t} n_{j,t} - \Phi^P_{j,t} y_t \right\}, \tag{33}$$

subject to the perceived law of motion of employment and the demand for its product. Here, r_t is a shock that, among others, affects the firm's decisions on labor and posting vacancies. This shock is introduced to capture decisions by firms to change their hiring, recruiting intensity and vacancy postings since the start of the pandemic. One might think of r_t as a labor demand disturbance.

The optimality conditions of households and firms as well as other details about the model can be found in Appendix D. We also consider fiscal policy as characterized by equation (28).

5.3 Numerical Results

Figure 8 summarizes the main numerical findings where we consider three cases: the modified model without fiscal policy (labeled "Benchmark, No FP"), with fiscal policy (labeled "FP, Variable s_u & s_v"), and the model with endogenous labor force participation but constant searching intensity and recruiting intensity (labeled "FP, Constant s_u & s_v"). The third one can be seen as "fiscal policy only" as there is no change in the efficiency of matching.

Consider the first case (i.e. the modified model without fiscal policy) following the shock, the desire to work initially falls, which is reflected in a fall in the labor force, employment, hours and search intensity. In addition, recruiting intensity and vacancy postings decline on impact. The job finding rate, output and inflation rate fall too. As the economy recovers, vacancies, recruiting intensity and labor market tightness start to rebound and later exceed their initial values.

Interestingly, the recovery of output is faster than the (slow) recovery of labor force participation, which is in line with the data. Wage inflation rises and then slowly reverts back to its initial level. The inflation rate and the nominal interest rate fall on impact but rebound after 2-3 quarters and later exceed their initial values.

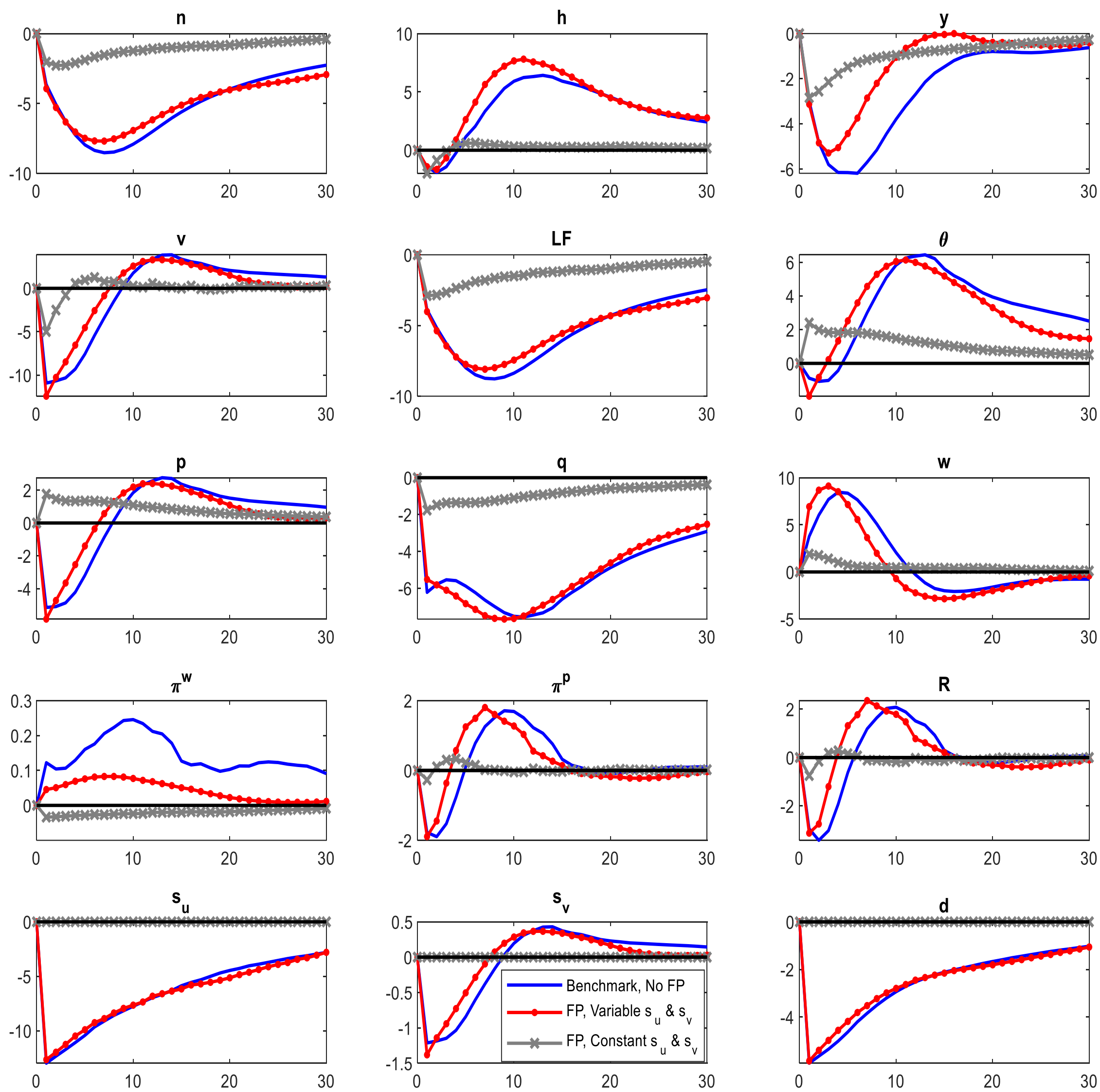

Figure 8: Impulse Responses- The Model with Endogenous Labor Force Participation, Search Intensity and Recruiting Intensity

Note: Model-based impulse responses- the model with endogenous labor force participation. Percentage deviations from the deterministic steady state. "Benchmark, No FP": the model with search intensity and recruiting intensity but no fiscal policy. "FP, Variable $s_u\&s_v$": the model with search intensity and recruiting intensity and fiscal policy. "FP, Constant $s_u\&s_v$": the model with fiscal policy, fixed search intensity and recruiting intensity. n: employment, h: hours per employed individual, y: output, v: vacancies, LF: labor force participation rate, θ: labor market tightness, p: job finding rate, q: job filling rate, w_t: real wage, π^w: wage inflation, π^p: price inflation, R: nominal interest rate, s_u: search intensity, s_v: recruiting intensity, d: efficiency of the search process.

When fiscal policy is introduced, we observe very similar patterns, including the behavior of the inflation rate. Fiscal policy, however, leads to faster reversal (e.g. in output, vacancies and labor market tightness) as well as to higher inflation in the first two years following the shock. As such, the extended model clearly demonstrates the potential role that fiscal policy has played in driving inflation dynamics. Starting from the third year after the shock, inflation begins to moderate and gradually declines, eventually returning to its initial value.

Turning to the third case, without initial drops in search and recruiting intensity, the fall in inflation is muted and the reversal happens quickly. The rise in inflation above its initial value is small and not long-lasting. The dynamics of some labor market variables, such as the job finding rate and labor market tightness, are at odds with the data. Therefore, while fiscal policy alone can lead to the observed behavior of inflation, it generates a relatively small and less persistent inflation rate, suggesting that the efficiency of the matching process remains crucial. Indeed, over longer horizons, the fall in the efficiency of matching is associated with a higher and more persistent inflation rate. We also learn that, due to labor market conditions, inflation was likely to rise above pre-Covid levels, albeit with a delay, even in the absence of an expansionary fiscal policy.

To further elaborate on the importance of search and recruiting intensities for the behavior of the inflation rate, we compare the model with a variable search intensity but constant recruiting intensity to the model with a variable recruiting intensity but constant search intensity, and to the model where both intensities are constant. Three points emerge in Figure 9. First, fixing either search or recruiting intensity leads to smaller response of inflation rate (compared to the model with variable search and recruiting intensities in Figure 8). Second, a variable search intensity better replicates the behavior of labor market variables at the early stage of the pandemic, but a variable recruiting intensity becomes more important in order to account for the behavior of these variables at the later stage. Third, the weakest response of the inflation rate is observed when both intensities are fully fixed.

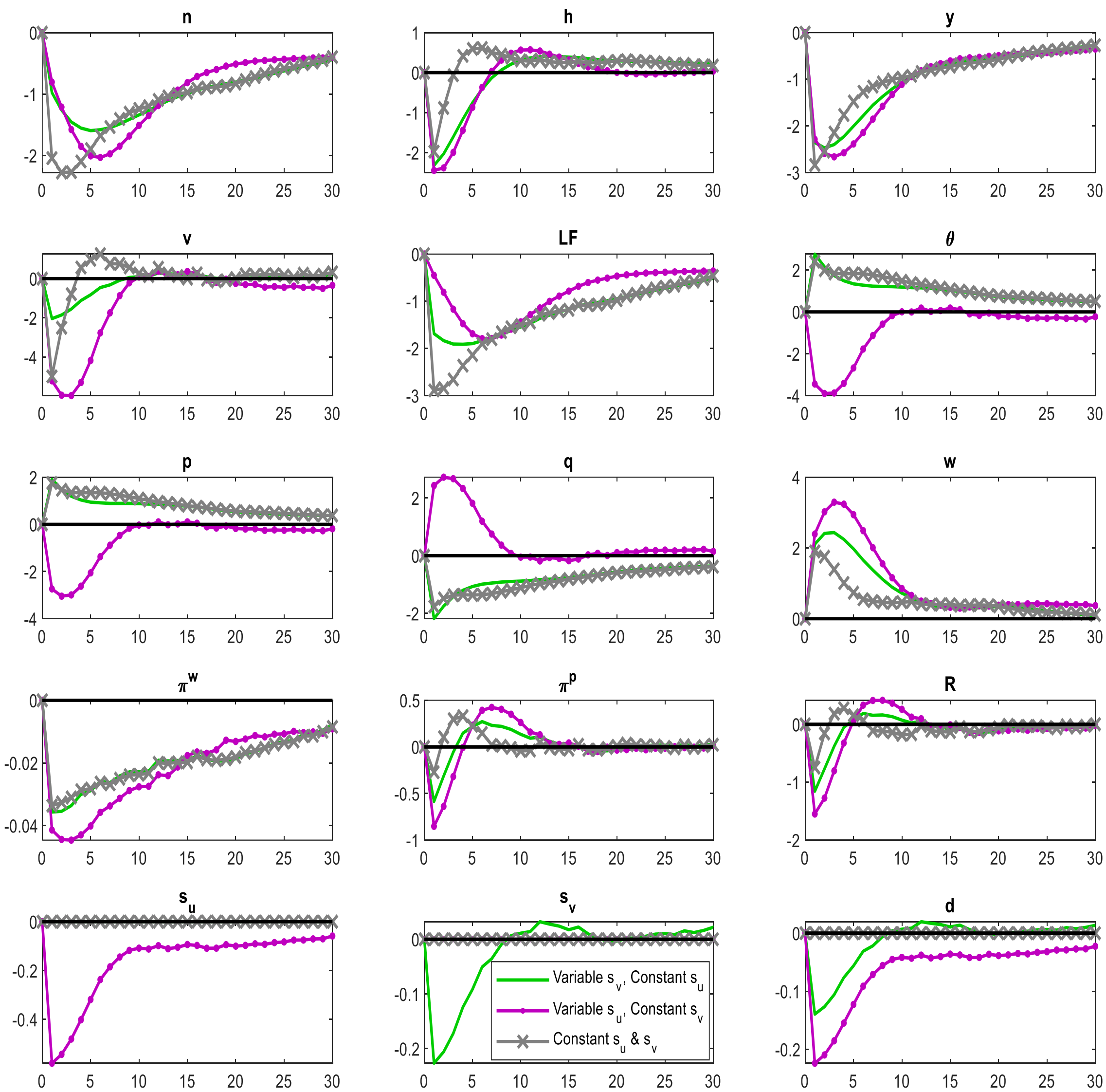

Figure 9: Impulse Responses- The Model with Endogenous Labor Force Participation, Search Intensity and Recruiting Intensity

Note: Model-based impulse responses. Percentage deviations from the deterministic steady state. "Variable s_v, Constant s_u": the model with fiscal policy, fixed search intensity and variable recruiting intensity. "Variable s_u, Constant s_v": the model with fiscal policy, variable search intensity and fixed recruiting intensity. "Constant s_u & s_v": the model with fiscal policy, fixed search intensity and fixed recruiting intensity. n: employment, h: hours per employed individual, y: output, v: vacancies, LF: labor force participation rate, θ: labor market tightness, p: job finding rate, q: job filling rate, w_t: real wage, π^w: wage inflation, π^p: price inflation, R: nominal interest rate, s_u: search intensity, s_v: recruiting intensity, d: efficiency of the search process.

5.4 Model Fit: Short-Run Dynamics

In the left panel of Figure 10, the results of the benchmark model are plotted, while in the right panel, the model with fiscal policy is shown. The analysis compares the model-based behavior of inflation to the corresponding behavior in the data. Four inflation measures are considered for the data: headline CPI, core CPI, headline PCE, and core PCE inflation rates. Each plot represents the deviation of the inflation rate from its initial value, referred to as "excess inflation," on a quarterly basis. The initial value is defined as the average inflation rate during the last three months before the Covid-19 pandemic (December 2019 - February 2020). As of the time of writing, the analysis covers 11 quarters since the start of the pandemic.[9]

The analysis highlights that the model successfully captures the observed dynamics of inflation, particularly when fiscal policy is incorporated. The introduction of fiscal expansion in the model helps explain the rapid rebound in inflation following the decline in 2020. The analysis suggests that without fiscal stimulus, the model predicts a longer duration of depressed economic activity and inflation, extending for approximately two more quarters. However, it is noted that fiscal policy does not appear to be essential in explaining the inflation dynamics during the initial months of the pandemic. Overall, the success of the model in accounting for the behavior of inflation since the beginning of the pandemic is noteworthy, especially considering that the model is calibrated based on pre-pandemic data.

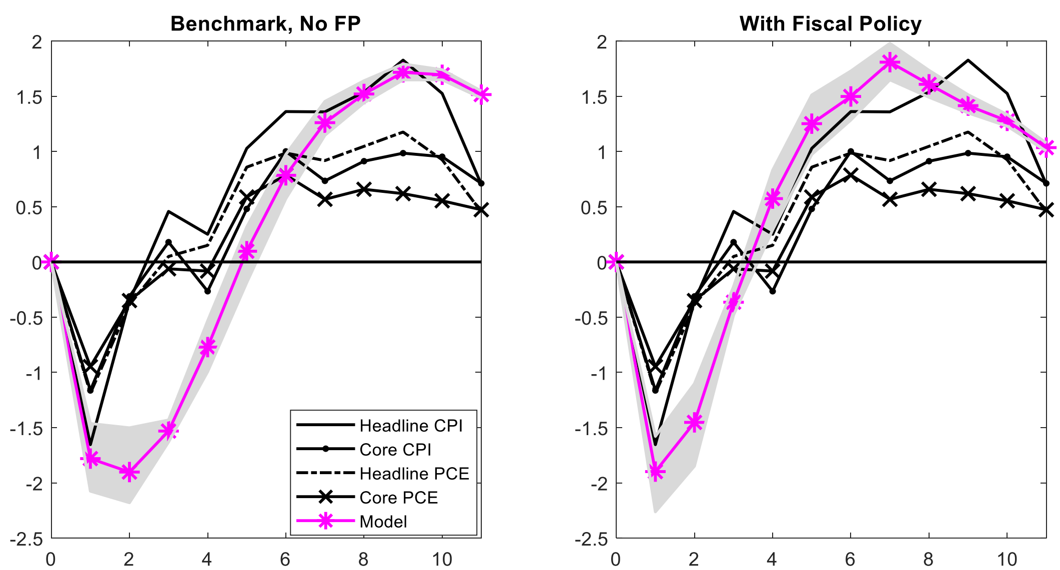

Figure 10: Excess Inflation Rate: Model vs. Data

Note: Data vs. model-based inflation rates (Quarterly). Model: Percentage deviations from the deterministic steady state. Data: percentage deviations from pre-Covid levels. Left panel: the model with no fiscal policy. Right Panel: the model with fiscal policy. Shaded areas: 90% confidence intervals around the model-based impulse response functions.

[9]Ideally, one would compare the impulse response functions implied by the model to those from the data, but the length of the available data poses a limitation for this exercise.

5.5 Model Fit: Correlations and Long-Run Dynamics

In this subsection, the analysis focuses on the correlations between the inflation rate and key labor market variables. The empirical correlation coefficients obtained from the data are compared to those implied by the model, as shown in Table 2. The data indicates that variables such as vacancies, labor market tightness, wage inflation, and other labor market indicators exhibit significant correlations with various measures of U.S. inflation rates. This finding aligns with the results reported in Ball et al. (2023), confirming the importance of labor market tightness in understanding inflation dynamics. The model used in the analysis demonstrates its ability to account for the correlations between inflation and these labor market variables. However, it is noted that the model with flexible wages tends to underestimate the correlation coefficients. This suggests that the dynamics of wages continue to play a crucial role in explaining the dynamics of inflation.

Table 2: Correlations of Labor Market Variables with Inflation

Measure	Wage inflation	Vacancies	Labor market tightness	Job finding rate	Job filling rate
Headline CPI	0.4168	0.7648	0.6108	0.5909	-0.7276
Core CPI	0.3414	0.7791	0.6469	0.6265	-0.7348
Headline PCE	0.5953	0.7740	0.6106	0.5880	-0.7662
Core PCE	0.5651	0.7602	0.6005	0.5771	-0.7678
Benchmark, No FP	0.4297	0.6289	0.6876	0.6937	-0.5514
With Fiscal Policy	0.3474	0.6628	0.6974	0.7131	-0.6885
Flexible Wage	0.3518	0.1645	0.0938	0.2593	0.2547

Note: Correlation coefficients of labor market variables with the inflation rates, data vs. model.

In Figure 11, the analysis presents the labor market tightness and inflation rate generated by numerous simulations of the model, alongside the corresponding U.S. labor market tightness and inflation rates. The model, whether with or without fiscal policy, produces a labor market tightness and inflation locus that aligns with the observed data, particularly when considering the core CPI and core PCE inflation rates. However, notable deviations are observed with the headline CPI, primarily due to the impact of the rise in inflation following the Russian invasion of Ukraine. It is expected that the model is smoother than the real world and does not account for every event that could influence the dynamics of inflation and other macroeconomic aggregates.

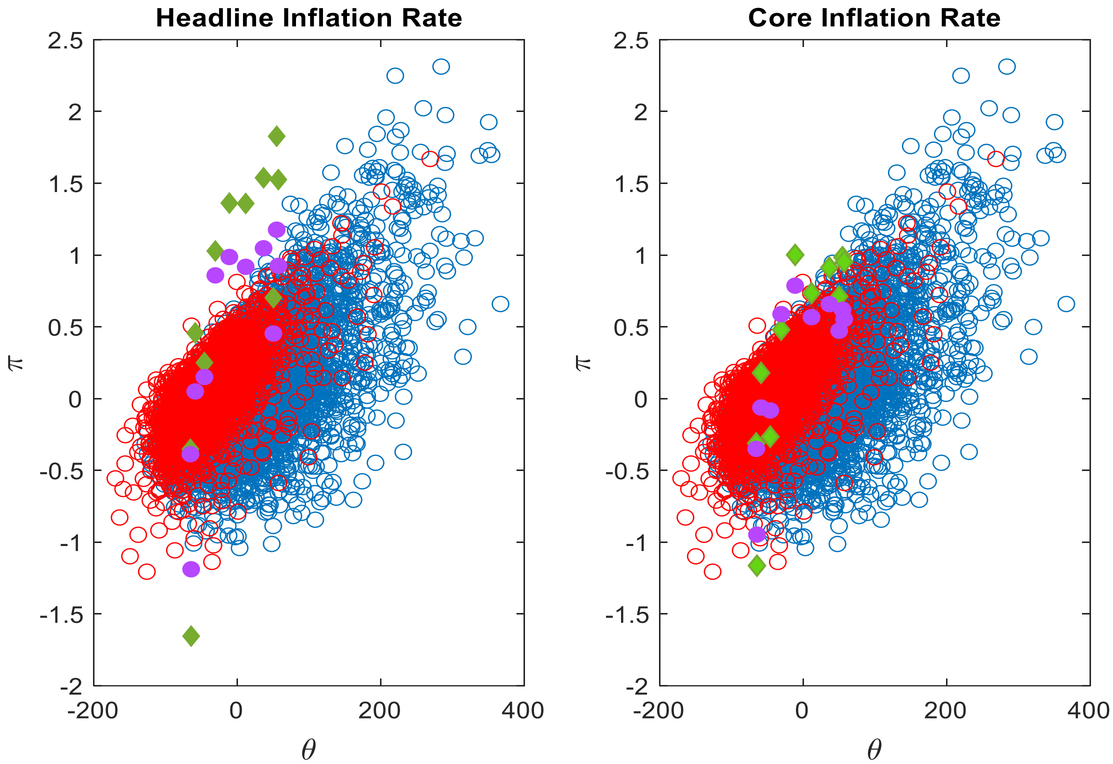

Figure 11: Inflation Rate vs. Labor Market Tightness

Note: Data vs. model-based inflation rates vs. labor-market tightness. Model: Percentage deviations from the deterministic steady state. Data: percentage deviations from pre-Covid levels (Quarterly). Left panel: headline CPI and PCE inflation rates. Right panel: core CPI and PCE inflation rates. Blue circles: the model with no fiscal policy. Red circles: the model with fiscal policy. Green diamond: CPI-based inflation rates. Purple filled circle: PCE index-based inflation rate.

The negative values observed primarily reflect the initial negative demand shock experienced during the analyzed period. It is worth noting that the majority of observations fall within a reasonable range, and extreme realizations of labor market tightness are relatively rare. Overall, Figure 11 demonstrates that the model, despite being estimated using pre-shock data, is capable of generating labor market tightness and inflation patterns that are consistent with the observed data since 2020, offering valuable insights into the dynamics of inflation in different scenarios.

6 Conclusions

Our proposed labor search and matching model incorporates a shock that affects economic activity and the inflation rate through the demand side and labor market matching. In the aftermath of a negative shock, we observe a decline in labor, vacancies, and the inflation rate. In the short term, this shock acts as a negative demand disturbance, leading to reduced economic activity and inflation. However, as time progresses, the supply-side effect of the shock becomes more pronounced, causing inflation to exceed its pre-shock levels.

We demonstrate that the inflation rate dynamics closely resemble those of vacancies and labor market tightness. Around 2-3 quarters after the shock, we observe an increase in vacancies and labor market tightness, which creates upward pressure on wages and subsequently leads to higher prices. Our model effectively captures the dynamics of U.S. inflation rates and their correlation with labor market variables since the onset of the pandemic.

In our extended model, we introduce an explicit labor force participation margin and consider changes in the efficiency of the matching process. This allows us to account for variations in search intensity by individuals and recruiting intensity by firms. The extended model showcases its capability to effectively capture the substantial correlations observed between inflation and the labor market variables in the data. The model, whether with or without fiscal policy, generates a labor market tightness and inflation locus that aligns with the observed data, particularly when focusing on the core CPI and core PCE inflation rates.

We demonstrate that fiscal policy has an impact on the dynamics of inflation, mainly by facilitating a faster recovery in economic activity and inflation in the model that incorporates labor market shocks. However, it is important to note that fiscal policy alone cannot generate a sustained increase in the inflation rate. Our findings indicate that even in the absence of expansionary fiscal policy, the shocks to the labor market would have eventually led to a similar outcome in terms of inflation, albeit with a delay of 2-3 quarters. This highlights the significance of labor market shocks as a driving force behind inflation dynamics, suggesting that fiscal policy's role in inflation behavior should be understood within the broader context of labor market conditions.

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Appendix

A Bayesian Estimation

The Bayesian estimation procedure proceeds as follows: 1) We use the observed data to estimate the model. 2) We calculate parameter values, means and standard deviations of shocks using Bayesian estimation. The posterior distribution is obtained using the Metropolis-Hastings algorithm. 3) We use these parameter values to simulate the model.

Since our model has only one shock, we can only use one observed variable. to improve the estimation, we expand the model by including more observed variables. Since we maintain that the number of observed variables equals the number of shocks in the model, the shock structure is enlarged by allowing for potential measurement errors. As observed variables, we use the growth rates of GDP, real wage, employment and consumption, we follows:

$$
\begin{aligned}
g_y &= y_t/y_{t-1} + \varepsilon_{y,t} \\
g_w &= w_t/w_{t-1} + \varepsilon_{w,t} \\
g_n &= n_t/n_{t-1} + \varepsilon_{n,t} \\
g_c &= c_t/c_{t-1} + \varepsilon_{c,t}
\end{aligned}
$$

We use the following data series:

- y_t: Real Gross Domestic Product, Billions of Chained 2012 Dollars, Seasonally Adjusted Annual Rate
- w_t: Nonfarm Business Sector: Real Hourly Compensation for All Employed Persons, Index 2012=100, Seasonally Adjusted.
- n_t: All Employees, Total Nonfarm, Thousands of Persons, Seasonally Adjusted.
- c_t: Real Personal Consumption Expenditures, Billions of Chained 2012 Dollars, Seasonally Adjusted Annual Rate.

All data are quarterly and obtained from the FRED database of the Federal Reserve Bank of St. Louis.

Table A.1: Bayesian Estimation Results- Benchmark, No Fiscal Policy

	Prior Distribution			Posterior Distribution	
Parameter	Density	Mean	Std. Dev.	Mean	Std. Dev.
β	Beta	0.99	0.01	0.9919	0.0003
σ	Normal	2.00	0.10	2.1274	0.0539
ϑ	Normal	2.00	0.10	2.2548	0.0079
ρ_π	Normal	1.50	0.10	1.4973	0.0047
ρ_y	Normal	0.50	0.01	0.4941	0.0051
ϕ^π	Normal	20.00	2.00	29.7257	0.5342
ϕ^w	Normal	80.00	2.00	79.3519	4.5812
ψ	Normal	2500	200.00	2362.5102	105.4704
q_d	Normal	8.00	0.20	7.2676	0.0282
q_e	Normal	1.00	0.05	0.9292	0.0314

Notes: The posterior distribution is obtained using the Metropolis-Hastings algorithm. Results for the benchmark model with demand-side shock and a shock to the efficiency of the matching process. No fiscal policy.

Table A.2: Bayesian Estimation Results- With Fiscal Policy

	Prior Distribution			Posterior Distribution	
Parameter	Density	Mean	Std. Dev.	Mean	Std. Dev.
β	Beta	0.99	0.01	0.9924	0.0003
σ	Normal	2.00	0.10	2.1907	0.0260
ϑ	Normal	2.00	0.10	2.2642	0.0332
ρ_π	Normal	1.50	0.10	1.4972	0.0061
ρ_y	Normal	0.50	0.01	0.4993	0.0023
ϕ^π	Normal	20.00	2.00	30.2587	0.3480
ϕ^w	Normal	80.00	2.00	78.7537	2.4056
ψ	Normal	2500	200.00	2427.2297	76.4722
q_d	Normal	8.00	0.20	7.3997	0.0436
q_e	Normal	1.00	0.05	0.8997	0.0062
ρ_g	Normal	0.90	0.01	0.9007	0.0017
ρ_{gy}	Normal	1.30	0.20	1.1911	0.1735

Notes: The posterior distribution is obtained using the Metropolis-Hastings algorithm. Results for the benchmark with demand-side shock, a shock to the efficiency of the matching process and fiscal policy.

B The Model With No Lags

We now discuss the case when the supply-side effect is introduced without a lag. As Figure B.1 shows, this version of the model largely accounts for the observed behavior of inflation and other variables. However, there are two main differences compared to the benchmark model. First, the reversal happens sooner, roughly one quarter after the initial fall. Second, labor market tightness falls on impact, but does not exceed its initial level, which contradicts the observed behavior in the data.

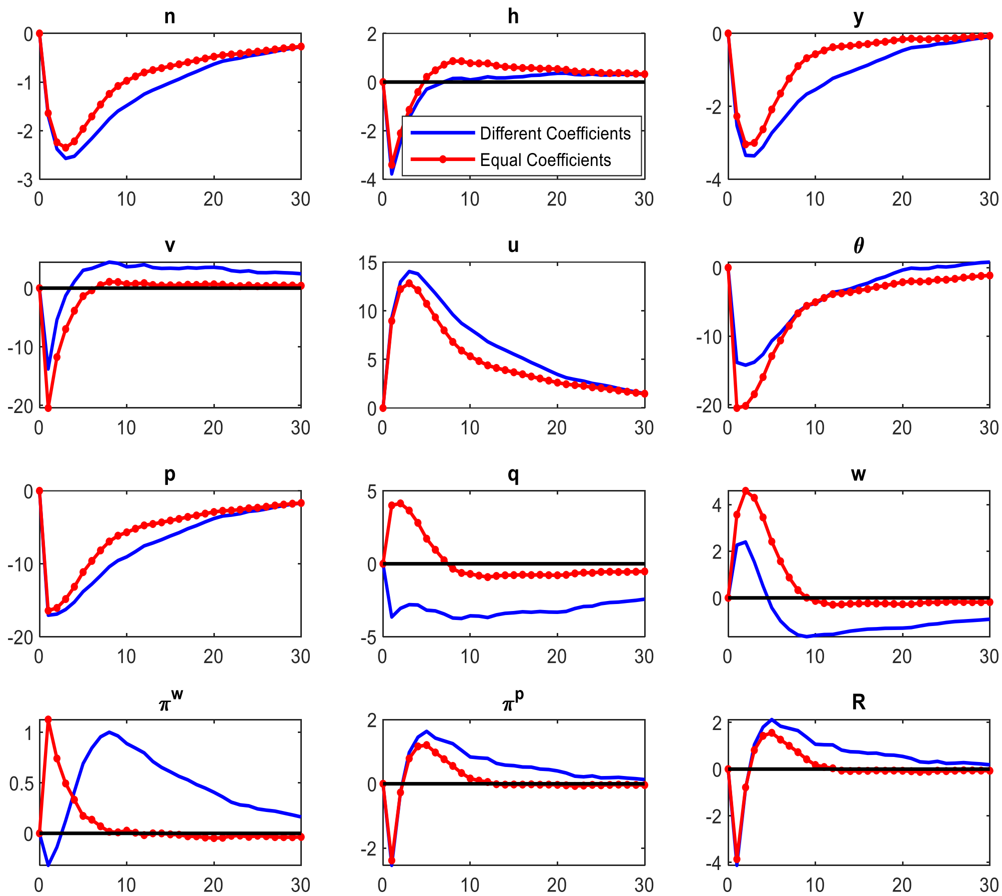

Figure B.1: Impulse Responses- The Model With No Lags

Note: Model-based impulse responses. Percentage deviations from the deterministic steady state. The results of the model with no lags on the supply side. "Different Coefficients": $q_d \neq q_e$. "Equal Coefficients": $q_d = q_e$.

The figure also shows results when the coefficients q_d and q_e are forced to be equal, implying that the two effects operate equally on the economy. The model continues to well describe the dynamics of inflation and most of other variables. The main shortcoming concerns the behavior of vacancies three quarters after the shock and, consequently, the behavior of labor market tightness. On this basis, the benchmark model that allows for differentiated supply and demand effects is moderately preferred.

C A Change in Transfers

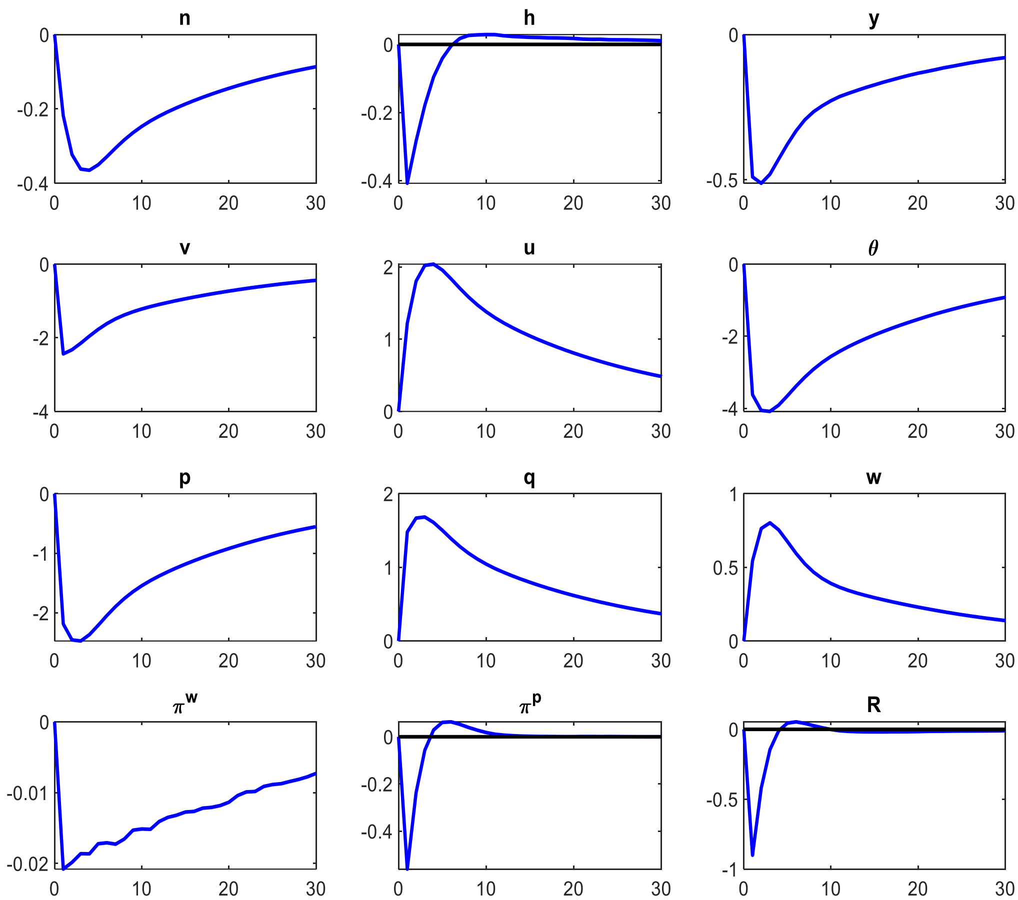

Figure C.1: Impulse Responses- The Model With Transfers.

Note: Model-based impulse responses. Percentage deviations from the deterministic steady state. The results of the model with transfers and a demand-side effect only ($q_d = 0$). In this version of the model, the government raises transfers (T_t) without changing government spending (g_t).

D Extended Model

This section provides more details about the extended model that we discuss in Section 5.

D1 Households

The household's problem then is to maximize:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[e_t u(c_t) - a_t[n_t v(h_t) + u_t k(s_{u,t})]\right], \tag{D.1}$$

subject to:

$$c_t + \frac{B_t}{P_t} = \frac{n_t h_t W_t}{P_t} + u_t s + \frac{R_{t-1} B_{t-1}}{P_t} + \frac{T_t}{P_t} + \frac{\Theta_t}{P_t}, \tag{D.2}$$

$$n_t = (1-\rho)\left(n_{t-1} + p_t u_t\right), \tag{D.3}$$

Optimization with respect to bonds, consumption, employment, unemployment and search intensity give:

$$\lambda_t = \beta R_t E_t \left(\frac{\lambda_{t+1}}{\pi^p_{t+1}}\right) \tag{D.4}$$

$$a_t k(s_{u,t}) = s\lambda_t + (1-\rho)p_t \, \mathbb{E}_t \left[\lambda_t w_t h_t - a_t v(h_t) + \beta \frac{a_{t+1} k(s_{u,t+1}) - s\lambda_{t+1}}{p_{t+1}}\right] \tag{D.5}$$

$$u_t a_t k'(s_{u,t}) = (1-\rho)p_t \, \mathbb{E}_t \left[\lambda_t w_t h_t - a_t v(h_t) + \beta \frac{u_{t+1} a_{t+1} k'(s_{u,t+1})}{p_{t+1}}\right] \tag{D.6}$$

with $\lambda_t = e_t u_{c,t}$ being the marginal utility of consumption. Condition (D.4) is the Euler Equation. Condition (D.5) governs the labor force participation, and it is obtained from combining the first-order condition with respect to labor and unemployment. It states that, at the optimum, the households equates the expected marginal cost of one additional searching member to the expected marginal benefit. The former includes the disutility of search (e.g. in the form of forgone leisure). The expected marginal benefit of being unemployed (and searching for a job) first includes unemployment benefits. With probability p_t, the search effort is successful. Then, the expected marginal benefit would include, if the matching survives separation, the value of labor income net of disuility of work as well as future employment relationship by the household member (a household member who remains employed next period does not have to search again, thus saving on net potential searching costs). Condition (D.6) describes the choice of search intensity; the left-hand side describes the increases in the disutility of raising the search intensity multiplied by the number of searching members. If the search is successful and the match survives separation, the marginal benefit is labor income net of the disutility of working as well as the continuation value (the search disutility that is saved next period if employment continues).

The disutility function of households of raising search intensity is given by:

$$k(s_{u,t}) = \chi_u \frac{s_{u,t}^{1+\kappa}}{1+\kappa} \tag{D.7}$$

with $\kappa, \chi_u > 0$. The disutility function of raising the search effort is convex, similar to the disutility function of raising the number of hours worked.

D2 Firms

A firm j adjusts its recruiting intensity $s_{v,j,t}$, but adjusting intensity entails a resource cost:

$$\Phi_{j,t}^S(s_{v,j,t}) = \frac{\phi^s}{2}\left(s_{v,j,t} - \overline{s_v}\right)^2 \tag{D.8}$$

with ϕ^s being the adjustment cost parameter and $\overline{s_v}$ the steady-state value of the recruiting intensity. The firm then chooses its price, vacancies, recruiting intensity and next-period employment to maximize:

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{r_t \lambda_t}{r_0 \lambda_0} \left\{ \frac{P_{j,t}}{P_t} y_{j,t} - n_{j,t} w_{j,t} h_{j,t} - \gamma v_{j,t} - \Phi_{j,t}^S v_{j,t} - \Phi_{j,t}^W n_{j,t} - \Phi_{j,t}^P y_t \right\}, \tag{D.9}$$

subject to:

$$n_{j,t} = (1-\rho)(n_{j,t-1} + q_t v_{j,t}), \tag{D.10}$$

$$z_t n_{j,t} f(h_{j,t}) = \left[\frac{P_{j,t}}{P_t}\right]^{-\varepsilon} y_t. \tag{D.11}$$

Optimization and imposing symmetry among firms yield the modified job creation condition, the condition that govern the choice of recruiting intensity and Phillips Curve:

$$\frac{\gamma + \Phi_t^S}{q_t} = (1-\rho)\left\{ mc_t z_t f(h_t) - w_t h_t - \Phi_t^W + \beta E_t \left(\frac{r_{t+1}\lambda_{t+1}}{r_t \lambda_t}\right)\left(\frac{\gamma + \Phi_{t+1}^S}{q_{t+1}}\right)\right\}, \tag{D.12}$$

$$\frac{\Phi^{S'}(s_{v,t})}{q_t} = (1-\rho)\left\{ mc_t z_t f(h_t) - w_t h_t - \Phi_t^W + \beta E_t \left(\frac{r_{t+1}\lambda_{t+1}}{r_t \lambda_t}\right)\left(\frac{\Phi^{S'}(s_{v,t+1})}{q_{t+1}}\right)\right\}, \tag{D.13}$$

$$1 - \phi^p(\pi_t^p - \overline{\pi}^p)\pi_t^p + \beta \phi^p E_t \left[\left(\frac{r_{t+1}\lambda_{t+1}}{r_t \lambda_t}\right)(\pi_{t+1}^p - \overline{\pi}^p)\pi_{t+1}^p \frac{y_{t+1}}{y_t}\right] = \varepsilon(1 - mc_t). \tag{D.14}$$

The job creation condition is modified to account for the cost of adjusting the recruiting intensity. In equilibrium, the firm equates the vacancy-creation cost and the cost of changing recruiting intensity to the expected present discounted value of profits from the match. Raising the recruiting intensity raises the likelihood of filling a vacancy, and if the match survives separation, it yields a future steam revenues net of wage costs and the cost of adjusting nominal wages as well as saves on future costs of raising recruiting intensity.

Note that the individual firm's level, the probability fill a vacancy is $q_{j,t} = s_{v,j,t}m_t/v_t s_{v,t}$, thus implying $q_{j,t}/q_t = s_{v,j,t}/s_{v,t}$. The likelihood that a firm j with intensity $s_{v,j,t}$ fills a vacancy relative to the economy-side probability depends on its intensity relative to the economy-wide intensity (all economy-wide quantities are taken as given by the firm). In a symmetric equilibrium: $q_{j,t} = q_t$. Similarly, for a member i of the household, we obtain $p_{i,t}/p_t = s_{u,i,t}/s_{u,t}$, which becomes one in a symmetric equilibrium.

D3 The Shocks

The demand (preference) shifter evolves according to the following rule:

$$\ln\left(\frac{e_t}{\overline{e}}\right) = \rho_s \ln\left(\frac{e_{t-1}}{\overline{e}}\right) + q_e \iota_t \tag{D.15}$$

The shock to the desire to engage in the labor market:

$$\ln\left(\frac{a_t}{\overline{a}}\right) = \rho_s \ln\left(\frac{a_{t-1}}{\overline{a}}\right) + q_a \iota_t \tag{D.16}$$

The shock to firms' desire to hire and post vacancies:

$$\ln\left(\frac{r_t}{\overline{r}}\right) = \rho_s \ln\left(\frac{r_{t-1}}{\overline{r}}\right) - q_r \iota_t \tag{D.17}$$

where ρ_s is the persistence of the shock, $\iota_{H,t} \sim \mathcal{N}(0, \sigma_H^2)$, $q_a, q_e, q_r > 0$ and $\overline{a} = \overline{e} = \overline{r} = 1$. This set of shock allows the model to capture the initial fall in economic activity and inflation, the fall in search intensity as well as the rise in recruiting intensity and vacancies above their pre-Covid levels. We also note that one can capture the observed behavior of labor market variables and inflation without assuming any lags in the model.

D4 Market Clearing

In equilibrium, the labor force (lf_t) is given by:

$$lf_t = n_t + u_t, \tag{D.18}$$

and $1 - lf_t$ measures the fraction of individuals who are out of the labor force.

The resource constraint of the economy:

$$y_t = c_t + \gamma v_t + \Phi_t^S v_t + \Phi_t^W n_t + \Phi_t^P y_t. \tag{D.19}$$

When fiscal policy is introduced, the resource constraint is adjusted accordingly.

D5 Parameterization

Table D.1 presents the parameter values that we use with the model with endogenous labor force participation, search intensity and recruiting intensity (Figure 8 in the text).

Table D.1: Values of the Parameters- Model with Endogenous Labor Force Participation

Parameter	Description	No FP	With FP
β	Households' utility discount factor	0.99	0.99
σ	Consumption curvature parameter	2.00	2.00
ϑ	Inverse labor supply elasticity	2.00	2.00
α	Elasticity of output with respect to hours per worker	2/3	2/3
ε	Elasticity of substitution between products	11.00	11.00
$\overline{\pi}^p$	Steady-state gross price inflation rate	1.005	1.005
ρ_π	Response of the interest rate to inflation	1.51	1.50
ρ_y	Response of the interest rate to output	0.51	0.51
q_e	Demand shock	0.67	0.31
q_a	Labor supply shock	6.22	6.39
q_r	Labor demand shock	1.21	0.60
ρ_s	Persistence of the shock	0.95	0.95
ζ	Contribution of an unemployed individual to a match	0.40	0.40
ϕ^p	Price rigidity	23.80	24.95
ϕ^w	Wage rigidity	79.07	81.44
ψ	Asymmetry parameter of wage rigidity	2605.34	2580.33
κ_u	Disutility of search curvature parameter	8.1147	7.74
ϕ^s	Adjustment cost of recruiting intensity parameter	0.11	0.10
ρ_g	Persistence of government spending		0.91
ρ_{gy}	Response of government spending to output		1.74

Note: This table summarizes the values of the parameters in the benchmark analyses. $\overline{\pi}^w = \overline{\pi}^p$ and $\eta = \zeta$. Productivity: $z_t = 1$ for all t. Part of the parameter values are based on Bayesian estimation.

D6 Search Intensity: Alternative Approach

In this subsection, we present an alternative approach to estimating search intensity, which follows Davis (2011). The latter relates the intensity of search to the (average) duration of unemployment: $s_{u,t} = \alpha_1 - \alpha_2 Duration_t$. Leduc and Liu (2020) used a similar approach, but the median of unemployment duration replacing the mean of duration. In Figure D.1, we show the implied search intensity using both the mean and the median, with the values of α_1 and α_2 being obtained from Davis (2011). Throughout the majority of the time since the start of the pandemic, this measure points to the same phenomenon that we identify in the text- reduced search intensity for work following the Covid-19 shock.

This measure, however, suggests higher search intensity in the early stages of the pandemic, which is unreasonable. This occurs for the following reason: prior to March 2020, there have been nearly 6 million unemployed in the U.S. The number of unemployed rose to nearly 23 million in April 2020. Therefore, nearly three quarters of all unemployed in April 2020 were newly unemployed, which reduced the mean and the median duration of unemployment, particularly the former. As this measure negatively depends on the mean/median duration of unemployment, it shows more intensive search for work.

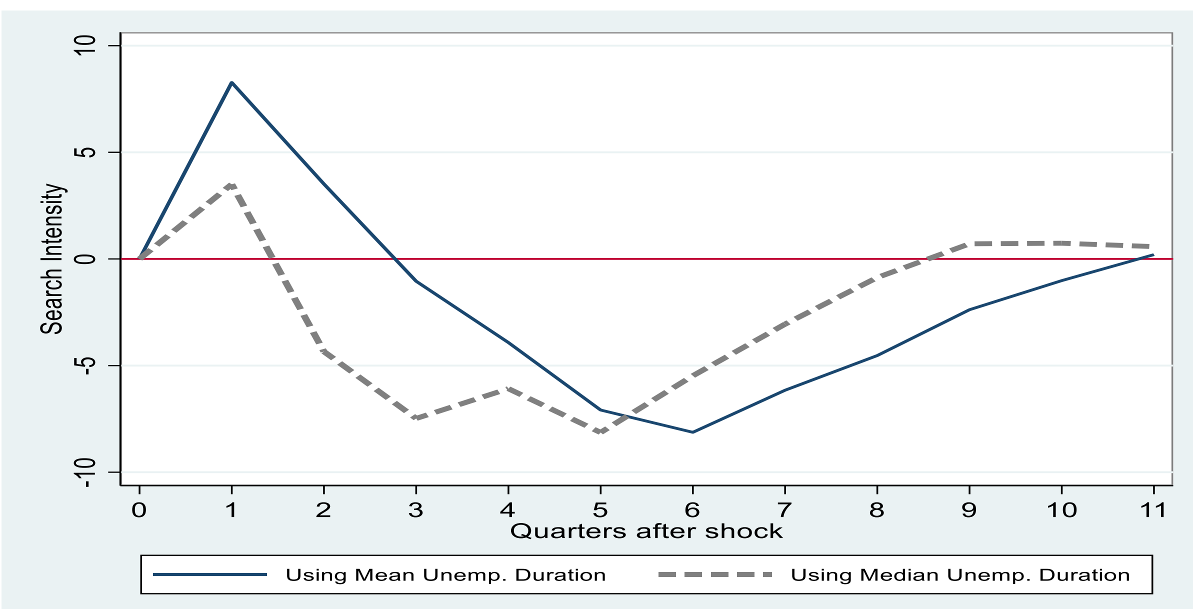

Figure D.1: Search Intensity- Alternative Approach

Note: calculating the search intensity following Davis (2011) and Leduc and Liu (2020). We use: $\alpha_1 = 122.30$ and $\alpha_2 = 0.90$.