

Business Cycle, Great Recession and Part-time Jobs

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Abstract

During the Great Recession, the U.S. economy witnessed a substantial rise in part-time employment for sustained periods. We extend the New Keynesian-unemployment model by Galí et al. (2012) to allow substitution between full-time and part-time labor and estimate the model's parameters using the Bayesian method. In our model, households and firms can optimally allocate full-time and part-time labor. Moreover, disturbances exist in part-time labor supply (household disutility in part-time labor) and part-time labor demand (firms' efficiency to utilize part-time labor). Although several shocks were found to cause the transition to part-time jobs during the recession, the most important factor was the part-time labor supply shock that increases part-time participation. The transition from full-time to part-time jobs, caused by part-time labor market shocks, mitigated the contraction in output during the recession. Part-time labor supply shock also explains a significant portion of slow recovery in gross wage during the recession, as the shock lowers part-time wage as well as the proportion of full-time workers in total employment.

Keywords: Part-time labor, Great Recession, Unemployment, New Keynesian model

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1 Introduction

During the Great Recession, the U.S. economy experienced substantial rise in part-time employment¹ for sustained periods. Historically, this is not new because, in the U.S., part-time share of employment has been increasing in recessions and decreasing in expansions, as shown in Figure 1 (a). This counter-cyclical movement in part-time jobs has gone unnoticed despite its non-negligible size.² Yet, recently, policymakers have paid attention to the rise of part-time jobs, since this phenomenon may indicate an additional slackness in the labor market. For example, Yellen (2014) pointed out that the unemployment rate these days may not fully capture the extent of the slack in the labor market, considering the high percentage of involuntary part-time jobs. As Figure 1 (b) shows, the proportion of part-time workers in the labor force increased during this recession and has only slowly declined, even though the unemployment rate has come down to its pre-crisis level. This could signal that the economy fails to employ at full capacity even at a low unemployment rate.

In addition, the prevalence of part-time jobs during the Great Recession can be related to another recent puzzle in the U.S. labor market: the “flattening” of the wage Phillips curve (WPC hereafter), which refers to a situation wherein wages move up slowly despite falling unemployment. Indeed, unemployment rate in the U.S. decreased by a remarkable extent, that is, by 5.5 percentage points from 2010:1Q to 2017:2Q. However, during the same period, nominal median weekly usual earning of full-time workers increased by only 1.9% annually and that of part-time workers increased by an even less degree, 1.8%.³ Considering that wages in part-time jobs are lower than those in full-time jobs on average, the fact that the part-time share in total employment remains relatively high compared with previous recoveries could be associated with this flattening of WPC (a composition effect). Such complications call for deeper understanding of what caused part-time jobs to rise and how it affected the overall economy during the recession and its recovery.

[Figure 1 here]

In this respect, our main research question can be summarized as follows: How does part-time employment react to economic shocks? Especially, what are the main causes of the transition to part-time employment during the Great Recession? Why did part-time employment remain high until recently, while full-time jobs seem to have recovered? How do part-time jobs affect labor force, unemployment, and macroeconomic variables such as output and inflation? Is there a connection between part-time jobs and slow wage recovery?

¹The U.S. Bureau of Labor Statistics defines part-time employment as employees working fewer than 35 hours per week.

²The share of part-time employment is about one-sixth of the total on average since the 1990s in the U.S.

³These two wage series, from the Current Population Survey (CPS), are currently the only publicly available wage series for full-time and part-time jobs in the U.S. We use these series as full-time and part-time wages in our analysis.

To capture the dynamics of part-time jobs along the business cycle, we extend the New Keynesian dynamic stochastic general equilibrium (DSGE) model by Galí et al. (2012) (GSW hereafter), which incorporates unemployment into the benchmark medium-sized DSGE model of Smets and Wouters (2007) (SW hereafter). Our extension of the model mainly involves introducing the additional building block of labor, in which agents exclusively work part time. This approach has merits for analyzing part-time job dynamics from several perspectives. In principle, we can use a number of actual macroeconomic data series to identify the structural shocks and explain the interaction between macroeconomic variables and labor type transitions. Moreover, the estimated model is suitable for counter-factual policy experiments, such as for evaluating possible consequences if this transition to part-time jobs did not occur. In a practical sense, because we maintain the basic structure of SW and GSW, still considered as workhorse models by many central banks for forecast and policy analyses, we can focus on the dynamics of part-time jobs by using standard analytical methods and without too much complication from other sectors of the model.

In our model, a large representative household has full-time and part-time available population and determines the labor participation of each type. The household can effectively substitute labor types by reducing one type of participation and increasing the other. Firms' production technology includes both types of labor, and firms choose the level of full-time and part-time employment given their wages. Once agents are employed either full or part time, their labor is indivisible in the sense that the labor hour per person is constant (no change in the intensive margin for each labor type).⁴ We define "part-time labor supply shock" as a disturbance term that governs relative disutility between full-time and part-time labor. This term reflects that each labor type has different utility implications in various aspects, arising from the differences in average working hour, degree of stress, and preference of demographic groups toward part-time jobs.⁵ In addition, it captures that the relative preference between the two types can change over time, either because the preference itself or population share of certain demographic groups that favor part-time jobs can change. On the other hand, we define "part-time labor demand shock" as a disturbance that affects firms' relative productivity of part-time labor. This term captures, as Valletta et al. (2015) suggest, improvements in monitoring and scheduling technology that help schedule part-time workers more efficiently, or the share change of certain industry groups that rely more heavily on part-time jobs. Moreover, it might reflect the firm's cost concerns that are

⁴Previous studies estimate the Frisch elasticities of labor supply that consider the intensive margins along with extensive margins. For example, Altonji and Paxson (1988), Altonji and Paxson (1992), French (2005), Rogerson and Wallenius (2009) consider models with a continuous hours choice, while Chang et al. (2011) propose a model with a discrete hours choice. In this study, we model and interpret labor as the number of employment to match with the aggregate macroeconomic data.

⁵For example, Bardasi and Gornick (2000) show that the level of the spouse's income and motherhood affect the household's decision to work part time.

not captured in the usual concept of wage.⁶ Following GSW, frictions in the labor market arise from nominal wage rigidity and the monopolistic power of labor unions reflected in the wage markup. This wage markup leads to unemployment, in the sense that the household is willing to supply certain level of labor at a given wage, but firms cannot hire all of them because of the wage markup.⁷

Our estimated model does capture some key characteristics of part-time variables along the business cycle. For example, the model exhibits high volatility of part-time employment and wage, negative correlation between full-time and part-time employment, and positive correlation between unemployment and part-time employment. Although the model does not exhibit negative correlation between part-time employment and gross domestic product (GDP), which suggests counter-cyclicality of part-time jobs, it still shows that part-time employment has significantly weaker correlation with GDP (about 0.05) than full-time employment does (about 0.5).

Several shocks – part-time labor supply and demand shocks, full-time wage markup, risk premium, and policy interest rate shocks – are found to be able to cause substitutions between labor types. Although all these five shocks were realized in a way to increase part-time employment during the Great Recession, most of the rise of part-time employment is explained by the increase in part-time labor supply. In addition, the positive part-time labor demand shock, risk premium shock in 2008, and full-time wage markup shock around 2009–2012 contributed less but non-negligibly to the rise of part-time employment. On the other hand, reduction in full-time employment is jointly attributable to risk premium, investment technology, monetary policy, and gross labor supply shocks. Increased supply of part-time labor also induced the labor force to decline slowly during the recession, in contrast with the rapid contraction in total employment. Moreover, the long-lasting effect of this shock will keep part-time employment high even after full-time employment recovers once the effect of the shocks that originally caused the recession diminishes.

Shock decomposition also suggests that part-time labor supply and demand shocks during the Great Recession are realized in a way to mitigate the contraction of output, consumption, and investment. After removing the trend, the output in 2010–2014 is about 5-7% below the level at the end of 2007, but the combined effect of part-time shocks on output is positive and about 1.1% at its maximum. This result implies that part-time jobs can play the role of a buffer to absorb the negative impact of the adverse shocks. Nevertheless, the

⁶For example, Carrington et al. (2002) show that the cost for full-time employees' health benefits is an element of the labor cost that may cause the use of part-time labor. Even and Macpherson (2015) find out that the mandate for providing health benefits in the Affordable Care Act induces an increase in involuntary part-time work.

⁷We assume that nominal rigidity and wage markup exist in not only the full-time labor market but also the part-time labor market. Later, we experiment on another specification that assumes that part-time wage is completely flexible. The results are very similar in both specifications.

impact of part-time shocks on prices is small and deflationary.

Finally, our estimated WPC for full-time jobs has parameters similar to those estimated from GSW, while WPC for part-time jobs shows higher wage flexibility. Regarding the recent flattening of the WPC, part-time labor supply shock explains a significant portion of slow recovery in gross wage, by lowering part-time wage as well as the proportion of full-time workers in total employment. Part-time labor demand shock has a significant positive effect on part-time wage, but its effect on gross wage is largely reduced, as the shock also lowers the proportion of well-paid full-time workers.

1.1 Related literature

The study of part-time employment, specifically from a cyclical perspective, has been developed only recently. Valletta and Bengali (2013) and Robertson and Terry (2015) provide evidence from historical data that the recent rise of part-time employment during the Great Recession can be explained as a cyclical movement. Cajner et al. (2014) and Canon et al. (2014) point out that involuntary part-time employment was the main driving force for the increase of part-time jobs during the Great Recession, by constructing transition probabilities with stock and flow data.⁸ Valletta et al. (2015) confirm that the movement of this involuntary part-time employment is affected by cyclical factors through state-level panel data regressions. Borowczyk-martins and Lalé (2017) show that the cyclical behavior of part-time employment share is explained by individual transitions between part-time and full-time jobs within the same employer, as a process in which firms adjust the intensive margin in response to negative shocks. Additionally, there are also approaches to understand part-time employment using search and matching frictions, as Warren (2015) and Lariau (2016) suggest models that capture the counter-cyclicity of involuntary part-time employment in this perspective.⁹

This study is also related to the literature analyzing macroeconomic dynamics using DSGE models with various frictions. Benchmark models such as that of Christiano et al. (2005) and SW, which include frictions such as nominal rigidity, habit formation, and investment adjustment costs, are widely used for both academia and central banks for policy analysis and forecast purposes. In addition, Bayesian techniques we use to estimate the parameters of the model, summarized by An and Schorfheide (2007) and Herbst and Schorfheide (2016), have become a standard for empirical studies using these models. Later, especially going through the Global Financial Crisis and the Great Recession, developments in these models help to better understand specific issues, such as financial friction (for example, Gerali et al. (2010), Iacoviello and Neri (2010), Gertler and Kiyotaki (2010), Angeloni

⁸See also Borowczyk-martins and Lalé (2016).

⁹Tavares (2015) uses a directed search model to identify the conditions for involuntary part-time employment.

and Faia (2013), and Christiano et al. (2014)) or labor market dynamics (for example, Gertler et al. (2008), Christiano et al. (2011), and GSW). For the latter strand of research, Gertler et al. (2008) and Christiano et al. (2011) adopt search and matching frictions to explain extensive and intensive margins of labor along the business cycle. As mentioned earlier, GSW introduce unemployment to the SW model, enabling the model to exploit the information from the unemployment rate, which has long been regarded as one of the most important variable for policymakers. By extending this GSW model, our study introduces a practical way of analyzing the dynamics of part-time jobs, especially during the Great Recession, within the standard New Keynesian DSGE framework.

2 Model: full-time and part-time labor

In this section, we introduce a model that can be used to analyze the transition between full-time and part-time jobs along the business cycle. The model can be seen as an extension of GSW, which incorporates the concept of unemployment into a benchmark medium-sized DSGE model of SW. The key departure of our model from GSW is that our model allows households and firms to allocate full-time and part-time labor optimally, while there is no such labor type distinction in GSW. Given the widespread awareness of SW, we only describe the wage setting and unemployment block here and abstract from the rest of the model that resembles SW and GSW.¹⁰

We assume a large representative household with two types of members: full-time and part-time available groups. The two groups are indexed by $(i, j) \in [0, 1] \times [0, 1]$ and $(i, k) \in [0, 1] \times [0, 1]$, respectively. In each pair, the first dimension, indexed by i , represents the type of specialized labor services. In the second dimension, j and k determine disutility from the work for full-time and part-time labor, respectively. Although family members cannot move between the two types, households can still reallocate labor between full time and part time by adjusting the level of employment in each type. To ensure labor reallocation, it is also assumed that the population of each group is sufficiently large compared with the labor force, which prohibits the employment-population ratio of each type from reaching 1. The sizes of the full-time and part-time available groups are π and $1 - \pi$, respectively.

We also assume perfect risk sharing of consumption among household members, and

¹⁰For a more detailed discussion on the remaining part of the model, refer to the full description in SW and the appendix in GSW. In addition, we provide the full set of log-linearized equations in our model in the Appendix.

the representative household's utility is defined as integral over its members' utilities,

$$\begin{aligned}
& E_0 \sum_{t=0}^{\infty} \beta^t U_t(C_t, \{N_{f,t}\}, \{N_{p,t}\}) \\
& \equiv E_0 \sum_{t=0}^{\infty} \beta^t \left[\log \tilde{C}_t - \chi_t \Theta_t \int_0^1 \left(\pi \int_0^{N_{f,t}(i)} j^{\varphi_f} dj + (1 - \pi) \int_0^{N_{p,t}(i)} \Omega_t k^{\varphi_p} dk \right) di \right] \\
& = E_0 \sum_{t=0}^{\infty} \beta^t \left[\log \tilde{C}_t - \chi_t \Theta_t \int_0^1 \left(\pi \frac{N_{f,t}(i)^{1+\varphi_f}}{1+\varphi_f} + (1 - \pi) \Omega_t \frac{N_{p,t}(i)^{1+\varphi_p}}{1+\varphi_p} \right) di \right],
\end{aligned} \tag{1}$$

where $\tilde{C}_t \equiv C_t - hC_{t-1}$ denotes consumption with habit, and $h \in (0, 1]$. $N_{f,t}$ and $N_{p,t}$ denote full-time and part-time labor, respectively. The above expression implies that labor disutilities of j th full-time member and k th part-time member are given by $\chi_t \Theta_t j^{\varphi_f}$ and $\Omega_t \chi_t \Theta_t k^{\varphi_p}$, respectively. χ_t is an exogenous labor preference shock, and Θ_t is the endogenous labor preference shock, adopted by GSW in order to reduce the wealth effect on labor supply. It is defined by

$$\Theta_t \equiv \frac{Z_t}{C_t - hC_{t-1}}, \tag{2}$$

where $Z_t = (Z_{t-1})^{1-\nu} (C_t - hC_{t-1})^\nu$. Thus Θ_t can be interpreted as the “consumption externality factor,” lowering marginal disutility of labor when current consumption is higher than the “trend consumption” Z_t . Ω_t is part-time labor supply shock, an exogenous shock that captures time-varying disutility difference between full-time and part-time work, arising from factors such as differences in labor hours, required efforts, degree of stress or demographic changes.

Under the given preference, marginal rate of substitution (MRS) between consumption and each type of labor is

$$MRS_{f,t}(i) \equiv -\frac{U_{N_{f,t}(i)}}{U_{C,t}} = \pi \chi_t \Theta_t \tilde{C}_t N_{f,t}(i)^{\varphi_f} = \pi \chi_t Z_t N_{f,t}(i)^{\varphi_f}, \tag{3}$$

$$MRS_{p,t}(i) \equiv -\frac{U_{N_{p,t}(i)}}{U_{C,t}} = (1 - \pi) \chi_t \Theta_t \tilde{C}_t N_{p,t}(i)^{\varphi_p} \Omega_t = (1 - \pi) \chi_t Z_t N_{p,t}(i)^{\varphi_p} \Omega_t. \tag{4}$$

By combining (3) and (4), we have

$$\frac{MRS_{f,t}(i)}{MRS_{p,t}(i)} = \frac{\pi}{1 - \pi} \cdot \frac{N_{f,t}(i)^{\varphi_f}}{N_{p,t}(i)^{\varphi_p} \Omega_t}. \tag{5}$$

Note that in a frictionless world, this MRS differential is equivalent to the wage differential ratio between full-time and part-time labor. Using lower-case letters to denote the natural logarithms of original variables, we can derive the average MRS in the log-linearized form

by integrating over all labor types i as follows:

$$mrs_{f,t} = z_t + \psi_t + \varphi_f n_{f,t}, \quad (6)$$

$$mrs_{p,t} = z_t + \psi_t + \varphi_p n_{p,t} + \eta_t, \quad (7)$$

where $n_{f,t} \equiv \int_0^1 n_{f,t}(i) di$, $n_{p,t} \equiv \int_0^1 n_{p,t}(i) di$, $\psi_t \equiv \log \chi_t$, and $\eta_t \equiv \log \Omega_t$.

On the production side, the production technology of intermediate goods producers is given by

$$Y_t = A_t (K_t^s)^\alpha \left[\left\{ (\pi N_{f,t})^{\frac{\epsilon_n-1}{\epsilon_n}} + (\nu_t (1-\pi) N_{p,t})^{\frac{\epsilon_n-1}{\epsilon_n}} \right\}^{\frac{\epsilon_n}{\epsilon_n-1}} \right]^{1-\alpha} - \gamma^t \Phi, \quad (8)$$

where A_t is total factor productivity (TFP), K_t^s is the capital service, γ is the deterministic growth trend, Φ is the fixed cost, ϵ_n is a parameter that governs the elasticity of substitution between full-time and part-time labor, and ν_t is a disturbance that affects the relative productivity of part-time workers, possibly capturing scheduling and monitoring technology involving part-time workers. We call ν_t as part-time labor demand shock, and its steady-state value is assumed to be less than 1. The total cost function of this firm is defined by $W_{f,t} \cdot \pi N_{f,t} + W_{p,t} \cdot (1-\pi) N_{p,t} + R_t^K K_t$, where $W_{f,t}$ and $W_{p,t}$ are nominal wages for full-time and part-time labor, respectively, R_t^K is the rental rate of capital, and K_t is the physical capital. Then, cost minimization yields

$$\frac{W_{N_{f,t}}}{W_{N_{p,t}}} = \left(\frac{\pi}{1-\pi} \right)^{-\frac{1}{\epsilon_n}} \left(\frac{N_{p,t}}{N_{f,t}} \right)^{\frac{1}{\epsilon_n}} \left(\frac{1}{\nu_t} \right)^{\frac{\epsilon_n-1}{\epsilon_n}}. \quad (9)$$

Workers in each labor type are assumed to be represented by a labor union. Workers who do not have the chance to set wages with probabilities $\theta_{w,f}$ and $\theta_{w,p}$ adopt the following wage indexation scheme:

$$W_{f,t+k|t} = W_{f,t+k-1|t} \Pi^x (\Pi_{t-1}^p)^{\gamma_{w,f}} (\Pi^p)^{1-\gamma_{w,f}}, \quad (10)$$

$$W_{p,t+k|t} = W_{p,t+k-1|t} \Pi^x (\Pi_{t-1}^p)^{\gamma_{w,p}} (\Pi^p)^{1-\gamma_{w,p}}, \quad (11)$$

where $W_{f,t+k|t}$ and $W_{p,t+k|t}$ are the nominal wages at time $t+k$ for full-time and part-time workers who last reoptimized at time t . Π^x is the steady state (gross) growth rate of productivity. $\Pi_t^p \equiv \frac{P_t}{P_{t-1}}$ denotes the (gross) price inflation rate, and Π^p is its steady state value.

When labor unions choose the optimal wages $W_{f,t}^* (\equiv W_{f,t|t}^*)$ and $W_{p,t}^* (\equiv W_{p,t|t}^*)$ with probabilities $(1 - \theta_{w,f})$ and $(1 - \theta_{w,p})$, respectively, their problems can be stated as maximizing the following expressions for each type:

$$\max \sum_{k=0}^{\infty} (\beta \theta_{w,f})^k E_t \left\{ \left(\frac{N_{f,t+k|t}}{C_{t+k}} \right) \left(\frac{W_{f,t+k|t}^*}{P_{t+k}} - \frac{N_{f,t+k|t}^{1+\varphi_f}}{1+\varphi_f} \right) \right\}, \quad (12)$$

subject to the demand schedule of

$$N_{f,t+k|t} = \left(\frac{W_{f,t+k|t}}{W_{f,t+k}} \right)^{-\epsilon_{w,f}} N_{f,t+k} \quad (13)$$

for full-time labor, and

$$\max \sum_{k=0}^{\infty} (\beta \theta_{w,p})^k E_t \left\{ \left(\frac{N_{p,t+k|t}}{C_{t+k}} \right) \left(\frac{W_{p,t+k|t}^*}{P_{t+k}} - \frac{N_{p,t+k|t}^{1+\varphi_p}}{1+\varphi_p} \right) \right\}, \quad (14)$$

subject to

$$N_{p,t+k|t} = \left(\frac{W_{p,t+k|t}}{W_{p,t+k}} \right)^{-\epsilon_{w,p}} N_{p,t+k} \quad (15)$$

for part-time labor. $N_{f,t+k|t}$ and $N_{p,t+k|t}$ denote the time $t+k$ employment of full-time and part-time workers whose wages were last reoptimized in t .

The optimality conditions are given by

$$\sum_{k=0}^{\infty} (\beta \theta_{w,f})^k E_t \left\{ \left(\frac{N_{f,t+k|t}}{C_{t+k}} \right) \left(\frac{W_{f,t+k|t}^*}{P_{t+k}} - MU_{w,f,t+k}^n MRS_{f,t+k|t} \right) \right\} = 0, \quad (16)$$

$$\sum_{k=0}^{\infty} (\beta \theta_{w,p})^k E_t \left\{ \left(\frac{N_{p,t+k|t}}{C_{t+k}} \right) \left(\frac{W_{p,t+k|t}^*}{P_{t+k}} - MU_{w,p,t+k}^n MRS_{p,t+k|t} \right) \right\} = 0, \quad (17)$$

where $MU_{w,f,t+k}^n \equiv \epsilon_{w,f,t} / (\epsilon_{w,f,t} - 1)$ and $MU_{w,p,t+k}^n \equiv \epsilon_{w,p,t} / (\epsilon_{w,p,t} - 1)$ are the natural wage markups for each type, meaning markups that can be obtained under flexible wages, which are allowed to exogenously fluctuate over time. As is clear from the expression, they are driven by the elasticity of substitution for each labor type, $\epsilon_{w,f,t}$ and $\epsilon_{w,p,t}$, and are also related to the degree of market power of specialized labor. $MRS_{f,t+k|t} \equiv \pi \chi_{t+k} Z_{t+k} N_{f,t+k|t}(i)^{\varphi_f}$ and $MRS_{p,t+k|t} \equiv (1 - \pi) \chi_{t+k} Z_{t+k} N_{p,t+k|t}(i)^{\varphi_p} \Omega_{t+k}$ are the relevant MRS between consumption and employment for each type at time $t+k$.

Under the given assumptions, we can define the aggregate wage index as follows

$$\begin{aligned} W_{f,t} &\equiv \int_0^1 \frac{W_{f,t}(i)^{1-\epsilon_{w,f,t}}}{1-\epsilon_{w,f,t}} di \\ &\equiv \left[\theta_{w,f} (W_{f,t-1} \Pi^x (\Pi_{t-1}^p)^{\gamma_{w,f}} (\Pi^p)^{1-\gamma_{w,f}})^{1-\epsilon_{w,f,t}} + (1 - \theta_{w,f}) (W_{f,t}^*)^{1-\epsilon_{w,f,t}} \right]^{\frac{1}{1-\epsilon_{w,f,t}}}, \end{aligned} \quad (18)$$

$$\begin{aligned}
W_{p,t} &\equiv \int_0^1 \frac{W_{p,t}(i)^{1-\epsilon_{w,p,t}}}{1-\epsilon_{w,p,t}} di \\
&\equiv \left[\theta_{w,p} (W_{p,t-1} \Pi^x (\Pi_{t-1}^p)^{\gamma_{w,p}} (\Pi^p)^{1-\gamma_{w,p}})^{1-\epsilon_{w,p,t}} + (1-\theta_{w,p}) (W_{p,t}^*)^{1-\epsilon_{w,p,t}} \right]^{\frac{1}{1-\epsilon_{w,p,t}}},
\end{aligned} \tag{19}$$

Following Galí (2011), it is possible to show nominal wage inflations, $\pi_{f,t}^w \equiv w_{f,t} - w_{f,t-1}$ and $\pi_{p,t}^w \equiv w_{p,t} - w_{p,t-1}$, from log-linearizing (18) and (19) around a perfect foresight steady state as follows:¹¹

$$\pi_{f,t}^w = \alpha_{w,f} + \gamma_{w,f} \pi_{t-1}^p + \beta E_t \{ \pi_{f,t+1}^w - \gamma_{w,f} \pi_t^p \} - \lambda_{w,f} (\mu_{w,f,t} - \mu_{w,f,t}^n), \tag{20}$$

$$\pi_{p,t}^w = \alpha_{w,p} + \gamma_{w,p} \pi_{t-1}^p + \beta E_t \{ \pi_{p,t+1}^w - \gamma_{w,p} \pi_t^p \} - \lambda_{w,p} (\mu_{w,p,t} - \mu_{w,p,t}^n), \tag{21}$$

where

$$\alpha_{w,f} \equiv (1-\beta)[(1-\gamma_{w,f})\pi^p + \pi^x],$$

$$\alpha_{w,p} \equiv (1-\beta)[(1-\gamma_{w,p})\pi^p + \pi^x],$$

$$\lambda_{w,f} \equiv [(1-\beta\theta_{w,f})(1-\theta_{w,f})]/[\theta_{w,f}(1+\epsilon_{w,f}\varphi_f)],$$

$$\lambda_{w,p} \equiv [(1-\beta\theta_{w,p})(1-\theta_{w,p})]/[\theta_{w,p}(1+\epsilon_{w,p}\varphi_p)],$$

$$\mu_{w,f,t} \equiv (w_{f,t} - p_t) - mrs_{f,t}, \quad \mu_{w,f,t}^n \equiv \log MU_{w,f,t}^n,$$

$$\mu_{w,p,t} \equiv (w_{p,t} - p_t) - mrs_{p,t}, \quad \mu_{w,p,t}^n \equiv \log MU_{w,p,t}^n.$$

An individual supplying type i labor will participate in the full-time or part-time labor force in period t if and only if

$$\left(\frac{1}{\bar{C}_t} \right) \left(\frac{W_{f,t}(i)}{P_t} \right) \geq \pi \chi_t \Theta_t j^{\varphi_f}, \tag{22}$$

$$\left(\frac{1}{\bar{C}_t} \right) \left(\frac{W_{p,t}(i)}{P_t} \right) \geq (1-\pi) \chi_t \Theta_t k^{\varphi_p} \Omega_t. \tag{23}$$

If we denote the marginal supplier of type i labor by $L_{f,t}(i)$ and $L_{p,t}(i)$, we have the following equality conditions:

$$\frac{W_{f,t}(i)}{P_t} = \pi \chi_t Z_t L_{f,t}(i)^{\varphi_f}, \tag{24}$$

$$\frac{W_{p,t}(i)}{P_t} = (1-\pi) \chi_t Z_t L_{p,t}(i)^{\varphi_p} \Omega_t. \tag{25}$$

By taking natural logs and integrating over labor type i , we get

¹¹Detailed derivation for this WPC can be also found in Attey (2015).

$$w_{f,t} - p_t = z_t + \psi_t + \varphi_f l_{f,t}, \quad (26)$$

$$w_{p,t} - p_t = z_t + \psi_t + \varphi_p l_{p,t} + \eta_t, \quad (27)$$

where $l_{f,t} \equiv \int_0^1 l_{f,t}(i) di$ and $l_{p,t} \equiv \int_0^1 l_{p,t}(i) di$ can be interpreted as the log aggregate full-time and part-time labor force. Additionally, the log gross labor force l_t can be defined as $l_t = \pi \frac{L_f}{L} l_{f,t} + (1 - \pi) \frac{L_p}{L} l_{p,t}$, where L_f and L_p are the steady state values of full-time and part-time labor force.

Following Galí (2011), we define the unemployment rates for each labor force in the following way:

$$u_{f,t} \equiv l_{f,t} - n_{f,t}, \quad (28)$$

$$u_{p,t} \equiv l_{p,t} - n_{p,t}. \quad (29)$$

Note that the gross unemployment rate can be also defined as the weighted average between the full-time and part-time unemployment rates as follows:

$$u_t = \pi \frac{L_f}{L} u_{f,t} + (1 - \pi) \frac{L_p}{L} u_{p,t}. \quad (30)$$

It should be also noted that the above aggregation involves a normalizing assumption that $\frac{N_f}{N_p} = \frac{L_f}{L_p} = 1$ in the steady state. This assumption is discussed in more detail in the estimation section.

By combining the definition of the (log) full-time wage markup, $\mu_{w,f,t}$, with (6), (26), and (28), and the (log) part-time wage markup, $\mu_{w,p,t}$, with (7), (27), and (29), the relationship between the average wage markup and unemployment rate can be derived as

$$\mu_{w,f,t} = \varphi_f u_{f,t}, \quad (31)$$

$$\mu_{w,p,t} = \varphi_p u_{p,t}. \quad (32)$$

The natural rate of unemployment, u_t^n , defined as the unemployment rate in the absence of nominal wage rigidities, can be similarly determined from

$$\mu_{w,f,t}^n = \varphi_f u_{f,t}^n, \quad (33)$$

$$\mu_{w,p,t}^n = \varphi_p u_{p,t}^n. \quad (34)$$

The remaining equations describing the rest of the model are identical to SW, and are presented in the Appendix. The rest of the model's equations consist of consumption and investment Euler equations, value of the capital stock, price-setting under nominal rigidities

with indexation, capital accumulation, optimal input choice, monetary policy, and goods market clearing. In addition to the aforementioned wage markup shocks ($\varepsilon_t^{w_f}$, $\varepsilon_t^{w_p}$), labor preference shock (ε_t^ψ), and part-time labor supply (ε_t^η) and demand (ε_t^ν) shocks, the model includes a neutral productivity shock (ε_t^q), risk premium shock (ε_t^b), government spending shock (ε_t^g), monetary policy shock (ε_t^r), price markup shock (ε_t^p), and investment-specific technology shock (ε_t^i). The shock processes are assumed to follow the autoregressive model or AR(1), except the price and wage markup shocks given as an autoregressive-moving-average or ARMA(1,1) process:¹² $\varepsilon_t^k = \rho_k \varepsilon_{t-1}^k + \eta_t^k - \mu_k \eta_{t-1}^k$ for $k = \{p, w_f, w_p\}$.

3 Estimation

The model is estimated with Bayesian estimation techniques using 11 U.S. macroeconomic variables as observable. As in SW, the data series include GDP, consumption, investment, GDP deflator, and federal funds rate. In addition, we use median usual weekly nominal earnings and employment and unemployment rates for full-time and part-time labor from CPS statistics. We divide the wage series by the GDP deflator to convert them into real terms. All data series are available from Federal Reserve Economic Data. The sample period runs from 2000:1Q to 2017:2Q. We cannot extend the sample to earlier periods due to part-time wage data availability. However, considering that the estimated parameters are, for the most part, well-aligned with standard estimates, as we will see later, sample length may not be a significant issue in analyzing our main research questions.

The measurement equations consist of the log-differenced series, except for the federal funds rate and unemployment rates. For the federal funds rate, its level is used, while for the unemployment rate, level difference is used in the measurement equations.

$$\Delta \ln Y_t^{data} = \bar{\gamma} + y_t - y_{t-1}$$

$$\Delta \ln C_t^{data} = \bar{\gamma} + c_t - c_{t-1}$$

$$\Delta \ln I_t^{data} = \bar{\gamma} + i_t - i_{t-1}$$

$$\pi_t^{data} = \bar{\pi} + p_t - p_{t-1}$$

$$FFR_t^{data} = \bar{r} + r_t$$

$$\Delta \ln W_{f,t}^{data} = \bar{w} + w_{f,t} - w_{f,t-1}$$

$$\Delta \ln W_{p,t}^{data} = \bar{w} + w_{p,t} - w_{p,t-1}$$

$$\Delta \ln N_{f,t}^{data} = \bar{n} + n_{f,t} - n_{f,t-1}$$

¹²The MA term is introduced to capture high-frequency fluctuations in prices and wages.

$$\Delta \ln N_{p,t}^{data} = \bar{n} + n_{p,t} - n_{p,t-1}$$

$$\Delta Unemp_{f,t}^{data} = u_{f,t} - u_{f,t-1}$$

$$\Delta Unemp_{p,t}^{data} = u_{p,t} - u_{p,t-1}$$

GDP, consumption, and investment share the common deterministic trend, $\bar{\gamma}$. Real wage and employment also have common trends for full time and part time, considering that the steady state wage and employment ratios between full-time and part-time labor exist in our model.

In the estimation procedure, population of the full-time available group, steady-state full-time wage to part-time wage ratio, depreciation rate, steady state government spending share in GDP, the curvature of Kimball aggregator in the goods market, the steady-state elasticity of substitution between specialized labor, and persistence of exogenous labor supply shock are calibrated in the model, while other structural parameters and shock processes are estimated. In our model, steady state full-time labor force and employment are πL_f and πN_f , respectively, and those for part-time are $(1 - \pi)L_p$ and $(1 - \pi)N_p$, respectively. Moreover, the sample means for full-time share in total labor force and in total employment are almost identical at 0.82, which means the full-time labor force to part-time labor force ratio ($\equiv \pi L_f / [(1 - \pi)L_p]$) is the same as the full-time employment to part-time employment ratio ($\equiv \pi N_f / [(1 - \pi)N_p]$) in the steady state. Now, we impose a normalizing assumption that $L_f/L_p = N_f/N_p = 1$, which yields the value for π , the population of full-time available group, at 0.82. The steady-state full-time wage to part-time wage ratio, which is set at 3.28 from the sample mean, is necessary to determine the steady state value of part-time labor supply and demand shocks.

The quarterly depreciation rate is chosen as 0.025. The government spending-output ratio in the steady state is set at 0.18 by matching the national account expenditure ratio. As in SW, the curvature parameter of the Kimball aggregator in the good market is set at 10. The steady-state elasticity of substitution of full-time specialized labor is calibrated to 5, consistent with the steady state markup estimate in GSW. The same parameter for part-time labor is set to 10. The persistence parameter of (total) exogenous labor supply shock is fixed at 0.99, following GSW.

Prior distributions of structural parameters and shock processes are chosen based on the standard specification in previous literature. The parameters for price and wage rigidity, inflation indexation, monetary policy rigidity and habit formation follow a beta distribution, while capital share in production, elasticity of labor substitution in the production function, inverse Frisch labor elasticity and monetary policy reaction to inflation, GDP gap, and growth rate follow a normal distribution. The steady state inflation rate and nominal interest rate with a positive sign follow a gamma distribution. Their posterior distributions are

obtained by the Markov chain Monte Carlo method. We simulate 300,000 sets of posterior parameters by using the Metropolis-Hastings algorithm, and we use the last 210,000 draws to formulate the posterior distributions.

We compare the results from the baseline (KPS1 hereafter) with two other cases. The first case is referred to as KPS2, where the model assumes the part-time wage is fully flexible. In the baseline model, the part-time wage rigidity is estimated to be close to zero. Thus, we consider this flexible part-time wage specification to check the robustness of the model. In this specification, we replace the sectoral unemployment data with gross unemployment data in the set of observable variables and eliminate the part-time wage markup shock.

The second case (GSW hereafter) is the model that does not distinguish between the two labor types, which is identical to GSW. However, for consistency with the KPS models, we use the employment-weighted average of median weekly earnings of the two labor types, instead of the original wage data series used in GSW.

Tables 1 and 2 report the estimated structural parameters in KPS1, KPS2, and GSW. The following is worth mentioning. First, the parameters are very similar in KPS1 and KPS2. This result mainly stems from the fact that the Calvo probability of part-time wage changes, $1 - \theta_{w,p}$, is estimated at 0.99 in KPS1. This suggests that the part-time wage is almost as flexible as assumed in KPS2. Still, the elasticity of labor substitution between full-time and part-time labor in the production function, ϵ_n , is estimated to be greater in KPS2 than that in KPS1, which implies that the steady state productivity of a part-time worker relative to a full-time worker, ν , should be greater in KPS2. Second, the estimated parameters are mostly in line with the results from SW and the original GSW, despite the difference in the sample period.¹³ Inverse Frisch labor elasticity is estimated around 3.5. The degrees of price and full-time wage stickiness are 0.77 and 0.68, and the degrees of price and full-time wage indexation are 0.25 and 0.4 in KPS1. The exception is the parameter ν that governs the short-run wealth effects on labor supply. While the original GSW reports ν as 0.02, it is estimated to be 0.71 to 0.74 in KPS1 and KPS2, and 0.52 in our GSW model. Third, the estimated values of ϵ_n from 3 to 3.6 are somewhat greater than the commonly accepted estimates of the elasticity between skilled and unskilled labor, which is around 1.5, following Katz and Murphy (1992) and Ciccone and Peri (2005). The difference may arise from the fact that the two elasticities are comparable but not exactly identical: while the former is about employment types, the latter is related to the level of human capital typically measured by the year of schooling. Moreover, recent studies on the elasticity between skilled and unskilled labor report that industry-level estimates of elasticity are in excess of the consensus value in most industries, and the estimated values of world elasticity are similar to our estimates of the elasticity between full-time and part-time labor (Mollick (2011) and Blankenau and Cassou

¹³The sample periods of SW and original GSW are 1966:Q1 to 2004:Q4 and 1966:Q1 to 2007:Q4, respectively.

(2011)).

[Table 1 - Table 2 here]

4 Findings

This section discusses in detail how our estimated model can be used to address the questions raised in the introduction section.

4.1 The model's ability to capture key features of part-time jobs along the business cycle

The second moments generated by our estimated model show that the model is capable of capturing some, if not all, key characteristics of part-time jobs along the business cycle. Tables 3 and 4 report the sample standard deviations and correlations of key variables, along with unconditional estimates of those moments from each model. In Table 3, the standard deviations of key macroeconomic variables in KPS models are very close to those in GSW, and they are quite in line with those in the sample data. Moreover, the table shows that KPS models generate higher volatility for part-time employment and wage compared with their full-time counterparts, consistent with the observations from actual data.

In addition, Table 4 suggests that KPS models are able to capture some key correlations associated with part-time variables. For example, consistent with data, the models exhibit negative correlation between full-time and part-time employment and between unemployment and full-time employment, as well as positive correlation between unemployment and part-time employment. Although the models do not exhibit negative correlation between part-time employment and GDP, which will suggest countercyclicality of part-time jobs that appears in data, they still show that part-time employment has significantly weaker correlation with GDP (0.04 to 0.05) than full-time employment does (0.48 to 0.49). At the same time, regarding non-part-time variables such as the comovements among output, consumption, investment, and total employment, KPS and GSW models exhibit similar values of correlations.

[Table 3 - Table 4 here]

4.2 Factors that caused the rise of part-time employment during the Great Recession

Analysis of impulse response functions of the estimated model suggests that several shocks induce substitutions between full-time and part-time employment. In fact, there are five

such shocks – part-time labor supply, part-time labor demand, risk premium, monetary policy, and full-time wage markup shocks. Figure 2 presents impulse response functions of key variables from the KPS1 and KPS2 models upon one standard deviation part-time labor supply and demand shocks. Since the estimated parameters of the shock processes can also affect the responses, we assume that the shocks follow the same processes across models as those estimated from KPS1 models, to focus on how impulse responses are differentiated by model design.

Figure 2 shows that a sudden increase in part-time labor supply or demand causes part-time employment to increase and full-time employment to decrease, causing a substitution between the two types. However, each shock influences two types of employment asymmetrically. Increase in part-time labor supply generates a large increase in part-time employment but a relatively very small reduction in full-time employment. Compared to this, part-time labor demand shock brings a more balanced exchange between part-time and full-time employment. Interestingly, part-time labor supply shock increases both total employment and unemployment rate, because this shock increases total labor participation. Meanwhile, both part-time labor shocks result in higher GDP and lower inflation overall by increasing production input (part-time labor supply shock) and enhancing labor productivity (part-time labor demand shock). Regarding wages, as expected, part-time wage falls after a part-time labor supply shock but rises after a part-time labor demand shock.

Three other shocks – risk premium, monetary policy, and full-time wage markup – are also found to cause substitutions between labor types. Figures 3-4 display the impulse response functions after these shocks from the KPS1, KPS2, and GSW models.¹⁴ It is common for these shocks to directly affect the production cost of firms by raising either the interest rate or wage of full-time labor. Responses from risk premium and policy interest rate shocks are quite similar, as they create recessionary pressure on the economy and lead both full-time and part-time wages to fall, the latter falling especially deeply. Full-time employment decreases but part-time employment increases, indicating that to some degree, firms switch from full-time to the now cheaper part-time labor. Meanwhile, a rise in full-time wage markup lowers GDP and raises inflation, and it causes a similar transition from full-time to part-time labor. However, interest rate shocks and full-time wage markup shock have different implications as regards part-time wage, as the latter shock causes part-time wage to rise. Finally, it should be noted that the macroeconomic consequence of labor type substitutions, against the shocks illustrated in Figures 3–4, is not large. There is not much difference in the responses of GDP, inflation, total employment, and unemployment across the GSW and KPS models.

¹⁴Impulse response function analysis of shocks that do not cause labor type substitution is provided in the Appendix.

[Figure 2 - Figure 4 here]

Figure 5 plots the time series of structural shocks in KPS models, estimated and smoothed by using the Kalman filter. The figure helps us understand, at least qualitatively, how the model interprets the Great Recession, as well as how those shocks contributed to the rise of part-time jobs. Recent studies in the New Keynesian DSGE literature, such as Brzoza-Brzezina and Kolasa (2013), Negro and Schorfheide (2013), Lindé et al. (2016), and Suh and Walker (2016), suggest that those models can only interpret the Great Recession as a joint outcome of large shocks hitting the economy at the same time. Figure 5 reveals a similar finding in our model. A sharp rise in risk premium and a large negative investment technology shock around 2008–2009 triggered the recession. Monetary policy shock is very accommodative during the early crisis but soon becomes contractionary, due to the existence of a zero lower bound (ZLB) in the policy rate, as suggested by GSW, Negro and Schorfheide (2013), and Lindé et al. (2016). Full-time wage markup remains high until around 2012, again consistent with GSW, because of nominal wage rigidity that prevents a large drop in full-time wage despite strong recessionary pressure. Regarding labor market shocks, there is a sharp rise in household total labor disutility, which reduces the total labor supply during the early crisis. On the other hand, the shock in household part-time labor disutility (part-time labor supply shock) falls, increasing part-time labor supply. Combining these two patterns strongly suggests that households switch their supply of labor from full time to part time at the outset of the crisis. In addition, a shock to the firm’s technology to utilize part-time labor (part-time labor demand shock) also increases during the crisis, helping firms faced with adverse conditions use more part-time labor. In sum, the figure shows that all five shocks that can cause labor type substitution – part-time labor supply, part-time labor demand, risk premium, monetary, full-time wage markup shocks – moved in a direction that caused a transition to part-time jobs.

[Figure 5 here]

Of course, the quantitative contribution of each shock to the rise of part-time jobs varies. Figure 6 presents the historical decomposition of part-time and full-time employment to population ratio. Focusing on the Great Recession period, a lion’s share in the rise of part-time employment is explained by a part-time labor supply shock. In addition, the part-time labor demand shock, risk premium shock in 2008, and full-time wage markup shock around 2009–2012 contributed less but non-negligibly to the rise of part-time employment. Reduction in full-time employment is jointly attributable to the risk premium, investment technology, monetary policy, and labor supply shocks.

[Figure 6 here]

Variance decomposition¹⁵ in Table 5 also confirms the importance of part-time labor supply shock to part-time employment dynamics. The shock explains the majority of part-time employment fluctuation, while there is only 5–10% contribution from part-time labor demand shock. Other than these two shocks, there are only very small contributions from TFP, risk premium, and full-time wage markup shocks. On the other hand, fluctuation in full-time employment is explained by various factors, such as TFP and risk premium shock (about 26–27% each), government spending shock (12%), labor supply and monetary policy shock (about 8–9% each).

[Table 5 here]

4.3 Explanation on why part-time employment remains high while full-time employment seems to recover

Since 2010, it has been observed that part-time employment remains high for a sustained period while full-time employment recovers at a steady pace. The explanation for this difference can be found in the historical decomposition in Figure 6. Part-time employment remains high until the end of the estimation period (2017:2q), for the most part due to the long-lasting effect of part-time labor supply shock. In other words, households are still willing to work part time. This shock is highly persistent with the AR(1) parameter being greater than 0.95. Moreover, from Figure 5, this shock was found to have a negative value frequently even after 2010, implying an increase in part-time labor supply. In contrast, steady recovery is shown in full-time employment as the effect of the shocks that caused the recession, for example, risk premium, investment technology, and labor supply shocks, dissipates. In addition, the full-time wage markup shock shows a downward trend after 2010, helping full-time employment to recover.

4.4 Effects of part-time jobs on total employment, labor force, and unemployment rate

Figures 7–8 present the historical decompositions for total employment, labor participation, and unemployment rates. The effects of part-time shocks on total employment are a combination of their effects on part-time and full-time employment shown in Figure 6. Because full-time jobs account for the majority of total employment, the shocks that reduce full-time employment during the recession similarly drag down total employment. However, the decomposition also shows that the part-time labor supply shock, by increasing part-time

¹⁵Forecast error variance decomposition informs how each structural shock contributes to the forecast error variances of variables.

employment, plays a significant role in preventing total employment from declining further. On the other hand, the effect of part-time labor demand shock on total employment seems negligible. The figure also shows that there is a strong offsetting effect between total labor supply shock and part-time labor supply shock, implying that there was a strong force within the household sector driving the transition from full-time to part-time employment.

Total labor participation also fell during the recession. The difference between total employment and labor participation is that the former variable decreased sharply to reach the lowest point in 2010, while the latter variable declined slowly and gradually until 2014. It is remarkable that there is an even stronger offsetting effect between total labor supply shock and part-time labor supply shock, causing a transition from full-time to part-time participation as well. One conjecture is that this transition is related to retirement or resignation from full-time jobs by baby boom generations and their re-entry into part-time labor force. In fact, the U.S. civilian participation rate during the recession fell in all age groups, except for those aged 55 and over.¹⁶ This conjecture is also consistent with the micro evidence by Valletta et al. (2015), who break down the employment status in CPS. According to this study, the share of part-time employment in total employment rose from 17.3% in 2003 to 17.9% in 2014, and the age 55 and over group explains most of the increase; the ratio of this age group's part-time employment to all-age total employment rose from 2.9% to 3.9%. It is also notable that the full-time wage markup shock has a positive effect on total participation. This is because it contributes positively to both full-time and part-time wages, thus increasing the participation of both types. After 2014, the participation rate displays clear signs of recovery, mainly because the negative effect from the total labor supply shock vanishes, while the effect of part-time labor supply shock still lingers.

Regarding unemployment, its significant rise during the recession is jointly explained by high-risk premium, low investment efficiency, contractionary monetary policy due to ZLB, and high full-time wage markup. Among these shocks, the risk premium shock displays the largest impact. Although total labor supply shock plays an important role for total employment and participation, its role is limited for unemployment dynamics. It is worthwhile to note that increased part-time labor supply and demand commonly increase unemployment rate rather than decrease it. Still, this observation is consistent with the impulse response functions shown in Figure 2. Unemployment rate continuously declines after 2010, moving opposite to total employment rate. This decline is, for the most part, explained by the weakening of factors that led to the initial rise, most notably the fall in full-time wage markup.

[Figure 7 - Figure 8 here]

¹⁶According to the U.S. Bureau of Labor Statistics, participation rate changed from 59.2% at the end of 2007 to 54.9% at the end of 2014 for ages 16–24, from 83.1% to 81.3% for ages 25–34, from 83.9% to 81.9% for ages 35–44, from 82.2% to 79.5% for ages 45–54, and from 38.9% to 39.9% for ages 55 and over.

4.5 Macroeconomic consequence of the increase in part-time employment

Figures 9–10 present the historical decomposition of output, consumption, investment, and inflation. The previous impulse response function analysis shows that although some non-part-time shocks create substitutions between labor types, the macroeconomic consequence of the substitutions given those shocks is not evident. However, in the case of part-time labor supply and demand shocks, they seemed to work in a way to mitigate the contraction of output during the Great Recession. Their quantitative contribution is non-trivial. After removing the trend, output in 2010–2014 is about 5–7% below the level at the end of 2007. During this period, the combined positive effect of part-time shocks on output is about 1.1% at peak. This result suggests that part-time labor played a role as a buffer against adverse economic conditions during the recession and that the Great Recession could have been more severe if this aggressive switch from full-time to part-time employment did not occur. These shocks also contribute positively to consumption and investment, as the combined positive effect of part-time shocks on consumption and investment are 1.1% and 3.6%, respectively, when largest. Considering that consumption accounts for a larger proportion of GDP than investment, and the drop in investment in percentage terms was much severe than that in consumption, it was mainly through the consumption channel that part-time shocks contributed to preventing further contraction of output by partially offsetting the labor income loss from the recession. Regarding inflation, both part-time shocks generated a small, deflationary pressure during the recession. The reason can be found from the impulse responses in Figure 2, as the increases in both part-time labor supply and demand are interpreted as a downward shift of aggregate supply, therefore lowering inflation.

[Figure 9 - Figure 10 here]

4.6 Role of part-time employment in the WPC, and explanation of slow wage recovery

One virtue of Galí (2011) and the GSW model setup is that they allow us to estimate WPC consistent with wage dynamics in the model. Estimated WPCs (combining equations (20)–(21) and (31)–(34)) for full-time and part-time wages using the posterior mean of KPS1 are reported in Equations (35)–(36). Equation (37) presents the estimated WPC for aggregate wage using the posterior mean of GSW. Note that constant terms are omitted from equations (35)–(37) as they are very close to zero.

$$\pi_{f,t}^w = 0.4022\pi_{t-1}^p + 1.0016\{E_t\pi_{f,t+1}^w - 0.4022\pi_t^p\} - 0.0291(u_{f,t} - u_{f,t}^n), \quad (35)$$

$$\pi_{p,t}^w = 0.5198\pi_{t-1}^p + 1.0016\{E_t\pi_{p,t+1}^w - 0.5198\pi_t^p\} - 9.0645(u_{p,t} - u_{p,t}^n), \quad (36)$$

$$\pi_t^w = 0.3832\pi_{t-1}^p + 1.0018\{E_t\pi_{t+1}^w - 0.3832\pi_t^p\} - 0.0309(u_t - u_t^n). \quad (37)$$

The above estimates indicate that aggregate WPC dynamics are mainly dominated by full-time wage determination. Full-time wage and aggregate wage have similar values for the response to the unemployment gap (the gap between actual unemployment and natural unemployment) and the response to the previous inflation. Indeed, these estimates (-0.03 for unemployment rate and 0.38–0.40 for the previous inflation) are very close to the estimates in Galí (2011) (-0.03 and 0.42), when its estimated equation only includes the current unemployment rate and previous period inflation rate as regressors.¹⁷ On the other hand, part-time WPC exhibits great sensitivity of wage inflation to the unemployment gap (9.07), mainly because of high wage flexibility (posterior mean for $\theta_{w,p}$ is 0.01) in part-time jobs. Despite this high flexibility, the effect of part-time wage determination on aggregate wage determination seems to be limited during the sample period.

However, the above result does not mean that part-time shocks were irrelevant for explaining why wage growth has remained stagnant while the unemployment rate has fully recovered from the Great Recession. Consistent with the model, gross wage W_t is defined as $W_t \equiv \pi(N_{f,t}/N_t)W_{f,t} + (1 - \pi)(N_{p,t}/N_t)W_{p,t}$. Obviously, this gross wage is affected by not only the wages of both types but also the composition of total employment ($\pi N_{f,t}/N_t, (1 - \pi)N_{p,t}/N_t$). Figure 11 presents the historical decompositions of this gross wage and part-time wage. The figure reveals that the long-lasting effect of increased part-time labor supply shock explains a significant portion of slow growth in gross wage as well as part-time wage. Interestingly, part-time labor demand shock has a positive effect on part-time wage, which is quite similar to the negative effect of part-time labor supply shock in terms of absolute magnitude. However, the former shock's effect on gross wage is largely reduced, while the latter shock's effect remains significant. This difference comes from the composition effect. By reducing the share of full-time employment, both shocks can lower gross wage, because the full-time wage is greater than the part-time wage¹⁸. This composition effect offsets the positive effect from part-time labor demand shock, but adds upon the negative effect from part-time labor supply shock. Other than part-time shocks, full-time wage markup shock, possibly arising from nominal wage rigidity and preventing further wage decline at the cost of unemployment rate during the Great Recession, also contributes to the sluggish wage increase and decrease in unemployment rate simultaneously during the recovery. As pointed out by Daly and Hobijn (2014), wage rigidity can cause WPC to flatten through “pent-up wage deflation” during recession. In addition to the full-time wage

¹⁷This refers to column (2) of Table 1 from Galí (2011).

¹⁸Although historical decomposition of full-time wage is not presented in this study, the contributions of both part-time shocks to full-time wage are very small.

markup shock, falling productivity shock and investment-specific shock also drag down wage recovery, which indicates that flattening of WPC may be structural, and wage growth may remain stalled for the time being. In contrast to employment, total labor supply shock does not have any visible effect on wages. This observation is consistent with the variance decomposition in Table 5, wherein the shock makes little contribution to the forecast error variance of wages.

[Figure 11 here]

5 Conclusion

This study analyzes the movement of part-time jobs along the business cycle and its implications, especially focusing on their rise during the Great Recession, through the lens of a New Keynesian DSGE model. Our results show that there was a large change in household preference to part-time labor during the recession, which increased labor supply for part-time jobs, and this change played a vital role in the rise and persistence of part-time jobs. This part-time labor supply shock also has other implications regarding what happened during the recession. First, despite the sharp contraction of total employment, total labor force declined relatively slowly due to increased participation in part-time jobs. Second, this shock, along with part-time labor demand shock, contributed to mitigating the severity of the recession by providing households and firms facing adverse economic conditions an alternative way of working and hiring. Third, this shock explains a significant portion of slow wage recovery, as it lowers part-time wage as well as the proportion of full-time jobs in total employment. This result confirms that the prevalence of part-time jobs can be an additional source of slackness in the labor market, as the shock, while explaining the most of part-time job increase, is also shown to deter wage growth.

This large influence of part-time labor supply shock is related to our model estimates. In our model, part-time wage exhibits higher flexibility than full-time wage, which normally leads to less fluctuation in employment. However, what happened during the Great Recession was the opposite: There was a large change in part-time employment, while the response of part-time wage was similar to that of full-time wage. This implies that the magnitude of the shocks inside the part-time labor market was significant.

The framework used in our study is quite practical, maintaining the basic structure of the SW model, and it can be easily applied to the analysis of part-time jobs in countries other than the U.S. However, to our knowledge, only a few countries currently compile and publish wage statistics for full-time and part-time jobs separately. Therefore, we believe improving the range and depth of employment and wage statistics can be a key to the development of this strand of research.

There is a chance that understanding the behavior of part-time jobs will become more important for business cycle analysis in the future if technological or demographic changes induce the convention of working part-time more prevalent. Several issues regarding part-time jobs need to be examined more thoroughly, aside from their role in the business cycle addressed here. Examples include how to use the information on part-time jobs to measure additional slackness in the labor market and welfare implications of part-time jobs, especially considering those jobs are categorized as voluntary and involuntary. We leave it to future research to address these issues.

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Table 1: Priors and posteriors of structural parameters

		Prior			Posteriors (KPS1)			Posteriors (KPS2)			Posteriors (GSW)		
		Dist.	Mean	SD	Mean	90% HPD		Mean	90% HPD		Mean	90% HPD	
Ψ	Investment adjustment cost curvature	N	4	1.5	4.68	2.72	6.57	4.83	2.89	6.74	4.63	2.81	6.45
h	Habit formation	B	0.7	0.1	0.58	0.50	0.68	0.59	0.48	0.69	0.56	0.46	0.66
φ_f	Inverse Frisch elasticity of full-time labor	N	2	0.75	3.54	2.82	4.26	3.50	2.80	4.20	4.56	3.74	5.39
φ_p	Inverse Frisch elasticity of part-time labor	N	2	0.75	3.48	2.67	4.34	3.65	2.74	4.51	—	—	—
v	Rigidity, aggregate consumption trend	B	0.5	0.15	0.74	0.57	0.92	0.71	0.52	0.92	0.52	0.29	0.75
θ_p	Calvo price stickiness	B	0.5	0.1	0.77	0.68	0.85	0.77	0.68	0.86	0.76	0.68	0.86
θ_{w_f}	Calvo full-time wage stickiness	B	0.5	0.1	0.68	0.59	0.76	0.67	0.59	0.76	0.67	0.60	0.74
θ_{w_p}	Calvo part-time wage stickiness	B	0.2	0.1	0.01	0.01	0.01	—	—	—	—	—	—
γ_p	Price indexation	B	0.5	0.15	0.25	0.08	0.41	0.25	0.09	0.40	0.25	0.08	0.40
γ_{w_f}	Full-time wage indexation	B	0.5	0.15	0.40	0.18	0.62	0.43	0.19	0.65	0.38	0.16	0.60
γ_{w_p}	Part-time wage indexation	B	0.5	0.15	0.52	0.29	0.77	—	—	—	—	—	—
ψ	Elasticity of capital utilization cost	B	0.5	0.15	0.65	0.43	0.89	0.64	0.41	0.87	0.55	0.27	0.82
\mathcal{M}_p	Steady state price markup	N	1.25	0.125	1.49	1.33	1.64	1.47	1.32	1.64	1.54	1.38	1.69
ρ	Rigidity, monetary policy	B	0.75	0.1	0.84	0.79	0.88	0.84	0.79	0.88	0.84	0.80	0.88
γ_π	Reaction to inflation, monetary policy	N	1.5	0.25	1.58	1.21	1.91	1.57	1.23	1.90	1.56	1.22	1.90
γ_y	Reaction to GDP gap, monetary policy	N	0.125	0.05	0.10	0.03	0.16	0.09	0.03	0.15	0.10	0.04	0.16
$\gamma_{\Delta y}$	Reaction to GDP growth rate, monetary policy	N	0.125	0.05	0.11	0.05	0.16	0.10	0.06	0.15	0.10	0.05	0.15
$\bar{\pi}$	Steady state inflation rate	G	0.625	0.1	0.50	0.40	0.59	0.49	0.39	0.59	0.49	0.40	0.58
\bar{r}	Steady state nominal interest rate	G	0.25	0.1	0.34	0.18	0.49	0.33	0.17	0.48	0.30	0.15	0.45
\bar{n}	Steady state employment growth rate	N	0	2	-0.11	-0.17	-0.05	-0.11	-0.17	-0.05	-0.09	-0.14	-0.05
$\bar{\gamma}$	Steady state GDP growth rate	N	0.4	0.1	0.24	0.14	0.34	0.24	0.14	0.35	0.23	0.14	0.31
\bar{w}	Steady state wage growth rate	N	0.4	0.1	0.18	0.11	0.26	0.19	0.12	0.26	0.16	0.09	0.22
α	Capital share in production	N	0.3	0.05	0.11	0.08	0.13	0.11	0.08	0.13	0.09	0.07	0.12
ϵ_n	Elasticity of labor substitution	N	2	0.75	2.96	2.10	3.92	3.61	2.67	4.53	—	—	—

Table 2: Priors and posteriors of shock processes

		Prior			Posteriors (KPS1)			Posteriors (KPS2)			Posteriors (GSW)		
		Dist.	Mean	SD	Mean	90% HPD		Mean	90% HPD		Mean	90% HPD	
Shock persistence													
ρ^a	Neutral productivity shock	B	0.5	0.2	0.94	0.90	0.99	0.94	0.90	0.99	0.94	0.89	0.98
ρ^b	Risk premium shock	B	0.5	0.2	0.82	0.74	0.90	0.81	0.73	0.91	0.85	0.78	0.92
ρ^g	Government spending shock	B	0.5	0.2	0.88	0.79	0.98	0.88	0.80	0.98	0.89	0.81	0.98
ρ^{ga}	Government spending response to productivity	N	0.5	0.25	0.44	0.32	0.57	0.44	0.31	0.56	0.50	0.36	0.64
ρ^q	Investment-specific shock	B	0.5	0.2	0.86	0.76	0.99	0.86	0.75	0.97	0.80	0.65	0.96
ρ^r	Monetary policy shock	B	0.5	0.2	0.32	0.18	0.45	0.32	0.18	0.47	0.31	0.17	0.45
ρ^p	Price markup shock	B	0.5	0.2	0.77	0.59	0.98	0.77	0.59	0.96	0.77	0.59	0.97
ρ^{wf}	Full-time wage markup shock	B	0.5	0.2	0.40	0.10	0.70	0.41	0.12	0.72	0.30	0.05	0.54
ρ^{wp}	Part-time wage markup shock	B	0.5	0.2	0.91	0.85	0.98	—	—	—	—	—	—
ρ^l	Part-time labor supply shock	B	0.5	0.2	0.96	0.93	0.99	0.95	0.92	0.99	—	—	—
ρ^v	Part-time labor demand shock	B	0.5	0.2	0.89	0.79	0.99	0.76	0.61	0.91	—	—	—
μ_p	MA(1), price markup shock	B	0.5	0.2	0.57	0.31	0.84	0.58	0.32	0.84	0.57	0.30	0.85
μ_{wf}	MA(1), full-time wage markup shock	B	0.5	0.2	0.44	0.21	0.68	0.44	0.20	0.68	0.49	0.26	0.81
μ_{wp}	MA(1), part-time wage markup shock	B	0.5	0.2	0.28	0.12	0.43	—	—	—	—	—	—
Standard error													
σ^a	SE, neutral productivity	IG	0.1	2	0.50	0.43	0.58	0.51	0.43	0.58	0.43	0.36	0.49
σ^b	SE, risk premium shock	IG	0.1	2	0.27	0.15	0.39	0.29	0.14	0.43	0.26	0.14	0.38
σ^g	SE, government spending shock	IG	0.1	2	0.30	0.25	0.34	0.30	0.26	0.35	0.29	0.25	0.34
σ^q	SE, investment-specific shock	IG	0.1	2	0.26	0.18	0.33	0.25	0.18	0.30	0.25	0.17	0.33
σ^r	SE, monetary policy shock	IG	0.1	2	0.09	0.08	0.11	0.09	0.08	0.11	0.09	0.08	0.11
σ^p	SE, price markup shock	IG	0.1	2	0.16	0.04	0.28	0.17	0.04	0.34	0.17	0.04	0.34
σ^{wf}	SE, full-time wage markup shock	IG	0.1	2	0.10	0.03	0.17	0.10	0.04	0.16	0.11	0.05	0.18
σ^l	SE, exogenous labor supply shock	IG	0.1	2	0.19	0.16	0.23	0.19	0.15	0.22	0.14	0.11	0.17
σ^l	SE, part-time labor supply shock	IG	0.1	2	0.55	0.42	0.68	0.55	0.43	0.68	—	—	—
σ^v	SE, part-time labor demand shock	IG	0.1	2	0.22	0.16	0.28	0.19	0.15	0.23	—	—	—
σ^{wp}	SE, part-time wage markup shock	IG	0.1	2	0.10	0.07	0.12	—	—	—	—	—	—

Table 3: Standard deviations of key variables

				(%)
	Sample	KPS1	KPS2	GSW
Output	0.60	0.78	0.78	0.75
Consumption	0.56	0.69	0.69	0.67
Investment	2.12	2.38	2.40	2.28
Inflation	0.24	0.38	0.40	0.37
Interest rate	0.50	0.35	0.36	0.35
Total employment	0.43	0.55	0.55	0.50
Unemployment rate	0.33	0.64	0.64	0.60
Full-time employment	0.65	0.62	0.62	-
Part-time employment	1.19	1.58	1.52	-
Full-time wage	0.67	0.78	0.79	0.70
Part-time wage	1.30	1.54	1.58	-

Note: The level of the interest rate is used to calculate standard deviation. For the unemployment rate, the level difference is used. For other variables, log differences are used. "Full-time wage" for GSW means gross wage.

Table 4: Correlation coefficients between key variables

	Sample	KPS1	KPS2	GSW
Output-consumption	0.70	0.78	0.78	0.80
Output-investment	0.71	0.57	0.58	0.57
Output-unemployment rate	-0.57	-0.41	-0.42	-0.53
Output-total employment	0.42	0.47	0.47	0.58
Output-FT employment	0.49	0.48	0.49	-
Output-PT employment	-0.37	0.05	0.04	-
FT employment-PT employment	-0.58	-0.13	-0.12	-
Unemployment rate-FT employment	-0.87	-0.74	-0.75	-
Unemployment rate-PT employment	0.47	0.27	0.27	-

Note: For the unemployment rate, level difference is used to calculate the correlation coefficient. For other variables, log differences are used.

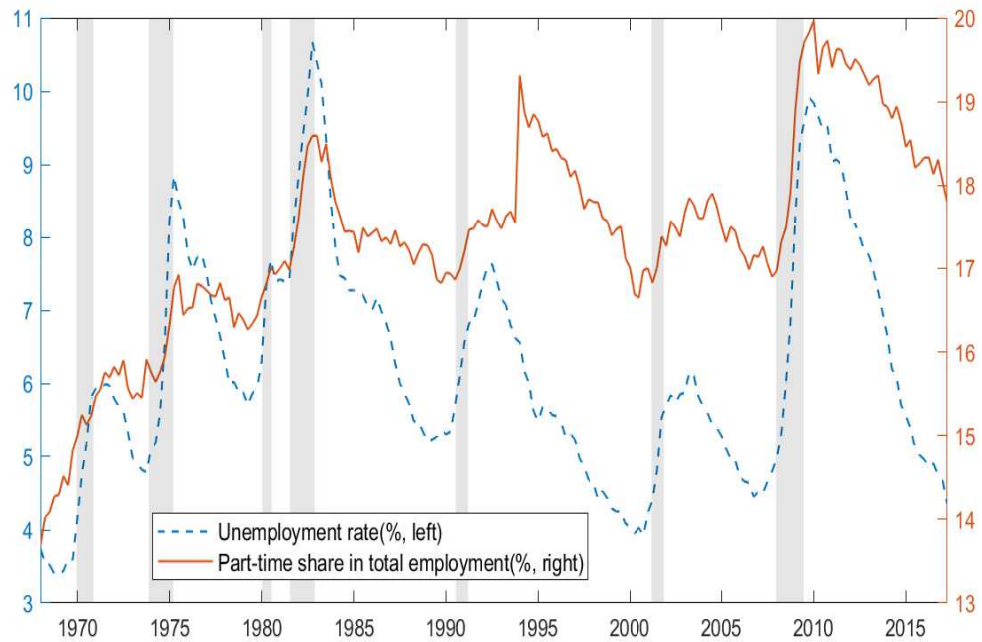
Table 5: 10- and 40-quarter forecast error variance decomposition (%)

10-Qtr	Output			Inflation			Total employment			Unemployment			FT emp.		PT emp.		FT wage			PT wage	
Tech.	27	28	24	6	6	4	27	26	22	10	10	11	27	27	1	0	1	1	0	0	0
Risk.	27	26	35	5	5	6	19	19	36	42	41	41	26	26	1	1	2	1	1	2	2
Gvt.	13	13	13	0	0	0	11	11	14	6	6	7	12	12	0	0	0	0	0	0	0
Inv.	5	6	4	1	1	1	4	5	4	1	1	1	4	4	0	0	1	1	0	0	0
Mon.	8	8	9	2	2	2	6	6	9	12	12	11	8	8	0	0	1	1	0	1	1
P. MU	7	8	8	81	82	70	5	6	7	3	4	4	5	7	0	0	17	18	11	5	5
W. MU	0	0	2	4	4	18	0	0	2	8	9	17	1	1	3	1	80	78	87	15	16
Labor	12	11	6	0	0		14	14	6	15	14	8	9	9	5	6	0	0	0	0	0
PT sup.	0	0		0	0		12	13		1	1		1	2	77	86	0	0		10	7
PT dem.	0	0		0	0		1	1		2	3		7	6	10	5	0	0		66	68
40-Qtr	Output			Inflation			Total employment			Unemployment			FT emp.		PT emp.		FT wage			PT wage	
Tech.	27	28	24	6	6	4	26	25	22	10	10	11	26	26	1	0	1	1	0	1	0
Risk.	26	26	35	5	5	6	19	19	36	41	40	41	26	26	1	1	2	2	1	2	2
Gvt.	13	12	13	0	0	0	11	11	14	6	6	7	12	12	0	0	0	0	0	0	0
Inv.	6	6	4	2	2	1	5	5	4	1	1	1	5	5	0	0	1	1	0	0	0
Mon.	8	8	9	2	2	2	6	6	9	12	12	11	8	8	0	0	1	1	0	1	1
P. MU	8	9	8	80	81	70	6	7	7	3	4	4	6	7	0	0	18	20	11	5	6
W. MU	0	0	2	4	4	18	0	0	2	8	9	17	1	1	3	1	78	76	87	15	16
Labor	11	10	6	0	0	0	14	13	6	15	14	8	9	8	5	6	0	0	0	0	0
PT sup.	0	0		0	0		12	13		1	1		1	1	77	86	0	0		10	7
PT dem.	0	0		0	0		1	1		2	3		7	5	10	5	0	0		66	68

Note: Numbers for each variable are from the KPS1, KPS2, GSW models in that order. “Full-time wage” for GSW means gross wage. “Wage markup shock” for KPS1 and KPS2 means full-time wage markup shock.

Figure 1: Unemployment and part-time jobs

(a) Unemployment rate and part-time share in total employment



(b) Unemployment rate and part-time employment to labor force rate

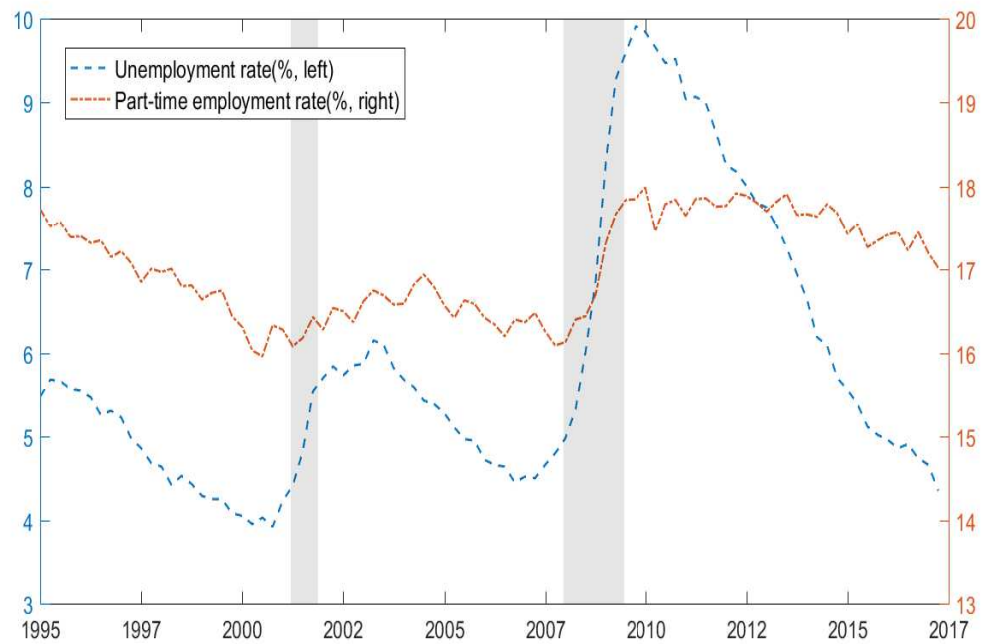
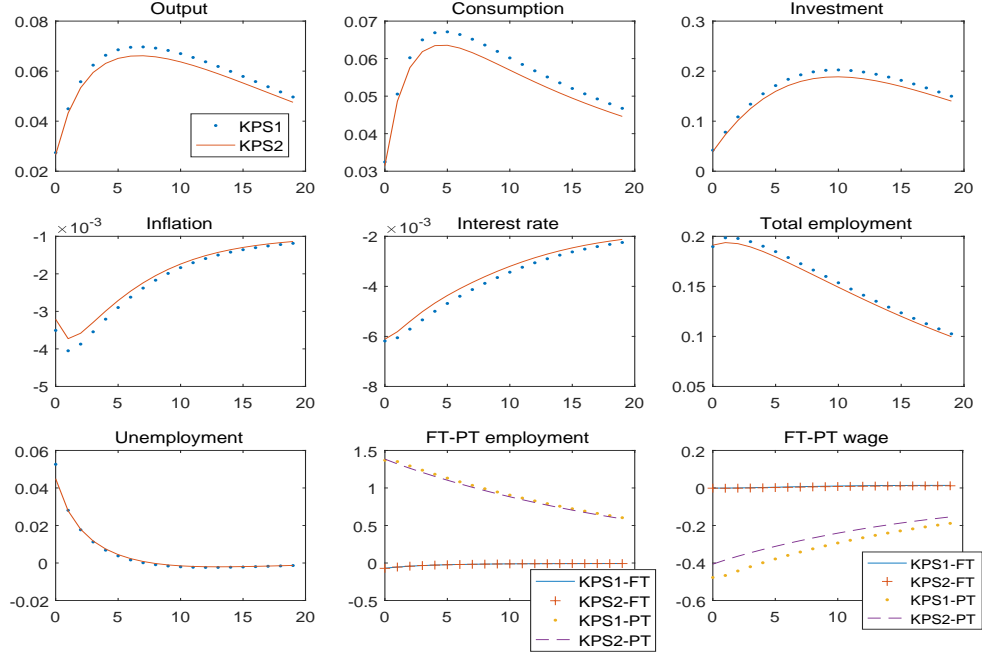
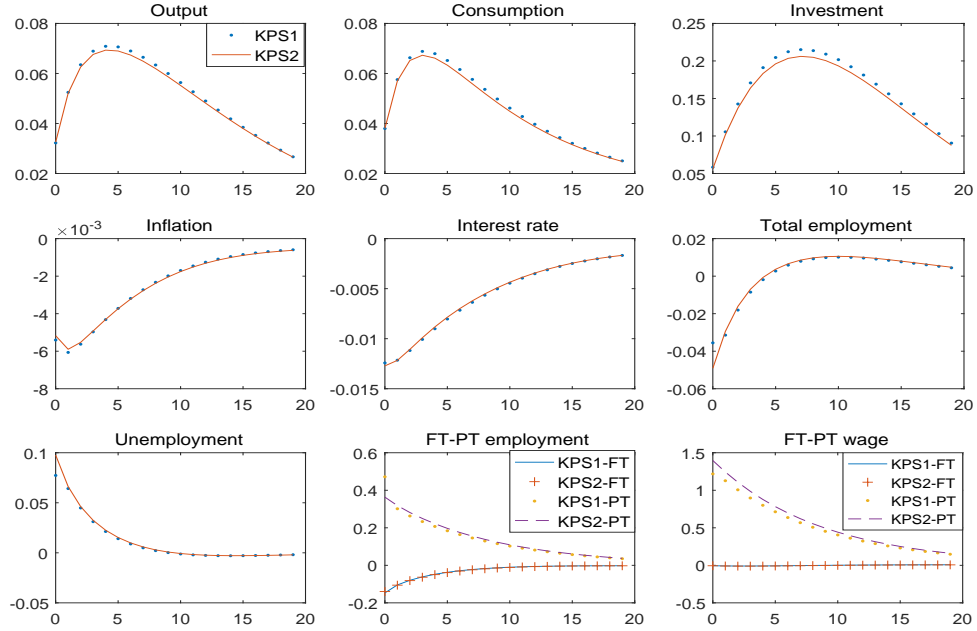


Figure 2: Impulse response functions: part-time shocks

(a) Part-time labor supply shock



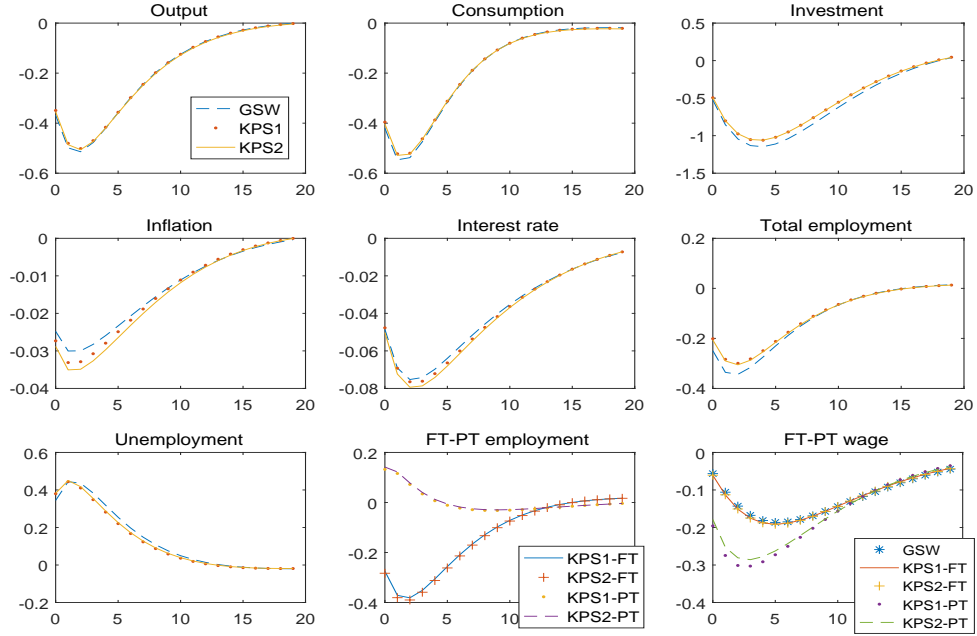
(b) Part-time labor demand shock



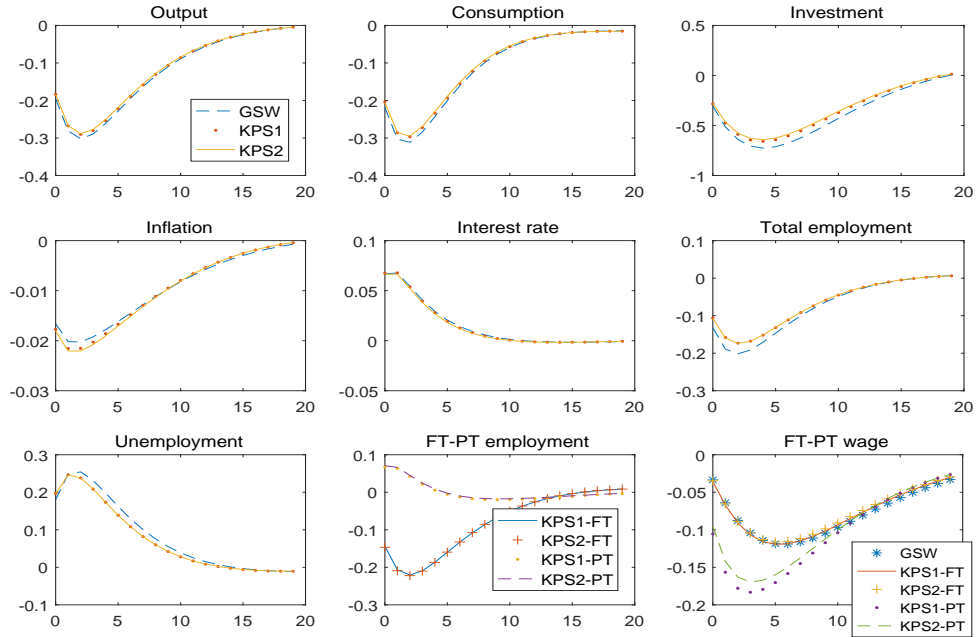
Note: Shock processes in all models are based on the KPS1 model.

Figure 3: Impulse response functions: shocks causing the FT-PT substitution

(a) Risk premium shock



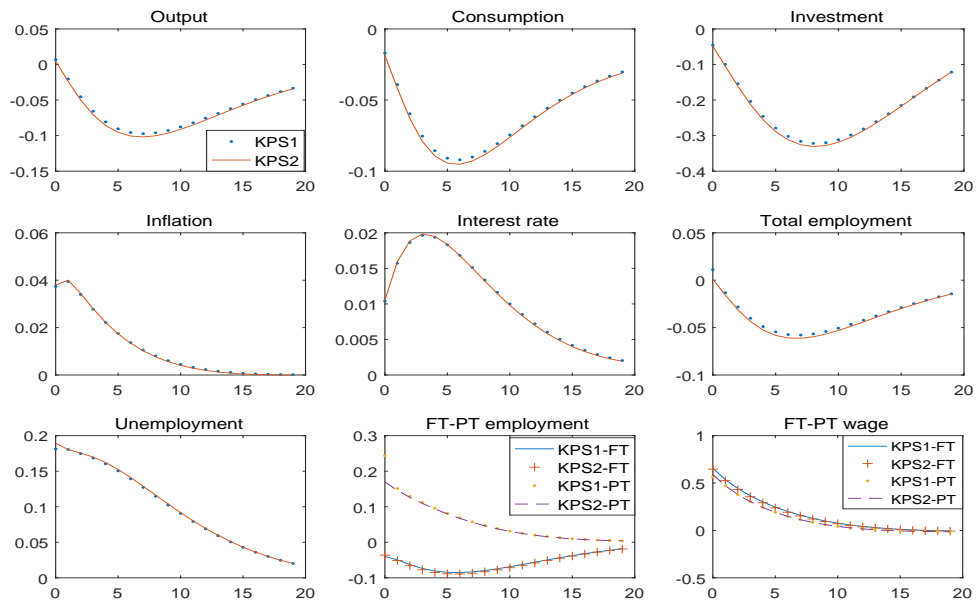
(b) Monetary policy shock



Note: Shock processes in all models are based on the KPS1 model.

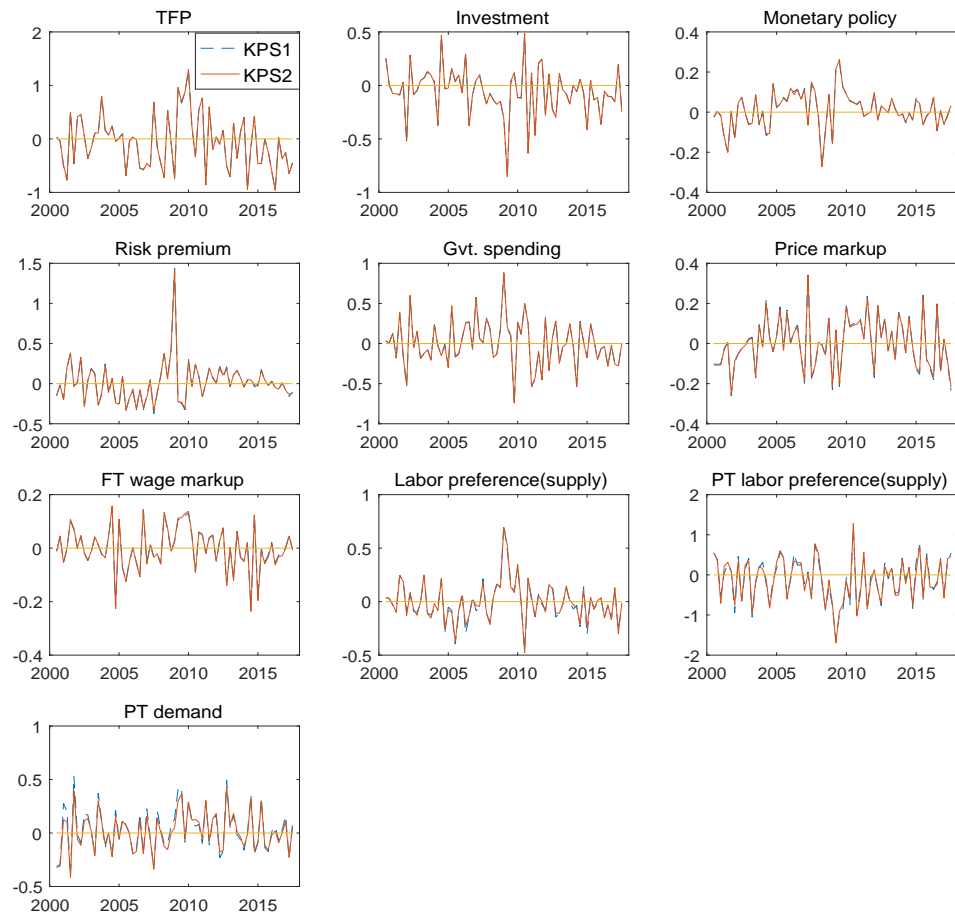
Figure 4: Impulse response functions: shocks causing FT-PT substitution (continued)

(a) Full-time wage markup shock



Note: Shock processes in all models are based on the KPS1 model.

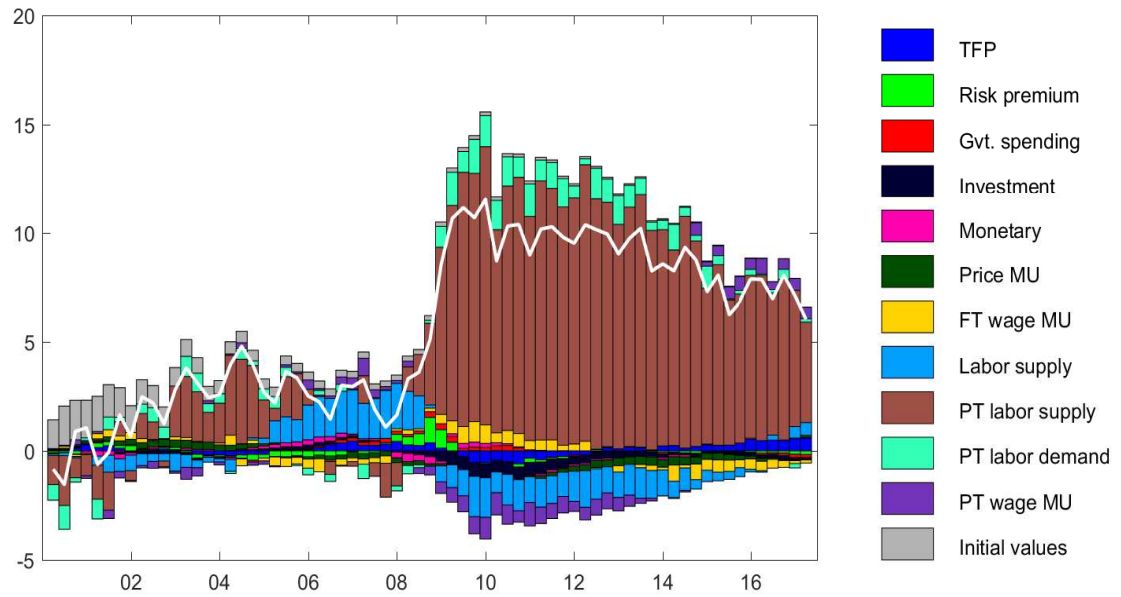
Figure 5: Estimated shocks



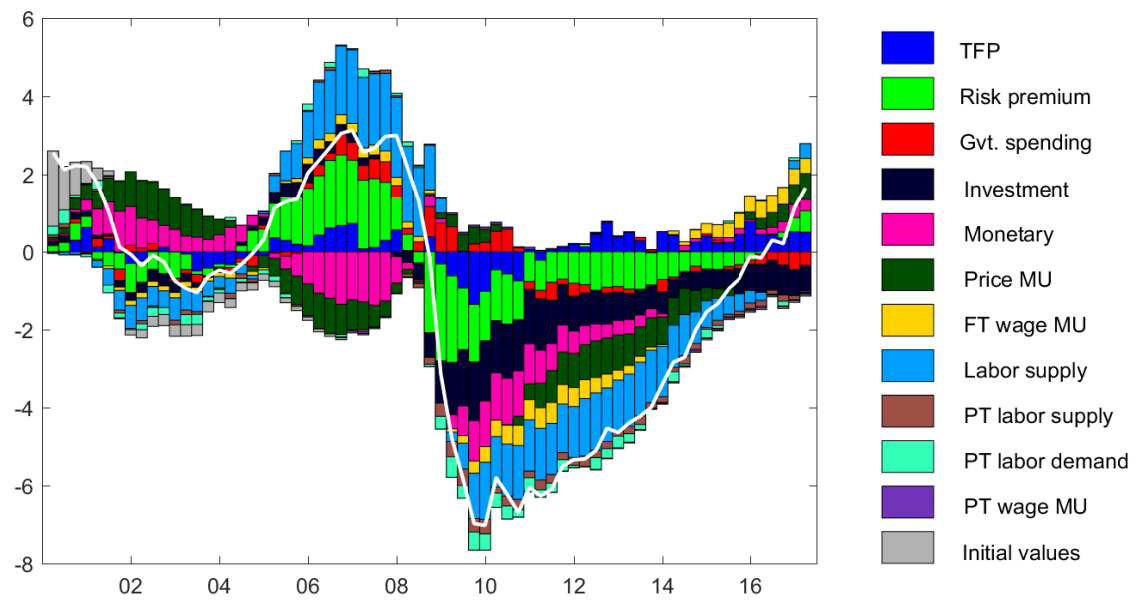
Note: Shocks are estimated and smoothed using the Kalman filter from KPS models.

Figure 6: Shock decomposition: PT and FT employment

(a) Part-time employment

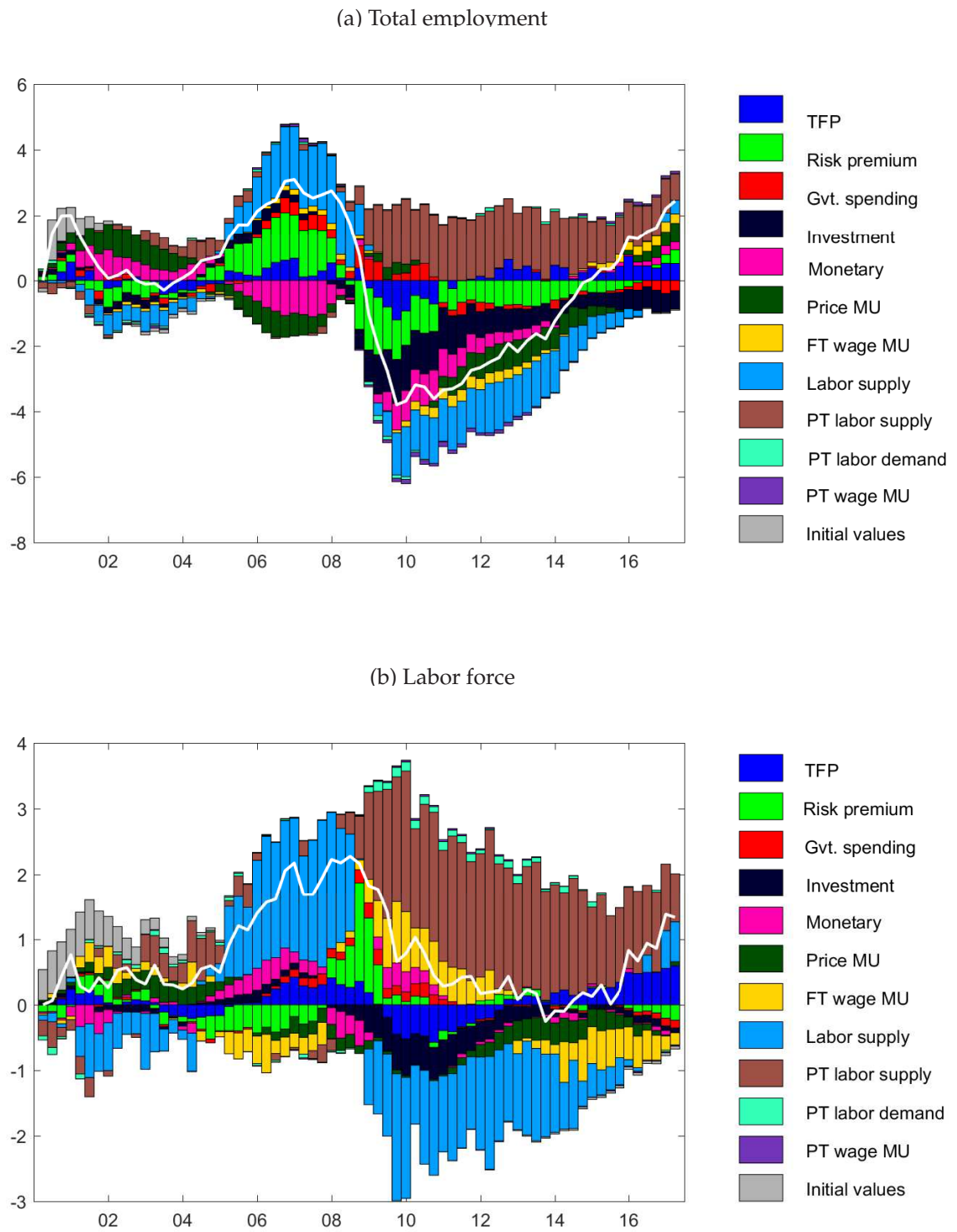


(b) Full-time employment



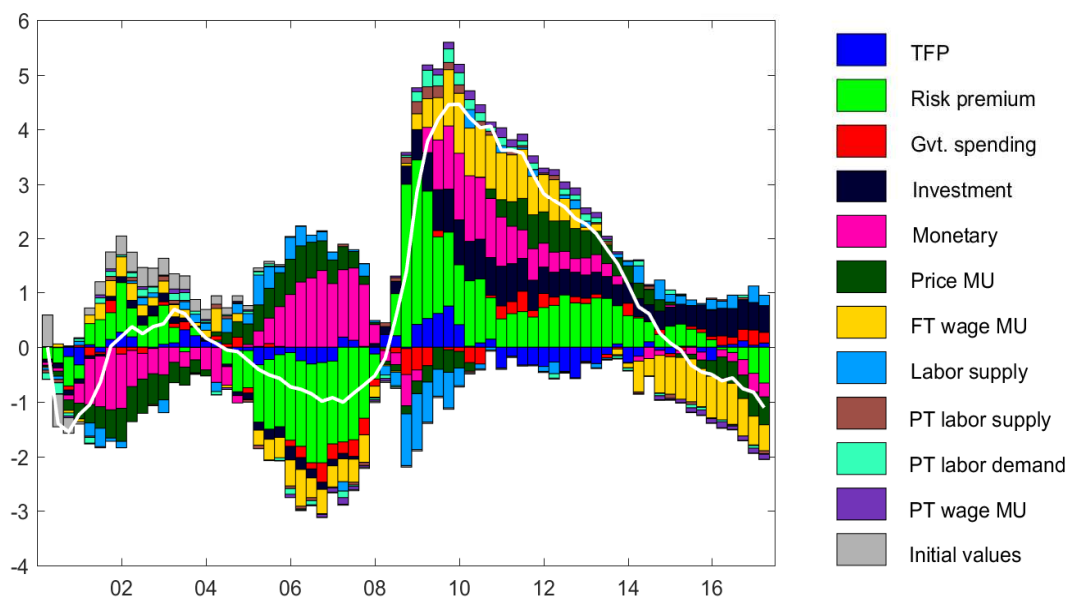
Note: Shock decompositions are calculated from the KPS1 model.

Figure 7: Shock decomposition: total employment rate and labor participation rate



Note: Shock decompositions are calculated from the KPS1 model.

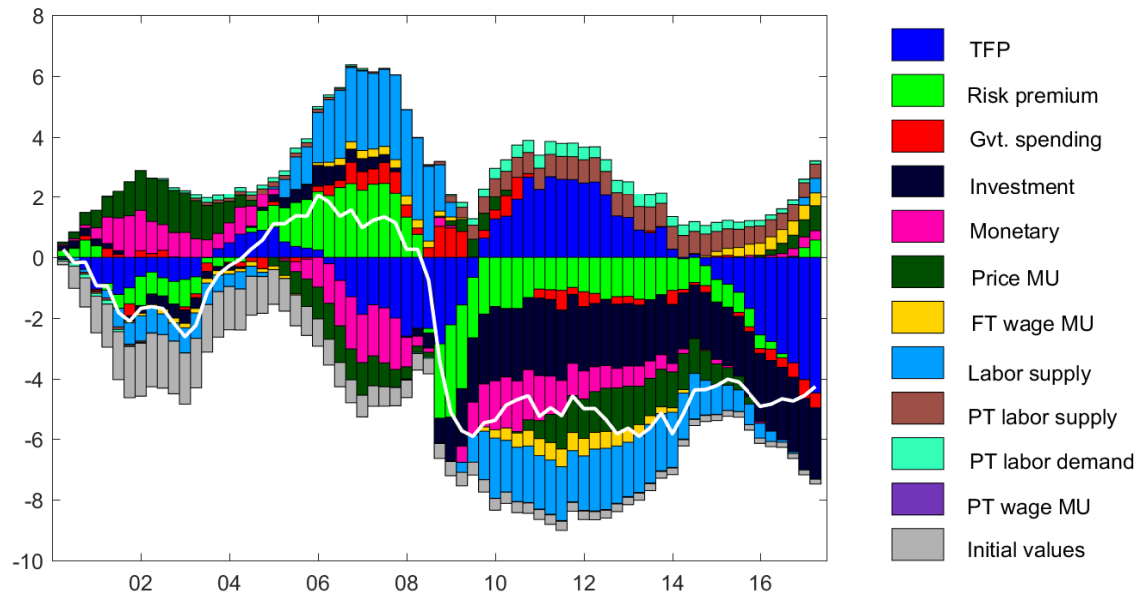
Figure 8: Shock decomposition: unemployment rate



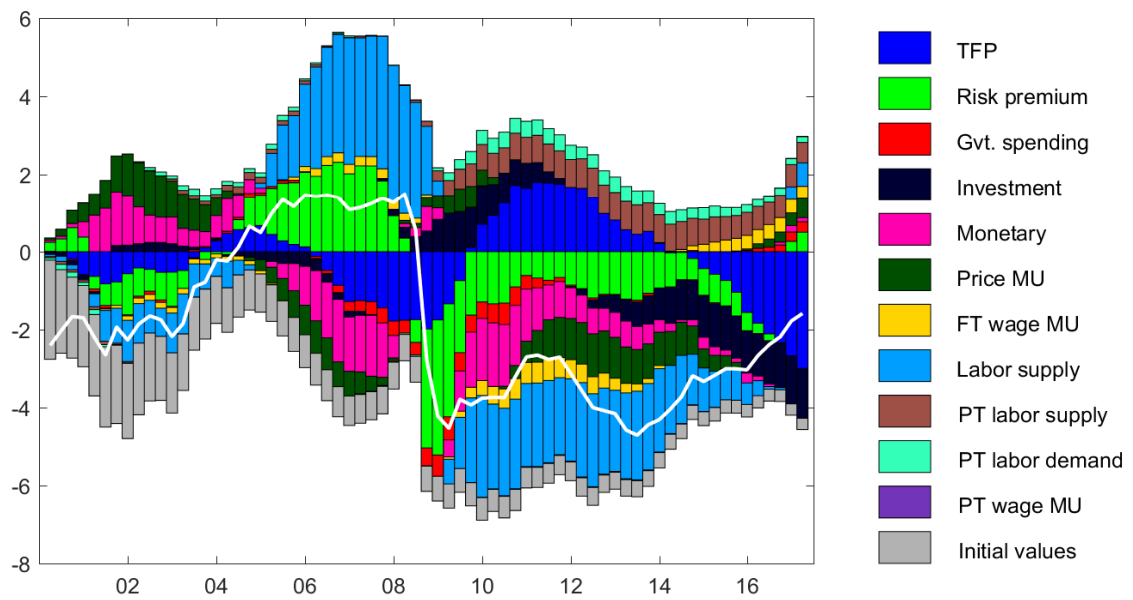
Note: Shock decompositions are calculated from the KPS1 model.

Figure 9: Shock decomposition: output and consumption

(a) Output



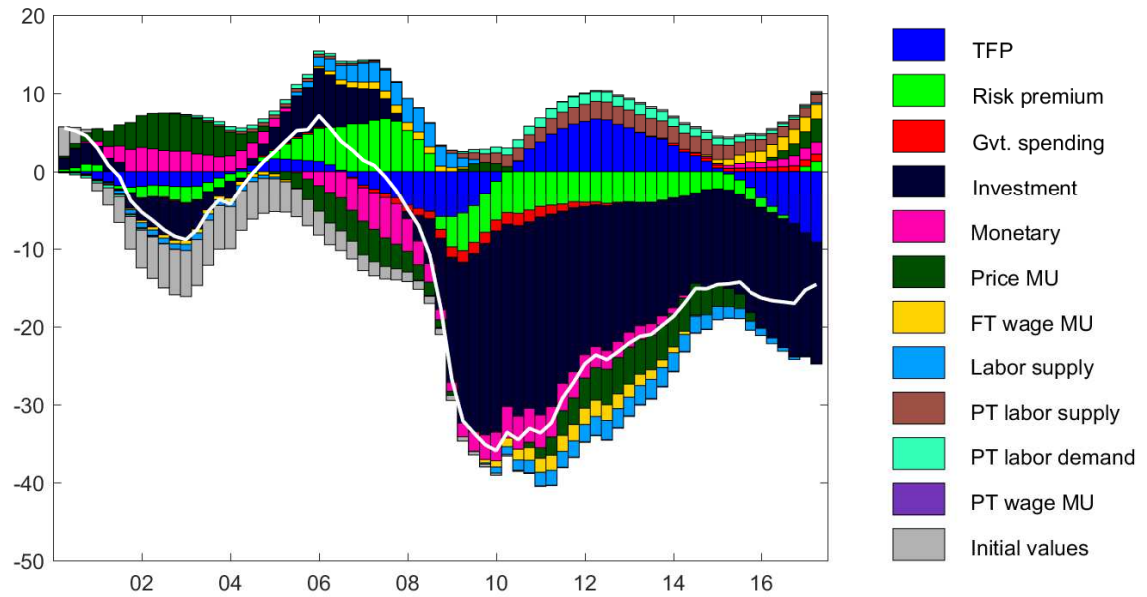
(b) Consumption



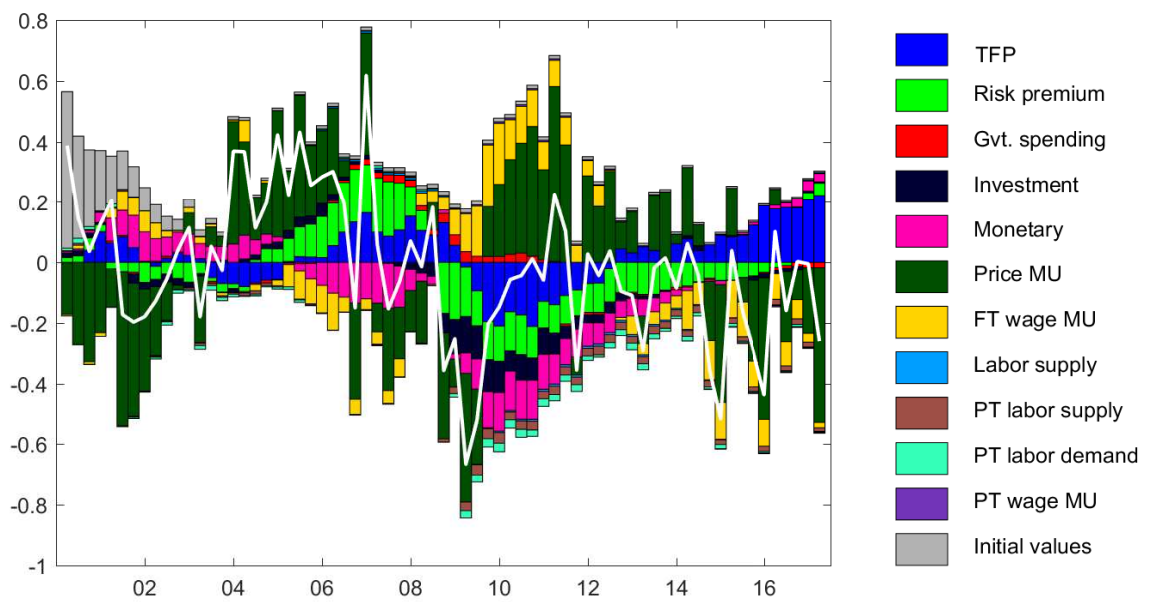
Note: Shock decompositions are calculated from the KPS1 model.

Figure 10: Shock decomposition: investment and inflation

(a) Investment

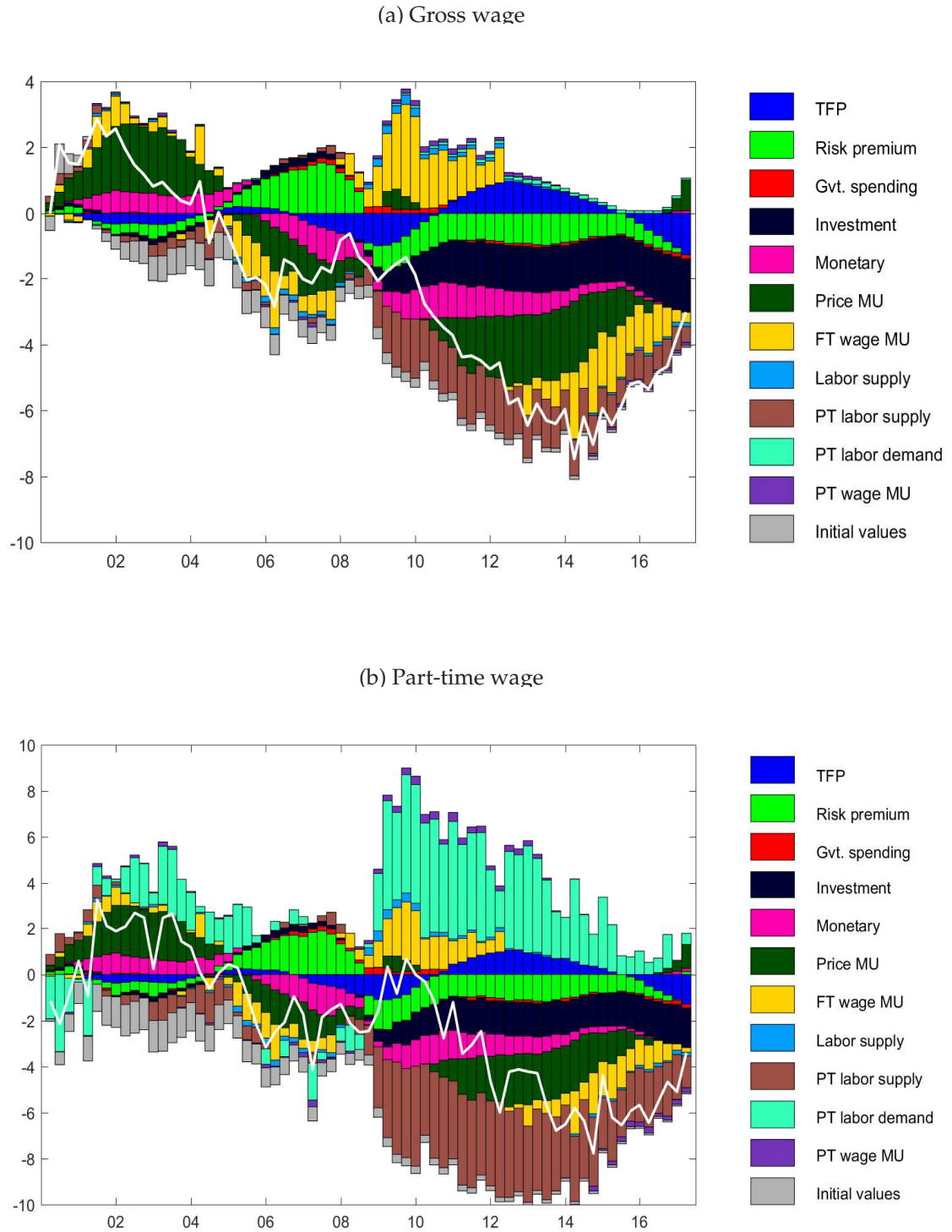


(b) Inflation



Note: Shock decompositions are calculated from the KPS1 model.

Figure 11: Shock decomposition: gross wage and part-time wage



Note: Shock decompositions are calculated from the KPS1 model.

A Log-linearized equations of the KPS2 model (the version that assumes part-time wage is flexible)

This appendix section presents log-linearized equations for the KPS2 model, which assumes that part-time wage is flexible. Lower case letters with a hat denote the deviation of log variables from the log steady state value. Equations for the KPS1 model are similar, except that there is staggering wage determination in part-time jobs as well.

Consumption Euler Equation:

$$\hat{c}_t = c_1 \hat{c}_{t-1} + (1 - c_1) E_t \hat{c}_{t+1} - c_2 (\hat{r}_t - E_t \hat{\pi}_{t+1} + \hat{\varepsilon}_t^b), \quad (38)$$

where $c_1 \equiv (h/\gamma)(1 + h/\gamma)$, $c_2 \equiv (1 - h/\gamma)(1 + h/\gamma)$.

Investment Euler Equation:

$$\hat{i}_t = i_1 \hat{i}_{t-1} + (1 - i_1) E_t \hat{i}_{t+1} + i_2 \hat{q}_t + \hat{\varepsilon}_t^q, \quad (39)$$

where $i_1 \equiv 1/(1 + \beta)$, $i_2 \equiv i_1/(\gamma^2 \Psi)$.

Value of capital stock:

$$\hat{q}_t = -(\hat{r}_t - E_t \hat{\pi}_{t+1} + \hat{\varepsilon}_t^b) + q_1 E_t \hat{r}_{t+1}^k + (1 - q_1) E_t \hat{q}_{t+1}, \quad (40)$$

where $q_1 \equiv r^k/(r^k - (1 - \delta))$.

Capital accumulation:

$$\hat{k}_t = \kappa_1 \hat{k}_{t-1} + (1 - \kappa_1) \hat{i}_t + \kappa_2 \hat{\varepsilon}_t^q, \quad (41)$$

where capital services used in production are defined as $\hat{k}_t = \hat{k}_{t-1} + \hat{v}_t$.

FOC for capital utilization:

$$\hat{v}_t = [(1 - \psi)/\psi] \hat{r}_t^k. \quad (42)$$

Output:

$$\hat{y}_t = c_y \hat{c}_t + i_y \hat{i}_t + \hat{\varepsilon}_t^g + v_y \hat{v}_t = \mathcal{M}_p [\alpha \hat{k}_t + (1 - \alpha) \{ (1 - pt) \hat{n}_{f,t} + pt (\hat{n}_{p,t} + \hat{v}_t) \} + \hat{\varepsilon}_t^a], \quad (43)$$

where $c_y \equiv C/Y$, $i_y \equiv I/Y$, $v_y \equiv R^k K/Y$. \mathcal{M} is the degree of returns to scale that corresponds to the price markup in the steady state. $pt \equiv \nu(1 - \pi)^{(\epsilon_n - 1)/\epsilon_n} / (\nu(1 - \pi)^{(\epsilon_n - 1)/\epsilon_n} + \pi^{(\epsilon_n - 1)/\epsilon_n})$.

Rate of return for capital:

$$\hat{r}_t^k = \hat{w}_{f,t} + \frac{\epsilon_n - 1}{\epsilon_n} [(1 - pt)\hat{n}_{f,t} + pt(\hat{n}_{p,t} + \hat{v}_t)] + \frac{1}{\epsilon_n} \hat{n}_{f,t} + \hat{\epsilon}_t^a. \quad (44)$$

Relationship between wage differential and employment differential:

$$\hat{w}_{f,t} - \hat{w}_{p,t} = -\frac{1}{\epsilon_n} (\hat{n}_{f,t} - \hat{n}_{p,t}) - \left(\frac{\epsilon_n - 1}{\epsilon_n} \right) \hat{v}_t. \quad (45)$$

Inflation Phillips curve:

$$\hat{\pi}_t^p - \gamma_p \hat{\pi}_{t-1}^p = \beta(E_t \hat{\pi}_{t+1}^p - \gamma_p \hat{\pi}_t^p) - \pi_1 (\hat{\mu}_{p,t} - \hat{\mu}_{p,t}^n), \quad (46)$$

where $\pi_1 \equiv (1 - \beta\theta_p)(1 - \theta_p) / [\theta_p\{1 + \zeta_p(\mathcal{M}_p - 1)\}]$, and γ_p , θ_p , and ζ_p are price indexation, Calvo price stickiness, and curvature of the Kimball aggregator parameters, respectively.

Average and natural price markup:

$$\hat{\mu}_{p,t} = -(1 - \alpha)\hat{\omega}_t - \alpha\hat{r}_t^k + \hat{\epsilon}_t^a, \quad (47)$$

$$\hat{\mu}_{p,t}^n = \hat{\epsilon}_t^p. \quad (48)$$

Full-time WPC:

$$\hat{\pi}_{f,t}^w - \gamma_w \hat{\pi}_{t-1}^w = \beta(E_t \hat{\pi}_{t+1}^w - \gamma_w \hat{\pi}_t^w) - \lambda_w (\hat{\mu}_{w,t} - \hat{\mu}_{w,t}^n), \quad (49)$$

where $\lambda_w \equiv (1 - \beta\theta_{w,f})(1 - \theta_{w,f}) / [\theta_{w,f}(1 + \varepsilon_{w,f}\varphi_f)]$.

Full-time wage markup and natural wage markup:

$$\hat{\mu}_{w,f,t} = (\hat{w}_{f,t} - p_t) - (\hat{z}_t + \hat{\epsilon}_t^x + \varphi_f \hat{n}_{f,t}) = \varphi_f \hat{u}_t, \quad (50)$$

$$\hat{\mu}_{w,f,t}^n = \hat{\epsilon}_t^w = \varphi_f \hat{u}_t^n. \quad (51)$$

Part-time wage determination:

$$\hat{w}_{f,t} - p_t = \hat{z}_t + \hat{\epsilon}_t^x + \varphi_p \hat{n}_{p,t} + \hat{\eta}_t. \quad (52)$$

Labor force, employment, and unemployment:

$$\hat{l}_t = \hat{n}_t + \hat{u}_t, \quad (53)$$

where $\hat{l}_t \equiv \pi \hat{l}_{f,t} + (1 - \pi) \hat{l}_{p,t}$, $\hat{n}_t \equiv \pi \hat{n}_{f,t} + (1 - \pi) \hat{n}_{p,t}$.

Monetary policy:

$$\hat{r}_t = \rho_r \hat{r}_{t-1} + (1 - \rho_r) (r_\pi \hat{\pi}_t^p + r_y \widehat{ygap}_t + r_{\Delta y} \Delta \widehat{ygap}_t) + \hat{\varepsilon}_t^r, \quad (54)$$

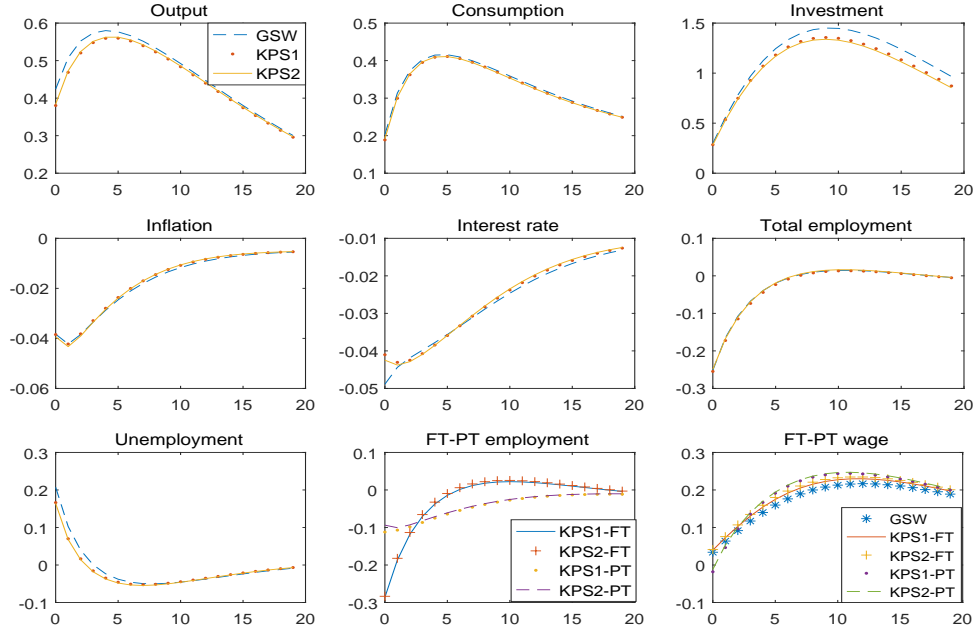
where \widehat{ygap}_t denotes the output gap defined by the difference between actual output and flexible price and wage output.

B Impulse response functions of the shocks that do not cause substitutions between labor types

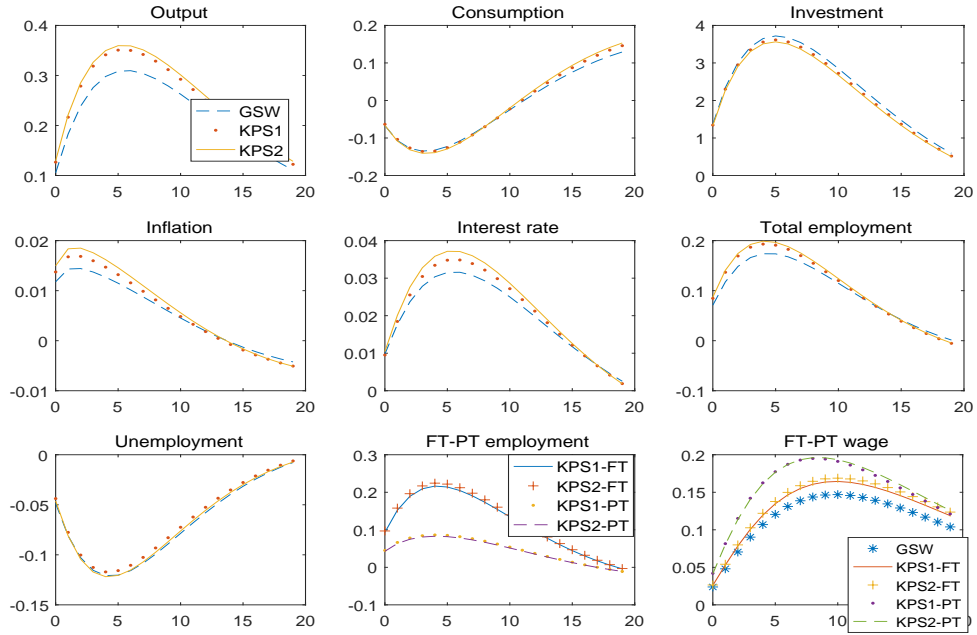
Figures 12–13 present the impulse response functions of shocks that do not cause labor type substitution, TFP, investment technology, price markup, or government spending shocks. Responses against labor supply shock are omitted because labor enters differently in the GSW and KPS models, and therefore comparison between the two models is inappropriate. Even though there is no switch between labor types, an evident pattern exists in full-time and part-time labor dynamics. Part-time wage responds more flexibly to these shocks, allowing part-time employment to be less volatile than its full-time counterpart. Other than this observation, impulse responses are typical for the respective shocks. One interesting observation is that positive TFP shock, although being expansionary, has an adverse impact on employment, lowering the total employment rate and raising the unemployment rate. In fact, this short-term contraction in labor after a TFP shock is quite common in the estimated DSGE models with nominal rigidities; it is similarly observed in SW and GSW. A most widely accepted explanation is that, as emphasized in the works of Galí (1999), Francis and Ramey (2005), and Basu et al. (2006), positive TFP shock allows firms to require fewer inputs to produce the same amount of goods, and thus production needs to increase sufficiently for firms to hire more labor. However, under rigidities in the price and interest rate, as well as the existence of habit formation and investment adjustment cost, aggregate demand might not increase that much in the short run, which would lead firms to cut employment.

Figure 12: Impulse response functions: TFP and investment technology shock

(a) TFP shock



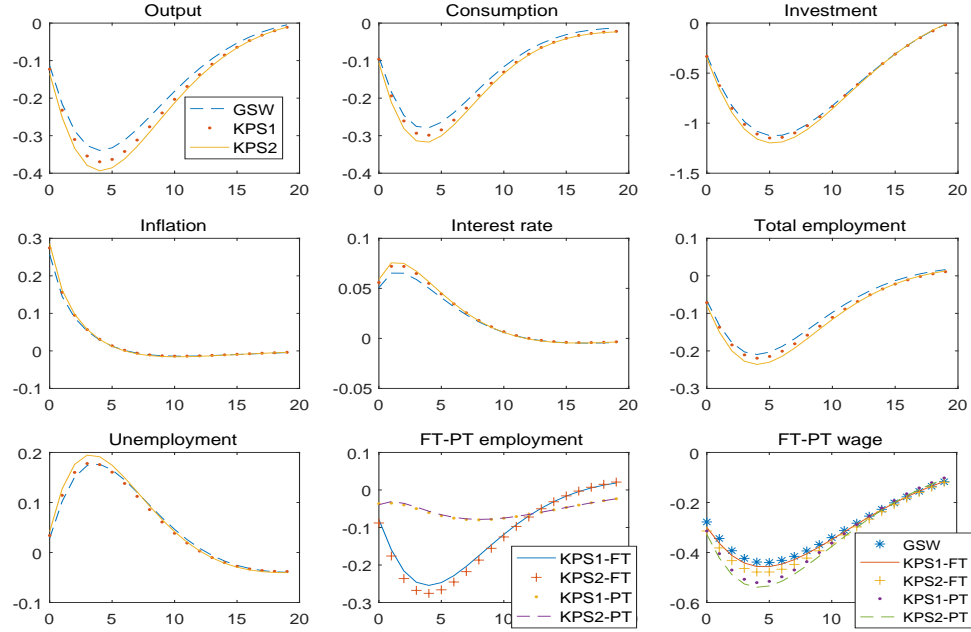
(b) Investment technology shock



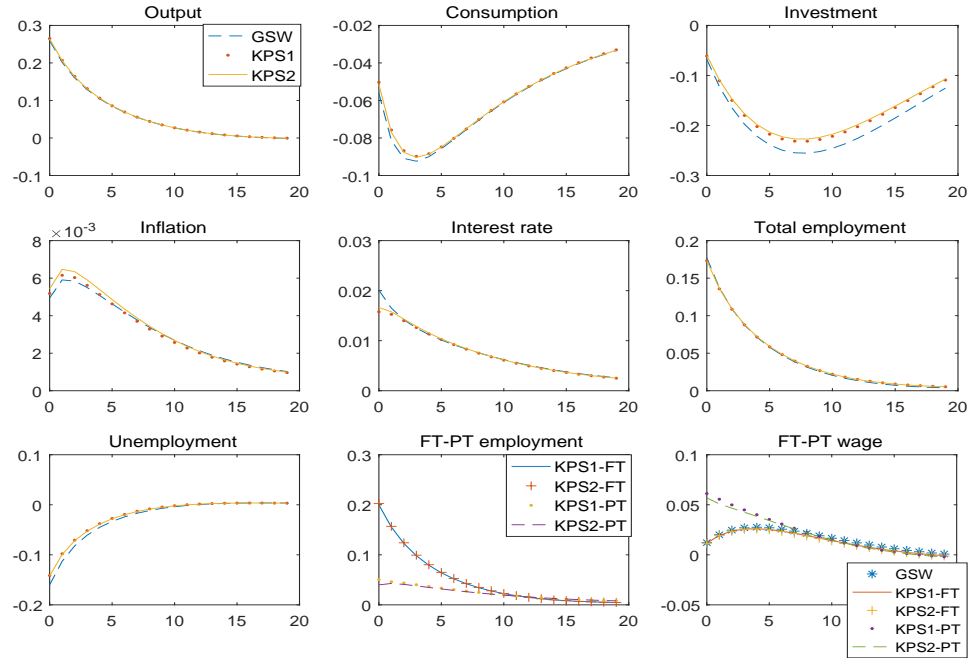
Note: Shock processes in all models are based on the KPS1 model.

Figure 13: Impulse response functions: price markup and government spending shock

(a) Price markup shock



(b) Government spending shock



Note: Shock processes in all models are based on the KPS1 model.