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BUSINESS CYCLE FLUCTUATIONS WITH THE DIVISION OF PERMANENT AND TEMPORARY EMPLOYMENT

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Abstract

In the mainstream real business cycle (RBC) model, labor can be viewed as temporary employment since the firm's demand for labor behaves directly in response to stochastic productivity shocks in each period. This paper provides a tractable way of analyzing fluctuations in permanent and temporary employment over the business cycle, as well as the underlying driving forces. This inclusion of heterogeneity helps reconcile the RBC model with the U.S. data given that temporary employees in general only account for a small proportion of total private-sector employment (about 2%–3%). We draw an explicit division between permanent and temporary employment and resort to this separation to account for stylized facts that characterize a two-tier labor market. In particular, with regard to the U.S. labor market, our benchmark model can well explain the motivating facts: (1) temporary employment is much more volatile than permanent employment, (2) the share of temporary employment (the ratio of temporary to aggregate employment) exhibits strong pro-cyclicality, (3) permanent employment lags by two quarters on average, and (4) the correlation between temporary employment and output is stronger than that involving the permanent counterpart. The quantitative analysis suggests that our proposed channels explain the main facts well and the model further provides plausible reasoning for a firm's labor hoarding. (JEL E24, E32)

ABBREVIATIONS

BLS
: U.S. Bureau of Labor Statistics

CES
: Constant Elasticity of Substitution

FRED
: Federal Reserve Economic Data

GDP
: Gross Domestic Product

GHH
: Greenwood, Hercowitz, and Huffman

HP

Hodrick-Prescott

RBC

Real Business Cycle

SMM

Simulated Method of Moments

TFP

Total Factor Productivity

I. INTRODUCTION

It is commonly believed that the volatility of macroeconomic variables is closely associated with the inflexibility and friction characterizing the labor market. In classic real business cycle (henceforth RBC) work (e.g., King, Plosser, and Rebelo 1988), labor can be viewed as temporary employment since the firm's demand for labor behaves directly in response to stochastic productivity shocks in each period. However, the U.S. data indicate that, in spite of the existence of slight differences across industry classifications, temporary workers in general account for about 2%–3% of total private-sector employment, revealing the fact that permanent workers constitute an essential component in the labor market.[1] Permanent employees are defined as wage workers whose jobs have an unspecified duration, which is featured by continuity in the working relationship with their current employers. This definition implies that permanent employees that have currently been hired are expected to retain their employment status in the next period even if the economy now experiences a severe negative shock. Obviously, the presence of permanent employment will limit the firm's capacity to adjust the number of its workers in a timely manner and hence it can be treated as a key ingredient in modeling the labor market's inflexibility/flexibility.

It is worth stressing that, in previous RBC studies, the discussion with regard to an explicit division between permanent and temporary labor inputs is rather scant. This is because standard RBC models mostly conduct their analysis solely on either type of employment: frictional or nonfrictional (e.g., Cogley and Nason 1995; Jaimovich and Rebelo 2009; Merz and Yashiv 2007) even though the two types coexist and can pervasively interact with each other. The data suggest that the workers employed in permanent positions currently account for 97%–98% of employment in the U.S. labor market, although the share of temporary employment is bec more significant over time. The changes in the composition of labor and in market flexibility can be tied to structural and institutional reforms (Boeri 2011) and they are shown to have a profound impact on business cycle fluctuations (Gnocchi, Lagerborg, and Pappa 2015).

The aim of this paper is to provide a tractable way of analyzing the cyclical behavior of permanent and temporary employment in the context of an RBC model that features stochastic total factor productivity (TFP) shocks. In contrast to the mainstream theoretical framework, we separate the permanent labor input from the temporary alternative, and resort to this separation to account for stylized facts that can characterize a two-tier labor market. In particular, with regard to the U.S. labor market, our benchmark model can well explain the motivating facts: (1) temporary employment is much more volatile than permanent employment, (2) the share of temporary employment (the ratio of temporary to aggregate employment) exhibits strong procyclicality, (3) permanent employment lags by two quarters on average, and (4) the correlation between temporary employment and output is stronger than that involving the permanent counterpart.

Aiming to fill the void, this paper sets up an RBC model that sheds light on the key distinction between permanent and temporary labor. Specifically, hiring permanent labor, which is considered as a quasi-fixed input, is subject to its past accumulation and frictions led by training new recruits (e.g., Oi 1962; Galeotti and Schiantarelli 1991; Blatter, Mühlemann, and Schenker 2012), while by contrast, temporary labor is hired for one period and firms can adjust this production input more flexibly when the economy experiences a realized TFP shock (e.g., Segal and Sullivan 1997). Importantly, the distinction between permanent and temporary labor that this paper adopts is very close in spirit to Boeri and Garibaldi (2007) since they consider a two-tier labor model in which permanent labor is predetermined while temporary labor can be flexibly chosen or freely dismissed by firms in each period.

To this end, this paper proposes three channels to capture the distinct and cyclical features of the permanent and temporary labor inputs and they are embedded into the standard RBC model. First, the degree of substitution between them is taken into account.[2] Second, a time-to-build mechanism related to job training is introduced to capture the training duration required for new recruits to become permanent employees.[3] In light of this, the stock of permanent employment rests not only on the current value of firm's profits but also on the expected discounted sum of future values. Meanwhile, the time-consuming job training leads permanent workers to be more productive than temporary ones. Third, when the firms hire the new recruits, they need to pay labor adjustment costs, which can be regarded as the costs arising from advertising for, screening, and training the new recruits.

Our quantitative result suggests that a high degree of substitution between permanent and temporary labor, the inclusion of the time-to-build mechanism, and the presence of labor adjustment costs are essential in explaining the documented facts about the two-tier labor market. Intuitively, when a persistent positive TFP shock hits the economy, a high degree of substitution between permanent and temporary labor will motivate the firms to hire more temporary workers as a short-run substitute for permanent ones during training periods. It follows that temporary employment exhibits volatile behavior much more than permanent employment, thereby leading to the emergence of a strong procyclicality of the share of temporary employment. Moreover, given the persistent positive TFP shock, the firms are also inclined to hire more new recruits because they will be treated as an investment for future production. They become permanent and productive workers after receiving training and this feature explains the multiquarter lagged behavior of permanent employment and how it smoothly responds to the realized shock.

In addition to formulating an RBC model that replicates the above stylized facts, this paper also provides an explanation for firms' labor hoarding behavior during 1990–1991, 2001, and 2007–2009 recessions by way of less-flexible labor markets (e.g., Galí and Gambetti 2009). Instead of adjusting along the margins of hours worked and number of employed (i.e., Burnside, Eichenbaum, and Rebelo 1993), the firms now consider modifying the relative amounts of the two alternative labor inputs in response to the TFP shock. In particular, given a high degree of substitutability between permanent and temporary workers, a calibrated version of the model suggests that a negative shock will trigger a less substantial decline in the stock of permanent ones. As a consequence, the falling share of temporary employment is found to result from long-term considerations for maintaining the trained and productive workers on the payroll. Moreover, both the other channels (i.e., the time required for job training and the presence of labor adjustment costs) are found to contribute to indirect responses of permanent employment to the TFP shock.

The empirical evidence that supports the presence of these features in labor markets is well documented in the literature. First, following the definition proposed by Mincer (1962), on-the-job training is referred to as the process by which new recruits acquire skills and turn into more productive employees. A related study by Bartel (1995) finds that on-the-job training can significantly improve an employee's performance and wages, thereby suggesting a positive relationship between training and productivity. Second, the convexity/nonconvexity in the structure of labor adjustment costs is empirically examined by Hamermesh (1989), Varejão and Portugal (2007), Merz and Yashiv (2007), and Mumtaz and Zanetti (2015). Labor adjustment costs serve as a key modeling device in reproducing mild changes in labor demand in response to shocks; see, for example, Burnside, Eichenbaum, and Rebelo (1993), Cogley and Nason (1995), and Jaimovich and Rebelo (2009), to name just a few. Lastly, a higher degree of substitution between permanent and temporary labor is shown in Jahn and Weber (2016) and Cappellari, Dell'Aringa, and Leonardi (2012). Thus, our simulated method of moments (SMM) estimate is consistent with their findings.

The findings of this paper are supported by several studies that investigate the two-tier labor market structure by using disaggregated data. Jahn and Bentzen (2012) find evidence of the procyclical behavior of temporary employment from an international perspective. In addition, our work is related to recent papers on how the changing nature of labor market will influence the business cycle dynamics. In particular, Barnichon (2010) and Galí and van Rens (2010) put forth the hypothesis that a flexible labor market could lead to the short-term acyclical behavior of labor productivity. A group of recent studies also investigate whether the labor market flexibility associated with labor market institutions is critical for aggregate fluctuations, including cyclical movements in labor productivity over the course of the business cycle, for example, Camp and Faia (2011), Thomas and Zanetti (2009), and Zanetti (2011).

The rest of this paper is organized as follows. Section II develops an RBC model and elaborates on the corresponding settings. Section III shows the empirical findings derived from aggregate data. Section IV presents the quantitative results based on possible extensions of the benchmark model and discusses the underlying implications. Section V discusses two extension exercises in light of the model generalizations. Section VI concludes this paper.

II. THE MODEL

In this section, we build a RBC model and derive the conditions that characterize the general equilibrium. The economy that we consider consists of two types of agents: households and firms. In what follows, we describe the behavior of each of these agents in turn.

A. *Households*

Assume that the economy is populated by a continuum of identical and infinitely lived households, and the population size is normalized to unity for simplicity. The representative household derives utility from consumption, c_t and incurs disutility from providing permanent and temporary labor services. In line with the studies of Rupert, Rogerson, and Wright (2000), Chang and Kim (2006), and Guner, Kaygusuz, and Ventura (2012a, 2012b), we suppose that the decisions are made by a family rather than an individual in the household sector. The family consists of two members: one provides temporary labor services h_t and the other provides permanent labor services n_t.[4] We specify the representative household's preference by following the setting of utility function proposed by Greenwood, Hercowitz, and Huffman (1988) (hereafter the GHH preference).[5] Accordingly, the preference is modeled specifically by the expected life-time utility

$$U_t = E_0 \sum_{t=0}^{\infty} \beta^t \frac{\left[c_t - \frac{\psi}{1+\chi}\left(n_t^{1+\chi} + h_t^{1+\chi}\right)\right]^{1-\theta} - 1}{1-\theta};$$
$$1 > \beta > 0, \theta > 0, \chi > 0, \psi > 0, \tag{1}$$

where E_0 is the expectation conditional on all information available at time 0, θ stands for the inverse of the intertemporal elasticity of substitution in consumption, β represents the household's subjective discount factor, ψ denotes a parameter that captures the taste for labor supply, and χ is the inverse of the Frisch elasticity of labor supply.[6]

The representative household supplies temporary labor h_t, permanent labor n_t, owns the capital stock k_t, and takes wage rates for permanent and temporary labor, $w_{h,t}$ and $w_{n,t}$, and the rental rate r_t as given. In addition, the household receives dividend income d_t by holding each unit of the firm's outstanding equity z_t at price p_t in each period. For simplicity, the total share of the firm's outstanding equity is normalized to unity. At each time period, the household allocates its income to consumption, investment i_t, and the accumulation of additional equities. The household budget constraint can be written as:

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$$p_t\left(z_{t+1} - z_t\right) = r_t k_t + w_{h,t} h_t + w_{n,t} n_t$$
$$+ d_t z_t - c_t - i_t. \tag{2}$$

Accordingly, the law of motion of the capital stock can be specified as

$$k_{t+1} = (1-\delta) k_t + i_t; 1 > \delta > 0, \tag{3}$$

where δ denotes the rate of capital depreciation.

The representative household's problem is to choose the sequences $\{c_t, h_t, n_t, k_{t+1}, z_{t+1}\}_{t=0}^{\infty}$ to maximize the expected life-time utility reported in Equation (1), subject to Equations (2) and (3). The first-order conditions that characterize solutions to the optimization problem are given by:

$$\psi h_t^{\chi} = w_{h,t}, \tag{4}$$

$$\psi n_t^{\chi} = w_{n,t}, \tag{5}$$

$$1 = \beta E_t \left\{ \left[\frac{c_t - \frac{\psi}{1+\chi}\left(n_t^{1+\chi} + h_t^{1+\chi}\right)}{c_{t+1} - \frac{\psi}{1+\chi}\left(n_{t+1}^{1+\chi} + h_{t+1}^{1+\chi}\right)} \right]^{\theta} \times \left(r_{t+1} + 1 - \delta\right) \right\}, \tag{6}$$

and

$$p_t = \beta E_t \left\{ \left[\frac{c_t - \frac{\psi}{1+\chi}\left(n_t^{1+\chi} + h_t^{1+\chi}\right)}{c_{t+1} - \frac{\psi}{1+\chi}\left(n_{t+1}^{1+\chi} + h_{t+1}^{1+\chi}\right)} \right]^{\theta} \times \left(p_{t+1} + d_{t+1}\right) \right\}. \tag{7}$$

Equations (4) and (5), respectively, indicate that the marginal rates of substitution between temporary labor supply and consumption and between permanent labor supply and consumption are equal to their corresponding wage rates. Equations (6) and (7) are standard Euler equations that state the household's optimal intertemporal holdings on physical capital and the firm's equity.[7]

B. *Firms*

The production sector is composed of many identical and competitive firms, which can be treated as a representative firm. Suppose that the firm hires temporary workers h_t, the stock of permanent workers x_t, and capital services k_t to produce output y_t.[8] The firm produces output according to the following constant elasticity of substitution (CES) production function:

$$y_t = A_t k_t^{\alpha} \left[x_t^{\sigma} + (\gamma h_t)^{\sigma} \right]^{\frac{1-\alpha}{\sigma}}; 0 < \gamma < 1, \sigma < 1, \tag{8}$$

where A_t represents the level of TFP, α denotes the share of capital services, and the parameter γ reflects the relative productivity between permanent and temporary labor. The elasticity of substitution between h_t and x_t is constant and equal to $1/(1 - \sigma)$ with an imperfect substitute $\sigma < 1$.

We then deal with the law of motion of permanent employment. In reality, we observe that new recruits may need several periods to complete their training.[9] Let $l_{a,t}$ denote the new recruits that the firm employs at time t, who are required to spend a periods accumulating experiences and skills before becoming permanent workers. Let b represent the total number of periods required for each new recruit to become permanently employed. Therefore, the aggregate new recruits at time t can be expressed as:

$$v_t = \sum_{a=1}^{b} l_{a,t}. \tag{9}$$

The law of motion of the recruits is given by:

$$l_{a,t+1} = l_{a+1,t}; a = 1, 2, \ldots, b - 1. \tag{10}$$

At time $t + 1$, as the amount $l_{1,t}$ of new recruits completes the training and becomes permanently employed, the law of motion of permanent employment can then be expressed as:

$$x_{t+1} = (1 - \mu) x_t + l_{1,t}; 0 < \mu < 1, \tag{11}$$

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where μ denotes an exogenous separation rate. It should be mentioned that, for simplicity, μ is treated as an exogenous variable. In Section V.A, this assumption will be relaxed.

Following Bentolila and Bertola (1990), Bloom (2009), and Belo, Lin, and Bazdresch (2014), we adopt the setup that the firm incurs asymmetric labor costs, including hiring costs and separation costs, when it hires and dismisses permanent workers.[10] The hiring costs are considered to be the induced costs from advertising for, screening, and training the new recruits (see Merz and Yashiv 2007). By contrast, the separation costs result from the termination of those in permanent employment. Nickell (1986) points out that the main source of separation costs is associated with the employment protection laws that lay down stricter criteria for dismissals. To this end, the quadratic labor adjustment costs are separately given by:

$$\Phi_{1,t} = \frac{\phi_1}{2}\left(\frac{l_{b,t}}{x_t}\right)^2 y_t; \phi_1 \geq 0,$$

(12a)

$$\Phi_{2,t} = \frac{\phi_2}{2}\left(\frac{\mu x_t}{x_t}\right)^2 y_t = \frac{\phi_2}{2}\mu^2 y_t; \phi_2 \geq 0,$$

(12b)

where the intensity parameters ϕ_1 and ϕ_2 govern the sizes of the hiring and separation costs and the variables $l_{b,\,t}$ and μx_t represent the numbers of new recruits and of dismissed workers. On the one hand, Equations (12a) and (12b) indicate that the adjustment costs are proportional to output. As noted by Merz and Yashiv (2007), this specification can capture the sense that the costs of disruption increase with the size of the firm. On the other hand, the hiring and separation costs in Equations (12a) and (12b) are specified as convex functions. Without loss of generality, the costs are further modeled as quadratic functions in an attempt to maintain tractability (e.g., Blatter, Mühlemann, and Schenker 2012; Cooper and Willis 2009; Galí and van Rens 2010; Sargent 1978). The setup of the adjustment costs is crucial for generating the observed lagged behavior of permanent employment, as proposed by Kydland and Prescott (1991), since it diminishes the demand for permanent workers and in turn the demand for currently new recruits.

Taking the adjustment costs into account, the firm's profits as well as the household's dividend incomes can be expressed as:

$$\begin{aligned} d_t = y_t - w_{n,t}\left(v_t + x_t\right) - w_{h,t}h_t - r_t k_t \\ - \Phi_{1,t} - \Phi_{2,t}. \end{aligned}$$

More concretely, Equation (13) implies that the new recruits in training v_t are paid at the sa

wage rate $w_{n,\,t}$ as permanent workers in production x_t. The objective of the representative firm is to maximize a stream of discounted profits π_t, which is the sum of the current profits d_t and the discounted value of expected future profits D_t:

$$\pi_t = d_t + D_t = d_t + E_t\left[\sum_{j=1}^{\infty}\beta^j \frac{\lambda_{t+j}}{\lambda_t} d_{t+j}\right],$$

(14)

where $\beta^j \frac{\lambda_{t+j}}{\lambda_t}$ is the discount factor for period $t+j$. The firm chooses the sequence $\{k_t, h_t, l_{b,\,t}, x_{t+1}\}$ to maximize (14), subject to Equations (8)–(13). Let η_t denote the corresponding Lagrange multiplier. The optimum conditions necessary for the firm with respect to the indicated variables are:

$$k_t : r_t = \alpha\left[1-\frac{\phi_1}{2}\left(\frac{l_{1,t+b-1}}{x_t}\right)^2-\frac{\phi_2}{2}\mu^2\right]\frac{y_t}{k_t}, \tag{15}$$

$$h_t : w_{h,t} = (1-\alpha)\left[1-\frac{\phi_1}{2}\left(\frac{l_{1,t+b-1}}{x_t}\right)^2 -\frac{\phi_2}{2}\mu^2\right]\frac{(\gamma h_t)^\sigma}{x_t^\sigma+(\gamma h_t)^\sigma}\frac{y_t}{h_t}, \tag{16}$$

$$l_{b,t} : E_t\left[\sum_{a=1}^{b}\beta^{a-1}\frac{\lambda_{t+a-1}}{\lambda_t}w_{n,t+a-1}\right] + \phi_1\left(\frac{l_{1,t+b-1}}{x_t}\right)\frac{y_t}{x_t} = E_t\left[\beta^{b-1}\frac{\lambda_{t+b-1}}{\lambda_t}\eta_{t+b-1}\right], \tag{17}$$

and

$$x_{t+1} : \eta_t = \beta E_t\left\{\frac{\lambda_{t+1}}{\lambda_t}\left[\frac{\left[1-\frac{\phi_1}{2}\left(\frac{l_{1,t+b}}{x_{t+1}}\right)^2-\frac{\phi_2}{2}\mu^2\right](1-\alpha)x_{t+1}^\sigma}{x_{t+1}^\sigma+(\gamma h_{t+1})^\sigma} \times\frac{y_{t+1}}{x_{t+1}}+\phi_1\left(\frac{l_{1,t+b}}{x_{t+1}}\right)^2\frac{y_{t+1}}{x_{t+1}} - w_{n,t+1}+(1-\mu)\eta_{t+1}\right]\right\}. \tag{18}$$

As exhibited in Equations (15) and (16), the inputs k_t and h_t are paid on the basis of their marginal product. Equation (17) indicates that the marginal cost of hiring new recruits $l_{b,t}$, which is reflected by the stream of wages and labor adjustment costs, equals the expected shadow price of permanent labor η_{t+b-1} at the moment that $l_{b,t}$ becomes permanent labor (i.e., at the end of period $t+b-1$). Thus, the firm's optimal intertemporal choice of hiring the new recruits embodies forward-looking decision-making. Moreover, in Equation (18), η_t reflects the net expected marginal benefit of accumulating an additional unit of permanent labor x_{t+1}, which is equal to its marginal product plus the benefit from lowering labor adjustment costs deducted from its wage and the loss raised by the separation in period $t+1$.

C. *The Competitive Equilibrium*

The competitive equilibrium condition is defined as a sequence of allocations $\{c_t, h_t, n_t, k_{t+1}, z_{t+1}\}$ of the representative household and $\{k_t, h_t, l_{b,t}, x_{t+1}\}$ of the representative firm such that given the prices $\{p_t, r_t, w_{h,t}, w_{n,t}\}$, the household maximizes (1) and the representative firm maximizes (14) and all of the markets are cleared. The market clearing conditions in the equity, permanent labor, and goods markets are given by

$$z_t = 1, \tag{19}$$

$$n_t = v_t + x_t, \tag{20}$$

and

$$\begin{aligned} c_t + k_{t+1} - (1-\delta)k_t &= \left[1 - \frac{\phi_1}{2}\left(\frac{l_{1,t+b-1}}{x_t}\right)^2 - \frac{\phi_2}{2}\mu^2\right] \\ &\times A_t k_t^{\alpha}\left[x_t^{\sigma} + (\gamma h_t)^{\sigma}\right]^{\frac{1-\alpha}{\sigma}}. \end{aligned} \tag{21}$$

Equation (19) implies the equilibrium condition for the equity market given that the outstanding equity of the economy is normalized to unity. Equation (20) illustrates that the of permanent labor equals the aggregate of new recruits and the workers actually engage production. The equilibrium condition for the goods market reported in Equation (21) is derived from combining Equations (2), (3), (8), and (12a)–(13) given Equation (19), in which $z_t = 1$ for all t.

Finally, the logarithm of TFP is set to follow a stationary first-order autoregressive process,

$$\log(A_t) = \rho \log(A_{t-1}) + \epsilon_t, \tag{22}$$

where ρ is the persistence parameter and the technology shock ϵ_t is a white noise with variance σ_ϵ^2.

III. THE FACTS

In this section, we briefly introduce the cyclical features regarding permanent and temporary employment that we can observe from the U.S. data. We then provide an overview of the targets to be explained by our theoretical model.

Based on the definition by the U.S. Bureau of Labor Statistics (BLS), temporary workers refer to those to be hired by temporary help services agencies and assigned to employers to meet temporary part- or full-time staffing needs. As stated in Kalleberg (2000), the origin of the service industry in the United States may date back to the 1920s, and for a long period its employees only accounts for a small proportion of aggregate employment. However, its share has not only been rising rapidly in the United States but also been very sensitive to business cycle fluctuations (see Segal and Sullivan 1997). One of the most plausible reasons is that temporary workers provide the hiring firms with the additional postproduction flexibility since their labor contracts are mostly signed on a fixed-term basis. As a result, a flexible labor market allows firms to adjust their production immediately when an adverse shock hits (see Berton and Garibaldi 2012).

The time series of temporary workers and the real gross domestic product (GDP) per capita for the United States that we use are obtained from the BLS and the Federal Reserve Economic Data (FRED) maintained by the Federal Reserve Bank of St. Louis. The time series that represents the share of temporary employment to total private-sector employment is subject to the change in industry classification system in the late 1990s, which results in the unavailability of a consistent measure for a long span of time.[11] Figure 1 illustrates the differences among three related industry categories, and the shaded areas in the figure denote the recessions identified by the National Bureau of Economic Research. It is obvious that the three series exhibit a similarly rising pattern, even though a persistent gap between any two of them exists. For example, the number of temporary workers measured by employment at the industry level, that is, personnel supply services (SIC-7360), increases at an annual rate of 8.9% during 1972–2000. Despite the existence of slight differences across industry classifications, temporary workers in general account for about 2%–3% of the total private-sector employment in 2000. Nowadays, the share measured by employment by industry of temporary help services (NAICS-56132) is nearly 2.1%.

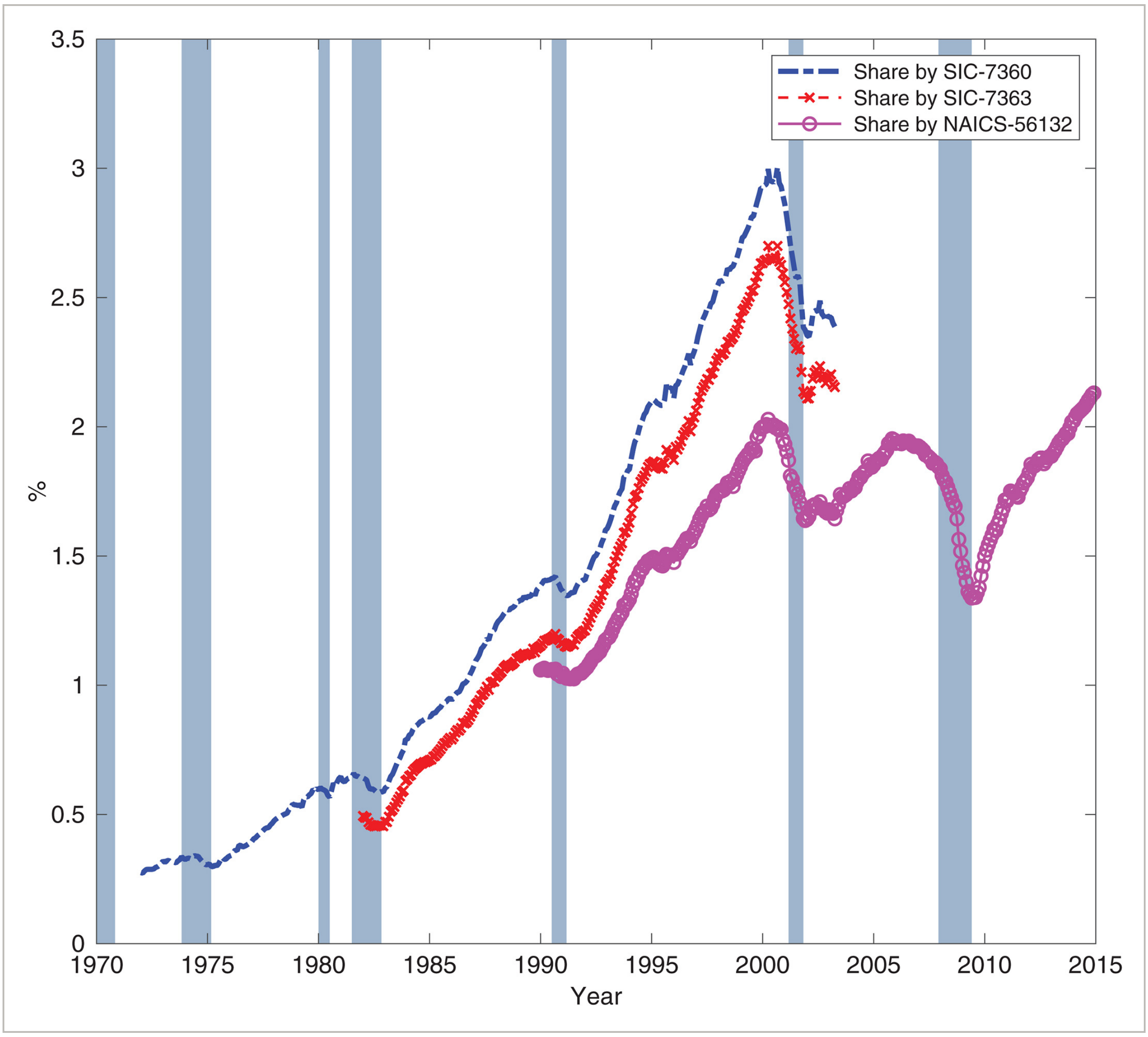

Figure 1

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The Share of Temporary Employment Measured by Different Industry Classifications

Source: BLS.

As displayed in Figure 1, the share of temporary to total workers exhibits a strong procyclic pattern, and in particular turns into another increasing stage after every recession. To high its periodicity, the Hodrick-Prescott (HP)-filtered cyclical components of GDP per capita are also plotted in Figure 2.[12] Obviously, the share drops significantly during the recent episodes of recessions and it attains higher values before the onsets of subsequent recessions.

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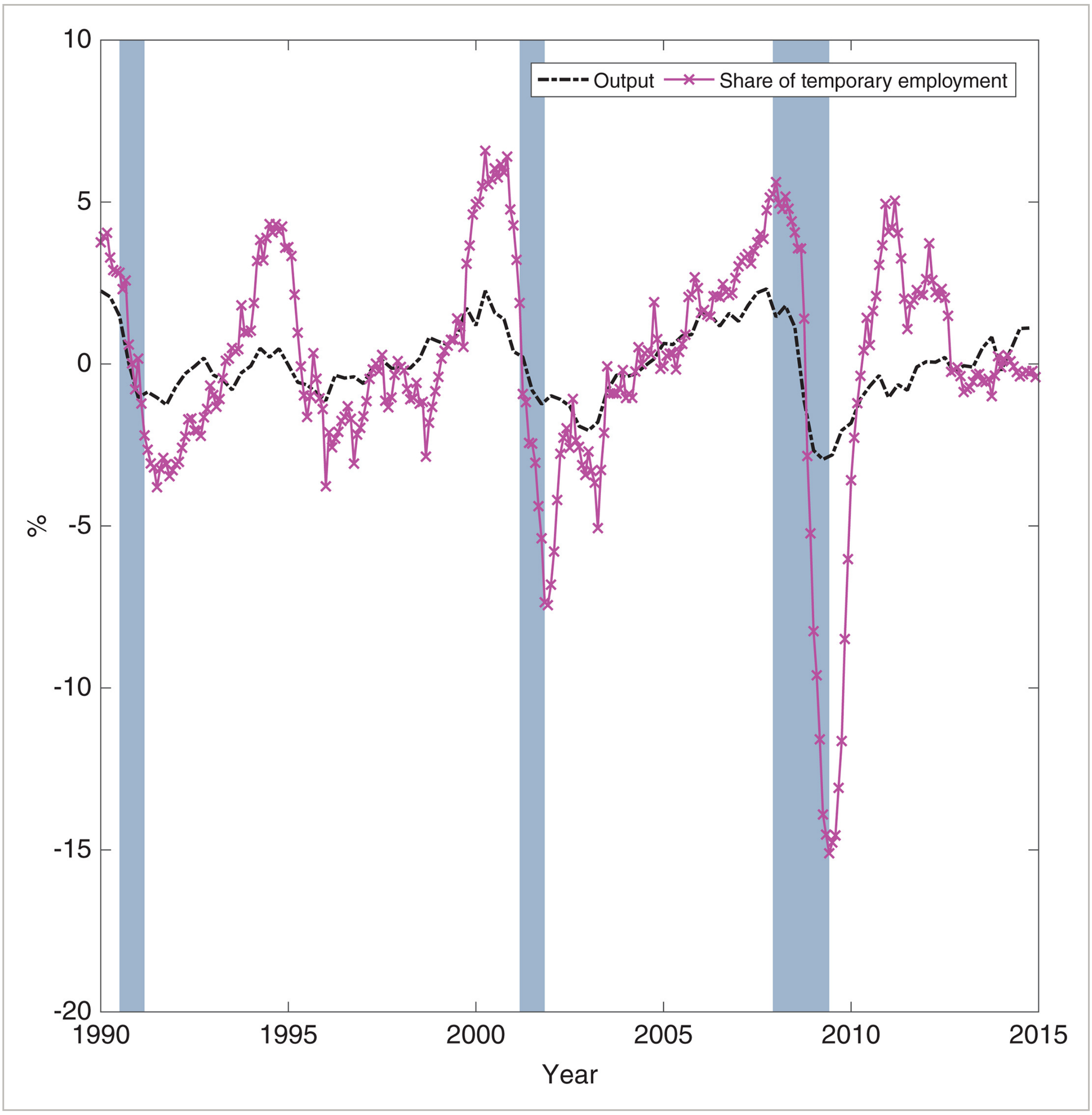

Figure 2

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The HP-Filtered Cyclical Components of Output and the Share of Temporary Employment

Sources: BLS and FRED.

Figure 3 further decomposes aggregate employment into detrended permanent and temporary components. It reveals that temporary employment has a much higher degree of volatility and higher correlation with output, and permanent employment lags behind in the cycles. As a consequence, the share experiences notable decreases almost simultaneously with real GDP per capita during past recessions. One of the possible reasons for this result is that hiring temporary workers functions as a "buffer" device for firms that hesitate to adjust their permanent employment level (see Segal and Sullivan 1997).

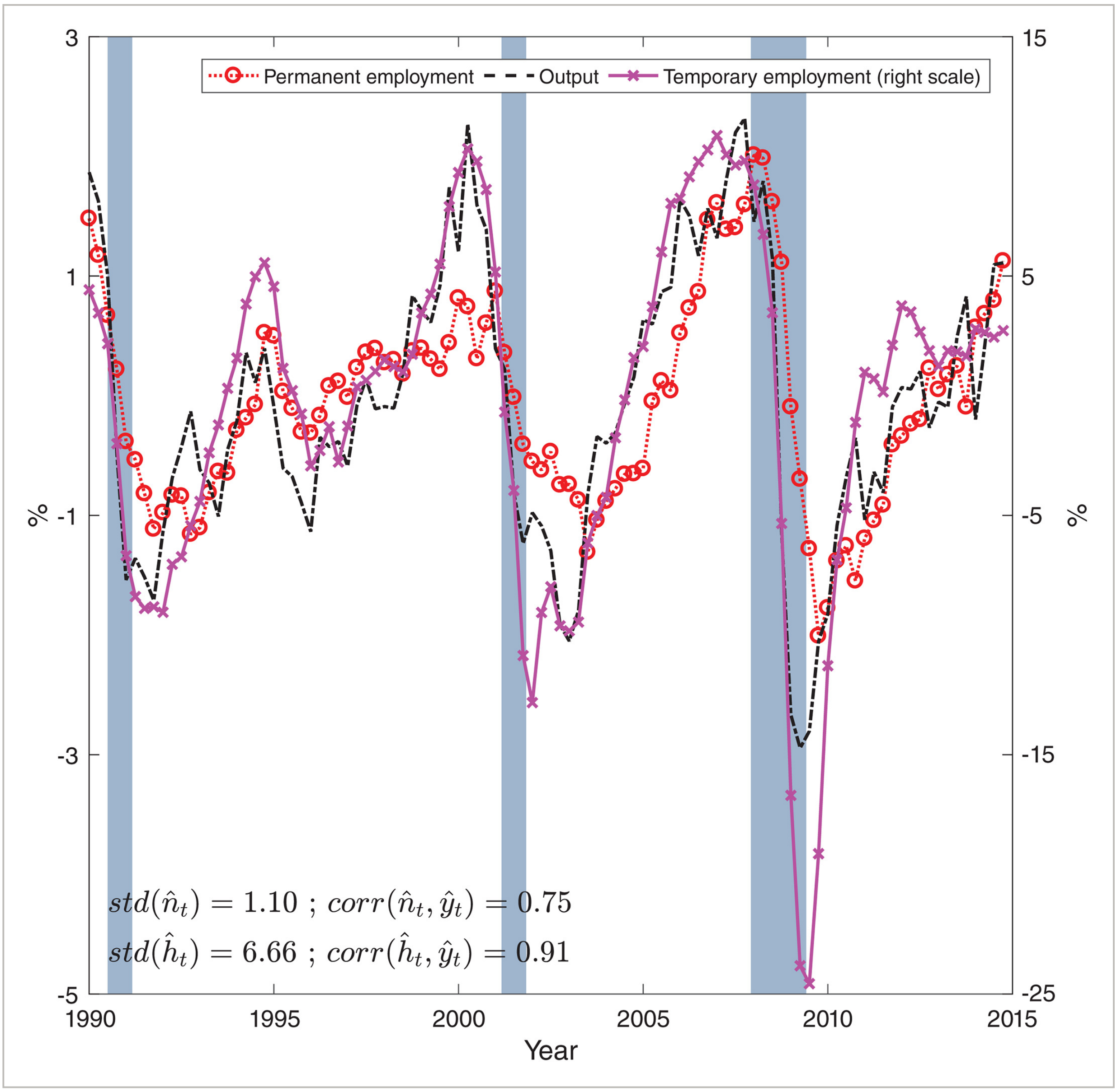

Figure 3

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The HP-Filtered Cyclical Components of Permanent and Temporary Employment (on the Right Scale) along with Output

Sources: BLS and FRED.

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Table 1 reports the descriptive statistics of the relevant macro variables and the results confirm these observations. First, the standard deviation of temporary employment $\text{std}\left(\hat{h}_t\right) = 6.66$ is higher than that of permanent employment $\text{std}\left(\hat{n}_t\right) = 1.10$. Second, the share of temporary employment and output are highly correlated and the correlation coefficient between them is equal to $\text{corr}\left(\hat{e}_t, \hat{y}_t\right) = 0.89$. Third, the correlation coefficient between temporary employment and output $\text{corr}\left(\hat{h}_t, \hat{y}_t\right) = 0.91$ is higher than that between permanent employment and output $\text{corr}\left(\hat{n}_t, \hat{y}_t\right) = 0.75$. Fourth, permanent employment is characterized by a lag that is two quarters in length since the value 0.87 is highest for the correlation coefficient between permanent employment and (lagged and leading) output in Table 1.

Table 1. Cyclical Behavior of Permanent and Temporary Employment in the U.S. Economy

Moments		
Standard deviation of output	std $(\hat{y}_t)$	1.10
Standard deviation of temporary employment	std $(\hat{h}_t)$	6.66
Standard deviation of permanent employment	std $(\hat{n}_t)$	1.10
Standard deviation of share of temporary employment	std $(\hat{e}_t)$	5.79
Correlation of coefficient between the share of temporary employment and output	corr $(\hat{e}_t, \hat{y}_t)$	.89
Correlation of coefficient between temporary employment and output	corr $(\hat{h}_t, \hat{y}_t)$	.91
Correlation of coefficient between		
Permanent employment and three-period lagged output	corr $(\hat{n}_{t+3}, \hat{y}_t)$	.81
Permanent employment and two-period lagged output	corr $(\hat{n}_{t+2}, \hat{y}_t)$	.87
Permanent employment and one-period lagged output	corr $(\hat{n}_{t+1}, \hat{y}_t)$	.84
Permanent employment and output (contemporaneous)	corr $(\hat{n}_t, \hat{y}_t)$	.75
Permanent employment and one-period lead output	corr $(\hat{n}_{t-1}, \hat{y}_t)$	.56
Permanent employment and two-period lead output	corr $(\hat{n}_{t-2}, \hat{y}_t)$	.34
Permanent employment and three-period lead output	corr $(\hat{n}_{t-3}, \hat{y}_t)$	.12

Notes: The sampling period is 1990:Q1–2014:Q4. All of the variables are detrended by the HP-filter and the smoothing parameter is set to 1,600. The standard deviations of output, temporary employment, permanent employment, and the share of temporary employment are reported in percentage terms.

In order to deliver a clear picture, the descriptive statistics and the extent to which our model fits these numbers will be discussed in Section IV.

IV. MAIN RESULTS

Given the model's complexity, we resort to numerical methods to solve the model by linearizing the dynamic equations around the steady state.[13] Let a variable with "∧"denote its percentage deviation from the stationary value, namely, $\hat{B}_t = (B_t - B)/B$ for any endogenous variable B_t in our model. We begin by characterizing a benchmark economy, in which the structural parameters are divided into two groups. Every parameter in the first group is either tied to a commonly used value or calibrated to match the U.S. data, and every parameter in the second group is estimated by using the SMM. We then show how the model produces aggregate variations in response to a shock to TFP given these parameter values. To better explain the role of each of the main channels, we also compare the model's responses to different structural parameters that bring about implications of interest.

A. *Benchmark Parameterization*

We first set the subjective discount factor $\beta = .99$, the intertemporal elasticity of substitution in consumption $1/\theta = 1$ (i.e., $\theta = 1$), the capital depreciation rate $\delta = 0.025$, the capital share $\alpha = .3$, and the values are selected from those commonly used in the business cycle literature. As for the value of the weight parameter in the utility function ψ, we set it to match the stationary value of the employment rate (the ratio of aggregate employment to population), namely, $N = n + h = 0.61$. As regards the productivity of temporary workers relative to permanent ones γ, we set it to match the stationary value of the wage gap between these two kinds of labor $w_h/w_n = 0.80$.[14]

Moreover, the parameter that governs the intertemporal elasticity of substitution in labor χ is set to be 0.055 to match the stationary value of the temporary to aggregate employment ratio $e = h/N = 0.0165$.[15] We follow Hall (2005) by setting the monthly separation rate at 3.5%, which corresponds to the quarterly separation rate of permanent labor $\mu = 1 - (1 - 0.035)^3 - 0.0165 = 0.0849$. In addition, we set the total number of periods required for each new recruit to accumulate the experiences and skills needed to become permanent workers as $b = 4$, which is consistent with the value used by Carneiro, Guimarães, and Portugal (2012). Finally, in line with the value set by Jermann (1998), we simply set $\rho = .99$. Also note that the calibrated values of ψ and γ will vary with respect to different SMM estimates of parameters.[16] Panel A of Table 2 reports the values of the calibrated parameters in the first group.

Table 2. Parameterization of the Benchmark Model

Panel A: Calibrated Parameters		
Category	**Parameter**	**Value**
Preference	Intertemporal elasticity of substitution in consumption ($1/\theta$)	1
	Subjective discount factor (β)	0.99
	Inverse of the Frisch elasticity of labor supply (χ)	0.055
	Disutility of temporary labor supply (ψ)	1.163 (varied)
Technology	Share of physical capital (α)	0.3
	Productivity of temporary relative to permanent workers (γ)	0.397 (varied)
	Capital depreciation rate (δ)	0.025
	Job separation rate (μ)	0.085
	Persistence parameter of the auto-regressive process (ρ)	0.99
	The number of periods required for job training (b)	4

Panel B: Parameters Estimated by the SMM					
σ	ϕ_1	ϕ_2	σ_ϵ^2	J	$\chi^2_{0.05}(1)$
0.9249	11.6759	6.0139	0.6918	0.36	3.84
(0.0024)	(0.6005)	(0.8352)	(0.0396)		

Notes: Based on the statistics for the targeted moments in Panel A of Table 2, the reported values of the SMM parameters with the standard deviations in the parentheses are computed by using the 500 replications of the estimation procedure. The variance of the technology shock is reported in percentage terms.

B. *SMM Estimation and the Quantitative Results*

We apply SMM to estimate the set of the remaining parameters in the second group, which is denoted by a 4 × 1 vector $\Theta = \{\sigma, \phi_1, \phi_2, \sigma_\epsilon^2\}$. The parameters are estimated by minimizing the distance between the moments from the data and the simulated moments based on our model. Let m stand for the vector of moments computed from real data, and m^s for the vector of averaged simulated moments over $M = 20$ simulations, the same sample size as for the data. Accordingly, given the sample size of data T, the estimation of the parameters will proceed by choosing $\tilde{\Theta}$ to solve the optimization problem

$$\tilde{\Theta} = \text{argmin} J(\Theta) = \frac{TM}{1+M}\left[m - m^s(\Theta)\right] \times W\left[m - m^s(\Theta)\right]', \tag{23}$$

where W is a positive-definite weighting matrix, which is computed by the Newey-West estimator.

The five targeted moments that we select are informative for estimating the SMM paramet
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The reason for choosing these targeted moments to estimate the vector of parameters $\Theta = \{\sigma, \phi_1, \phi_2, \sigma_\epsilon^2\}$ can be briefly stated as follows.

First, the standard deviation of the temporary employment $\text{std}(\hat{h}_t)$ is informative in determining the parameter σ, which governs the elasticity of substitution between permanent and temporary employment.[17] Second, the coefficients of correlation between temporary employment and output $\text{corr}(\hat{h}_t, \hat{y}_t)$ and between permanent employment and output $\text{corr}(\hat{n}_t, \hat{y}_t)$ are closely correlated with the intensity parameters of labor adjustment costs ϕ_1 and ϕ_2. Hence, they provide information about the values of ϕ_1 and ϕ_2.[18] Third, we will show that the standard deviations of output $\text{std}(\hat{y}_t)$ and consumption $\text{std}(\hat{c}_t)$ are crucial for determining the variance of the technology shock σ_ϵ^2. Accordingly, we use $\text{std}(\hat{y}_t)$ and $\text{std}(\hat{c}_t)$ to estimate the variance of the technology shock σ_ϵ^2.

Our data are obtained from the BLS and FRED databases during the period 1990:Q1–2014:Q4 in the quarterly frequency, and we thus have the sample size $T = 100$.[19] Panel B of Table 2 summarizes the SMM estimates of parameters. The targeted and selected (nontargeted) moments for the U.S. data are reported in Table 3, along with the simulated moments based on our model. Table 4 displays a summary of the simulated coefficients of correlation between employment and output.

Table 3. Quantitative Results of the Benchmark Model

	Moments	Data	Model
Targeted			
	$\text{std}(\hat{y}_t)$	1.10	1.08
	$\text{std}(\hat{c}_t)$	0.79 (0.72)	0.75 (0.69)
	$\text{std}(\hat{h}_t)$	6.66 (6.05)	6.29 (5.82)
	$\text{corr}(\hat{h}_t, \hat{y}_t)$	0.91	0.83
	$\text{corr}(\hat{n}_t, \hat{y}_t)$	0.75	0.74
Nontargeted (selected)			
	$\text{std}(\hat{i}_t)$	4.15 (3.77)	1.74 (1.61)
	$\text{std}(\hat{n}_t)$	1.10 (1.00)	0.73 (0.68)
	$\text{std}(\hat{N}_t)$	1.17 (1.06)	0.76 (0.70)
	$\text{std}(\hat{e}_t)$	5.79 (5.26)	5.97 (5.53)
	$\text{corr}(\hat{N}_t, \hat{y}_t)$	0.78	0.81
	$\text{corr}(\hat{e}_t, \hat{y}_t)$	0.89	0.77

Notes: The sampling period is 1990:Q1–2014:Q4. All of the variables are detrended by the HP-filter and the smoothing parameter is set to 1,600. The standard deviations of output, consumption, temporary employment, investment, permanent employment, aggregate employment, and the share of temporary employment are displayed in order and they are reported in percentage terms. In addition, the values in the parentheses are the ratios of the standard deviations of the variables to the standard deviations of output. The simulated moments are averages of variables across 1,000 replications and over 100 periods.

Table 4. Coefficients of Correlation between Detrended Output and Employment

Source	Data	Model

Coefficient of Correlation	$\hat{N}_t$	$\hat{h}_t$	$\hat{n}_t$	$\hat{e}_t$	$\hat{N}_t$	$\hat{h}_t$	$\hat{n}_t$	$\hat{e}_t$

Coefficient of Correlation	$\hat{N}_t$	$\hat{h}_t$	$\hat{n}_t$	$\hat{e}_t$	$\hat{N}_t$	$\hat{h}_t$	$\hat{n}_t$	$\hat{e}_t$
$\text{corr}\left(g_{t+3}, \hat{y}_t\right)$	.80	.52	.81	.44	.74	.03	.78	−.06
$\text{corr}\left(g_{t+2}, \hat{y}_t\right)$	.87	.73	.87	.67	.83	.27	.84	.18
$\text{corr}\left(g_{t+1}, \hat{y}_t\right)$	.86	.88	.84	.84	.86	.53	.83	.45
$\text{corr}\left(g_t, \hat{y}_t\right)$	.78	.91	.75	.89	.81	.83	.74	.77
$\text{corr}\left(g_{t-1}, \hat{y}_t\right)$	.60	.83	.56	.83	.57	.62	.51	.58
$\text{corr}\left(g_{t-2}, \hat{y}_t\right)$	.38	.68	.34	.70	.39	.48	.34	.46
$\text{corr}\left(g_{t-3}, \hat{y}_t\right)$	.16	.48	.12	.51	.26	.41	.21	.40

Notes: All the variables are expressed in quarterly frequencies. Then, the HP-filter is applied with respect to all variables to remove the effects of the trend components. Each amount represents the coefficient of correlation between a detrended (lagged or lead) variable and output. For example, the correlation between the one-quarter lead aggregate employment and output of the data equals 0.86.

As reported in Panel B of Table 2, the point estimate of the parameter σ is 0.9249, which implies that the elasticity of substitution between permanent and temporary labor equals 13.3. The intensity parameters of labor adjustment costs ϕ_1 and ϕ_2 are estimated to be around 11.7 and 6.0, respectively, and the variance of the technology shock σ_ϵ^2 is estimated to be 0.6918. Since the chi-square statistic at the 95% level is $\chi^2_{0.05}(1) = 3.84$, the test statistic $J = 0.36$ implies that the model cannot be rejected by the data. Therefore, from Table 3, we can find that the simulated moments of targets, namely, $\left\{\text{std}\left(\hat{y}_t\right), \text{std}\left(\hat{c}_t\right), \text{std}\left(\hat{h}_t\right), \text{corr}\left(\hat{h}_t, \hat{y}_t\right), \text{corr}\left(\hat{n}_t, \hat{y}_t\right)\right\}$, are very close to the corresponding data moments.

Tables 3 and 4 confirm that the benchmark model well characterizes the four stylized facts we have previously documented. First, temporary employment is more volatile than permanent employment. Specifically, the model generates the simulated standard deviation of temporary employment $\text{std}\left(\hat{h}_t\right) = 6.29$, which is much higher than that of permanent employment $\text{std}\left(\hat{n}_t\right) = 0.73$. Second, the model also generates a strong procyclicality of the share of temporary employment, which is exhibited by the simulated coefficient of correlation between the share of temporary employment and output $\text{corr}\left(\hat{e}_t, \hat{y}_t\right) = .77$. Third, the coefficient of correlation between temporary employment and output $\text{corr}\left(\hat{h}_t, \hat{y}_t\right) = .83$ is much higher than that between permanent employment and output $\text{corr}\left(\hat{n}_t, \hat{y}_t\right) = .74$. Fourth, Table 4 shows that our model can generate the two-quarter lagged behavior of permanent employment, since the value $\text{corr}\left(\hat{n}_{t+2}, \hat{y}_t\right) = .84$ is the largest in column 8.

The benchmark model generates simulated volatilities of investment and aggregate employment $\text{std}(\hat{i}_t)$ and $\text{std}(\hat{N}_t)$ equal to 1.74 and 0.76, respectively. These two values are too low to match the values of the data moments, which are 4.15 and 1.17. The reason why our model fails to fit the data well can be explained as follows. On the one hand, the model simulates a low volatility of investment because TFP shocks are highly persistent (i.e., $\rho = .99$). With this high degree of persistence, a large increase in consumption driven by the positive TFP shock restrains an increase in investment, thereby leading to a lower volatility of investment. On the other hand, in line with the RBC models in the literature, our model generates fluctuations in labor markets by resorting only to TFP shocks. Hence, a higher volatility of aggregate employment can be generated as the model is characterized by a larger elasticity of labor supply.[20]

C. *Impulse Response Analysis*

In this subsection, we show how the relevant variables will adjust in response to an unanticipated rise in TFP. Figure 4 depicts their impulse responses to the technology shock in the benchmark economy. Assume that the economy starts at its stationary equilibrium in period 0. In period 1, a 1% persistent increase in TFP leads to changes in the relevant macro variables.

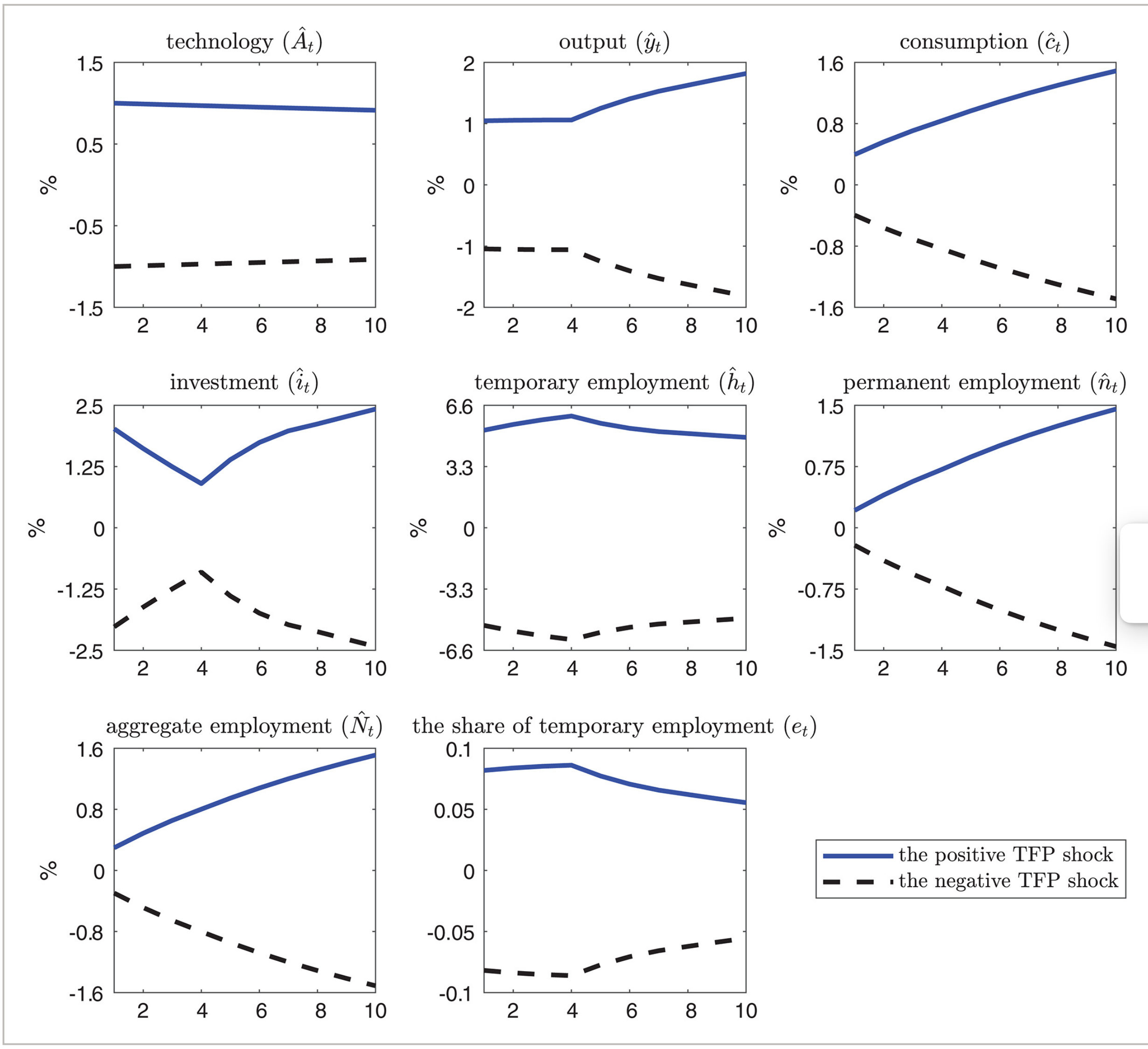

Figure 4

The Impulse Responses of the Main Variables to a 1% Positive (Negative) TFP Shock

First, we restrict our attention to the impulse responses of permanent employment and aggregate employment. Figure 4 shows that permanent employment is increased moderately upon the arrival of the positive shock at the beginning (in period 1), and then permanent employment keeps on rising but at a decreasing rate after period 1. This result can be explained intuitively as follows. When the positive shock occurs, the firm raises its expected future profits and in turn increases its demand for permanent workers because of its forward-looking decisions. Since training permanent workers takes time and incurs additional adjustment costs, this channel causes the rises in permanent employment to be lagged and also relatively smooth. In addition, given that permanent employment accounts for approximately 98% of aggregate employment, it is reasonable for the dynamics of the aggregate employment to be similar to that of permanent employment.

Second, we examine the impulse response of temporary employment to the positive shock. As exhibited in Figure 4, temporary employment rises by more than 5% in the first four periods upon the arrival of the shock and then it declines afterward. In addition, it is noteworthy that in period 1 the increase in temporary employment is considerably larger than that in the permanent counterpart. Here a question arises because of the result displayed in Figure 4. Why does the firm tend to hire temporary rather than permanent workers in the short run in response to the shock? To answer this question, we need to pay special attention to the following two points. First, the adjustment of permanent workers is time consuming since it takes a few periods for the new recruits to accumulate experiences and skills and to become permanent workers. Second, there exists a high degree of substitutability between permanent and temporary labor since the estimated elasticity of substitution is at a high level, that is, $1/(1-\sigma) = 13.3$. Based on these two reasons, when the positive shock arrives, the firm is motivated to hire more temporary workers to substitute for the permanent counterparts even though the former ones are less productive. In addition, when the time horizon is getting longer, the firm will accumulate the stock of permanent workers because their higher productivity is taken into account in the long run. This leads to the decline in temporary employment share after period 4 in which the recruits hi previously at the time of shock are now becoming productive.

Third, the last panel in Figure 4 depicts the impulse response of the share of temporary employment, which is similar to that of temporary employment. Because the share equals the ratio of temporary employment to aggregate employment, the changes in the share of temporary employment can be explained by the changes in both permanent and temporary employment. Given that permanent employment adjusts slowly, the immediate rise in the share of temporary employment upon the arrival of the positive shock mostly results from the increase in temporary employment (over 5%). Thereafter, the share of temporary employment continues to rise at a decreasing rate. This result is derived from the fact that temporary employment keeps on rising at a diminishing rate and meanwhile permanent employment keeps on rising at an increasing rate.

Finally, Figure 4 also indicates that, in response to the increase in TFP, the household tends to have a higher expected life-time income and this increase stimulates its consumption. Moreover, the rise in aggregate employment in response to the positive shock further stimulates investment in physical capital. The v-shaped impulse response of investment is due to the increase in permanent employment under the CES production function in Equation (8). As a result, this shock leads to persistent rises in output.

D. *Implications of Applying Sensitivity Analysis*

Recall that the benchmark model features the following three indispensable channels. The first channel is the substitutability between permanent and temporary labor. The second channel is concerned with the time-to-build mechanism for job training of permanent workers. The third one hinges on the costs of training permanent workers. In what follows, we would like to intuitively explain why our benchmark model can successfully capture the cyclical behavior of permanent and temporary employment in the U.S. economy. To this end, compared with the benchmark economy, we perform sensitivity analysis in the following three cases: (i) where there is a low degree of substitution between permanent and temporary labor (i.e., $\sigma = 0.01$), (ii) a shorter period required by job training (i.e., $b = 1$), and (iii) in the absence of the labor adjustment costs (i.e., $\phi_1 = \phi_2 = 0$).

Figures 5-7, respectively, depict the impulse responses of variables $\{\hat{y}_t, \hat{h}_t, \hat{n}_t, \hat{e}_t\}$ to a 1% persistent increase in TFP in the three cases, and Table 5 reports the simulated moments in association with these three cases. For the purpose of comparing the results of the benchmark economy, in each sensitivity analysis we solely turn off one mechanism without reestimating the parameters. More precisely, except for σ in (i), b in (ii), and ϕ in (iii), the remaining parameters that we use in doing the sensitivity analysis are the same as those calibrated in Section IV.A and estimated in Section IV.B.

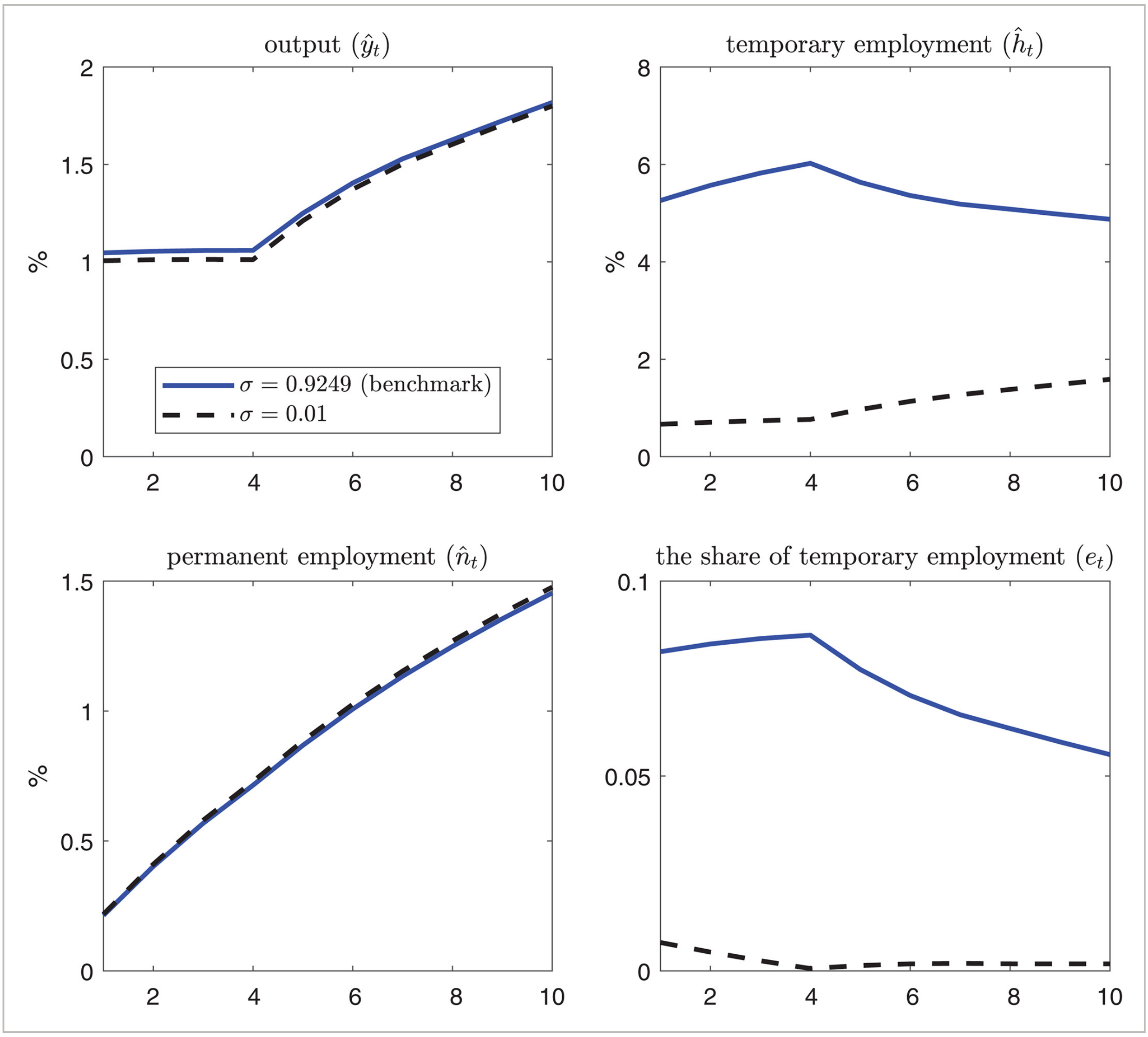

Figure 5

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The Impulse Responses to a 1% Positive TFP Shock Given $\sigma = 0.9249$ (Benchmark) and $\sigma = 0.01$

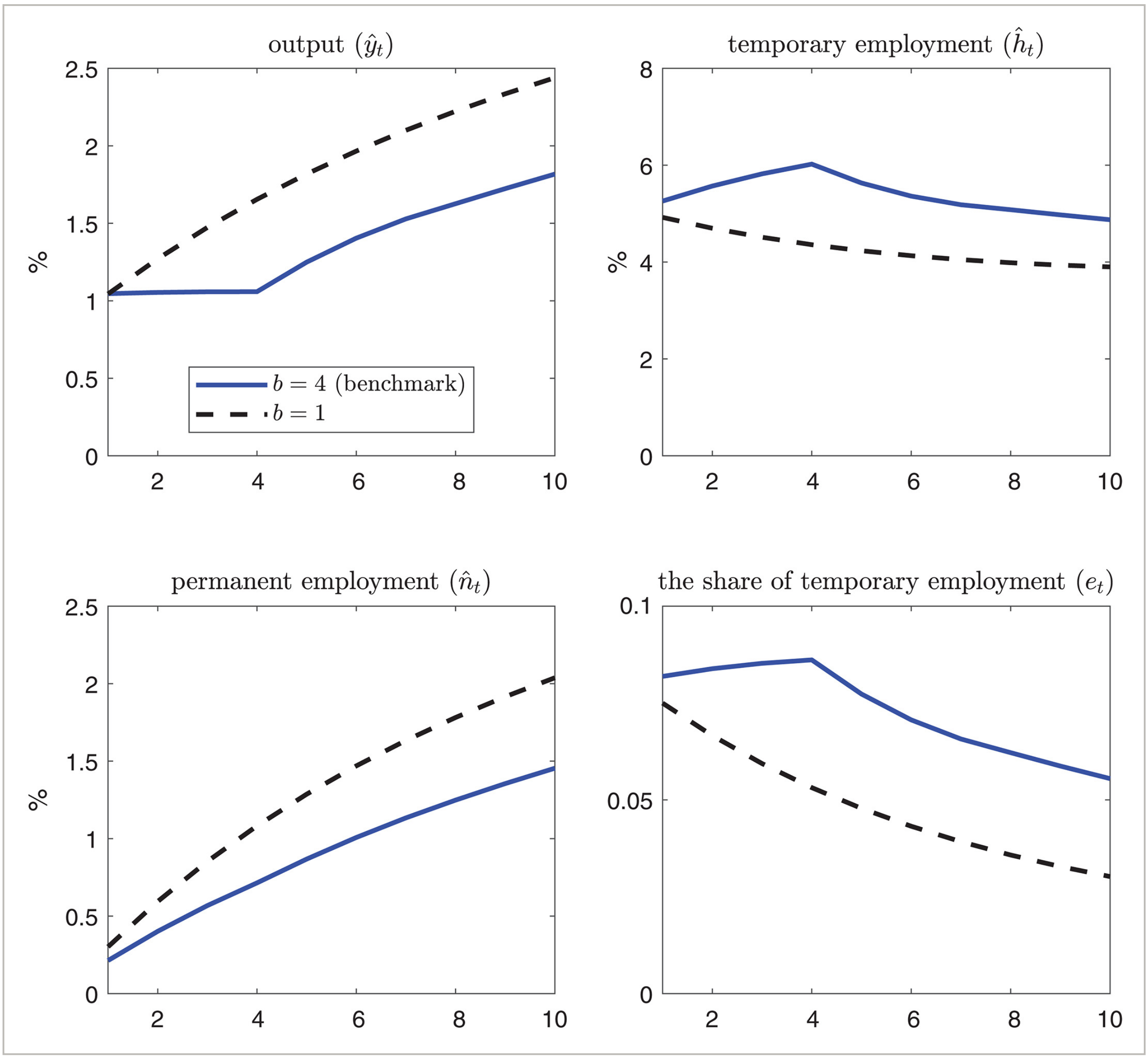

Figure 6

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The Impulse Responses to a 1% Positive TFP Shock Given $b = 4$ (Benchmark) and $b = 1$

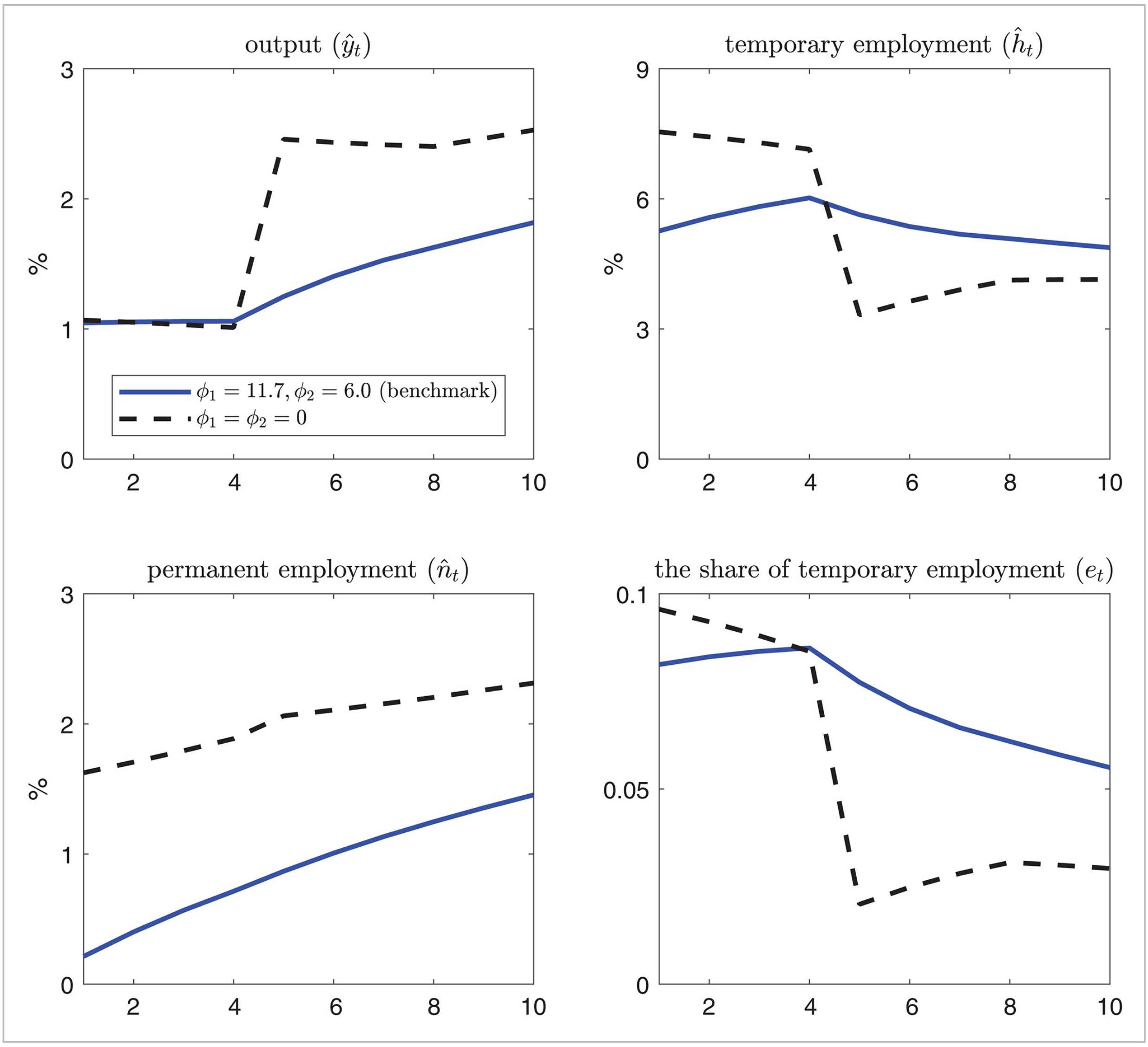

Figure 7

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The Impulse Responses to a 1% Positive TFP Shock Given $\phi_1 = 11.7$ and $\phi_2 = 6.0$ (Benchmark) and $\phi_1 = \phi_2 = 0$

Table 5. Sensitivity Analysis

Panel A: Simulated Moments

Moments	Data	Benchmark	$\sigma = 0.01$	$b = 1$	$\phi_1 = \phi_2 = 0$
$\text{std}\left(\hat{h}_t\right)$	6.66	6.29	0.81	5.06	8.23
$\text{std}\left(\hat{n}_t\right)$	1.10	0.73	0.75	1.09	1.82
$\text{std}\left(\hat{e}_t\right)$	5.79	5.97	0.37	4.71	6.79
$\text{corr}\left(\hat{h}_t, \hat{y}_t\right)$	.91	.83	.97	.78	.22
$\text{corr}\left(\hat{n}_t, \hat{y}_t\right)$	.75	.74	.76	.86	.76

Panel A: Simulated Moments					
Moments	Data	Benchmark	σ = 0.01	b = 1	$\phi_1 = \phi_2 = 0$
$\text{corr}\left(\hat{e}_t, \hat{y}_t\right)$	.89	.77	.57	.63	.06

Panel B: Coefficients of Correlation between Detrended Output and Employment										
Source	Data		Benchmark		σ = 0.01		b = 1		$\phi_1 = \phi_2 = 0$	
Coefficient of Correlations	$\hat{h}_t$	$\hat{n}_t$	$\hat{h}_t$	$\hat{n}_t$	$\hat{h}_t$	$\hat{n}_t$	$\hat{h}_t$	$\hat{n}_t$	$\hat{h}_t$	$\hat{n}_t$
$\text{corr}\left(g_{t+3}, \hat{y}_t\right)$	.52	.81	.03	.78	.52	.78	−.08	.83	−.25	.15
$\text{corr}\left(g_{t+2}, \hat{y}_t\right)$	.73	.87	.27	.84	.61	.84	.13	.92	−.10	.31
$\text{corr}\left(g_{t+1}, \hat{y}_t\right)$	.88	.84	.53	.83	.77	.85	.41	.94	.06	.52
$\text{corr}\left(g_t, \hat{y}_t\right)$	.91	.75	.83	.74	.97	.76	.78	.86	.22	.76
$\text{corr}\left(g_{t-1}, \hat{y}_t\right)$	.83	.56	.62	.51	.68	.54	.74	.67	.30	.68
$\text{corr}\left(g_{t-2}, \hat{y}_t\right)$	.68	.34	.48	.34	.45	.38	.67	.47	.42	.65
$\text{corr}\left(g_{t-3}, \hat{y}_t\right)$	.48	.12	.41	.21	.31	.26	.58	.29	.58	.68

Notes: See the note to Table 3.

In the first case, when we set $\sigma = 0.01$, the elasticity of substitution between permanent and temporary labor $1/(1-\sigma)$ is reduced to around unity (compared with $\sigma = 0.9249$ in the benchmark economy). Figure 5 depicts that, in response to a positive persistent TFP shock, the fall in th degree of substitution reduces the possibility of hiring temporary alternatives as a substitu permanent workers during the training periods. Put differently, given the same wage ratio between the two types of workers, the share of temporary employment is consequently decreased compared to the benchmark case (see the bottom right panel of Figure 5).

The simulated moments in association with the first case (i.e., $\sigma = 0.01$) are depicted in column 4 of Panel A in Table 5, which shows that the following three moments are too low to match the data: the standard deviation of temporary employment $\text{std}\left(\hat{h}_t\right)$, the standard deviation of the share of temporary employment $\text{std}\left(\hat{e}_t\right)$, and the correlation coefficient between the share of temporary employment and output $\text{corr}\left(\hat{e}_t, \hat{y}_t\right)$. We can explain this result by focusing on the impulse response displayed in Figure 5. Compared to the benchmark economy, a lowered σ induces the firm to hire more permanent workers and to lower its current demand for temporary ones. This change leads to the reductions in the volatilities of temporary employment and the share of temporary employment. Moreover, since the possibility of hiring temporary alternatives as a substitute for permanent workers is reduced, the decrease in σ leads the share of temporary employment to be less procyclical.

Intuitively, the above results can be explained by the firm's optimal decision on the allocation between temporary and permanent workers. By substituting Equation (17) into (18), we can infer the following expression:

$$\left[E_t\left(\frac{h_{t+1}}{x_{t+1}}\right)\right]^{1-\sigma} = \Omega_{t+1}, \tag{24}$$

where

$$\Omega_{t+1} = E_t\left[\frac{w_{n,t+1} - \left[(1-\mu)\,\eta_{t+1} - \frac{\lambda_t}{\beta\lambda_{t+1}}\eta_t\right] - \phi_1\left(\frac{l_{1,t+b}}{x_{t+1}}\right)^2 \frac{y_{t+1}}{x_{t+1}}}{w_{h,t+1}}\right] \times \gamma^{\sigma}.$$

Equation (24) states that the marginal rate of technical substitution between temporary and permanent workers $[E_t(h_{t+1}/x_{t+1})]^{1-\sigma}$ equals the marginal cost of hiring permanent workers relative to temporary ones Ω_{t+1}. Equipped with this expression, it is clear that the positive correlation between h_{t+1}/x_{t+1} and Ω_{t+1} hinges on σ. Accordingly, we can infer that a higher value of σ leads to the larger volatility of temporary employment.

In the second case, we discuss the scenario in which the period required by job training is shorter, that is, $b = 1$. In such a case, we show the transitional dynamics of the relevant variables $\left\{\hat{y}_t, \hat{h}_t, \hat{n}_t, \hat{e}_t\right\}$ in response to a positive TFP shock in Figure 6. As exhibited in Figure 6, permanent labor accumulates more rapidly in response to the positive TFP shock, and the temporary employment declines soon after its initial rises. Because job training now takes less time, the firm can quickly accumulate permanent labor to substitute for the temporary labor. Compared to the benchmark case, the shorter period required by job training raises the procyclicality of permanent employment but lowers the procyclicality of temporary employment.

The simulated moments in association with the shorter duration of job training (i.e., $b = 1$) are reported in column 5 of Panel A in Table 5. They illustrate that the correlation between temporary employment and output is lower than that involving the permanent counterpart. In contrast to the benchmark case, permanent employment lags by only one quarter. Figure 6 displays a stark comparison between the results of the two cases.

We then discuss the third case where labor adjustment costs are absent, that is, $\phi_1 = \phi_2 = 0$. The result in Figure 7 reveals that the fluctuations in $\hat{y}_t$, $\hat{h}_t$, $\hat{n}_t$, and $\hat{e}_t$ are amplified because of the reduction in labor adjustment costs. The interpretation is straightforward. Since a sharp increase in permanent workers now becomes less costly, the firm will immediately adjust its stock of permanent workers by creating more new recruits. Accordingly, the moderate decline in the share of temporary employment during the first four periods is largely explained by this immediate adjustment. Moreover, the significant increase in $\hat{y}_t$ and falls in $\hat{h}_t$ and $\hat{e}_t$ at $t = 5$ are derived from the fact that a number of recruits are becoming permanently workers.

Finally, the simulated moments in association with the absence of labor adjustment (i.e., $\phi_1 = \phi_2 = 0$) are reported in column 6 of Panel A in Table 5. In contrast to the smooth adjustment of permanent employment in the benchmark economy, the absence of labor adjustment costs leads to increases in the volatility of permanent labor and the synchronicity between permanent labor and output. As a consequence, the adjustment of permanent labor is more elastic, thereby causing permanent employment to not lag within the cycle.

The presence of the time-to-build mechanism for job training generates the training costs through the missed production opportunities and the wage payment paid to unproductive newly recruited permanent workers. Therefore, the time-to-build mechanism for job training seems to be overlapping with the channel of labor adjustment costs. It is necessary to analytically clarify the difference between the two channels. Based on the firm's optimization condition for the newly recruited permanent workers in Equation (18), we can infer that the wage of these new recruits is determined by:

$$w_{n,t} = E_t\left[\beta^{b-1}\frac{\lambda_{t+b-1}}{\lambda_t}\eta_{t+b-1}\right] - \underbrace{E_t\left[\sum_{a=2}^{b}\beta^{a-1}\frac{\lambda_{t+a-1}}{\lambda_t}w_{n,t+a-1}\right]}_{\text{costs generated by time-to-build}} - \underbrace{\phi_1\left(\frac{l_{1,t+b-1}}{x_t}\right)\frac{y_t}{x_t}}_{\text{marginal labor adjustment costs}}. \tag{25}$$

Equation (25) indicates that the wage of each of the new recruits equals the discounted expected shadow price of permanent labor η_{t+b-1} at the time that they become permanent workers (i.e., at the end of period $t + b - 1$) minus the costs generated by the time-to-build mechanism and the marginal labor adjustment costs. Two points deserve special mention here. First, it should be noted that the costs generated by the time-to-build mechanism are the sum of the wage payments to each of the unproductive new recruits during the periods for each of them to become permanently employed. It is obvious that the costs generated by the time-to-build mechanism are related to the parameter for the total training periods b. Second, the costs generated by the marginal labor adjustment costs reflect the fact that hiring the new recruits is costly under a convex function of new recruits, and hence they are closely related to the intensity parameter ϕ_1 that governs the size of the labor adjustment costs.

The distinction between the time-to-build mechanism and the labor adjustment costs mechanism can be clarified by using the following two special cases. First, in the case where $b = 1$, because job training now takes less time, the firm can then accumulate permanent labor more quickly as a substitute for temporary labor. However, the convexity of labor adjustment costs can still prevent the firm from hiring too many new recruits when the positive TFP shock impacts the economy. This special case can be taken to explain as shown in Figure 6 that permanent employment increases by only a tiny amount in period 1 and exhibits smooth transitional dynamics. Second, in the case where $\phi_1 = \phi_2 = 0$, the absence of labor adjustment costs indicates that the firm tends to hire more new recruits as the positive TFP shock is present. This is why Figure 7 depicts a sharp increase in permanent employment as the positive TFP shock occurs in period 1. In addition, the rise in new recruits further causes the firm to replace temporary workers with trained permanent counterparts in period 5.

E. *Labor Hoarding Behavior*

Figure 4 also displays how the firm reduces its demand for temporary workers but maintains a certain number of skilled and permanent workers during the recession. Since the firm shrinks its stock of permanent workers only slowly, the labor hoarding effect leads to a moderate variation of output in the short run. Specifically, the calibrated model predicts that a 1% decline in TFP brings about a 3.39% decrease in temporary employment as well as a 0.18% decrease in the permanent counterpart. Meanwhile, output drops by 1% upon the arrival of the negative shock and the figure is around 50% lower than the decline in output as the economy reaches another steady state (i.e., −1.5%). This result suggests that the loss of the stock of permanent workers has a persistent impact on the output in the long run.

V. THE EXTENSIONS

This section introduces two possible extensions based on the benchmark model. In Subsection V.A, we consider that the separations of permanent labor are endogenous. In Subsection V suppose that new recruits during training periods are also productive. We will briefly discu the main results in Section IV are still held under the model generalizations.

A. *Endogenous Permanent Labor Separations*

In reality, an explicit distinction between temporary and permanent employment contracts is that the latter are much harder to terminate since the separation costs may be very high. Therefore, the firm's decision as to whether to lay off permanent workers should be subject to the separation costs of permanent employment. However, our benchmark model abstracts from discussions on this fact because we suppose that the separation rate for permanent labor is exogenous. In order to capture this fact, in this subsection we attempt to endogenize the firm's decision to lay off permanent labor.[21]

For simplicity, we suppose that the representative firm produces with a CES production function and by hiring permanent workers x_t, unproductive permanent workers u_t, and temporary workers h_t. The inclusion of u_t is due to their skills having become outdated and no longer advantageous to production. To make the model tractable, we assume that the productivity of u_t is the same as that of temporary workers h_t and that the relative productivity between u_t and x_t is $\gamma < 1$. In addition, u_t and h_t are assumed to be perfect substitutes in production. To be more specific, the production function reported in Equation (8) is modified as:

$$y_t = A_t k_t^{\alpha} \left\{ x_t^{\sigma} + \left[\gamma \left(h_t + u_t \right) \right]^{\sigma} \right\}^{\frac{1-\alpha}{\sigma}}. \tag{26}$$

Similar to the benchmark model, we suppose that the logarithm of TFP ($\log(A_t)$) follows a stationary first-order autoregressive process described in Equation (22). As a result, in this extended model the business cycle fluctuations are driven by aggregate TFP shocks ϵ_t. Later, we will estimate the persistence and variance of aggregate TFP shocks by resorting to the SMM estimation.

In each period, there exists a fixed probability ζ that x_t is transformed into u_t because of physiological and psychological factors. This provides the firm with an incentive to lay off outdated less-productive permanent workers u_t, since it pays the same wages to x_t and u_t.[22] By letting s_t denote the number of workers dismissed, the law of motion of x_t and u_t can be specified as:

$$x_{t+1} = (1-\zeta) x_t + l_{1,t}; 0 < \zeta < 1, \tag{27a}$$

$$u_{t+1} = u_t + \zeta x_t - s_t. \tag{27b}$$

Similar to Equations (12a) and (12b) in the benchmark model, we specify that the hiring costs and dismissal costs of permanent workers are convex functions of the new hire rate $\frac{l_{b,t}}{x_t+u_t}$ and the separation rate $\frac{s_t}{x_t+u_t}$, respectively, and these labor adjustment costs are proportional to output:

$$\Phi_{1,t} = \frac{\phi_1}{2} \left(\frac{l_{b,t}}{x_t + u_t} \right)^2 y_t, \tag{28a}$$

$$\Phi_{2,t} = \frac{\phi_2}{2}\left(\frac{s_t}{x_t + u_t}\right)^2 y_t.$$

(28b)

Equation (28b) indicates that dismissals of permanent workers s_t can generate additional labor adjustment costs. Moreover, the higher intensity of separation costs ϕ_2 reflects the fact that it is harder for the firm to terminate the permanent workers' contracts during recessions.

Based on the above specifications, we provide a detailed derivation of the competitive equilibrium conditions for the modified model in Appendix B. One point should be highlighted here. Based on Equations (27b), (28b), and (B4), the extended model reveals that separation costs are closely related to the firm's forward-looking decision to hire permanent workers. This is because hiring more permanent workers today may cause the firm to separate more permanent workers, in turn generating higher separation costs in the future.[23]

$$\eta_t = E_t \sum_{j=1}^{\infty} \left\{ (1-\zeta)^{j-1} \beta^j \frac{\lambda_{t+j}}{\lambda_t} \left[MP_{x,t+j} - w_{n,t+j} - \frac{\partial \left(\Phi_{1,t+j} + \Phi_{2,t+j}\right)}{\partial x_{t+j}} - \frac{\partial \Phi_{2,t+j}}{\partial s_{t+j}} \frac{\partial s_{t+j}}{\partial x_{t+j}} \right] \right\}.$$

This equation indicates that the shadow price of permanent labor (on the left-hand side) equals the discounted sum of the expected future marginal benefit from accumulating permanent labor (on the right-hand side). More importantly, it reveals that the separation costs are closely related to the firm's forward-looking decision to hire permanent labor.
However, when the separation rate is exogenous in the benchmark model, the average separation costs are fixed as a constant (i.e., $\frac{\Phi_{2,t}}{y_t} = \frac{\phi_2}{2}\mu^2$), and hence separation costs are less relevant to the firm's forward-looking decision to hire permanent workers. This is the reason why we extend our analysis to discuss the situation where the separation of permanent labor is endogenous.

In what follows, we state the parameterization of the extended model. We set the parameters {θ, β, χ, α, δ, b} identical to those in the benchmark model. In addition, similar to the benchmark, we calibrate ψ and γ so as to match $N = 0.61$ and $w_h/w_n = 0.8$. In the present case, the value of ϕ_2 is set to pin down the stationary value of the separation rate $s/(x + u) = 0.085$. Since we do not have the data for the measure of permanent employment with low productivity u in the steady state, we simply assume that u is the same as the stationary value of temporary worker h. Thus, the transition rate from x_t to u_t (i.e., ζ) is set to 0.087 so as to match $u/N = h/N = 0.0165$. Finally, we set the value of ρ to .95. The parameterization of the model with endogenous separations is summarized in column (b) of Panel A in Table 6.

Table 6. Parameterization of the Extended Models

Panel A: Calibrated Parameters

Parameter	Model (a)	(b)	(c)
Preference			
Intertemporal elasticity of substitution in consumption ($1/\theta$)	1	1	2
Subjective discount factor (β)	0.99	0.99	0.99
Inverse of the Frisch elasticity of labor supply (χ)	0.055	0.055	0.055
Disutility of temporary labor supply (ψ)	1.163*	1.196*	1.567*
Technology			
Share of physical capital (α)	0.3	0.3	0.3
Productivity of temporary relative to permanent workers (γ)	0.397*	0.546*	0.490*
Capital depreciation rate (δ)	0.025	0.025	0.025
Job separation rate (μ)	0.085	-	0.085
Persistence parameter of the auto-regressive process (ρ)	0.99	0.95	0.99
The number of periods required for job training (b)	4	4	4
The transition rate from x_t to u_t (ζ)	—	0.087	—

Panel B: Estimated Parameters by the SMM

Model	σ	ϕ_1	ϕ_2	σ_ϵ^2	J	$\chi^2_{0.05}(1)$
(a)	0.9249	11.6759	6.0139	0.6918	0.36	3.84
	(0.0024)	(0.6005)	(0.8352)	(0.0396)		
(b)	0.9903	6.9103	—	0.3990	0.60	3.84
	(0.0014)	(0.3581)	—	(0.0317)		
(c)	0.7755	12.9076	7.0328	0.7693	1.42	3.84
	(0.0075)	(0.3258)	(2.0015)	(0.0461)		

Notes: Models (a), (b), and (c) are the benchmark model, the model with endogenous separations, and the model with productive new recruits, respectively. In Panel A, the values of the parameters with superscript "*" are varied in the SMM estimation. In Panel B, based on the statistics for the targeted moments in Panel A of Table 7, the reported values of the

SMM parameters with the standard deviations in the parentheses are computed by using the 500 replications of the estimation procedure. The variance of the technology shock is reported in percentage terms.

We use the targeted moments $\{\text{std}(\hat{y}_t), \text{std}(\hat{c}_t), \text{corr}(\hat{h}_t, \hat{y}_t), \text{corr}(\hat{n}_t, \hat{y}_t)\}$ to estimate the parameters $\{\sigma, \phi_1, \sigma_\epsilon^2\}$ by applying the SMM. The estimated parameters are reported in column (b) of Panel B in Table 6. The point estimate of the parameter σ is 0.9903, which implies that the permanent and temporary labors are nearly perfect substitutes in production. The estimates of the intensity parameters associated with the labor adjustment costs ϕ_1 and variance of the technology shock σ_ϵ^2 are 6.9103 and 0.3990, respectively. Since the chi-square statistic at the 95% level is $\chi^2_{0.05}(1) = 3.84$, the test statistic $J = 0.60$ implies that the model cannot be rejected by the data.

The simulated moments in column (b) of Panels A and B of Table 7 show that the model with endogenous separations can capture the four stylized facts in labor markets. First, temporary employment is more volatile than permanent employment (i.e., $\text{std}(\hat{h}_t) = 13.63 > \text{std}(\hat{n}_t) = 0.84$). Second, the model also generates a strong procyclicality of the share of temporary employment (i.e., $\text{corr}(\hat{e}_t, \hat{y}_t) = 0.73$). Third, the coefficient of correlation between temporary employment and output is much higher than that between permanent employment and output (i.e., $\text{corr}(\hat{h}_t, \hat{y}_t) = 0.77 > \text{corr}(\hat{n}_t, \hat{y}_t) = 0.65$). Fourth, permanent employment lags behind output by two quarters (i.e., $\text{corr}(\hat{n}_{t+2}, \hat{y}_t) = 0.90$ is the largest in the second subcolumn of column (b)).

Table 7. Quantitative Results of the Extended Models

Panel A: Simulated Moments				
Moments	**Data**	**Model**		
		(a)	**(b)**	**(c)**
$\text{std}(\hat{y}_t)$	1.10	1.08	1.04	1.03
$\text{std}(\hat{c}_t)$	0.79	0.75	0.78	0.67
$\text{std}(\hat{i}_t)$	4.15	1.74	3.31	1.76
$\text{std}(\hat{h}_t)$	6.66	6.29	13.63	6.04
$\text{std}(\hat{n}_t)$	1.10	0.73	0.84	0.76
$\text{std}(\hat{N}_t)$	1.17	0.76	0.86	0.76
$\text{std}(\hat{e}_t)$	5.79	5.97	13.41	5.90
$\text{corr}(\hat{h}_t, \hat{y}_t)$	.91	.83	.77	.75
$\text{corr}(\hat{n}_t, \hat{y}_t)$	.75	.74	.65	.69

Panel A: Simulated Moments			
Moments	Data		Model

Panel B: Coefficients of Correlation between Detrended Output and Employment								
			Model					
Source	Data		(a)		(b)		(c)	
Coefficient of Correlations	$\hat{h}_t$	$\hat{n}_t$	$\hat{h}_t$	$\hat{n}_t$	$\hat{h}_t$	$\hat{n}_t$	$\hat{h}_t$	$\hat{n}_t$
$\mathrm{corr}(g_{t+3}, \hat{y}_t)$	.52	.81	.03	.78	−.19	.86	−.22	.79
$\mathrm{corr}(g_{t+2}, \hat{y}_t)$	.73	.87	.27	.84	.03	.90	−.10	.83
$\mathrm{corr}(g_{t+1}, \hat{y}_t)$	.88	.84	.53	.83	.34	.85	.21	.80
$\mathrm{corr}(g_t, \hat{y}_t)$	.91	.75	.83	.74	.77	.65	.75	.69
$\mathrm{corr}(g_{t-1}, \hat{y}_t)$	.83	.56	.62	.51	.66	.44	.61	.44
$\mathrm{corr}(g_{t-2}, \hat{y}_t)$	.68	.34	.48	.34	.55	.26	.47	.24
$\mathrm{corr}(g_{t-3}, \hat{y}_t)$	.48	.12	.41	.21	.45	.11	.36	.07

Notes: Models (a), (b), and (c) are the benchmark model, the model with endogenous separations, and the model with productive new recruits, respectively. In the estimation of models (a) and (c), the target moments are $\mathrm{std}(\hat{y}_t)$, $\mathrm{std}(\hat{c}_t)$, $\mathrm{std}(\hat{h}_t)$, $\mathrm{corr}(\hat{h}_t, \hat{y}_t)$, and $\mathrm{corr}(\hat{n}_t, \hat{y}_t)$, and in the estimation of model (b), the target moments are $\mathrm{std}(\hat{y}_t)$, $\mathrm{std}(\hat{c}_t)$, $\mathrm{corr}(\hat{h}_t, \hat{y}_t)$, and $\mathrm{corr}(\hat{n}_t, \hat{y}_t)$. The calculation process of the simulated moments is in accordance with those in Tables 3 and 4 (see the notes in Tables 3 and 4).

We now turn our attention to the labor hoarding behavior in the presence of endogenous separations of permanent employment. In order to focus on the labor hoarding behavior i recessions, as shown in Figure 8, we only depict the impulse responses to a 1% negative TFP shock in the extended model with endogenous separations. It should be noted that in this extended model, we process the quantitative results (in Table 7) by using aggregate TFP shocks which are normally distributed with zero mean and finite variance σ_ϵ^2. As shown in Figure 8, the solid line denotes the case of the intensity of separation costs $\phi_2 = 5.513$, which is the calibrated value we use for the estimation, and the dashed line represents the case where $\phi_2 = 20$ as a comparison exercise.[24] Then, in the case where $\phi_2 = 5.513$ (the calibrated value of ϕ_2), two points regarding the labor hoarding behavior merit special attention. First, a 1% decline in TFP instantly decreases temporary employment by 17.42 percentage points and it also decreases the permanent counterpart by 0.08 percentage points. The outcome shows that more labor hoarding occurs during recessions since it is much harder for firms to terminate permanent employment contracts because of higher separation costs. Second, the persistent decline in the stock of permanent employment strengthens the contraction of output in the long run. Moreover, by comparing the cases where $\phi_2 = 5.513$ and $\phi_2 = 20$, we find that at the moment of the negative TFP shock the firm is inclined to lay off fewer permanent workers and hire fewer temporary ones when it faces the higher separation costs.

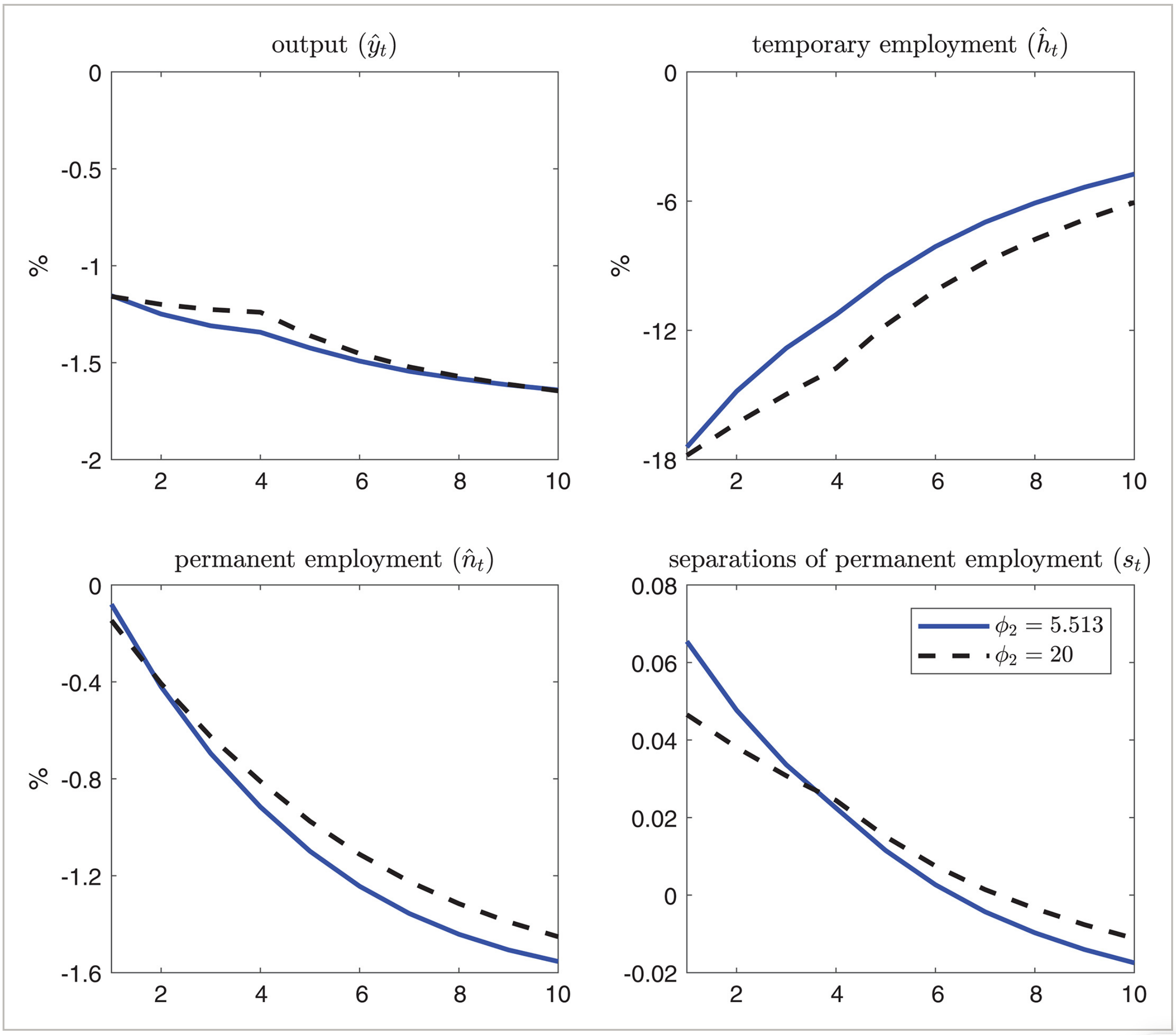

Figure 8

Open in figure viewer | PowerPoint

The Impulse Responses to a 1% Negative TFP Shock in the Extended Model with Endogenous Separations

B. *Productive New Recruits of Permanent Workers*

In this subsection, we would like to extend our model to consider the case where the newly recruited permanent workers are productive but less than fully trained permanent workers during their training periods, and then check whether the main results in the benchmark model still hold. In this extended model, we assume that the productivity of new recruits v_t is the same as that of temporary workers h_t. We also assume that v_t and h_t are perfect substitutes in production. To be more specific, the modified production function of the firm can be expressed as:

$$y_t = A_t k_t^{\alpha} \left\{ x_t^{\sigma} + \left[\gamma \left(h_t + v_t \right) \right]^{\sigma} \right\}^{\frac{1-\alpha}{\sigma}} ; \gamma < 1. \tag{29}$$

As indicated in Equation (29), the productivity of the new recruits v_t is lower than the productivity of permanent workers that have completed their job training x_t (i.e., $\gamma < 1$). Based on the specification of the modified production function in Equation (29), we provide a detailed derivation of the competitive equilibrium conditions for the extended model in Appendix C.

In this extended model, we assume that $\theta = 2$ to smooth consumption. The calibrated values of $\{\beta, \chi, \alpha, \delta, \mu, \rho, b\}$ are set to be identical to those in the benchmark model. In addition, the calibration procedure of ψ and γ is similar to that implemented in the benchmark model (i.e., we calibrate ψ and γ so as to match $N = 0.61$ and $w_h/w_n = 0.8$). Accordingly, the parameterization of the model with productive new recruits is summarized in column (c) of Panel A in Table 6.

Similar to the estimation in the benchmark model, we select the targeted moments $\{\text{std}(\hat{y}_t), \text{std}(\hat{e}_t), \text{std}(\hat{h}_t), \text{corr}(\hat{h}_t, \hat{y}_t), \text{corr}(\hat{n}_t, \hat{y}_t)\}$ to estimate the parameters $\{\sigma, \phi_1, \phi_2, \sigma_\epsilon^2\}$ by applying the SMM. The estimates of the model parameters are reported in column (c) of Panel B in Table 6. The point estimate of σ is 0.7755. The estimated intensity parameters of the labor adjustment costs ϕ_1 and ϕ_2 are 12.9076 and 7.0328, respectively. In addition, the estimate of the variance of the technology shock σ_ϵ^2 is 0.7693. Since the chi-square statistic at the 95% level is $\chi^2_{0.05}(1) = 3.84$, the test statistic $J = 1.42$ implies that the model cannot be rejected by the data.

From the simulated moments shown in column (c) of Panels A and B in Table 7, we show that the model with endogenous separations can capture the four stylized facts in the labor market. First, temporary employment is more volatile than permanent employment (i.e., $\text{std}(\hat{h}_t) = 6.04 > \text{std}(\hat{n}_t) = 0.76$). Second, the model also generates a strong procyclicality of the share of temporary employment (i.e., $\text{corr}(\hat{e}_t, \hat{y}_t) = 0.67$). Third, the coefficient of correlation betwee temporary employment and output is still higher than that between permanent employme output (i.e., $\text{corr}(\hat{h}_t, \hat{y}_t) = 0.75 > \text{corr}(\hat{n}_t, \hat{y}_t) = 0.69$). Fourth, permanent employment is featured by the two-quarter lagged behavior (i.e., $\text{corr}(\hat{n}_{t+2}, \hat{y}_t) = 0.83$ is the largest in the second subcolumn of column (c)).

VI. CONCLUSION

The data for the U.S. labor market reveal the following stylized facts involving permanent and temporary employment: (1) a much higher volatility of temporary employment than of permanent employment; (2) a strong procyclicality of the share of temporary employment; (3) the lagged behavior of permanent employment; and (4) a stronger correlation between temporary employment and output than in the case of the permanent counterpart. Given that the standard

RBC model does not draw an explicit distinction between permanent and temporary employment, it is unable to provide a plausible explanation for these observed facts.

This paper proposes three channels related to distinguishing temporary employment from permanent employment. The first channel has to do with the substitutability between permanent and temporary workers. The second channel is concerned with the time-to-build mechanism for job training, which leads new recruits to become productive permanent workers. The third channel relates to the costs of training permanent workers. By incorporating these three channels into the standard RBC model, this paper finds that the modified model is able to explain the above stylized facts in the U.S. labor market. Moreover, this paper also finds that the modified model provides a plausible explanation for the firms' decision to hoard labor when the economy experiences a recession.

Before we end this paper, one point deserves special attention. Following the canonical RBC model, the labor matching friction is absent from the current setup since we are ruling out the relevance of unemployment for the main facts of interest in this paper. In future work, it could be interesting to incorporate the matching friction and use it to deliver a clearer understanding of why firms hire labor on a temporary or permanent basis.

APPENDIX A A

This Appendix provides a brief derivation of the stationary values of essential macro-variables. Given $\lambda_t = \left[c_t - \frac{\psi}{1+\chi}\left(n_t^{1+\chi} + h_t^{1+\chi}\right)\right]^{-\theta}$, the competitive equilibrium for the economy is composed of 16 conditions (3)–(10), (13), and (15)–(21). The endogenous variables are the sequences of quantities $\{y_t, c_t, h_t, n_t, x_t, v_t, l_{1,t}, i_t, k_t, z_t, d_t\}$ and prices $\{r_t, w_{h,t}, w_{n,t}, \eta_t, p_t\}$. Given $A = 1$ in the steady state, the stationary relationship at the competitive equilibrium can be expressed as:

$$z = 1, \tag{A1}$$

$$w_h = \left(1 - \frac{\phi_1 + \phi_2}{2}\mu^2\right)(1-\alpha)\frac{\left(\frac{\gamma h}{x}\right)^{\sigma} A}{1 + \left(\frac{\gamma h}{x}\right)^{\sigma}} \times \left(\frac{k}{x}\right)^{\alpha}\left(\frac{h}{x}\right)^{-1}\left[1 + \left(\frac{\gamma h}{x}\right)^{\sigma}\right]^{\frac{1-\alpha}{\sigma}}, \tag{A2}$$

$$w_n = w_h (1 + b\mu)^{\chi}\left(\frac{h}{x}\right)^{-\chi}, \tag{A3}$$

$$\eta = \frac{\beta}{1-\beta}\frac{1-\beta^{b}}{\beta^{b}}w_{n} + \frac{\phi_{1}\mu y}{\beta^{b-1}x},$$

(A4)

$$h = \left(\frac{w_{h}}{\psi}\right)^{\frac{1}{\chi}},$$

(A5)

$$\gamma = \left\{\frac{\frac{\beta D_{1}}{1-\beta(1-\mu-D_{1})} + \left[\frac{\beta D_{1}(D_{2}+\phi_{1}\mu^{2})}{1-\beta(1-\mu-D_{1})} - D_{2}\right]\frac{1}{D_{3}}}{\frac{(h/x)^{\sigma-1}}{w_{h}/w_{n}} - \left[\frac{\beta D_{1}(D_{2}+\phi_{1}\mu^{2})}{1-\beta(1-\mu-D_{1})} - D_{2}\right]\frac{(h/x)^{\sigma}}{D_{3}}}\right\}^{\frac{1}{\sigma}},$$

(A6)

where $D_{1} = \frac{1-\beta}{1-\beta^{b}}\beta^{b-1}, D_{2} = \frac{1-\beta}{1-\beta^{b}}\phi_{1}\mu$, and

$$D_{3} = \left(1 - \frac{\phi_{1}+\phi_{2}}{2}\mu^{2}\right)(1-\alpha),$$

(A6)

$$\frac{k}{x} = \left\{\frac{\frac{1}{\beta} - 1 + \delta}{\left(1 - \frac{\phi_{1}+\phi_{2}}{2}\mu^{2}\right)\alpha A\left[\gamma^{\sigma}\left(\frac{h}{x}\right)^{\sigma} + 1\right]^{\frac{1-\alpha}{\sigma}}}\right\}^{\frac{1}{\alpha-1}},$$

$$\frac{c}{k} = \frac{\frac{1}{\beta} - 1 + \delta}{\alpha} - \delta,$$

(A8)

$$y = Ak^{\alpha}\left[x^{\sigma} + (\gamma h)^{\sigma}\right]^{\frac{1-\alpha}{\sigma}},$$

(A9)

$$i = \delta k,$$

(A10)

$$l_1 = \mu x,$$

(A11)

$$v = b l_1,$$

(A12)

$$n = x + v,$$

(A13)

$$d = \left(1 - \frac{\phi_1 + \phi_2}{2}\mu^2\right)(1-\alpha)\,y - w_h h - w_n n,$$

(A14)

$$p = \frac{\beta}{1-\beta}d,$$

(A15)

$$r = \frac{1}{\beta} - 1 + \delta.$$

(A16)

APPENDIX B B

This Appendix demonstrates the competitive equilibrium conditions for the model with endogenous separations. In this modified model, the firm chooses the sequence {k_t, h_t, $l_{b,t}$ u_{t+1}} to maximize Equation (14), subject to Equations (10)–(11), (13), and (26)–(28b). Let η_t denote the corresponding Lagrange multiplier. The optimum conditions necessary for the firm with respect to the indicated variables are:

$$k_t : r_t = \alpha\left[1 - \frac{\phi_1}{2}\left(\frac{l_{1,t+b-1}}{x_t + u_t}\right)^2 - \frac{\phi_2}{2}\left(\frac{s_t}{x_t + u_t}\right)^2\right]\frac{y_t}{k_t},$$

(B1)

$$h_t : w_{h,t} = (1-\alpha)\left[1 - \frac{\phi_1}{2}\left(\frac{l_{1,t+b-1}}{x_t + u_t}\right)^2 - \frac{\phi_2}{2}\left(\frac{s_t}{x_t + u_t}\right)^2\right] \times \frac{\left[\gamma\left(h_t + u_t\right)\right]^{\sigma}}{x_t^{\sigma} + \left[\gamma\left(h_t + u_t\right)\right]^{\sigma}} \frac{y_t}{h_t + u_t},$$

(B2)

$$l_{b,t} : E_t\left[\sum_{a=1}^{b} \beta^{a-1} \frac{\lambda_{t+a-1}}{\lambda_t} w_{n,t+a-1}\right] + \phi_1\left(\frac{l_{1,t+b-1}}{x_t + u_t}\right)\frac{y_t}{x_t + u_t} = E_t\left[\beta^{b-1}\frac{\lambda_{t+b-1}}{\lambda_t}\eta_{t+b-1}\right],$$

(B3)

$$x_{t+1} : \eta_t = \beta E_t\left\{\frac{\lambda_{t+1}}{\lambda_t}\left[\frac{\left[1 - \frac{\phi_1}{2}\left(\frac{l_{1,t+b}}{x_{t+1}+u_{t+1}}\right)^2 - \frac{\phi_2}{2}\left(\frac{s_{t+1}}{x_{t+1}+u_{t+1}}\right)^2\right](1-\alpha)x_{t+1}^{\sigma}}{x_{t+1}^{\sigma} + \left[\gamma\left(h_{t+1}+u_{t+1}\right)\right]^{\sigma}} \times \frac{y_{t+1}}{x_{t+1}} - w_{n,t+1} + \left(\frac{\phi_1 l_{1,t+b}^2 + \phi_2 s_{t+1}^2}{\left(x_{t+1}+u_{t+1}\right)^2} - \frac{\phi_2 \zeta s_{t+1}}{x_{t+1}+u_{t+1}}\right) \times \frac{y_{t+1}}{x_{t+1}+u_{t+1}} + (1-\zeta)\,\eta_{t+1}\right]\right\},$$

and

$$u_{t+1} : \phi_2 \frac{s_t y_t}{\left(x_t + u_t\right)^2} + \beta E_t\left\{\frac{\lambda_{t+1}}{\lambda_t}\left[\left(\frac{\phi_1 l_{1,t+b}^2 + \phi_2 s_{t+1}^2}{\left(x_{t+1}+u_{t+1}\right)^2} - \frac{\phi_2 s_{t+1}}{x_{t+1}+u_{t+1}}\right) \times \frac{y_{t+1}}{x_{t+1}+u_{t+1}}\right]\right\} = \beta E_t\left[\frac{\lambda_{t+1}}{\lambda_t}\left(w_{n,t+1} - w_{h,t+1}\right)\right].$$

(B5)

The competitive equilibrium for the economy is composed of 18 conditions (3)–(7), (10), (13), (19)–(21), (26)-(27b), and (B1)–(B5). The endogenous variables are the sequences of quantities $\{y_t, c_t, h_t, n_t, x_t, s_t, u_t, v_t, l_{1,t}, i_t, k_t, z_t, d_t\}$ and prices $\{r_t, w_{h,t}, w_{n,t}, \eta_t, p_t\}$.

APPENDIX C C

This Appendix provides a brief derivation to show the competitive equilibrium conditions for the model when the newly recruited permanent workers are productive during their training periods. In this modified model, the firm chooses the sequence $\{k_t, h_t, l_{b,t}, x_{t+1}\}$ to maximize Equation (14), subject to Equations (9)–(13) and (29). Let η_t denote the corresponding Lagrange multiplier. The optimum conditions necessary for the firm with respect to the indicated variables are:

$$k_t : r_t = \alpha \left[1 - \frac{\phi_1}{2}\left(\frac{l_{1,t+b-1}}{x_t}\right)^2 - \frac{\phi_2}{2}\mu^2\right]\frac{y_t}{k_t}, \tag{C1}$$

$$\begin{aligned} h_t : w_{h,t} = (1-\alpha)\left[1 - \frac{\phi_1}{2}\left(\frac{l_{1,t+b-1}}{x_t}\right)^2 - \frac{\phi_2}{2}\mu^2\right] \\ \times \frac{[\gamma(h_t+v_t)]^\sigma}{x_t^\sigma + [\gamma(h_t+v_t)]^\sigma}\frac{y_t}{h_t+v_t}, \end{aligned} \tag{C2}$$

$$\begin{aligned} l_{b,t} : E_t\left[\sum_{a=1}^{b}\beta^{a-1}\frac{\lambda_{t+a-1}}{\lambda_t}\left(w_{n,t+a-1} - w_{h,t+a-1}\right)\right] \\ + \phi_1\frac{l_{1,t+b-1}}{x_t^2}y_t = E_t\left[\beta^{b-1}\frac{\lambda_{t+b-1}}{\lambda_t}\eta_{t+b-1}\right], \end{aligned}$$

and

$$\begin{aligned} x_{t+1} : \eta_t = \beta E_t\left\{\frac{\lambda_{t+1}}{\lambda_t}\left[\frac{\left[1 - \frac{\phi_1}{2}\left(\frac{l_{1,t+b}}{x_{t+1}}\right)^2 - \frac{\phi_2}{2}\mu^2\right](1-\alpha)x_{t+1}^\sigma}{x_{t+1}^\sigma + [\gamma(h_{t+1}+v_{t+1})]^\sigma}\right.\right. \\ \times\frac{y_{t+1}}{x_{t+1}} + \phi_1\left(\frac{l_{1,t+b}}{x_{t+1}}\right)^2\frac{y_{t+1}}{x_{t+1}} \\ \left.\left. - w_{n,t+1} + (1-\mu)\eta_{t+1}\right]\right\}. \end{aligned}$$

(C4)

The competitive equilibrium for the economy is composed of 16 conditions (3)–(7), (9)–(10), (13), (19)–(21), (29), and (C1)–(C4). The endogenous variables are the sequences of quantities $\{y_t, c_t, h_t, n_t, x_t, v_t, l_{1,t}, i_t, k_t, z_t, d_t\}$ and prices $\{r_t, w_{h,t}, w_{n,t}, \eta_t, p_t\}$.

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