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Abstract

In line with New-Keynesian predictions and certain historical trajectories that tracked by inflation during past crises, the context of the Great Recession should have spurred a sharp fall in inflation or even deflation. On the contrary, the sensitivity of inflation to changes in unemployment has diminished, giving rise to the paradox of missing disinflation. By investigating this paradox, this article develops a variant of the New-Keynesian models where mechanisms of depreciation of human capital are implemented. In the model, rising unemployment translates into a relatively large increase in long-term unemployment. Unemployed people with low levels of human capital become dominant and more workers are now likely to suffer from depreciation of human capital. The depreciation weakens the intensity with which the unemployed prospect new jobs and moderates the decline in wages and prices. Calibrated to the United States economy, model simulations show that this model variant compares relatively better the highlights of missing disinflation than a New-Keynesian without depreciation of human capital. In response to shocks of the same size, the response of inflation in the model with depreciation of human capital is 3 to 4-fold less than in standard New-Keynesian models.

JEL classification: E31, E32, J24.

Key words: Missing Disinflation, Deflation, Human Capital Depreciation, Unemployment, Great Recession

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1 Introduction

Following the Great Recession (GR), the decline in inflation (Figure 7 in Appendix) in most advanced economies, particularly in the United States, was relatively moderate in view of the unemployment (Figure 8 in appendix). In line with New-Keynesian predictions and certain historical trajectories observing inflation during past crises, the context of the GR should have triggered a sharp fall in inflation or deflation (Blanchard et al., 2015). The disinflation of the GR was relatively less sustained than the disinflation following the recessions of July 1990 and March 2001 (Figure 9 in the appendix). However, the rise of unemployment during these two crises was less important than that of the GR. In fact, the rise of unemployment was effectively 5.6% to 7.5% for the 1990 recession, 4% to 6% for the 2001 crisis, and 4.6% to 9.6% for the GR (OECD, 2018). Simon et al. (2013) argue that the 2008 crisis should have led to about 3% deflation in the United States. Clearly, the decline in inflation following the GR seems to have not been in line with predictions or expectations, hence the paradox of missing disinflation.

In view of the importance of the unemployment-inflation relationship for both the design of economic policies and the structure of certain theoretical models, this paradox has become an interesting subject of economic analysis. In particular, the validity of the Phillips curve following the GR has been the subject of numerous investigations. Most of them conclude that it is valid but point to an equally important change in the traditionally accepted relationship between inflation and unemployment. The curve is now a reflection of the Phillips curve of the 1960s, where the negative relationship is held by the unemployment rate and the level of inflation instead of changes in inflation (Ball and Mazumder, 2018; Blanchard et al., 2016). This change marks a flattening of the Phillips curve, and thus a slump in the sensitivity of inflation to changes in unemployment (Ball and Mazumder, 2011; Blanchard et al., 2015; Simon et al., 2013; Stock, 2011).

Because of this evidence, investigations into the causes and mechanisms of missing disinflation are proving successful in contributing to economics. Factors such as globalization, demographic aging, anchoring expectations and long-term unemployment have already been identified in the literature as possible causes of the missing disinflation. However, the extent of these factors in the explanation of the paradox in New-Keynesian theoretical models has rarely been investigated. These models remain the theoretical frameworks most proven for the analysis of the unemployment-inflation relationship. This article contributes to this strand of literature and develops a variant of the New-Keynesian models to illustrate the mechanisms underlying the missing disinflation.

The missing disinflation is possibly the product of the effect of one of the identified factors or a combination of these. Plausibly, due to globalization, trading between advanced and emerging countries causes the inflation of advanced economies to be less sensitive to domestic factors (Ihrig

et al., 2010; Neely and Rapach, 2011). Another factor is that the aging of the population contributes to the collapse of the relationship by generating a kind of viscosity of wages and prices given its negative effect on participation in the labor market (Anderson et al., 2014; Katagiri et al., 2014). Another interesting argument is that the missing disinflation is due to the success of central banks in anchoring inflation expectation (Ball and Mazumder, 2011; Blanchard et al., 2015; Simon et al., 2013). The gain in credibility acquired by central banks since the 1990s would contribute to further strengthening expectations. As a result, workers and firms are becoming less and less aware of future price increases and decreases by being very weighted in wage adjustments. Ball and Mazumder (2011) and Gordon (2013), however, argue that the worsening of the unemployment-inflation relationship lies in the rise of long-term unemployment during the crisis.

Although the literature emphasizes the potential role of each of these factors, the GR context seems to favor some factors more than others. The argument of anchoring expectations due to the gain in credibility of central banks is certainly of indisputable relevance in the missing disinflation of recent decades. However, the GR does not seem to devote a major change in expectations; expectations became anchored and universalized well before the crisis (Rogoff, 2003). While the long-term unemployment rate, measured by the proportion of people unemployed for at least 12 months among the total unemployed, has increased relatively following the GR in United States (Figure 10 in the appendix). In the aftermath of the crisis, this rate has more than doubled compared to the recessions of 1990 and 2001. The remoteness of the Beveridge curve from the origin illustrated in Figure 11 in the appendix attests to the change from cyclical unemployment to long-term unemployment.

Since the 1990s, long-term unemployment has never been greater in the United States. The thesis relating to the rise in unemployment seems the most decisive in the explanation of the missing disinflation. This theory is also backed by stimulating arguments that highlight the role of this type of unemployment in the depreciation of human capital (Jackman and Layard, 1991; Pissarides, 1992). This refers to the gradual deterioration of skills and know-how of workers once unemployed. The work of Esteban-Pretel (2005); Esteban-Pretel and Faraglia (2010); Laureys (2014) for example, provide evidence, in the New Keynesian models, on the role of productivity losses related to the depreciation of human capital in the spread of macroeconomic shocks,. This article, while retaining the typical structure of existing literature, goes further in the theoretical approach by integrating the effects of the depreciation of capital on the intensity of job search by the unemployed. In addition to the negative impact on productivity, the literature provides evidence on the effects of the depreciation of human capital on job-seeking skills or abilities. Such effects are manifested by the presence of workers discouraged or marginally attached to the labor market. The presence of these workers at the GR is also noted later in this article. This relatively large presence of discouraged workers has reduced labor market participation and may have moderated the

downward trend in wages (Figure 12 in the appendix) and, subsequently, that of prices at the GR. This article on missing disinflation aims to provide theoretical arguments on the extent to which human capital depreciation mechanisms may emerge in the presence of this paradox. This theoretical investigation, especially that concerning the New-Keynesian models, seems not to have yet been explored in the existing literature.

To conduct this investigation, the article develops a variant of the New Keynesian models in which the effects of the depreciation of human capital on productivity and the job search capacity of workers lead to a reduction in labor force participation, and in turn a moderation of the downward trend in wages and prices. The downward trend is driven by the effect of the depreciation of human capital on productivity and moderation by its effect on the intensity of job search. The model is an extension of that by Esteban-Pretel and Faraglia (2010). The extension consists of integrating the effects of the depreciation of human capital on the job-seeking capacities of workers according to Krusell et al. (2010) and Kehoe et al. (2016). The model of Esteban-Pretel and Faraglia provides the structure of the model for the mechanism underlying the effects of the depreciation of human capital on productivity. Calibrated on the United States economy, the simulations show that this variant of the model reproduces relatively better the highlights of the missing disinflation than the standard New- Keynesian models. In response to shocks of the same size, the response of inflation in the model with depreciation of human capital is 3 to 4-fold less than in the standard New Keynesian models.

The rest of the article is organized as follows. Section 2 presents the evidence of the depreciation of human capital. Section 3 presents the model. Section 4 details the calibration of the model. Section 5 reports and discusses the results of the numerical simulations. Section 6 concludes the article.

2 Human capital depreciation effects on the labor market

The effects of long-term unemployment on the worker human capital are manifested in a number of ways. They may consist – among other things – a gradual degradation of know-how or skills. Such degradations are likely to lead to discouragement or a decrease in motivation in the search for new jobs. The literature provides evidence on the presence of workers affected by these symptoms during periods of unemployment. In general, the proportion of the labor force affected by these symptoms, known in terms of labor saving as the effect of workers discouraged or marginally attached to the labor market, is relatively important in long-term unemployment. This proportion is the labor force available and willing to work, but does not actively seek work (Lee and Parasnis, 2014). In their study, the authors point out that the proportion of these discouraged workers is substantial in advanced economies, especially in the countries of the Organization for Economic Co-

operation and Development (OECD), where it accounted for about 0.5% of the workforce in 2012. By looking at the dynamics of the proportion of these workers in the United States, Van Zandweghe (2012) reports that the proportion of the labor force marginally attached increased from an average of 1.5 million people over the period 1994-2007 to an average of 2.2 million people for the period from 2008 to 2011, a 50% increase after the GR. For the same periods, he also mentions a 100% increase in the proportion of discouraged workers. A proportion that DeLoach and Kurt (2013) estimates at about 1 million people in February 2011.

While the literature provides evidence for the increase in marginally attached or discouraged workers after GR, very few studies have attempted to assess the impact of these discouraged workers on participation in the labor market. This is plausibly due to the potential technical difficulties that such an evaluation could generate. Van Zandweghe proposes to do this indirectly by assessing the effect of long-term unemployment on participation in the labor market, because the probability of finding a job decreases with the duration of unemployment. Using the Beveridge-Nelson decomposition, he argues that long-term unemployment accounted for 90% of the 1.9 percentage point decline in the US labor force participation rate from 2007 to 2011. DeLoach and Kurt (2013) also find in their study that the time spent looking for a job fell by an average of 35% from 2007 to 2011.

3 Model

The model is a variant of New-Keynesian theoretical models where the economic environment consists of families, firms producing goods, and a monetary authority. Families are composed of an infinity of members materialized by a unitary interval. In each period, a member may be employed in the production sector or unemployed. When a member is unemployed, their human capital is likely to depreciate according to their unemployed status. This status can be that of a short-term or long-term unemployed person. Short-term unemployed status is an unemployed member at the beginning of a given period while employed at the end of the previous period, whereas the long-term unemployed person is the unemployed household member for at least two successive periods. Based on the evidence of the literature on the effects of long-term unemployment, the existence of a difference in the level of human capital is assumed between these two types of unemployed. The short-term unemployed are thus considered to be workers with a high capital level and the long-term unemployed as workers with a low level of human capital.

The presence of these two types of workers is capable of affecting the labor market. A reorganization of the unemployment structure with a preponderance of the long-term unemployed is likely to lead to a decrease in labor market participation and a decrease in productivity. These two effects have different impacts on wages and prices. The decline in participation has a nondecreasing effect

while the decline in productivity has a decreasing effect. The mechanism linking the depreciation of human capital and participation in the labor market is represented by a matching technology whose specificity is to capture the differences in job search intensity between the two groups of workers. The link between capital depreciation and productivity is captured by goods-producing technology that integrates differences in the level of human capital between the two groups of workers.

The rest of the model's environment is similar to the basic New-Keynesian frameworks with the presence of monopolistic competition and price rigidity, with the exception of certain points. Also, the model shares the highlights of the labor market friction models with wage determination through Nash bargaining and the presence of matching technology. The presence of the monetary authority is also there to capture the impact of its guidance on the dynamics of inflation.

3.1 Families

The family environment provides a framework for formalizing decisions about consumption, savings, and participation in the labor market. The families are identical, and each family is formed by a continuum of members materialized by a unitary interval. Consumption and savings decisions are supposed to be made at the family level and labor market participation decisions at the individual level. In each period, a member is either employed in the production sector or unemployed. Participation in the labor market depends on the level of human capital. For simplicity, it is assumed that members have only two levels of human capital. This can be high or low. Two groups of labor market participants are considered. The short-term unemployed and the long-term unemployed. The former has a high level of human capital and the latter have a low capital level. Both groups interact with production firms by offering their level of human capital.

Since consumption and savings decisions are supposed to be independent of the family member's employment status or unemployment status, the problem of the representative family is presented in two stages. The first stage presents the problem at the family level and the second stage the problem at the individual level.

3.1.1 Family problem

In this economy, the family is a consumer insurance against unemployment risk for each member. Thus, consumption and savings decisions are taken at the family level. In order to focus on the interaction between participation in the labor market and price dynamics, the intensive margin is ignored. The representative family saves by investing in a one-year bond, B_t. The consumer basket, C_t of the family consists of a set of differentiated goods and domestic production by unemployed members in the production sector

$$C_t = C_t^m + (1 - n_t)d_t(h_t)$$

with C_t^m all the differentiated goods and $(1-n_t)d(h_t)$ the domestic production made by the unused members, $(1-n_t)$ where n_t is the total number of members employed in the production sector. Domestic production is based on the human capital h_t of the unemployed member. $d_t(h_t)$ is assumed to be linear in h_t

$$d(h_t) = d_0 + d_1 h_t$$

The set of differentiated goods is an aggregation at Dixit-Stiglitz

$$C_t^m = \left[\int_0^1 C_t^m(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right]^{\frac{\varepsilon}{\varepsilon-1}}$$

where $C_t^m(j)$ is the production realized by the firm j and ε is the elasticity of subsistence between the differentiated goods.
At the family level, consumption and savings decisions are made by solving the value function:

$$V(B_t, \xi_t) = \xi_t U(C_t) + \beta E_t V(B_{t+1}, \xi_{t+1})$$

under the constraint of:

$$B_t + P_t C_t = P_t \left(W_t + (1 - n_t)\, d(h_t)\right) + (1 + r_{t-1})B_{t-1} + \Pi_t \tag{1}$$

$$C_t = C_t^m + (1 - n_t)b(h_t) \tag{2}$$

$$log\xi_t = \rho log\xi_{t-1} + \varepsilon_t \tag{3}$$

where β is the discount factor, ξ_t the shock of preference, r_t the nominal interest rate, Π_t the profits from the goods-producing sectors and $U(C_t)$ the defined and increasing utility function

$$U\left(C_t\right) = log(C_t)$$

P_t is the general price level defined as the price index $P_t(j)$ of differentiated goods, given by

$$P_t = \left[\int_0^1 P_t(j)^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}} \tag{4}$$

Maximizing C_t^m under the constraint of $\int_0^1 P_t(j) C_t^m(j) dj$ gives the claim for each differentiated property j

$$C_t^m(j) = \left[\frac{P_t(j)}{P_t} \right]^{-\varepsilon} C_t^m \tag{5}$$

The Euler equation resulting from the resolution of the value function is:

$$\frac{1}{C_t} = \beta(1 + r_t) E_t \left(\frac{\xi_{t+1} P_t}{\xi_t P_{t+1} C_{t+1}} \right) \tag{6}$$

The stochastic discount factor for discounting the nominal income of the $t+1$ period of the economy is:

$$Q_{t,t+1} = \beta E_t \left(\frac{C_t P_t}{C_{t+1} P_{t+1}} \right) \tag{7}$$

3.1.2 Problem at the individual level

In each period, family members have one of two options: (i) participation in the labor market and (ii) unemployment or domestic production. The value of both options is a function of the member's human capital. For simplicity, the distribution of human capital specific to the labor market in each family is assumed to take two values. Thus, each member has a high human capital $\overline{h}$ or a low human capital $\underline{h}$. Members with a $\overline{h}$ starting capital at the beginning of the t period are the active agents at the $t-1$ period, while members who have been unemployed for the $t-1$ period have at the t period of a $\underline{h}$ capital level. Depreciation occurs when the capital goes from $\overline{h}$ to $\underline{h}$ as a result of more than one period of unemployment by a member. Similary, the capital also goes from $\underline{h}$ to $\overline{h}$ when a member with $\underline{h}$ spends at least two successive periods in employment. The value of the two options then depends on the type of capital held by the family member. Thus, the value of the option to be in employment $N_t(h_t)$ in the production sector for a representative member with a capital h_t at the period t is the sum of salary received $w_t(h_t)$ and the present value of future options, who may have remained employed with a $(1-\sigma)$ probability or unemployed with the probability σ. In each period, a σ share of jobs is exogenously defeated. The value of this option for a member with a $\overline{h}$ is written

$$N_t(\overline{h}) = w_t(\overline{h}) + \beta E_t Q_{t,t+1} \left[(1-\sigma) N_{t+1}(\overline{h}) + \sigma U_{t+1}(\overline{h}) \right] \tag{8}$$

and that of a member with $\underline{h}$

$$N_t(\underline{h}) = w_t(\underline{h}) + \beta E_t Q_{t,t+1} \left[(1-\sigma) N_{t+1}(\overline{h}) + \sigma U_{t+1}(\underline{h}) \right] \tag{9}$$

The value of the option to be unemployed $U_t(h_t)$ is equal to the member's domestic production and the discounted value of future options. The value of this option for a $\overline{h}$ holder is

$$U_t(\overline{h}) = d_t(\overline{h}) + \beta E_t Q_{t,t+1} \left[(1-\sigma) N_{t+1}(\overline{h}) + \sigma U_{t+1}(\underline{h}) \right] \tag{10}$$

and that of a member with $\underline{h}$

$$U_t(\underline{h}) = d_t(\underline{h}) + \beta E_t Q_{t,t+1} \left[(1-\sigma) N_{t+1}(\underline{h}) + \sigma U_{t+1}(\underline{h}) \right] \tag{11}$$

3.2 Intermediate goods firms

Intermediate goods are produced in the economy by a continuum of firms represented by a unit interval. These firms operate in a competitive environment by expressing a demand for work with family members and by selling their output P^I their output to producers of final goods. In each period, the representative firm solicits the job offer from family members by posting vacancies v_t. The cost of posting a vacancy is κ. As a result of matching, the firm's output is subject to the specific level of human capital of family members engaged in its production process. Matching takes place when vacancies posted by the firm agree with certain family members. The distribution of the human capital of the representative firm is then similar to that characterizing the representative family. The representative firm realizes its production with technology:

$$y_t = A_t(n_t^e \overline{h} + n_t^f \underline{h}) \tag{12}$$

With A_t as the total factor productivity, n_t^e the number of employees with human capital $\overline{h}$ and n_t^f those with capital $\underline{h}$. The actual employment offer made by the representative firm and the level of overall productivity are given by equations (13) and (14)

$$n_t = n_t^e + n_t^f \tag{13}$$

$$A_t = \rho_a A_{t-1} + \epsilon_t^a \tag{14}$$

with ρ_a the autoregressive parameter and ϵ_a the supposed technological innovation $iid(0, \sigma_a)$. The problem of the representative firm is to solve at each period the objective function

$$E_t \sum_{\substack{k=0 \\ \left\{n_k^e, n_k^f, v_k\right\}}}^{\infty} Q_{t,t+k} \left\{ \frac{P_k^I}{P_k} A_t \left(n_k^e \overline{h} + n_k^f \underline{h} \right) - n_k^e w_k^e - n_k^f w_k^f - \kappa v_k \right\}$$

under constraint of

$$n_k^e = (1-\sigma)(n_{k-1}^e + n_{k-1}^f) + \lambda_{mk}^e u_k^e v_k \tag{15}$$

$$n_k^f = (1-\sigma) n_k^f + \lambda_{mk}^f u_k^f v_k \tag{16}$$

with w_k^e wages paid to employees of capital $\overline{h}$, w_k^e paid to employees with capital $\underline{h}$, u_k^e and u_k^f the unemployed with the capital levels $\overline{h}$ and $\underline{h}$, respectively. The law of motion for these expressions is:

$$u_k^e = \sigma \left(n_{t-1}^e + n_{t-1}^f \right) + \left(1 - \lambda_{mk-1}^e \right) u_{k-1} \tag{17}$$

$$u_k^f = \sigma n_{k-1}^f + \left(1 - \lambda_{mk-1}^f \right) \left(u_{k-1}^f + u_{k-1}^e \right) \tag{18}$$

λ_m^e and λ_m^f the matching probabilities of family members with the capital levels $\overline{h}$ and $\underline{h}$. The expressions of these probabilities are developed later in the document. The total number of unemployed in the economy is

$$u_t = u_t^e + u_t^f$$

The profit made by the firm is then the difference between its real income and its real costs. Actual costs include the amount of wages of both types of workers and the costs incurred for posting vacancies. Considering ψ_{and} and ψ_{ft} the Lagrange multipliers of equations (15) and (16) and $p_t = \frac{u_t^f}{u_t}$ the proportion of long-term unemployed in total unemployment, the resolution of the problem of the firm to the period t gives the following conditions of first order:

$$\kappa = \psi_{et}\lambda^e_{mt}(1-p_t) + \psi_{ft}\lambda^f_{mt}p_t \tag{19}$$

$$\psi_{et} = \frac{P^I_t}{P_t}A_t\overline{h} - w^e_t + (1-\sigma)E_tQ_{t,t+1}\psi_{et+1} \tag{20}$$

$$\psi_{ft} = \frac{P^I_t}{P_t}A_t\underline{h} - w^f_t + (1-\sigma)E_tQ_{t,t+1}(\psi_{et+1} + \psi_{ft+1}) \tag{21}$$

In addition, the value of the opening of a vacancy, evaluated in terms of the consumption of a period t is:

$$V_t\left(\overline{h}, \underline{h}\right) = -\kappa + \lambda^e_{ft}J_t\left(\overline{h}\right) + \lambda^f_{ft}J_t\left(\underline{h}\right) + (1-\lambda^e_{ft})(1-\lambda^f_{ft})E_tQ_{t,t+1}V_{t+1} \tag{22}$$

with $J_t(\overline{h})$ and $J_t(\underline{h})$ the respective values of the matching with workers $\overline{h}$ and $\underline{h}$:

$$J_t\left(\overline{h}\right) = A_t\overline{h} - w^e_t + (1-\sigma)E_tQ_{t,t+1}J_{t+1}\left(\overline{h}\right) \tag{23}$$

$$J_t\left(\underline{h}\right) = A_t\underline{h} - w^f_t + (1-\sigma)E_tQ_{t,t+1}J_{t+1}\left(\underline{h}\right) \tag{24}$$

and λ^e_{ft} and λ^e_{ft} the matching probabilities of the vacant job to workers $\overline{h}$ and $\underline{h}$. The expressions of these probabilities are developed in the section on matching technology.

3.3 Matching technology

In each period, intermediary production firms make recruiting announcements to fill vacancies v_t. Family members, regardless of the level of their human capital, compete for the same vacancies. With this in mind, they strive to look for vacancies, subsequently apply, and possibly pass job interviews. The search for employment in this theoretical model refers to these steps. The intensity of a family member's search for a job is assumed to depend on the level of his human capital h_t. Matching vacancies to family members looking for work is done through technology:

$$m_t(v_t, u_t, h_t) = B_tg(h_t)\frac{u_tv_t}{\left[u^\eta_t + v^\eta_t\right]^{\frac{1}{\eta}}} \tag{25}$$

with B_t the matching shock, $g(h_t)$ the matching efficiency specific to the type of job seeker and η the vacancy elasticity. By asking $\theta_t = \frac{v_t}{u_t}$, the ratio of vacancies, v_t to the total number of unemployed, u_t, the probability for a family member with a capital level of h_t to match a vacancy:

$$\lambda_{mt} = \frac{m_t}{u_t} = B_tg(h_t)\frac{\theta_t}{(1+\theta^\eta_t)^{\frac{1}{\eta}}}$$

and the probability that the vacancy of a firm will match a job seeker with h_t as the level of human capital:

$$\lambda_{ft} = \frac{B_t g(h_t)}{(1+\theta_t^{\eta})^{\frac{1}{\eta}}}$$

λ_{wt} and λ_{ft} depend positively on the applicant's human capital. By normalizing the specific search intensity $g(h_t)$ of members with a level $\overline{h}$ to 1 and assuming a δ depreciation rate of human capital, the probabilities λ_{mt}^{e} and λ_{mt}^{f} are written:

$$\lambda_{mt}^{e} = B_t \frac{\theta_t}{(1+\theta_t^{\eta})^{\frac{1}{\eta}}} \tag{26}$$

$$\lambda_{mt}^{f} = B(1-\delta) \frac{\theta_t}{(1+\theta_t^{\eta})^{\frac{1}{\eta}}} \tag{27}$$

and the expressions of the probabilities λ_{ft}^{e} and λ_{ft}^{e} are:

$$\lambda_{ft}^{e} = \frac{B_t}{(1+\theta_t^{\eta})^{\frac{1}{\eta}}} \tag{28}$$

$$\lambda_{ft}^{f} = \frac{B_t(1-\delta)}{(1+\theta_t^{\eta})^{\frac{1}{\eta}}} \tag{29}$$

3.4 Wages Determination

In the model environment, wage negotiations are held at each period between firms and workers to determine the remuneration of each stakeholder in the matching process. As in the literature, the negotiations consist of a Nash share of the surplus $S_t(h) = N_t(h_t) - U_t(h_t) + J_t(h_t) - V_t(h_t)$ of the match. This division gives the worker a constant b of the surplus, and the wage bargaining problem arises:

$$\underset{w_t(h_t)}{max}(N_t(h_t) - U_t(h_t)^b (J_t(h_t) - V_t)^{1-b}$$

Since the condition of free market entry implies that $V_t = 0$ at equilibrium, the first order conditions give:

$$bS_t(h_t) = N_t(h_t) - U_t(h_t) \tag{30}$$

$$(1-b)S_t(h_t) = J_t(h_t) \tag{31}$$

The combination of equations (10), (11), (23), (24) (30), (31) makes it possible to determine the wages w_t^e and w_t^f of the two groups of workers.

$$w_t^e = b\left[A\overline{h} + (1-\sigma)Q_{t,t+1}J_{t+1}\left(\overline{h}\right)\right] + (1-b)\left[d_t\left(\overline{h}\right) + Q_{t,t+1}\left\{\lambda_{mt+1}^e N_{t+1}\left(\overline{h}\right) - (1-\sigma)N_{t+1}\left(\overline{h}\right) + \left(1-\lambda_{mt+1}^f\right)U_{t+1}\left(\overline{h}\right) - \sigma U_{t+1}\left(\overline{h}\right)\right\}\right] \tag{32}$$

$$w_t^f = b\left[A\underline{h} + (1-\sigma)\,Q_{t,t+1}J_{t+1}\left(\underline{h}\right)\right] + (1-b)\left[d_t\left(\underline{h}\right) + Q_{t,t+1}\left\{(1-\sigma)\,N_{t+1}\left(\underline{h}\right) - \lambda_{mt+1}^f N_{t+1}\left(\underline{h}\right) - \sigma U_{t+1}\left(\underline{h}\right) - (1-\lambda_{mt+1})\,U_{t+1}\left(\underline{h}\right)\right\}\right] \tag{33}$$

3.5 Final Goods Production Firms

Intermediate goods produced in the economy are used by a continuum of firms operating in a monopoly environment to produce final goods. The differentiated goods thus produced are sold to family members. The continuum of firms is represented by a unitary interval and each differentiated good is produced by reprocessing an intermediate good according to the following technology:

$$Y_t(j) = y_t(j) \tag{34}$$

$Y_t(j)$ is the final good produced by the firm j and $y_t(j)$ the quantity of intermediate good used as a factor of production by the same firm j. The final goods demand of the representative family Y_t to the producers in the sector is a Dixit-Stigliz aggregation of the differentiated goods $Y_t(j)$

$$Y_t = \left[\int_0^1 Y_t(j)^{\frac{\varepsilon-1}{\varepsilon}} dj\right]^{\frac{\varepsilon}{\varepsilon-1}}$$

The price adjustment is supposed to be done at Calvo so that at each period, a fraction θ_p of the firms of the sector adjust their prices while a proportion θ_p maintains prices unchanged. When a firm has the opportunity to adjust its price, it chooses P_t^* to maximize the objective function below:

$$\sum_{k=0}^{\infty} \theta_p^k E_t\left[Q_{t,t+k}\left(P_t^* - P_{t+k}^I\right)Y_{t,t+k}\left(j\right)\right]$$

under the constraint of the demand for the good j in $t+k$ when the adjustment takes place in t

$$Y_{t,t+k}(j) = \left[\frac{P_t(j)}{P_{t+k}}\right]^{-\varepsilon} Y_{t+k} \tag{35}$$

with P_{t+k} the general level of prices at the period t + k, P_{t+k}^I the nominal marginal cost or the price of the intermediate good. In addition, the general level of prices in the economy is given by:

$$P_t = \left[\theta_p (P_{t-1})^{1-\varepsilon} + (1-\theta_p)(P_t^*)^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}} \tag{36}$$

3.6 Monetary policy

The monetary authority conducts its policy in the economy using the nominal interest rate instrument. It sets a target value based on inflation and output. The interest rate is influenced by a monetary shock ϵ_t^m assumed as $iid(0, \sigma_m)$. The target value of the rate is then given by the following Taylor rule:

$$R_t = \rho_r (R_{t-1})^{\rho_m} (\frac{P_t}{P_{t-1}})^{\gamma_\pi (1-\rho_m)} (\frac{Y_t}{Y})^{\gamma_y (1-\rho_m)} e^{\epsilon_t^m} \tag{37}$$

with $R_t = 1 + r_t$; $\gamma_{\,pi}$ and γ_y, both positive and representing the sensitivities of the central bank respectively to inflation and away from the production of its equilibrium level $\overline{Y}$.

4 Calibration of the model

Considering a duration of at least 27 weeks for long-term unemployment, the dynamics of the model are evaluated in semester from the United States economy data. The assignment of the values to the parameters is based on a proven literature and takes into consideration the characteristics of the United States economy before the GR. The dynamic of the model is contrasted with that of a basic New Keynesian model (henceforth, NKS model), obtained by homogenizing the distribution of human capital within single families, and by excluding research frictions. Thus, unlike the parameters related to the depreciation mechanism and the matching technology of the model developed above (now HCD model), the values assigned to the parameters in the two models are identical.

The calibration of the parameters common to both models is standard in the New Keynesian literature. The discount factor β is thus fixed at 0.98 for an annual interest rate of 4 % given the Euler equation, the elasticity of substitution between the differentiated goods ε to 6, the price rigidity parameter θ_p to 0.75, the autoregressive preference shock parameter ρ to 0.90, the productivity shocks ρ_a and monetary ρ_m at 0.95 and 0.91, respectively, the parameters of the Taylor rule, $\gamma_{\,pi}$ and γ_y at 1.5 and 0.5, respectively, the domestic production d_0 at 0.54 , and the overall productivity of the factors of production normalized to 1. For the parameters specific to the model HCD, the values of the parameters of the matching technology η and the bargaining power of the workers b are assigned to 0.5 following the work of Ravenna and Walsh (2012). The overall job search efficiency factor assumes the value of 1 in the steady state, and, in accordance with Kehoe et al. (2016), the d_1 factor

of the domestic production value is set to 0.25. The σ probability of jobs breaking is identical to the US job destruction rate of 0.2105 before GR (Acharya et al., 2017). In the absence of empirical evidence on the value of the δ depreciation rate of human capital, equations (26) and (27) are used for assignment. These equations are combined with the evidence provided by Shimer (2008) on the odds of matching unemployed persons aged less than 6 months and over six months between data from January 1976 to October 2007. Probabilities are estimated on average 0.31 for the first group of unemployed and 0.19 for the second group. Solving equation (26) yields a value of 0.93 for θ, and since both types of unemployed share the same labor market, the depreciation rate δ s is set to 0.20. The value of $\overline{h}$ is set to 2.44 following the work of Kehoe et al.. Additionally, following Laureys (2014), whom estimates the productivity gap between the short-term unemployed and the long-term unemployed at 30 %, the value of $\underline{h}$ is established at 1.708.

5 Results

5.1 The evidence of the model

Figures 1 and 2 present the results of the numerical simulations of the model. These simulations compare the impulse responses of inflation, unemployment, employment, and the production of the standard New Keynesian model (Model-NKS) to those of the variant developed in this article (Model-HCD). The blue lines represent the responses of the NKS-model and the red lines of the HCD-model.

Figure 1 illustrates the impulse responses of the variables to a 1% negative demand shock. In both models, the shock is reflected in both disinflationary pressures and rising unemployment. However, the tendency to vary inflation in the opposite direction to unemployment is relatively less accentuated in the HCD model. In this model, a rise in unemployment, although relatively high, induces a lower disinflationary pressure than the NKS model. While a 1% increase in unemployment is accompanied by just 0.25% disinflation in the HCD model, a moderate increase of 0.75% in unemployment is combined with a disinflation of unemployment in the order of 1% in the NKS model. Disinflation is 4-fold more pronounced in the latter than in the HCD model. The impulse responses following a positive monetary shock for the same variables are shown in the Figure 2. Like the demand shock, the monetary shock is reflected in increases in unemployment coupled with disinflationary pressures in both models. Inflation deviations also remain more anchored to unemployment in the NKS model than in the HCD model. As a result of the shock, an increase in unemployment of 1.25% is followed by a disinflation of about 1.80% in the NKS model, while, in the HCD model, a rise in unemployment of 1.5% has a disinflation of 0.80%. With this type of shock, the disinflationary pressures are about 3-fold less significant in the HCD than in a NKS.

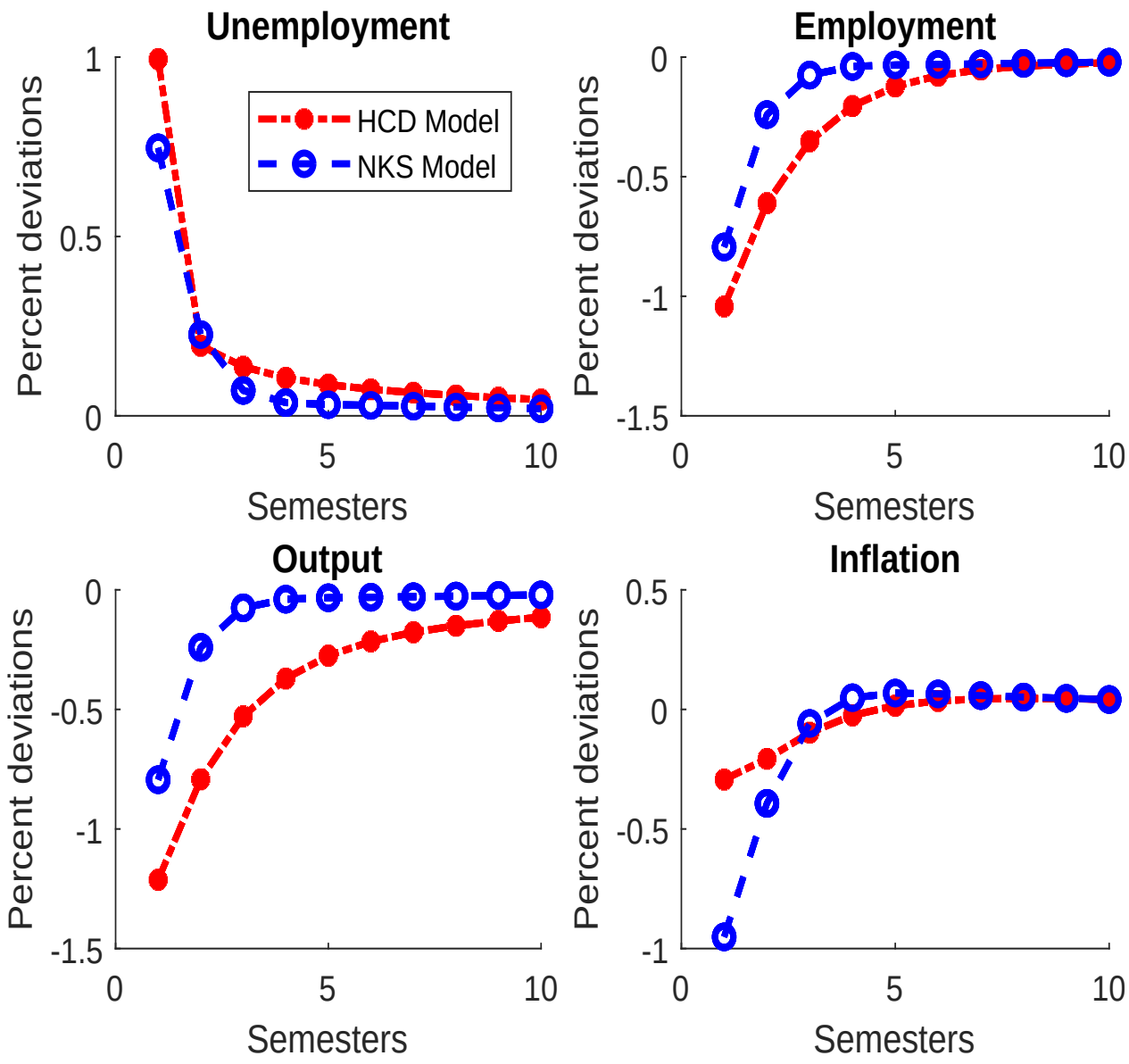

Figure 1: Impulse Responses of Unemployment, Employment, Output and Inflation to a 1% negative preference shock.

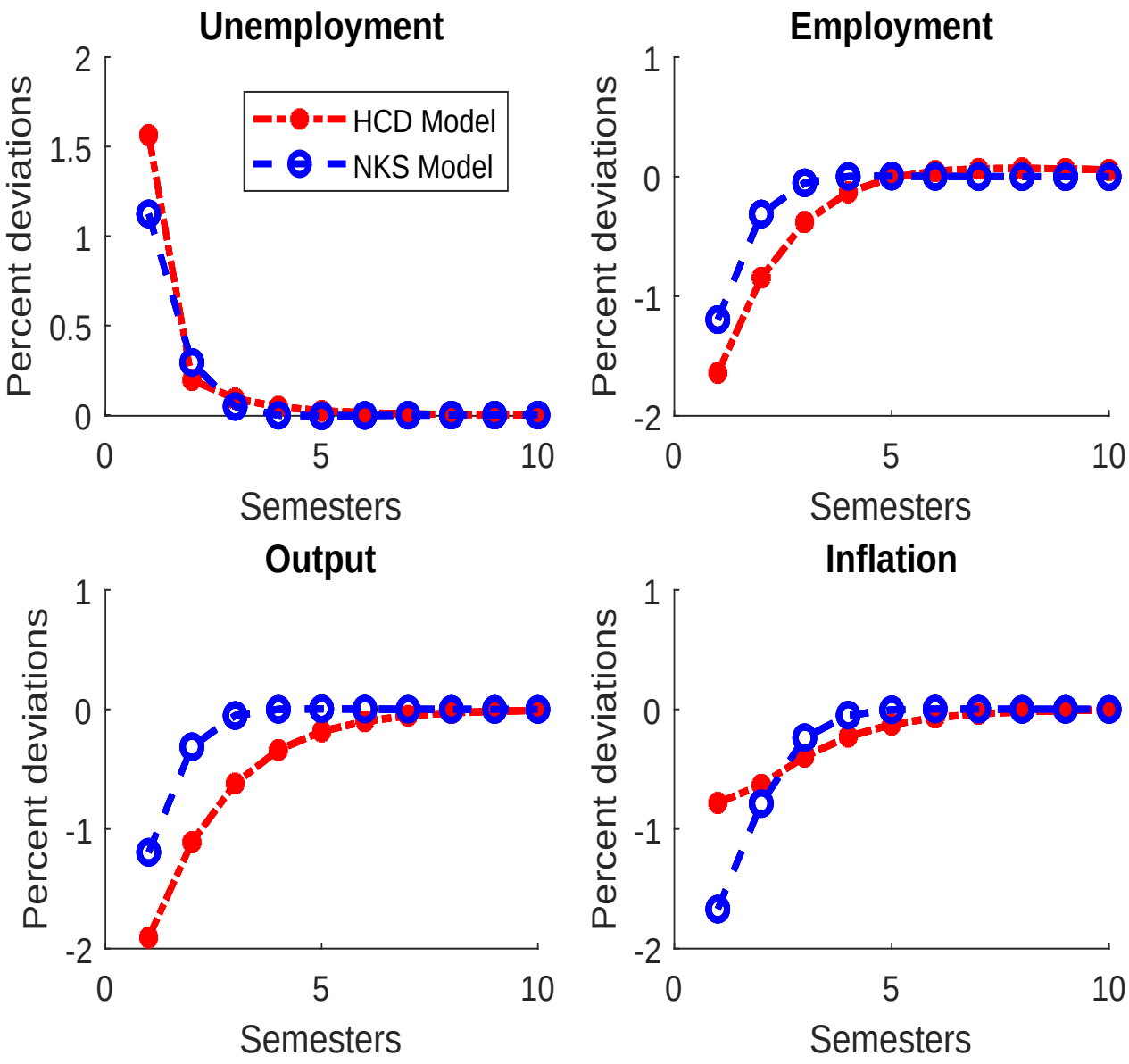

Figure 2: Impulse Responses of Unemployment, Employment, Output and Inflation to a 1% positive monetary shock.

5.2 Mechanisms of the model

Figures 3, 4, 5 and 6 shed light on the mechanisms underlying the relatively moderate disinflation in the human capital depreciation model. In the model environment, monetary or demand shocks weaken the ability of firms to make new job-recruitment announcements as evidenced by the drop in vacancies (Figure 5 and 6). The number of family members working in the production sector decreases and in turn the level of unemployment increases in the economy. However, this rise in unemployment is accompanied by a relatively large increase in long-term unemployment as shown

in Figures3 and 4. The share of workers with low human capital falls in employment and increases in the composition of the workforce. The preponderance of these unemployed in the structure of unemployment exerts so-called composition effects on the level of wages. Such effects translate into a relatively moderate decline in wage levels compared to an environment without human capital depreciation (Figures 5 and 6). This wage moderation then reduces the disinflationary pressures.

Indeed, the dominance of the long-term unemployed in the structure of unemployment as a result of shocks is a sign that many workers may suffer from depreciation of human capital. As a result of this depreciation, many unemployed people may be less likely to look for a job or even get discouraged, and this ultimately weakens their likelihood of being hired compared to the short-term unemployed in a low job creation environment. In such an environment, where the unemployed are not able to compete effectively in the job search, the wages of employed workers and the prices of goods become less sensitive to unemployment. This is in contrast to an environment like the NKS model where, in case of rising unemployment, workers compete in the job search so that wages and prices eventually drop considerably.

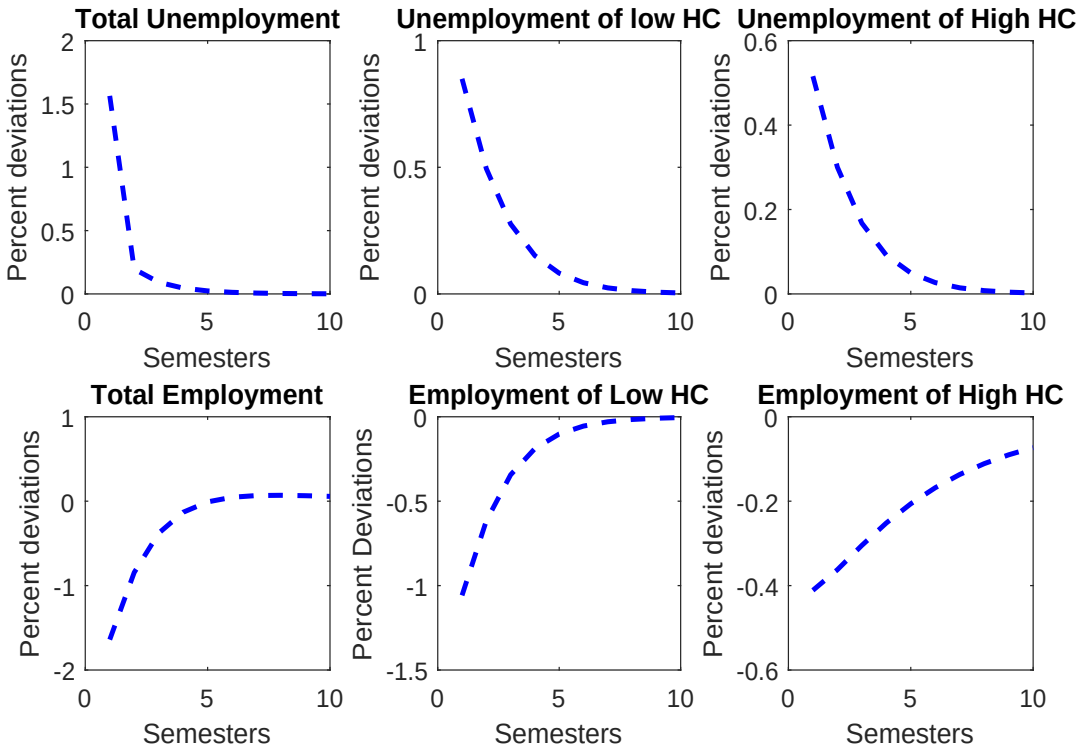

Figure 3: Impulse Responses of the key variables of the depreciation mechanism to 1% negative of preference shock

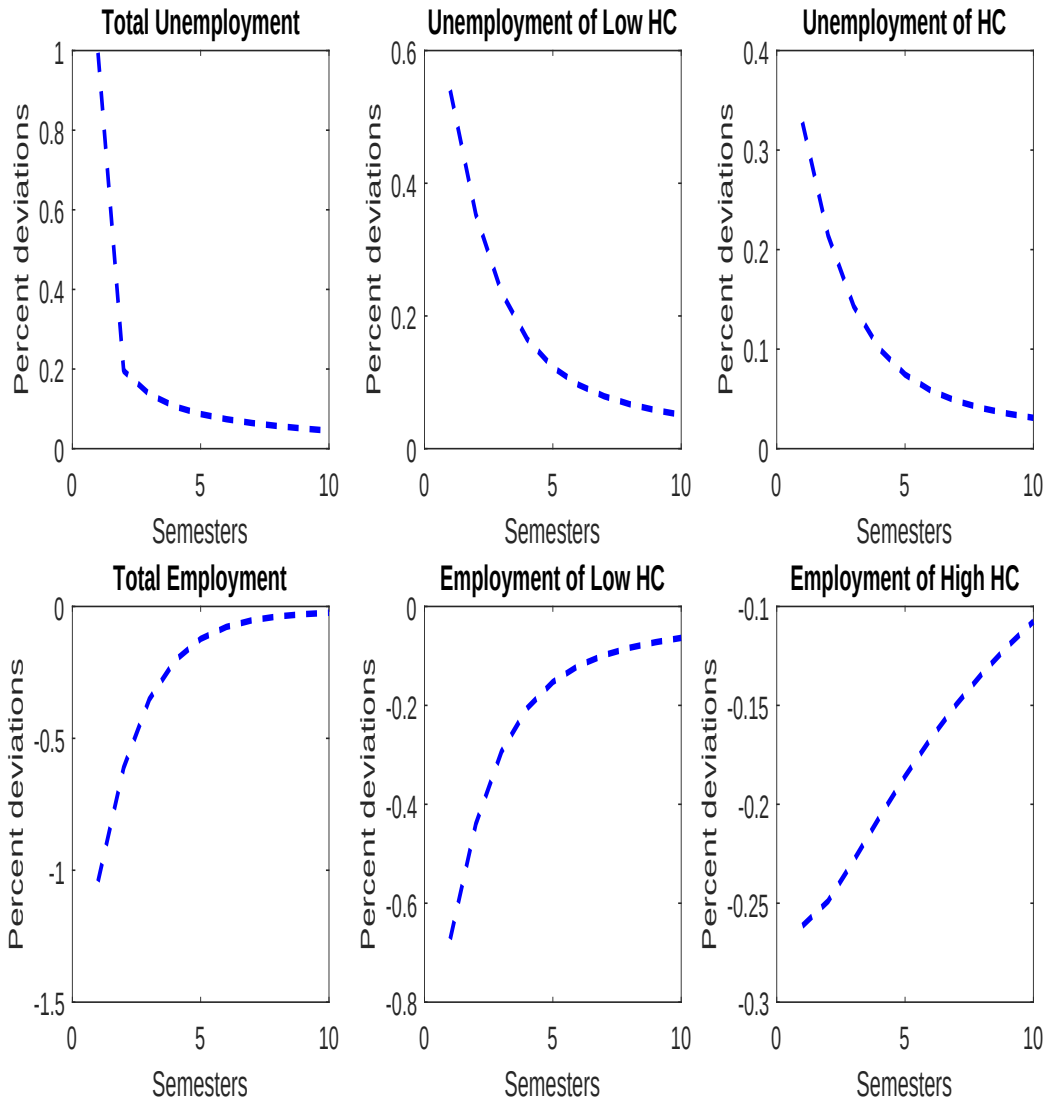

Figure 4: Impulse Responses of the key variables of the depreciation mechanism to 1% positive monetary shock.

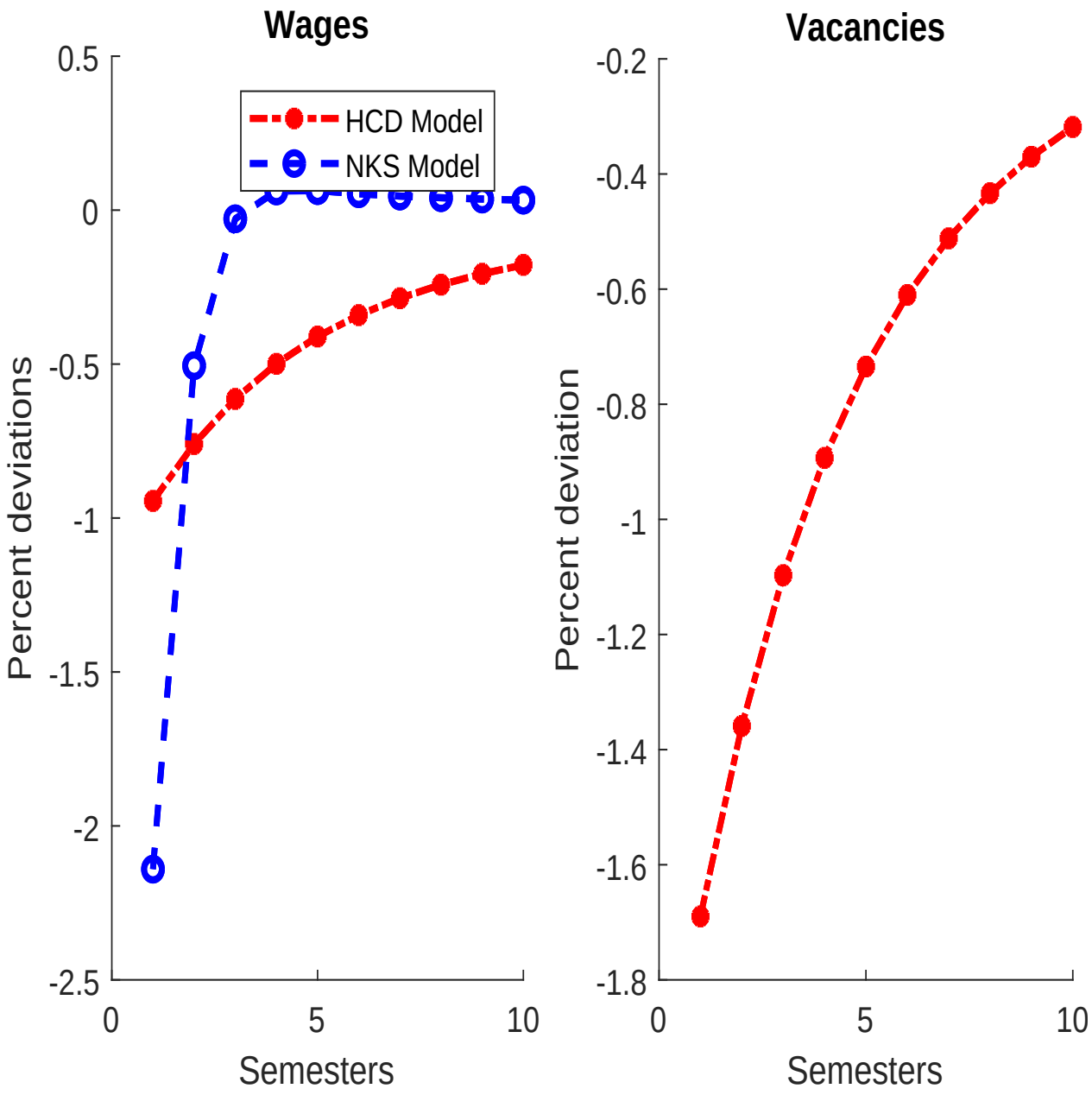

Figure 5: Impulse Responses of the Wages and Vacancies to 1% negative of preference shock

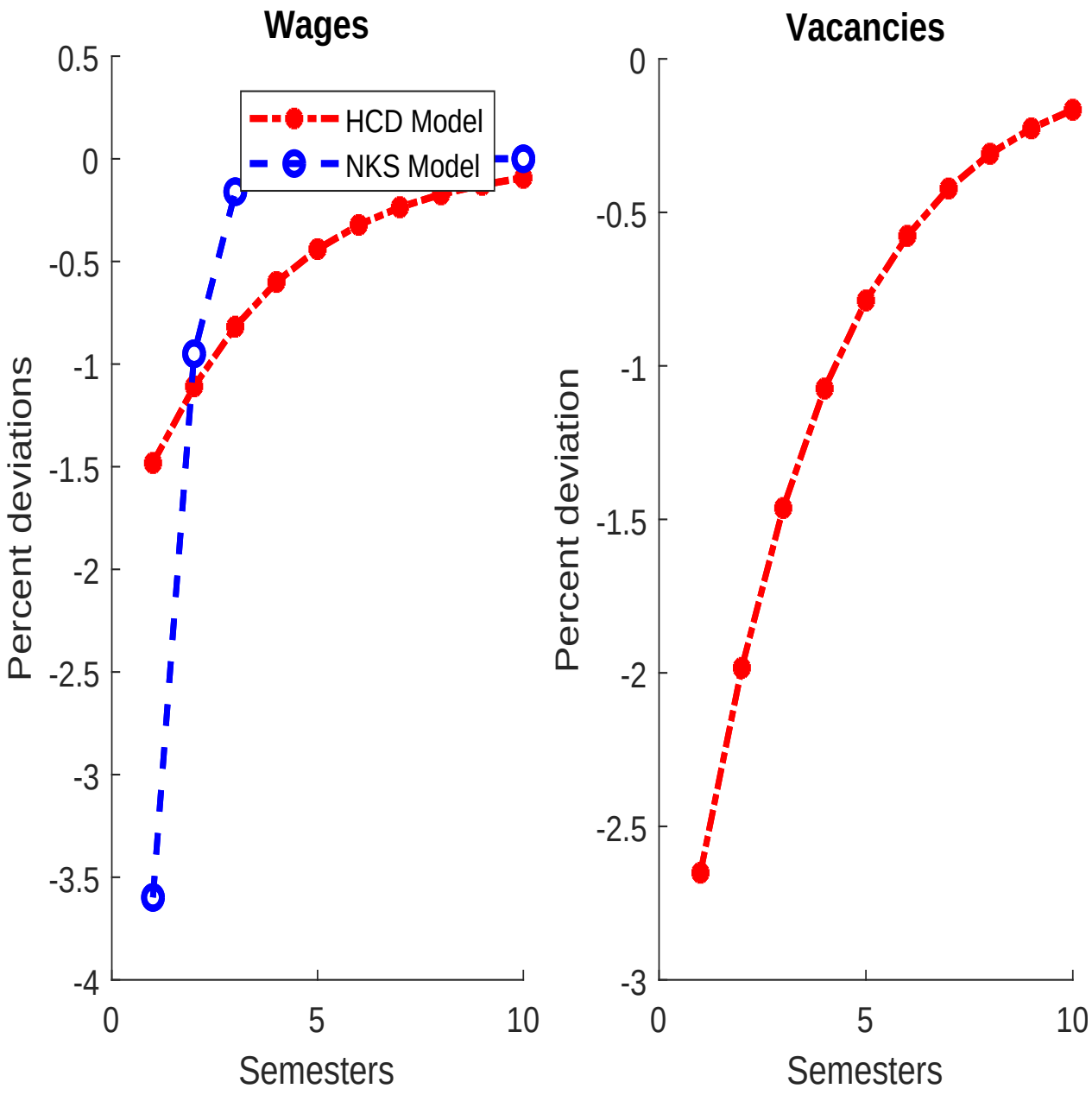

Figure 6: Impulse Responses of the Wages and Vacancies to 1% positive monetary shock.

6 Conclusion

With the GR, the sensitivity of inflation to changes in unemployment has been relatively weaker in most advanced economies. Long-term unemployment has also increased with the presence of workers discouraged or marginally attached to the labor market. A number of interesting literature attribute this presence to the depreciation of human capital suffered by the long-term unemployed. Drawing on this literature, this article looked at the role of human capital depreciation in lowering the sensitivity of inflation to changes in unemployment. Despite the predictions of the standard New-Keynesian frameworks and certain historical trajectories tracking inflation, a qualified subsidence of missing disinflation was observed.

To conduct the investigation, the article develops a variant of the New-Keynesian frameworks where workers are likely to suffer from depreciation of human capital when they spend some time unemployed. Compared to the New-Keynesian frameworks, simulations of this developed model pro- vide evidence to better capture the salient points of missing disinflation. Calibrated to the US economy, the response of inflation to similar shocks in the human capital depreciation model is 3 to 4-fold less than in the New-Keynesian models without depreciation of human capital.

References

Acharya, S., Bengui, J., Dogra, K., and Wee, S. L. (2017). Escaping unemployment traps. Technical report, Staff Report.

Anderson, M. D., Botman, D. P., and Hunt, M. B. (2014). *Is Japan's Population Aging Deflationary?* Number 14-139. International Monetary Fund.

Ball, L. and Mazumder, S. (2018). A phillips curve with anchored expectations and short-term unemployment. *Journal of Money, Credit and Banking*.

Ball, L. M. and Mazumder, S. (2011). Inflation dynamics and the great recession. Technical report, National Bureau of Economic Research.

Blanchard, O., Cerutti, E., and Summers, L. (2015). Inflation and activity–two explorations and their monetary policy implications. Technical report, National Bureau of Economic Research.

Blanchard, O. et al. (2016). The us phillips curve: back to the 60s? *Policy Brief*, (1).

DeLoach, S. B. and Kurt, M. (2013). Discouraging workers: Estimating the impacts of macroeconomic shocks on the search intensity of the unemployed. *Journal of Labor Research*, 34(4):433–454.

Esteban-Pretel, J. (2005). The effects of the loss of skill on unemployment fluctuations. *CIRJE Working Paper F-371*.

Esteban-Pretel, J. and Faraglia, E. (2010). Monetary shocks in a model with skill loss. *Journal of Money, Credit and Banking*, 42(7):1235–1265.

Gordon, R. J. (2013). The phillips curve is alive and well: Inflation and the nairu during the slow recovery. Technical report, National Bureau of Economic Research.

Ihrig, J., Kamin, S. B., Lindner, D., and Marquez, J. (2010). Some simple tests of the globalization and inflation hypothesis. *International Finance*, 13(3):343–375.

Jackman, R. and Layard, R. (1991). Does long-term unemployment reduce a person's chance of a job? a time-series test. *Economica*, pages 93–106.

Katagiri, M., Konishi, H., and Ueda, K. (2014). Aging and deflation from a fiscal perspective.

Kehoe, P., Pastorino, E., and Midrigan, V. (2016). Debt constraints and employment. Technical report, National Bureau of Economic Research.

Krusell, P., Mukoyama, T., and Şahin, A. (2010). Labour-market matching with precautionary savings and aggregate fluctuations. *The Review of Economic Studies*, 77(4):1477–1507.

Laureys, L. (2014). Optimal monetary policy in the presence of human capital depreciation during unemployment. Technical report, London School of Economics and Political Science, LSE Library.

Lee, G. H. and Parasnis, J. (2014). Discouraged workers in developed countries and added workers in developing countries? unemployment rate and labour force participation. *Economic*

Modelling, 41:90–98.

Neely, C. J. and Rapach, D. E. (2011). International comovements in inflation rates and country characteristics. *Journal of International Money and Finance*, 30(7):1471–1490.

Pissarides, C. A. (1992). Loss of skill during unemployment and the persistence of employment shocks. *The Quarterly Journal of Economics*, 107(4):1371–1391.

Ravenna, F. and Walsh, C. E. (2012). Screening and labor market flows in a model with heterogeneous workers. *Journal of Money, Credit and Banking*, 44:31–71.

Rogoff, K. (2003). Globalization and global disinflation. *Economic Review (Kansas City)*, 88(4):45–80.

Shimer, R. (2008). The probability of finding a job. *American Economic Review*, 98(2):268–73.

Simon, J., Matheson, T., and Sandri, D. (2013). The dog that didn't bark: Has inflation been muzzled or was it just sleeping? *World Economic Outlook*, pages 79–95.

Stock, J. (2011). Discussion of ball and mazumder," inflation dynamics and the great recession. *Brookings Papers on Economic Activity*.

Van Zandweghe, W. (2012). Interpreting the recent decline in labor force participation. *Economic Review-Federal Reserve Bank of Kansas City*, page 5.

Appendix

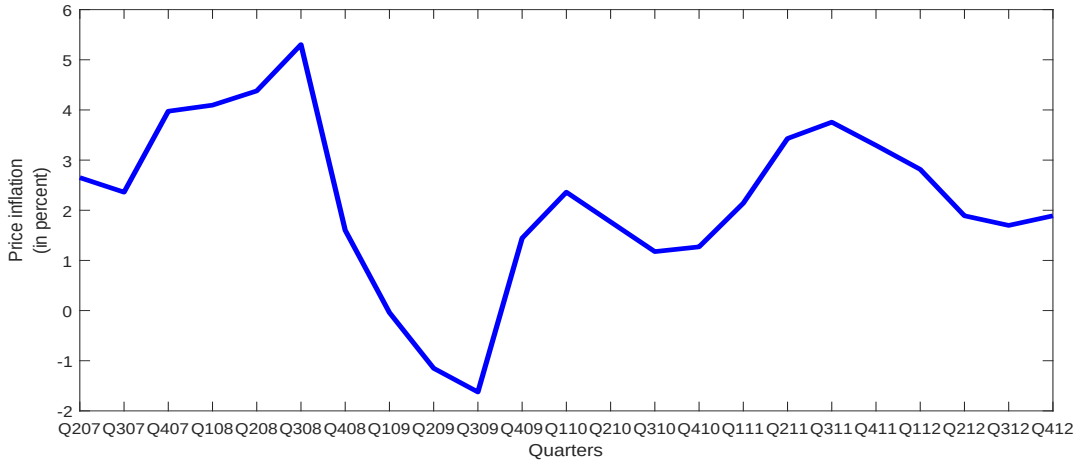

Figure 7: Evolution of price inflation, measured by the CPI in the US following the GR
Source: Organisation for Economic Co-operation and Development (OECD)

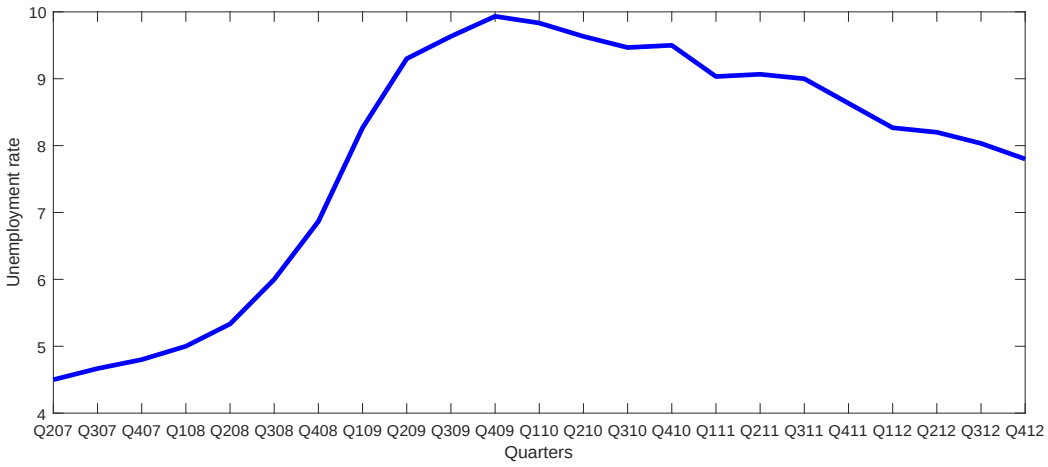

Figure 8: Percentage change of the unemployment rate in the United States following the GR
Source: OCDE

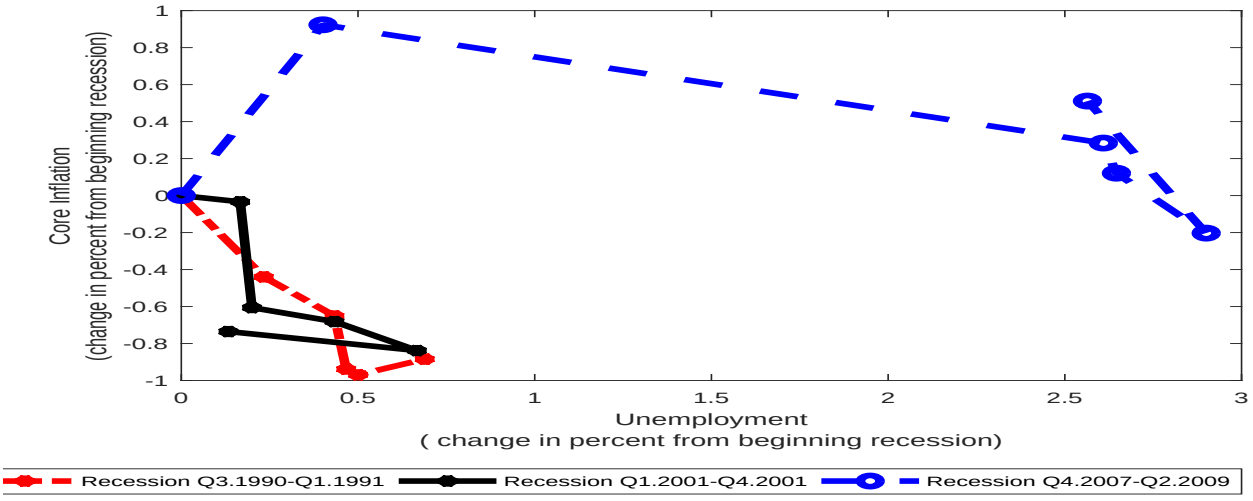

Figure 9: *Changes of Inflation and Unemployment during Recessions*
Source: World Economic Outlook, IMF

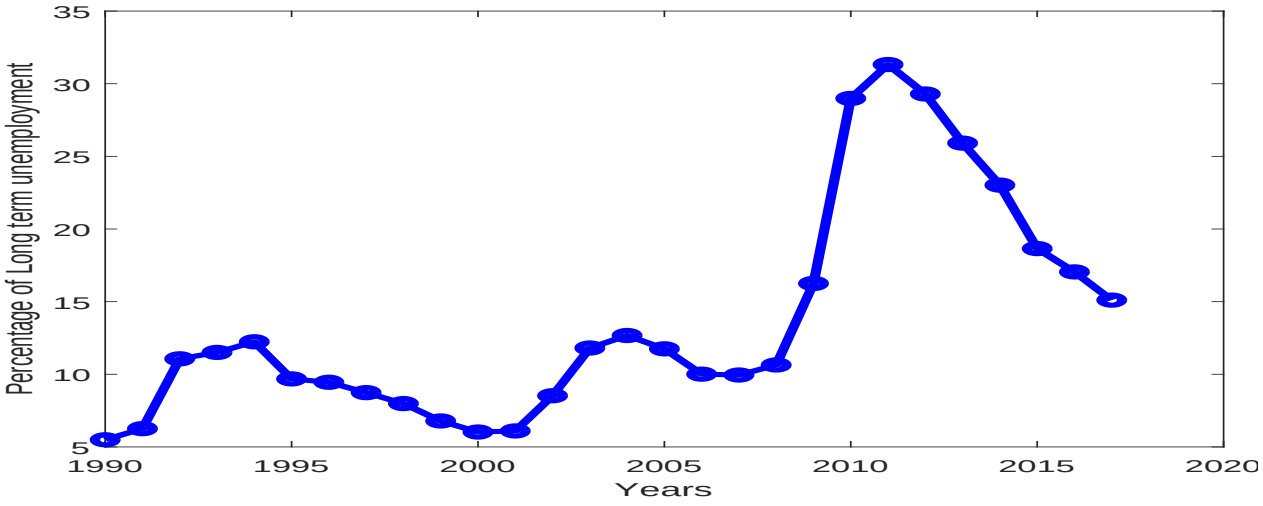

Figure 10: Long-term unemployment (people who have been unemployed for 12 months or more and who are available for work) in United States
Source: OECD

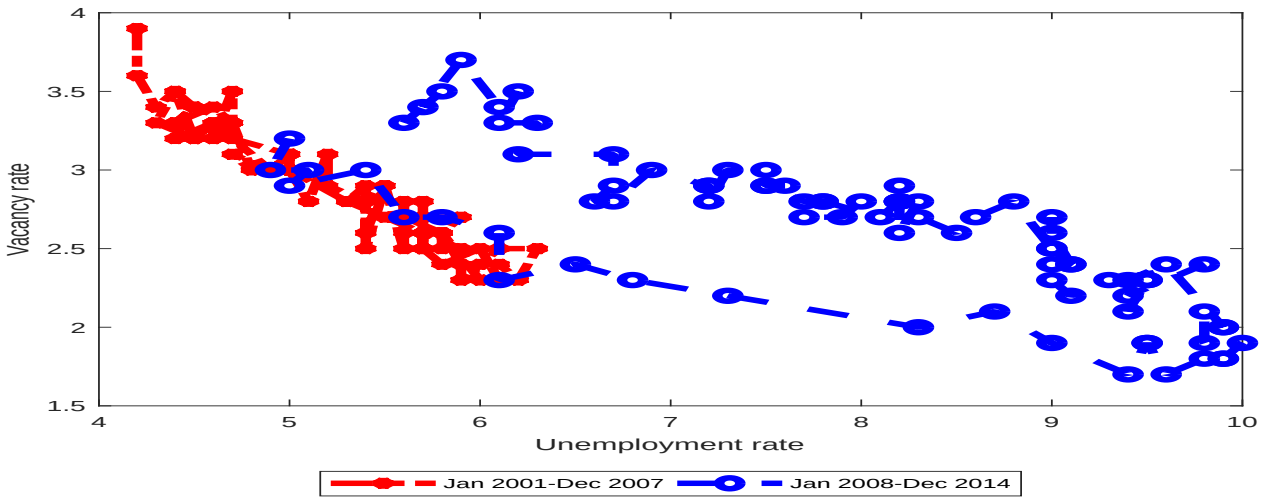

Figure 11: Beveridge curve between 2001-2007 and 2008-2014
Source:Labor Market Statistics Office (United States)

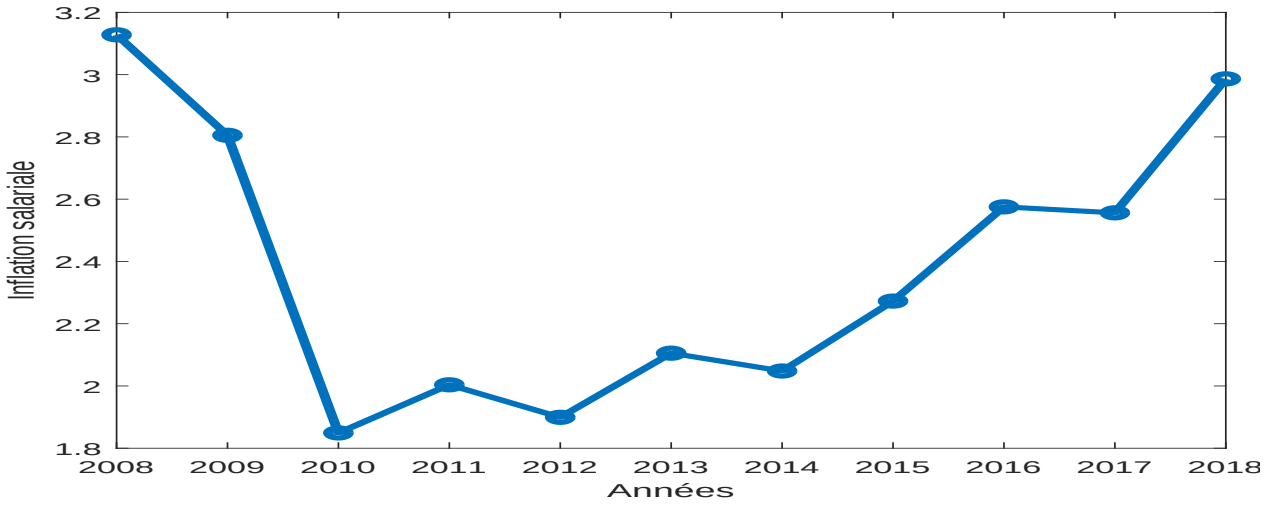

Figure 12: Average hourly earnings of all employees, total private
Source: Federal Reserve Bank of St. Louis