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Cyclical Job Upgrading, Wage Inequality, and Unemployment Dynamics

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Cyclical Job Upgrading, Wage Inequality, and Unemployment Dynamics

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ABSTRACT   This paper studies the implications of a monetary policy shock on the skill premium and the unemployment persistence. A VAR demonstrates that a contractionary policy induces a lagged decline in the skill premium and a larger and more persistent increase in the unemployment ratio of the unskilled relative to that of the skilled. A new Keynesian framework characterized by labor search frictions is developed. The labor force is divided into high and low educated. Firms post two types of vacancies: the complex that can be matched with the high educated, and the simple that can be matched with both the high and the low educated. A positive shock to the nominal interest rate induces the high educated unemployed to compete with the low educated, as they increase their search intensity for simple vacancies. As the high educated occupy simple vacancies, they crowd out the low educated into unemployment. This downgrading of jobs, and the subsequent crowding out of the low educated into unemployment, provide a possible explanation to unemployment persistence and the response of the skill premium.

KEY WORDS: Monetary policy, unemployment, search and matching, sticky prices
JEL Classification: E12, E52, J24, J41

1.   Introduction

A considerable amount of research is devoted to analyzing the implications of the conduct of monetary policy on economic activities. In this context, comprehending the repercussions that labor markets face after the economy is exposed

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to a monetary policy shock captured the attention of a lot of these studies. Nevertheless, although labor market participants, who are distinguished by their observable skills, have distinct cyclical experiences in terms of the relative demand for and the return to their labor supply, a study of the effect of monetary shocks on this heterogeneous environment is not sufficiently considered. This paper assumes the task of filling this gap by analyzing the effect of a monetary policy shock on the skill premium, the total unemployment rate, and the unemployment rates of the skilled and the unskilled.

Using the Outgoing Rotation Group of the Current Population Survey for the period from 1979 to 2004, the participants are divided into those employed and those unemployed. The two groups are further divided into those high and low educated, where the former are those with at least some college education. The employed types are further divided into those working in complex and in simple occupations, where the former are those jobs that require at least some college education. Therefore, a dataset is compiled including the unemployment rates of the high and the low educated, the total unemployment rate, the skill premium, as well as a measure of the crowding out of the low educated by the high educated in occupying simple jobs.

To understand the implications of a monetary policy shock, a vector autoregressive analysis is undertaken where the set of endogenous variables includes the Fed funds rate, the inflation rate, real gross domestic product, the skill premium, the total unemployment rate, the unemployment rates of the skilled and the unskilled, and the crowding out. A positive shock to the Fed funds rate causes a decline in the inflation rate, and in real gross domestic product, besides a lagged decline in the skill premium. The shock causes a lagged increase in the crowding out of the unskilled by the skilled workers in occupying unskilled jobs. The shock also induces a highly persistent unemployment rate, and a more persistent increase in the unemployment rate of the unskilled relative to that of the skilled. This indicates that the unskilled bear the brunt of the increase in unemployment after a contractionary policy. The cross-correlation coefficients between these variables and output show that the cyclical behavior of these variables exhibit similar patterns with a cyclical downturn.

These observations can be intuitively interpreted to reflect a lagged countercyclical downgrading of jobs by the skilled workers, or a lagged decline in their labor input from jobs that require college education to ones that do not. In a cyclical downturn the skilled workers compete with the unskilled workers over unskilled jobs, and thus crowd out the unskilled into unemployment. The increase in the unemployment of the unskilled, who have a lower probability of finding a job, increases the persistence of unemployment Thus, the unemployment is exacerbated in a cyclical downturn due to this crowding out effect. This provides a possible explanation to unemployment persistence. In addition, as the skilled move to unskilled jobs their weighted average wage declines. This provides a possible explanation to the lagged decline in the skill premium.

The paper develops a model to identify the underlying market interactions that are critical in generating the observed behavior along the lines of this intuition. The paper incorporates a theoretical setup that features search frictions into a new Keynesian framework with nominal rigidities. The model relies on search

frictions as it became the standard environment in analyzing the cyclical behavior of labor market variables ever since Merz (1995) and Andolfatto (1996) introduced a two-sided search into an otherwise real business cycle model and succeeded in reproducing some stylized facts that the Walrasian model either resolved in an unsatisfactory manner or has not been able to address at all. On the other hand, the new Keynesian paradigm that integrates imperfect competition and nominal rigidities into an optimizing general equilibrium setup gained consensus as an appropriate framework to analyze the economy's response to monetary policy shocks. Nevertheless, a drawback of the new Keynesian model is attributed to its failure to address a set of stylized facts that characterize the labor market due to its lack of frictions that can generate equilibrium unemployment. This stimulated the incorporation of search frictions into new Keynesian models. These extensions focused on the demand channel of monetary policy in which nominal rigidities in the Calvo (1983) sense allows monetary transmission through its influence on aggregate demand, as adopted in Cheron & Langot (2000), Soto (2003), Riascos (2002), Krause & Lubik (2007), Gerke & Rubart (2003), Trigari (2003, 2009), Christoffel & Linzert (2010), Walsh (2005), Tang (2010) and Moyen & Sahuc (1995).

This paper builds upon the progress established in these studies and extends their framework, which combines labor search and an optimizing based monetary policy model, into one that is characterized by heterogeneity of workers and jobs. In this context, the labor force is divided into the high educated and the low educated. There are two types of firms: wholesalers and retailers. Wholesalers post two types of vacancies: the complex that can be matched with the high educated and the simple that can be matched with both the high educated and the low educated. The high educated in simple occupations are allowed to continue searching on-the-job for a complex occupation. The wholesalers use labor as their only factor of production, and sell their output to retailers in a perfectly competitive market. The retailers use the wholesale output as their intermediate good, which they differentiate costlessly and sell to households in a monopolistically competitive market. Nominal rigidities occur as only a portion of the retailers are assumed to adjust their prices every period. The monetary authority utilizes the nominal interest rate as the instrument for the conduct of monetary policy. A positive monetary policy shock induces the high educated unemployed to compete with the low educated, as they increase their search intensity for simple vacancies. As the high educated occupy simple vacancies, they crowd out the low educated into unemployment. This downgrading of jobs in a cyclical downturn, or the increase in the labor input of the high educated in simple occupations, and the subsequent crowding out of the low educated into unemployment, provide a possible explanation to unemployment persistence and the response of the skill premium. An adverse aggregate technological shock causes the variables of interest to exhibit similar patterns.

2.   Relevant Literature

This paper adopts a different approach compared with previous studies that attempted to explain the persistence of unemployment. For instance,

Esteban-Pretel (2005) and Esteban-Pretel & Faraglia (2010) include the aspect of skill loss by the high educated if unemployed for an extended period of time, in order to explain the persistence of unemployment. When the economy suffers an adverse shock, unemployment increases and the creation of vacancies declines, thus lengthening unemployment spells. The increase in the duration of unemployment causes workers to lose their skills, which leads to an increase in the unemployment of the unskilled. The increase in the unemployment of the unskilled, who have a lower probability of finding a job, raises the average duration of unemployment in the economy and accordingly the persistence of unemployment. Pries (2004) argues that even though unemployed workers find jobs quickly, due to the high job finding rate following a shock that triggers a burst of job loss, the newly found jobs often last only a short time. After an initial job loss, a worker may experience several short lived jobs before settling into more stable employment. This recurring job loss contributes to the persistence of unemployment. Eriksson & Gottfries (2005) argue that employers use information on whether the applicant is employed or unemployed as a hiring criterion, since the perceived productivity of an unemployed worker may be lower than that of an employed worker, as human capital is lost in unemployment. This ranking of job applicants by employment status increases the level and persistence of unemployment. Eriksson (2006) extends this framework to argue that long-term unemployed workers do not compete well with other job applicants because they have lost the abilities that employers find attractive. In a model with short-term and long-term unemployed workers, firms prefer to hire the unemployed who have not lost their human capital. This ranking of job applicants results in a lengthy adjustment process, and is capable of generating persistence after an adverse shock.

This paper also adopts a different approach compared with previous studies that focused on the features of capital skill complementarity and variable utilization of capital to explain the lagged procyclical pattern of the skill premium. For instance, Lindquist (2004) argued that capital skill complementarity allows the model to reproduce the cyclical pattern of the skill premium. However, Young (2003) argued that the success of the model in Lindquist (2004) is attributed to its abstraction from variable utilization of capital, whose introduction implies strong procyclical skill premium. Another criticism of the Lindquist (2004) framework is its inability to replicate the cyclical behavior of the underlying wages. Both Lindquist (2004) and Young (2003) argued that the Walrasian aspects of the model cause the wages, which are equal to the marginal product of labor, to be strongly correlated with output. They suggested the introduction of implicit contracts to solve this problem. Pourpourides (2011) developed a model with implicit contracts and demonstrated that the feature of variable utilization of capital, rather than capital skill complementarity, is essential in reproducing the observation that the skill premium is uncorrelated with contemporaneous output.

This paper, however, argues that the cyclical pattern of the skill premium and the persistence of unemployment can be reproduced in a model of job competition and crowding out. The success of this model is attributed to the additional dynamics that it introduces, such as competition between those distinguished by their educational levels for a job with a particular educational requirement, the

crowding out of the unsuccessful by the successfully matched, and the possibility of a mismatch between the educational level of the successful and the educational requirement of the job they occupy. This downgrading of jobs can explain the persistence of unemployment and the cyclical behavior of the skill premium.

The remainder of the paper is organized as follows: Section 3 covers the empirical evidence, Section 4 includes the model, Section 5 includes the calibration, Section 6 analyzes the results, Section 7 concludes. The data and derivations are given in the appendices.

3.   Empirical Evidence

The task of examining the effect of a monetary policy shock on the skill premium, and the unemployment across skills is undertaken by compiling a time series from the Outgoing Rotation Group of the Current Population Survey.[1] This Survey provides monthly information from January 1979 until December 2004 on the participants' employment status, level of education, type of occupation, weekly earnings, and weekly hours of work. To compile a time series out of this survey, the observations in each monthly file are divided into those employed and those unemployed. Each of these groups is further divided into those high and low educated, where the former are those who obtained at least some college education. Each of the two employed groups is further divided into those working in a complex occupation and those working in a simple occupation, where the former is a job that requires at least some college education or higher. This allows for four employed and two unemployed types as follows: the high educated employed in a complex occupation, the high educated employed in a simple occupation, the high educated unemployed, the low educated employed in a complex occupation, the low educated employed in a simple occupation, and the low educated unemployed.

The low educated employed in a complex occupation type are dropped from the sample due to their insignificant proportion out of all the low educated and out of all those employed in complex occupations. For the remainder of the employed types, weighted average hourly wages[2] are calculated as the ratio of the weighted average weekly earnings to the weighted average weekly hours for each group. Using the three hourly wages, the skill premium is defined as the ratio of the weighted average wage of the two high educated types to that of the low educated in simple occupations. For the two unemployed types, levels of unemployment are calculated. Ratios of unemployment of the respective types as a proportion of the total sample are also considered. Using the average hours and the level of employment of all types, the labor input or the total hours of work of each type is calculated. Finally, a crowding out variable is defined as the proportion of the total hours of the high educated amongst the total hours of all those employed in simple occupations, such that its increase reflects an increase in the crowding out

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[1]Detailed data description is included in Appendix A.1.

[2]Some studies examined the effect of composition bias on the cyclicality of average wages. However, according to Lindquist (2004) and Castro & Coen-Pirani (2008), if one controls for composition effects the induced behavior of real wages is similar to that of mean wages.

process of the low educated by the high educated in occupying this type of job. The data used in the analysis are quarterly.

In this section, a vector autoregressive VAR analysis is conducted to demonstrate the dynamic response of an identified exogenous monetary policy shock on the skill premium, the crowding out, and the unemployment measures that are compiled, where the short-term interest rate is taken to be the instrument of monetary policy. The vector autoregression is given by

$$Z_t = \eta + \sum_{i=1}^{p} \Phi_i Z_{t-i} + \epsilon_t$$

where ϵ is an independently and identically distributed error term with zero mean and constant variance. The identification of structural shocks in the VAR is done using the Cholesky decomposition. The vector of endogenous variables in the first VAR is given by

$$Z_t = [U_t, Premium_t, Crowding_t, Y_t, \pi_t, r_t]$$

The vector of endogenous variables in the second VAR is given by

$$Z_t = [U_t^h, U_t^l, Premium_t, Crowding_t, Y_t, \pi_t, r_t]$$

where U_t is total unemployment rate, U_t^h is the proportion of the high educated unemployed, U_t^l is the proportion of the low educated unemployed, $Premium_t$ is the logged skill premium, $Crowding_t$ is the crowding out variable, Y_t is the logged real gross domestic product, π_t is the inflation rate and r_t is the Fed funds rate. The vector autoregression is estimated using two lags, $p = 2$, as suggested by the Akaike information criterion and the Hannan-Quinn information criterion. Figures 1–2 display the impulse responses to a one percentage standard deviation innovation to Fed funds rate. The impulse responses demonstrate that a positive shock to the Fed funds rate causes a decline in real gross domestic product and in the inflation rate. The shock also causes an initial increase and a lagged decline in the skill premium. The shock induces an increase in the crowding out, the total unemployment rate, and the unemployment rates of the low and the high educated, with a larger and more persistent response of that of the former compared to that of the latter. Table 8 displays the serial correlations of the total unemployment rate, and that of the unemployment rates of the high and the low educated. The observations from the data show the high persistence of total unemployment, and that the persistence of the unemployment of the low educated is higher than that of the high educated.

The cross-correlation coefficients between real gross domestic product in period t and each of these variables in lag and lead periods are displayed in Table 5. These patterns demonstrate that the proportion of the high educated unemployed is countercyclical and lags the cycle where the cross-correlation coefficient with output reaches -0.6298 and is statistically significant, while the proportion of the low-educated unemployed is countercyclical where the cross-correlation
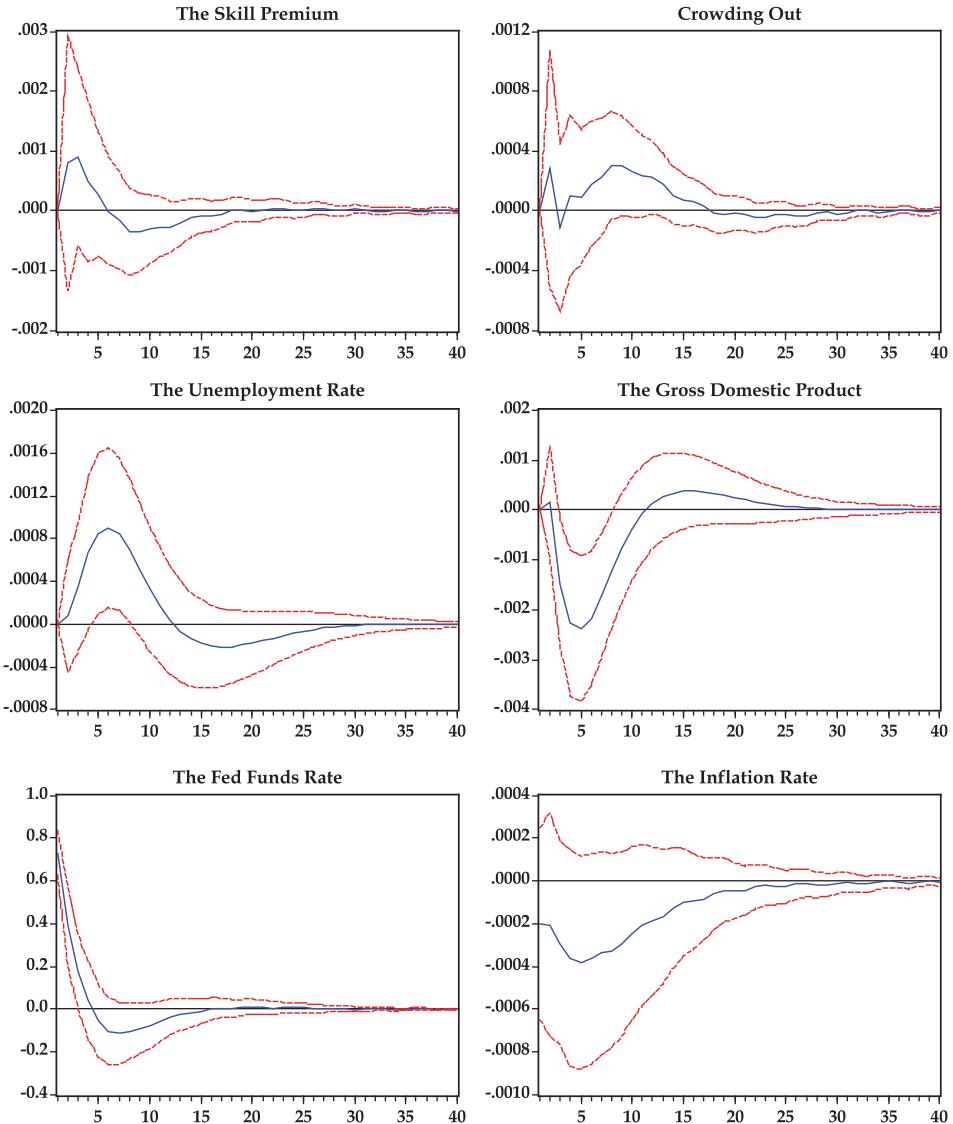
Figure 1. VAR1 impulse responses to a shock to Fed funds rate.

coefficient with contemporaneous output of −0.8863 is also statistically significant. The total unemployment rate is countercyclical where the cross-correlation coefficient of −0.8199 is statistically significant. The crowding out effect is countercyclical with a lag, as the fourth lagged cross-correlation coefficient of −0.3680 is statistically significant. Finally, the skill premium is procyclical with a lag, where the fourth lagged cross-correlation coefficient of 0.2482 is statistically significant.

These observations can be intuitively interpreted to reflect a lagged countercyclical downgrading of jobs by the skilled workers. This can explain the lagged increase in the crowding out, as the high educated crowd the low educated out of
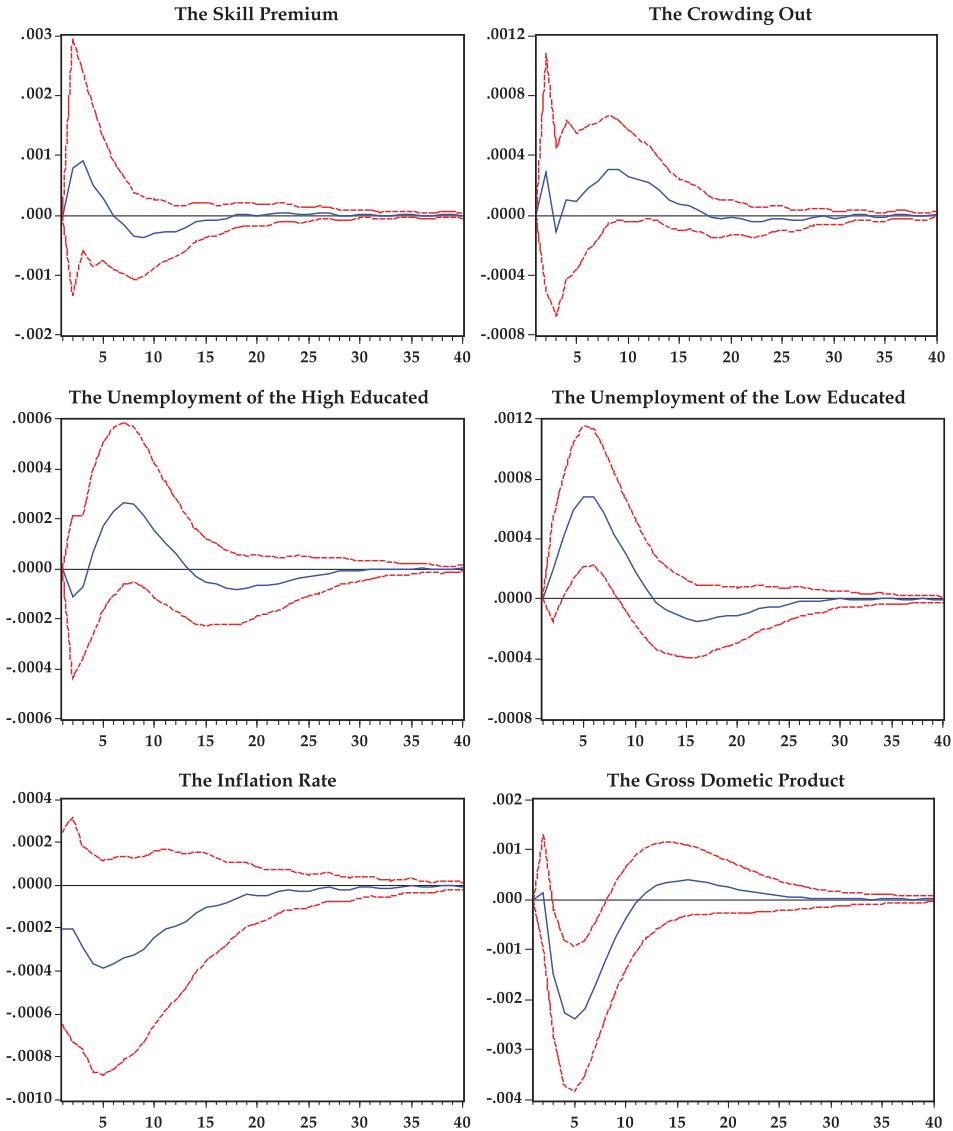
Figure 2. VAR2 impulse responses to a shock to Fed funds rate.

Table 1. Extracted variables.

Variable	Definition
MONTH	Month of interview
MLR	Monthly labor force recode
GRDHI	Highest grade attended
GRDATN	Educational attainment
OCC	Occupation of job last week
HOURS	Total hours worked last week
ERNWGT	Earnings weight

Table 2. Ranges for high and low education levels.

Period	High Educated	Low Educated
1979–1988	$14 \leqslant \text{GRDHI} \leqslant 19$	$1 \leqslant \text{GRDHI} \leqslant 13$
1989–1991	$13 \leqslant \text{GRDHI} \leqslant 18$	$1 \leqslant \text{GRDHI} \leqslant 12$
1992–2004	$40 \leqslant \text{GRDATN} \leqslant 46$	$31 \leqslant \text{GRDATN} \leqslant 39$

Table 3. Ranges for complex and simple occupation types.

Period	Complex Occupation	Simple Occupation
1979–1982	1–85	86–90
	91–96	100–101
	102–246	260–995
1983–1991	0–173	174–177
	178–242	243–991
1992–2002	0–163	164–165
	166–173	174–177
	178–242	243–999
2003–2004	10–1960	2000–2060
	2100–3650	3700–9830

Table 4. Calibration of model parameters.

Parameter	Value	Description
δ	0.5	proportion of the high educated in the population
β	0.98	household discount factor
χ^{hc}	0.35	separation rate from complex occupations
χ^{hs}	0.02	separation rate of the high educated from simple occupations
χ^{ls}	0.02	separation rate of the low educated from simple occupations
T^{hc}	0.3	efficiency in the complex occupation matching function
T^{hs}	0.15	efficiency in the simple occupation matching function with the high educated
T^{ls}	0.05	efficiency in the simple occupation matching function with the low educated
γ	0.5	elasticity of complex matches with respect to complex vacancies
μ	0.5	elasticity of output to complex occupation output
ω^c	1.043	cost of posting a complex vacancy
ω^s	0.08	cost of posting a simple vacancy
ξ^{hc}	0.5	firm share from bargaining with a high educated in a complex occupation
ξ^{hs}	0.5	firm share from bargaining with a high educated in a simple occupation
ξ^{ls}	0.5	firm share from bargaining with a low educated in a simple occupation
τ^h	1.0	parameter in the utility of leisure of the high educated unemployed
τ^l	0.7	parameter in the utility of leisure of the low educated unemployed
τ^{hc}	1.5	parameter in the utility of leisure of the high educated in complex occupations
τ^{hs}	0.7	parameter in the utility of leisure of the high educated in simple occupations
τ^{ls}	0.1	parameter in the utility of leisure of the low educated in simple occupations
σ_m	0.1	standard deviation of the monetary policy shock
σ	0.75	proportion of retailers that do not adjust
θ	11	elasticity of substitution across differentiated goods
α_r	0.85	interest rate smoothing parameter
α_π	1.5	coefficient of inflation in the Taylor rule
α_Y	0.5	coefficient of output in the Taylor rule

Table 5. Data moments. Standard errors in () calculated by bootstrapping.

x	Cross correlations of output (t) and $x(t+i)$								
	$x(t-4)$	$x(t-3)$	$x(t-2)$	$x(t-1)$	$x(t)$	$x(t+1)$	$x(t+2)$	$x(t+3)$	$x(t+4)$
Premium	−0.1350	−0.0666	0.0083	0.0051	0.1103	0.1368	0.1778	0.2251	0.2482
	(0.0987)	(0.0974)	(0.0969)	(0.0889)	(0.0850)	(0.0774)	(0.0755)	(0.0774)	(0.0671)
U^b	−0.0115	−0.1488	−0.3038	−0.4524	−0.5754	−0.6298	−0.6083	−0.5299	−0.4389
	(0.0728)	(0.0704)	(0.0663)	(0.0613)	(0.0542)	(0.0481)	(0.0499)	(0.0550)	(0.0694)
U^l	−0.2148	−0.3846	−0.5670	−0.7668	−0.8863	−0.8486	−0.7131	−0.5141	−0.2949
	(0.0973)	(0.0878)	(0.0809)	(0.0452)	(0.0261)	(0.0364)	(0.0609)	(0.0886)	(0.1090)
U	−0.1430	−0.3119	−0.4966	−0.6893	−0.8199	−0.8189	−0.7236	−0.5620	−0.3823
	(0.0932)	(0.0843)	(0.0737)	(0.0519)	(0.0379)	(0.0379)	(0.0502)	(0.0722)	(0.0937)
Crowding	0.2411	0.2157	0.1057	−0.0060	−0.1321	−0.2031	−0.3128	−0.3367	−0.3680
	(0.0983)	(0.0903)	(0.1010)	(0.0900)	(0.0968)	(0.1008)	(0.0969)	(0.0910)	(0.0890)

simple jobs to unemployment. Thus, in a downturn, as the high educated compete with the low educated in occupying simple jobs, they crowd out the low educated into unemployment, which contributes to the persistence of total unemployment, and the higher persistence of the unemployment of the low educated compared with that of the high educated. This also means that as the high educated move to simple jobs, their weighted average wage declines. This causes the gap between the wage of the high educated and that of the low educated to diminish with a lag, and accordingly can provide a possible explanation to the lagged decline in the skill premium.

The decline in the inflation rate and real gross domestic product is a standard result in the literature. The responses of the unemployment rates of the high and the low educated are consistent with the results of several studies. For instance, Kydland (1984) concluded that 'unskilled workers in the United States labor force exhibit greater employment fluctuations over the business cycle than do skilled workers.' Similarly, Hoynes (2000) provided evidence that the employment rates of those with lower education exhibit more cyclical fluctuation and variability than those with higher education. Keane *et al*. (1988) found that 'those with observed characteristics corresponding to lower education are more likely to leave employment in a cyclical downturn.' Finally, Farber (2005) concluded that 'there is a strong cyclical pattern in job loss rates for less educated workers, but the cyclical pattern is weaker for more educated workers.' The lagged procyclicality of the skill premium is supported by evidence from previous studies as well. For instance, Lindquist (2004) found the mean skill premium uncorrelated with contemporaneous output and lags the business cycle. Evidence on the procyclical upgrading of jobs is provided by Devereux (2000, 2004) who used the Panel Study of Income Dynamics for the period 1976–1992, and found that in a recession the skilled occupy jobs that would normally be occupied by the unskilled.

4.   Model

Consider an economy where time is infinite and discrete. The population is of measure 1, and there is a constant fraction δ of households that are ex ante high

educated and $(1 - \delta)$ that are low educated. There are two types of firms: wholesalers and retailers. Wholesalers post complex and simple vacancies. The complex vacancies are matched with the high educated only, while the simple vacancies are matched with both the high educated and the low educated. Wholesalers also choose the proportion of simple vacancies directed towards the high educated and that directed towards the low educated. A high educated worker in a simple occupation is allowed to continue searching on-the-job for a complex occupation. This is justified as the two types of vacancies differ according to their creation costs, and these costs generate rents, which give rise to equilibrium wage differentials between occupation types. The wholesalers produce using labor as their only factor of production, and sell their intermediate output to retailers in a perfectly competitive market. Retailers purchase these intermediate goods, costlessly transform and sell them to households in a monopolistically competitive market. Prices at the retail level are sticky as only a fraction of retail firms optimally adjust their price each period.

4.1 *Households*

The high- and low-educated household members are divided into those employed and those unemployed as follows

$$N_t^{hc} + N_t^{hs} + U_t^h = \delta \tag{1}$$

$$N_t^{ls} + U_t^l = 1 - \delta \tag{2}$$

where N_t^{ij} denotes the number of workers of education type i in occupation type j, where $i \in (h, l)$ for high and low educated workers, respectively, and $j \in (c, s)$ for complex and simple occupations, respectively. U_t^i denotes the unemployed of type i. Time for all types is normalized to one. A high-educated unemployed uses a portion S_t^{hc} of its time to search for a complex occupation, a portion S_t^{hs} to search for a simple occupation, and $(1 - S_t^{hc} - S_t^{hs})$ for leisure. A low-educated unemployed uses a portion S_t^{ls} of its time to search for a simple occupation, and $(1 - S_t^{ls})$ for leisure. A high-educated worker in a complex occupation spends a portion H_t^{hc} hours at work and $(1 - H_t^{hc})$ for leisure. A high-educated worker in a simple occupation spends a portion H_t^{hs} hours at work, a portion O_t to search on-the-job for a complex occupation, and $(1 - H_t^{hs} - O_t)$ for leisure. The low educated in a simple occupation spends a portion H_t^{ls} hours at work and $(1 - H_t^{ls})$ for leisure.

As different employment histories amongst members of a household can lead to heterogeneous wealth positions, we follow the literature in assuming that each household is thought of as an extended family whose members perfectly insure each other against variations in labor income due to employment or unemployment. Remaining within the confines of complete markets allows solving the program of a representative household, who chooses consumption, bond holdings and search intensities to maximize the expected discounted infinite sum of its instantaneous utility, which is separable in consumption and leisure. Assuming the

household has the following value function $\Gamma_t^H = \Gamma^H(H_t^{hc}N_t^{hc}, H_t^{hs}N_t^{hs}, H_t^{ls}N_t^{ls})$, the optimization problem of the household can be written in the following recursive form

$$\Gamma_t^H = \underset{\{C_t, B_t, S_t^{hc}, S_t^{hs}, O_t, S_t^{ls}\}}{Max} \{\mathfrak{U}(C_t) + U_t^h\Omega_t^h + U_t^l\Omega_t^l + N_t^{hc}\Omega_t^{hc} + N_t^{hs}\Omega_t^{hs}$$

$$+ N_t^{ls}\Omega_t^{ls} + \beta E_t[\Gamma_{t+1}^H]\} \tag{3}$$

where E_t is the expectation operator conditional on the information set available in period t, β is the discount factor and $\mathfrak{U}(C_t)$ is the utility of period t consumption of the household C_t. $\Omega_t^h = \Omega^h(1 - S_t^{hc} - S_t^{hs})$ and $\Omega_t^l = \Omega^l(1 - S_t^{ls})$ denote the utility of period t leisure of the high and the low educated unemployed, respectively. $\Omega_t^{hc} = \Omega^{hc}(1 - H_t^{hc})$, $\Omega_t^{hs} = \Omega^{hs}(1 - H_t^{hs} - O_t)$ and $\Omega_t^{ls} = \Omega^{ls}(1 - H_t^{ls})$ denote the utility of period t leisure of the employed types. This is subject to the following budget constraint

$$C_t + \frac{B_t}{\rho_t} = N_t^{hc}H_t^{hc}W_t^{hc} + N_t^{hs}H_t^{hs}W_t^{hs} + N_t^{ls}H_t^{ls}W_t^{ls} + \frac{B_{t-1}R_{t-1}^n}{\rho_t} + D_t \tag{4}$$

where W_t^{ij} is the period t real wage for type ij, ρ_t is the price of one unit of the final good, B_t is the households' holdings of a nominal one-period risk-free bond, R_t^n is the gross nominal interest rate on this bond, and D_t is the total dividends distributed by wholesale and retail firms. The households also take into consideration the employment dynamics of the three types of workers. The high educated workers in complex occupations in period $t + 1$ comprise those of that type who are not exogenously separated in period t according to the separation rate from complex occupations, χ^{hc}, in addition to the new matches from the searchers' pool whether they are high educated unemployed or on-the-job searchers

$$N_{t+1}^{hc} = (1 - \chi^{hc})N_t^{hc} + P_t^{hc}(S_t^{hc}U_t^h + O_tN_t^{hs}) \tag{5}$$

where $P_t^{hc} = \frac{M_t^{hc}}{S_t^{hc}U_t^h + O_tN_t^{hs}}$ is the probability that a high educated searcher is matched with a complex occupation, and $M_t^{hc} = M^{hc}(V_t^c, S_t^{hc}U_t^h + O_tN_t^{hs})$ represents the number of complex matches. Similarly, the high educated workers in simple occupations in period $t + 1$ comprise those of that type who are neither separated from simple occupations exogenously in period t according to the separation rate, χ^{hs}, nor are matched with complex occupations as a result of on-the-job search, in addition to the new matches from the searchers' pool of the high educated unemployed

$$N_{t+1}^{hs} = (1 - \chi^{hs})(1 - O_tP_t^{hc})N_t^{hs} + P_t^{hs}(S_t^{hs}U_t^h) \tag{6}$$

where $P_t^{hs} = \frac{M_t^{hs}}{S_t^{hs}U_t^h}$ is the probability that a high educated searcher is matched with a simple occupation, and $M_t^{hs} = M^{hs}(Z_tV_t^s, S_t^{hs}U_t^h)$ represents the number

of simple matches with the high educated. The matching functions are constant returns to scale, homogeneous of degree one, functions of the number of corresponding vacancies, V_t^c and V_t^s, and effective searchers. Z_t is the proportion of simple vacancies directed to the high educated.

Finally, the low educated workers in simple occupations in period $t + 1$ comprise those of that type who are not exogenously separated in period t according to the separation rate, χ^{ls}, in addition to the new matches from the searchers' pool of the low-educated unemployed

$$N_{t+1}^{ls} = (1 - \chi^{ls})N_t^{ls} + P_t^{ls}(S_t^{ls}U_t^l) \tag{7}$$

where $P_t^{ls} = \frac{M_t^{ls}}{S_t^{ls}U_t^l}$ is the probability that a low educated searcher is matched with a simple occupation, and $M_t^{ls} = M^{ls}((1 - Z_t)V_t^s, S_t^{ls}U_t^l)$ represents the number of simple matches with the low educated. The constant separation rates are justified by Hall (2005), who concludes that over the past 50 years job separation rates remained almost constant in the United States, and by Shimer (2005) who demonstrates that separation rates exhibit acyclicality. Households choose consumption such that the marginal utility of consumption equals the Lagrange multiplier λ_t

$$\frac{\partial \mho(C_t)}{\partial C_t} = \lambda_t \tag{8}$$

They choose the level of bonds to hold to satisfy the following condition for the marginal utility of income

$$\lambda_t = \beta E_t[R_t \lambda_{t+1}] \tag{9}$$

where R_t is the gross real interest rate defined as $R_t = E_t \frac{P_t}{P_{t+1}} R_t^n$. Combining these two first-order conditions yields the Euler equation

$$\frac{\partial \mho(C_t)}{\partial C_t} = \beta E_t \left[R_t \frac{\partial \mho(C_{t+1})}{\partial C_{t+1}} \right] \tag{10}$$

The household chooses the optimal proportion of time the high-educated unemployed allot to search for a complex occupation, S_t^{hc}, such that the disutility from increasing search by one unit is offset by the discounted expected value of an additional high educated in a complex occupation,

$$\frac{\partial \Omega^h}{\partial S_t^{hc}} + \beta P_t^{hc} E_t \left[\frac{\partial \Gamma_{t+1}^H}{\partial N_{t+1}^{hc}} \right] = 0 \tag{11}$$

The household chooses the optimal proportion of time the high educated unemployed allot to search for a simple occupation, S_t^{hs}, such that the disutility from

increasing search by one unit is offset by the discounted expected value of an additional high educated in a simple occupation,

$$\frac{\partial \Omega^h}{\partial S_t^{hs}} + \beta P_t^{hs} E_t \left[\frac{\partial \Gamma_{t+1}^H}{\partial N_{t+1}^{hs}} \right] = 0 \tag{12}$$

The household chooses the optimal proportion of time the low-educated unemployed allot to search for a simple occupation, S_t^{ls}, such that the disutility from increasing search by one unit is offset by the discounted expected value of an additional low educated in a simple occupation

$$\frac{\partial \Omega^l}{\partial S_t^{ls}} + \beta P_t^{ls} E_t \left[\frac{\partial \Gamma_{t+1}^H}{\partial N_{t+1}^{ls}} \right] = 0 \tag{13}$$

The household chooses on-the-job search intensity, O_t, such that the disutility from increasing search by one unit is offset by the difference between the discounted expected value to the household from an additional high educated worker in a complex occupation and that of an additional high educated worker in a simple occupation,

$$\frac{\partial \Omega^{hs}}{\partial O_t} + P_t^{hc} \beta E_t \left[\frac{\partial \Gamma_{t+1}^H}{\partial N_{t+1}^{hc}} \right] - P_t^{hc} \beta E_t \left[\frac{\partial \Gamma_{t+1}^H}{\partial N_{t+1}^{hs}} \right] (1 - \chi^{hs}) = 0 \tag{14}$$

From the envelope theorem, an additional high educated matched with a complex occupation accrue a value to the household that is given by

$$\frac{\partial \Gamma_t^H}{\partial N_t^{hc}} = \Omega^{hc}(1 - H_t^{hc}) - \Omega^h(1 - S_t^{hc} - S_t^{hs}) + \lambda_t W_t^{hc} H_t^{hc}$$

$$+ \beta(1 - \chi^{hc} - P_t^c S_t^{hc}) E_t \left[\frac{\partial \Gamma_{t+1}^H}{\partial N_{t+1}^{hc}} \right] - \beta P_t^{hs} S_t^{hs} E_t \left[\frac{\partial \Gamma_{t+1}^H}{\partial N_{t+1}^{hs}} \right] \tag{15}$$

Similarly, an additional high educated matched with a simple occupation accrue a value to the household that is given by

$$\frac{\partial \Gamma_t^H}{\partial N_t^{hs}} = \Omega^{hs}(1 - H_t^{hs} - O_t) - \Omega^h(1 - S_t^{hc} - S_t^{hs}) + \lambda_t W_t^{hs} H_t^{hs}$$

$$+ \beta((1 - \chi^{hs})(1 - O_t P_t^{hc}) - P_t^{hs} S_t^{hs}) E_t \left[\frac{\partial \Gamma_{t+1}^H}{\partial N_{t+1}^{hs}} \right]$$

$$+ \beta(P_t^{hc} O_t - P_t^{hc} S_t^{hc}) E_t \left[\frac{\partial \Gamma_{t+1}^H}{\partial N_{t+1}^{hc}} \right] \tag{16}$$

Finally, an additional low educated matched with a simple occupation accrue a value to the household that is given by

$$\frac{\partial \Gamma_t^H}{\partial N_t^{ls}} = \Omega^{ls}(1 - H_t^{ls}) - \Omega^l(1 - S_t^{ls}) + \lambda_t W_t^{ls} H_t^{ls} + (1 - \chi^{ls} - P_t^{ls} S_t^{ls}) E_t \left[\frac{\partial \Gamma_{t+1}^H}{\partial N_{t+1}^{ls}} \right]$$
(17)

Substituting the envelope conditions into the first-order conditions yields

$$\frac{\tau^b}{\beta P_t^{hc}} = -\tau^b E_t (1 - S_{t+1}^{hc} - S_{t+1}^{hs}) + E_t \left[\Omega^{hc}(1 - H_{t+1}^{hc}) \right] + E_t \left[\frac{H_{t+1}^{hc} W_{t+1}^{hc}}{C_{t+1}} \right]$$

$$+ E_t \left[(1 - \chi^{hc} - P_{t+1}^{hc} S_{t+1}^{hc}) \left(\frac{\tau^b}{P_{t+1}^{hc}} \right) \right] - E_t \left[\tau^b S_{t+1}^{hs} \right]$$
(18)

$$\frac{\tau^b}{\beta P_t^{hs}} = -\tau^b E_t (1 - S_{t+1}^{hc} - S_{t+1}^{hs}) + E_t \left[\Omega^{hs}(1 - H_{t+1}^{hs} - O_{t+1}) \right]$$

$$+ E_t \left[\frac{H_{t+1}^{hs} W_{t+1}^{hs}}{C_{t+1}} \right] + E_t \left[\tau^b (O_{t+1} - S_{t+1}^{hc}) \right]$$

$$+ E_t \left[((1 - \chi^{hs})(1 - O_{t+1} P_{t+1}^{hc}) - P_{t+1}^{hs} S_{t+1}^{hs}) \left(\frac{\tau^b}{P_{t+1}^{hs}} \right) \right]$$
(19)

$$\frac{\tau^l}{\beta P_t^{ls}} = -\tau^l E_t (1 - S_{t+1}^{ls}) + E_t [\Omega^{ls}(1 - H_{t+1}^{ls})]$$

$$+ E_t \left[\frac{H_{t+1}^{ls} W_{t+1}^{ls}}{C_{t+1}} \right] + E_t \left[(1 - \chi^{ls} - P_{t+1}^{ls} S_{t+1}^{ls}) \left(\frac{\tau^l}{P_{t+1}^{ls}} \right) \right]$$
(20)

These conditions are derived by forwarding the envelope conditions one period and substituting them into the optimal search intensity first-order conditions. τ^b and τ^l are the marginal utilities of leisure of the high and the low educated unemployed, respectively, as $\Omega_t^b = \tau^b (1 - S_t^{hc} - S_t^{hs})$ and $\Omega_t^l = \tau^l (1 - S_t^{ls})$.

4.2 *Wholesalers*

The representative wholesaler chooses the number of complex and simple vacancies to post, besides the proportion of the simple vacancies directed to the high educated, in order to maximize the discounted expected infinite sum of its future profit streams. The profit function is given by the difference between the value of its production and the total cost incurred for creating the two types of vacancies, as well as the wages of the three labor types. Assuming the firm has the following value function $\Gamma_t^F = \Gamma^F(N_t^{hc} H_t^{hc}, N_t^{hs} H_t^{hs}, N_t^{ls} H_t^{ls})$, the optimization problem can

be written in the following recursive form

$$\Gamma_t^F = \underset{\{V_t^s, V_t^c, Z_t\}}{Max} \left\{ X_t Y_t - \omega^s V_t^s - \omega^c V_t^c - N_t^{hc} H_t^{hc} W_t^{hc} - N_t^{hs} H_t^{hs} W_t^{hs} \right.$$
$$\left. - N_t^{ls} H_t^{ls} W_t^{ls} + \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \Gamma_{t+1}^F \right] \right\} \tag{21}$$

where X_t is the wholesale price of one unit of the intermediate good and Y_t is the intermediate output. ω^c is the cost of creating a complex vacancy and ω^s is the cost of creating a simple vacancy. The discount factor of firms is given such that it effectively evaluates profits in terms of the values attached to them by households, who ultimately own the firms. Thus, the utility based and time varying discount factor used by firms is given by $(\beta \frac{\lambda_{t+1}}{\lambda_t})$. The maximization is subject to the production function which is represented by a constant returns to scale Cobb-Douglas function

$$Y_t = A_t (H_t^{hc} N_t^{hc})^\mu (H_t^{hs} N_t^{hs} + H_t^{ls} N_t^{ls})^{1-\mu} \tag{22}$$

where $\mu \in (0, 1)$ is the elasticity of output with respect to the complex occupation output. The maximization problem of the firm is also subject to the following employment dynamics

$$N_{t+1}^{hc} = (1 - \chi^{hc}) N_t^{hc} + q_t^{hc} V_t^c \tag{23}$$

$$N_{t+1}^{hs} = (1 - \chi^{hs})(1 - O_t P_t^{hc}) N_t^{hs} + q_t^{hs} Z_t V_t^s \tag{24}$$

$$N_{t+1}^{ls} = (1 - \chi^{ls}) N_t^{ls} + q_t^{ls} (1 - Z_t) V_t^s \tag{25}$$

where $q_t^{hc} = \frac{M_t^{hc}}{V_t^c}$ is the probability of filling a complex vacancy, $q_t^{hs} = \frac{M_t^{hs}}{Z_t V_t^s}$ is the probability that a simple vacancy is filled by a high educated, and $q_t^{ls} = \frac{M_t^{ls}}{(1-Z_t)V_t^s}$ is the probability that a simple vacancy is filled by a low educated. The firm chooses the optimal level of complex vacancies to post, V_t^c, such that the expected marginal cost of posting this type of vacancy is equal to the discounted expected value for the firm of an additional high educated worker in a complex occupation

$$\omega^c = q_t^{hc} \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \frac{\partial \Gamma_{t+1}^F}{\partial N_{t+1}^{hc}} \right] \tag{26}$$

The firm chooses the optimal level of simple vacancies to post, V_t^s, such that the cost of posting a simple vacancy is equal to the discounted expected value of creating an occupation from this vacancy, whether it is filled by a high- or a low-educated worker

$$\omega^s = q_t^{hs} Z_t \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \frac{\partial \Gamma_{t+1}^F}{\partial N_{t+1}^{hs}} \right] + q_t^{ls} (1 - Z_t) \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \frac{\partial \Gamma_{t+1}^F}{\partial N_{t+1}^{ls}} \right] \tag{27}$$

The firm chooses the optimal proportion of simple vacancies directed to the high educated, Z_t, such that the discounted expected value of an additional high

educated worker in a simple occupation is equal to the discounted expected value of an additional low educated worker in a simple occupation

$$q_t^{hs} E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \frac{\partial \Gamma_{t+1}^F}{\partial N_{t+1}^{hs}} \right] = q_t^{ls} E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \frac{\partial \Gamma_{t+1}^F}{\partial N_{t+1}^{ls}} \right] \tag{28}$$

From the envelope theorem, the value of an additional high-educated worker in a complex occupation for the firm is given by the difference between its marginal productivity and the wage, in addition to the discounted expected value of the match in case the worker is not exogenously separated

$$\frac{\partial \Gamma_t^F}{\partial N_t^{hc}} = X_t \frac{\partial Y_t}{\partial N_t^{hc}} - H_t^{hc} W_t^{hc} + (1 - \chi^{hc}) \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \frac{\partial \Gamma_{t+1}^F}{\partial N_{t+1}^{hc}} \right] \tag{29}$$

Similarly, the value of an additional high-educated worker in a simple occupation for the firm is given by the difference between its marginal productivity and the wage, in addition to the discounted expected value of the match in case the worker is neither exogenously separated nor matched with a complex occupation as a result of on-the-job search

$$\frac{\partial \Gamma_t^F}{\partial N_t^{hs}} = X_t \frac{\partial Y_t}{\partial N_t^{hs}} - H_t^{hs} W_t^{hs} + (1 - \chi^{hs})(1 - O_t P_t^{hc}) \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \frac{\partial \Gamma_{t+1}^F}{\partial N_{t+1}^{hs}} \right] \tag{30}$$

Finally, the value of an additional low-educated worker in a simple occupation for the firm is given by the difference between its marginal productivity and the wage, in addition to the discounted expected value of the match in case the worker is not exogenously separated

$$\frac{\partial \Gamma_t^F}{\partial N_t^{ls}} = X_t \frac{\partial Y_t}{\partial N_t^{ls}} - H_t^{ls} W_t^{ls} + (1 - \chi^{ls}) \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \frac{\partial \Gamma_{t+1}^F}{\partial N_{t+1}^{ls}} \right] \tag{31}$$

Substituting the envelope conditions into the first-order conditions yields the firm's optimal conditions

$$\frac{\omega^c}{q_t^{hc}} = \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \left(X_{t+1} \frac{\partial Y_{t+1}}{\partial N_{t+1}^{hc}} - H_{t+1}^{hc} W_{t+1}^{hc} + (1 - \chi^{hc}) \frac{\omega^c}{q_{t+1}^{hc}} \right) \right] \tag{32}$$

$$\frac{\omega^s}{q_t^{hs}} = \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \left(X_{t+1} \frac{\partial Y_{t+1}}{\partial N_{t+1}^{hs}} - H_{t+1}^{hs} W_{t+1}^{hs} + (1 - \chi^{hs})(1 - O_{t+1} P_{t+1}^{hc}) \frac{\omega^s}{q_{t+1}^{hs}} \right) \right] \tag{33}$$

$$\frac{\omega^s}{q_t^{ls}} = \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \left(X_{t+1} \frac{\partial Y_{t+1}}{\partial N_{t+1}^{ls}} - H_{t+1}^{ls} W_{t+1}^{ls} + (1 - \chi^{ls}) \frac{\omega^s}{q_{t+1}^{ls}} \right) \right] \tag{34}$$

These conditions are derived by forwarding the envelope conditions one period, and substituting them into the firm's first-order conditions.

4.3   *Wages and Hours*

In equilibrium, matched firms and workers obtain from the match a total return that is strictly higher than the expected return of unmatched firms and workers, because if they separate each will have to go through an expensive and time-consuming process of search before being matched again. We assume that a realized match shares this surplus. Therefore, the wage of a high educated worker in a complex occupation is given by[3]

$$H_t^{hc}W_t^{hc} = (1 - \xi^{hc})\left[X_t \frac{\partial Y_t}{\partial N_t^{hc}} + P_t^{hc}S_t^{hc}\frac{\omega^c}{q_t^{hc}} \right]$$
$$+ \xi^{hc}C_t[\Omega^h(1 - S_t^{hc} - S_t^{hs}) - \Omega^{hc}(1 - H_t^{hc}) + S_t^{hs}\tau^h] \quad (35)$$

where ξ^{hc} is the firm's share of the surplus. The wage is a weighted average of two terms: the first indicates that the worker is rewarded by a fraction $(1 - \xi^{hc})$ of both the firm's revenues from the worker's productivity and the discounted expected value to the firm of the match. The second term indicates that the worker is compensated by a fraction ξ^{hc} for the foregone benefit from the worker's outside option or the difference between the leisure of a high-educated unemployed and that of a high educated in a complex occupation, in addition to the forgone benefit from being matched with a simple vacancy. Similarly, the wage of the high educated in a simple occupation is given by[4]

$$H_t^{hs}W_t^{hs} = (1 - \xi^{hs})\left[X_t \frac{\partial Y_t}{\partial N_t^{hs}} + P_t^{hs}S_t^{hs}\frac{\omega^s}{q_t^{hs}} \right] + \xi^{hs}C_t[\Omega^h(1 - S_t^{hc} - S_t^{hs})$$
$$- \Omega^{hs}(1 - H_t^{hs} - O_t) - (O_t - S_t^{hc})\tau^h] \quad (36)$$

where ξ^{hs} is the firm's share of the surplus. The wage is a weighted average of two terms: the first indicates that the worker is rewarded by a fraction $(1 - \xi^{hs})$ of both the firm's revenues from the worker's productivity and the discounted expected value of the match for the firm. The second term indicates that the worker is compensated by a fraction ξ^{hs} for the outside options or the difference between the leisure of a high-educated unemployed and that of a high educated in a simple occupation, in addition to the forgone benefit from being matched with a complex vacancy. Finally, the bargained wage of the low educated in a simple occupation is given by[5]

$$H_t^{ls}W_t^{ls} = (1 - \xi^{ls})\left[X_t \frac{\partial Y_t}{\partial N_t^{ls}} + P_t^{ls}S_t^{ls}\frac{\omega^s}{q_t^{ls}} \right] + \xi^{ls}C_t\left[\Omega^l(1 - S_t^{ls}) - \Omega^{ls}(1 - H_t^{ls}) \right]$$
$$(37)$$

where ξ^{ls} is the firm's share of the surplus. The wage is a weighted average of two terms: the first indicates that the worker is rewarded by a fraction $(1 - \xi^{ls})$ for the

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[3]Detailed derivations are included in Appendix A.2.1.
[4]Detailed derivations are included in Appendix A.2.2.
[5]Detailed derivations are included in Appendix A.2.3.

firm's revenues from the worker's productivity and the discounted expected value of the match for the firm. The second term indicates that the worker is compensated by a fraction ξ^{ls} for the outside options or the difference between the leisure of a low-educated unemployed and that of a low educated in a simple occupation. In this context, the skill premium is defined as the ratio of the weighted average wage of the two high educated types, $W_t^h = \frac{N_t^{hc} H_t^{hc} W_t^{hc} + N_t^{hs} H_t^{hs} W_t^{hs}}{N_t^{hc} H_t^{hc} + N_t^{hs} H_t^{hs}}$, to the wage of the low educated in simple occupations

$$Premium_t = \frac{W_t^h}{W_t^{ls}} \tag{38}$$

The hours of the high educated in complex occupations are chosen such that the disutility of leisure from increasing the hours of work by one unit is offset by the increase in marginal productivity due to an increase in hours by one unit[6]

$$\frac{X_t \partial \left(\frac{\partial Y_t}{\partial N_t^{hc}} \right)}{\partial H_t^{hc}} + \left(\frac{1}{\lambda_t} \right) \frac{\partial \Omega_t^{hc}}{\partial H_t^{hc}} = 0 \tag{39}$$

The hours of the high educated in simple occupations are chosen such that the disutility of leisure from increasing the hours of work by one unit is offset by the increase in marginal productivity due to an increase in hours by one unit[7]

$$\frac{X_t \partial \left(\frac{\partial Y_t}{\partial N_t^{hs}} \right)}{\partial H_t^{hs}} + \left(\frac{1}{\lambda_t} \right) \frac{\partial \Omega_t^{hs}}{\partial H_t^{hs}} = 0 \tag{40}$$

The hours of the low educated in simple occupations are chosen such that the disutility of leisure from increasing the hours of work by one unit is offset by the increase in marginal productivity due to an increase in hours by one unit[8]

$$\frac{X_t \partial \left(\frac{\partial Y_t}{\partial N_t^{ls}} \right)}{\partial H_t^{ls}} + \left(\frac{1}{\lambda_t} \right) \frac{\partial \Omega_t^{ls}}{\partial H_t^{ls}} = 0 \tag{41}$$

If the total hours are denoted $TH_t^{hc} = N_t^{hc} H_t^{hc}$, $TH_t^{hs} = N_t^{hs} H_t^{hs}$, and $TH_t^{ls} = N_t^{ls} H_t^{ls}$, the crowding out effect is defined as

$$Crowding_t = \frac{TH_t^{hs}}{TH_t^{hs} + TH_t^{ls}} \tag{42}$$

Total unemployment is defined as $U_t = U_t^h + U_t^l$. To close the model, we have

$$Y_t = C_t + \omega^c V_t^c + \omega^s V_t^s \tag{43}$$

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[6]Detailed derivations are included in Appendix A.2.4.
[7]Detailed derivations are included in Appendix A.2.5.
[8]Detailed derivations are included in Appendix A.2.6.

4.4 *Retailers*

There is a continuum of monopolistically competitive retailers indexed by j over the unit interval. Retailers buy the homogeneous intermediate output produced by wholesalers Y_t at a price X_t in a competitive market. They differentiate them with a technology that transforms a unit of wholesale good into a unit of retail good Y_{jt} at no cost, and then retailer j sells them to the households at a nominal price of ρ_{jt}. Final goods are the CES aggregate

$$Y_t = \left(\int_0^1 Y_{jt}^{\frac{\theta-1}{\theta}} \, dj \right)^{\frac{\theta}{\theta-1}} \tag{44}$$

where θ is the elasticity of substitution across the differentiated retail goods. Given the aggregate output index, the corresponding price index, which is defined as the minimum expenditure required to purchase retail goods resulting in one unit of the final good, is given by

$$\rho_t = \left(\int_0^1 \rho_{jt}^{1-\theta} \, dj \right)^{\frac{1}{1-\theta}} \tag{45}$$

As an optimizing household allocates its consumption spending across alternative differentiated goods at date t so as to minimize the total expenditure required to achieve a given value of the index C_t, each retailer faces a downward sloping demand curve for his goods given by

$$C_{jt} = \left(\frac{\rho_{jt}}{\rho_t} \right)^{-\theta} C_t \tag{46}$$

Each retailer takes as given the price of the wholesale output as its input besides the demand curve, and chooses its optimal price to maximize its discounted expected stream of future profits under the hypothesis that the price they set at date t applies at date $t + s$ with probability σ, and is given by

$$E_t \left\{ \sum_{s=0}^{\infty} \sigma^s \beta^s \frac{\lambda_{t+s}}{\lambda_t} \left[\frac{\rho_{jt}}{\rho_{t+s}} - \frac{X_{t+s}}{P_{t+s}} \right] C_{jt+s} \right\} \tag{47}$$

Substituting the demand curve yields

$$E_t \left\{ \sum_{s=0}^{\infty} \sigma^s \beta^s \frac{\lambda_{t+s}}{\lambda_t} \left[\frac{\rho_{jt}}{\rho_{t+s}} - \frac{X_{t+s}}{P_{t+s}} \right] \left(\frac{\rho_{jt}}{\rho_{t+s}} \right)^{-\theta} C_{t+s} \right\} \tag{48}$$

Each retailer chooses the optimal price P_{jt} such that[9]

$$\left(\frac{\rho_{jt}}{\rho_t} \right) = \left(\frac{\theta}{\theta - 1} \right) \frac{E_t \left\{ \sum_{s=0}^{\infty} \sigma^s \beta^s \frac{\lambda_{t+s}}{\lambda_t} \left[\frac{X_{t+s}}{P_{t+s}} (\frac{\rho_{t+s}}{\rho_t})^{\theta} C_{t+s} \right] \right\}}{E_t \left\{ \sum_{s=0}^{\infty} \sigma^s \beta^s \frac{\lambda_{t+s}}{\lambda_t} \left[(\frac{\rho_{t+s}}{\rho_t})^{\theta-1} C_{t+s} \right] \right\}} \tag{49}$$

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[9]Detailed derivations are standard in the literature and available from the author upon request.

A forward looking retailer sets its price equal to a markup over a weighted average of expected future marginal costs, where $\frac{\theta}{\theta-1}$ is the steady state markup. To introduce price stickiness, assume that each retailer can update its price with a fixed probability $(1 - \sigma)$ that is independent of the time elapsed since the last price adjustment. This can be perceived as a fraction $(1 - \sigma)$ of retailers who get to set a new price, while the remaining σ must continue to sell at their previously posted prices. Therefore, if all firms choose the same price $\rho_{jt} = \rho_t^*$, the aggregate price level evolution is given by

$$\rho_t = \left[\sigma(\rho_{t-1})^\theta + (1 - \sigma)(\rho_t^*)^{1-\theta}\right]^{\frac{1}{1-\theta}} \tag{50}$$

Combining the log linearized optimal condition and the log linearized aggregate price level yields the following forward looking Phillips curve[10]

$$\hat{\pi}_t = \frac{1 - \sigma}{\sigma}(1 - \sigma\beta)(\hat{X}_t - \hat{\rho}_t) + \beta E_t \hat{\pi}_{t+1} \tag{51}$$

where $\hat{\pi}_t$ is the period t log linearized inflation rate.

4.5 Monetary Authority

The monetary authority conducts monetary policy using the short-term nominal interest rate, R_t^n, as the policy instrument and lets the nominal amount of money adjust accordingly. The Taylor rule that is considered is forward looking as follows

$$R_t^n = [R_{t-1}^n]^{\alpha_r}[(E_t\pi_{t+1})^{\alpha_\pi}(Y_t)^{\alpha_Y}]^{1-\alpha_r}e^{\epsilon_t^m} \tag{52}$$

where the parameter α_r measures the degree of interest rate smoothing. The parameters α_π and α_Y are the response coefficients of inflation and output, respectively. Finally, ϵ_t^m is an independently and identically distributed monetary policy shock.

5. Calibration

The functional forms are determined and the parameters are calibrated in order to solve the model numerically. In this context, numerical values are assigned to the structural parameters in order to conduct a quantitative analysis. Table 4 shows the values chosen for the parameters of the model. In this context, some of the parameters are set as is standard in the literature. Since information may not be available for the other parameters, their values are computed in the steady state system of equations after setting values for variables quantifiable from the data.

The steady state values for certain variables are calculated from the averages in the dataset during the period under study. For instance, the proportion of the high educated in the population δ is set at 0.5, which equals the data average. Similarly, the proportions of the employed types are set at $N^{hc} = 0.23$, $N^{hs} =$

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[10]Detailed derivations are included in Appendix A.2.7.

0.25, $N^{ls} = 0.46$ and the unemployed types at $U^h = \delta - N^{hc} - N^{hs} = 0.02$, $U^l = 1 - \delta - N^{ls} = 0.04$, and $U = 0.06$, which are equal to the data averages during the period under study as well.

Given the proportion of employment of all types, the three wages, W^{hc}, W^{hs}, and W^{ls} are set equal to the data average, such that the steady state skill premium is 1.52, which is also equal to the data average of 1.51389439 in the period under study. In addition, given the proportion of employment of every type, the hours of work of every type is chosen equal to the data average, such that $Crowding = \frac{N^{hs}H^{hs}}{N^{hs}H^{hs}+N^{ls}H^{ls}} = 0.39$ is also set equal to the data average of 0.395251453.

The household's discount factor β is given by 0.98, which is standard in the literature. The instantaneous utility function of consumption is represented by the logarithm of consumption expenditures $\mho(C_t) = ln(C_t)$. The instantaneous utility functions of leisure are given by $\Omega_t^h = \tau^h(1 - S_t^{hc} - S_t^{hs})$, $\Omega_t^l = \tau^l(1 - S_t^{ls})$, $\Omega_t^{hc} = \tau^{hc}(1 - H_t^{hc})$, $\Omega_t^{hs} = \tau^{hs}(1 - H_t^{hs} - O_t)$, $\Omega^{ls} = \tau^{ls}(1 - H_t^{ls})$. The parameters in the utility of leisure for the high-educated unemployed τ^h is given by 1, for the low-educated unemployed τ^l is given by 0.7. The parameters in the utility of leisure for the high educated in complex occupations τ^{hc} is given by 1.5, for the high educated in simple occupations τ^{hs} is given by 0.7, and for the low educated in simple occupations τ^{ls} is given by 0.1. These parameters are solved for in the steady state equations for the optimal hours of work, given the proportion of employment and hours of work of every type. These equations are given by $X\mu^2(\frac{Y}{H^{hc}N^{hc}}) = \tau^{hc}C$, $XY(1 - \mu)\left[\frac{-\mu H^{hs}N^{hs}}{(H^{hs}N^{hs}+H^{ls}N^{ls})^2} + \frac{1}{(H^{hs}N^{hs}+H^{ls}N^{ls})}\right] = \tau^{hs}C$, and $XY(1 - \mu)\left[\frac{-\mu H^{ls}N^{ls}}{(H^{hs}N^{hs}+H^{ls}N^{ls})^2} + \frac{1}{(H^{hs}N^{hs}+H^{ls}N^{ls})}\right] = \tau^{ls}C$.

The matching functions for the complex and simple occupations are represented as a Cobb-Douglas specification with constant returns to scale, and are given by $M_t^{hc} = T^{hc}(V_t^c)^\gamma(S_t^{hc}U_t^h + O_tN_t^{hs})^{1-\gamma}$, $M_t^{hs} = T^{hs}(Z_tV_t^s)^\gamma(S_t^{hs}U_t^h)^{1-\gamma}$ and $M_t^{ls} = T^{ls}((1 - Z_t)V_t^s)^\gamma(S_t^{ls}U_t^l)^{1-\gamma}$, where $\gamma \in (0, 1)$ is the elasticity of matching with respect to vacancies. T^{hc}, T^{hs} and T^{ls} are the level parameters of the matching functions that capture all factors that influence the efficiency of matching. The elasticity of matches with respect to vacancies γ is set at 0.5, as is standard in the literature. The level parameters in the matching functions T^{hc}, T^{hs} and T^{ls} are given by 0.3, 0.15, and 0.05, respectively. The choice of the level parameters is determined to target the separation rates. In the steady state, the flows out of employment equal the flows out of unemployment. This ensures that the employment level of every type stays constant. Thus, we have $\chi^{hc}N^{hc} = M^{hc}$, $(\chi^{hs} + OP^{hc} - \chi^{hs}OP^{hc})N^{hs} = M^{hs}$, and $\chi^{ls}N^{ls} = M^{ls}$ in the steady state. Therefore, the choice of T^{hc}, T^{hs} and T^{ls} determines the matches, and accordingly targets the separation rates. The separation rates χ^{hc}, χ^{hs} and χ^{ls} from the complex and simple occupations are given by 0.35, 0.02 and 0.02, respectively.[11] These are selected such that their average is close

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[11]A sensitivity analysis is conducted for the separation rate for the high educated from complex occupations. A reduction of the rate causes a decline in the response of the unemployment of the high educated and its persistence.

to the weighted average separation rate calculated by Hall (2005) and Shimer (2005).

The costs of creating the complex vacancy ω^c and the simple vacancy ω^s are given by 1 and 0.08, respectively. These values are determined through the steady-state equations of the optimal number of vacancies. The firm's share of the surplus ξ^{hc}, ξ^{hs} and ξ^{ls} are set at 0.5, 0.5 and 0.5, respectively, as is standard in the literature. The bargaining power of the households are set equal to the elasticity of matching with respect to vacancies, which as shown in Hosios (1990) implies that the bargaining process yields a Pareto optimal allocation of resources.

The technological constraints faced by the firm is also represented by a constant returns to scale Cobb-Douglas function $Y_t = A_t (H_t^{hc} N_t^{hc})^\mu (H_t^{hs} N_t^{hs} + H_t^{ls} N_t^{ls})^{1-\mu}$. The logarithm of the aggregate technology A_t is assumed to follow an AR(1) process as follows

$$log A_{t+1} = \rho^A log A_t + \epsilon_{t+1}^A \tag{53}$$

where ϵ_{t+1}^A is an independently and identically distributed random variable drawn from a normal distribution with mean zero and standard deviation denoted by $\sigma_{\epsilon A}$. The elasticity parameter in the production function μ is given by 0.5, as in Krause & Lubik (2004). The autoregressive coefficient in the technological law of motion ρ^A is given by 0.9. As is common in the literature, an innovation variance is chosen such that the baseline model's predictions match the standard deviation of the US GDP, which is 1.62%. Consequently, the standard deviation of technology is set to $\sigma_{\epsilon A} = 0.0049$.

The last group includes the parameters of the new Keynesian aspects of the model whose calibration follows the pertinent literature. The elasticity of substitution across the differentiated goods θ is given by 11, to get a markup of 1.1 as is standard in the literature. The proportion of retailers that do not adjust their price σ is given by 0.75. The interest rate smoothing parameter α_r is given by 0.85, and the parameters α_π and α_Y are given by 1.5 and 0.5, respectively.

6. Analysis

The model is solved by computing the nonstochastic steady state around which the equation system is linearized. The resulting model is solved by the methods developed in Sims (2002). We examine the impact of a contractionary monetary shock and a negative aggregate technological shock.

6.1 *Monetary Shock*

Figures 3 and 4 capture the dynamic responses of the variables of interest to a monetary policy shock. A monetary authority that tightens through increasing the nominal interest rate causes an increase in the real interest rate due to nominal rigidities. Therefore, consumers face a higher trade-off between present and future consumption due to the increased returns on saving. This modifies the aggregate consumption behavior of households, and reduces current and future aggregate demand. Since monopolistic competitive retailers produce to meet demand, this
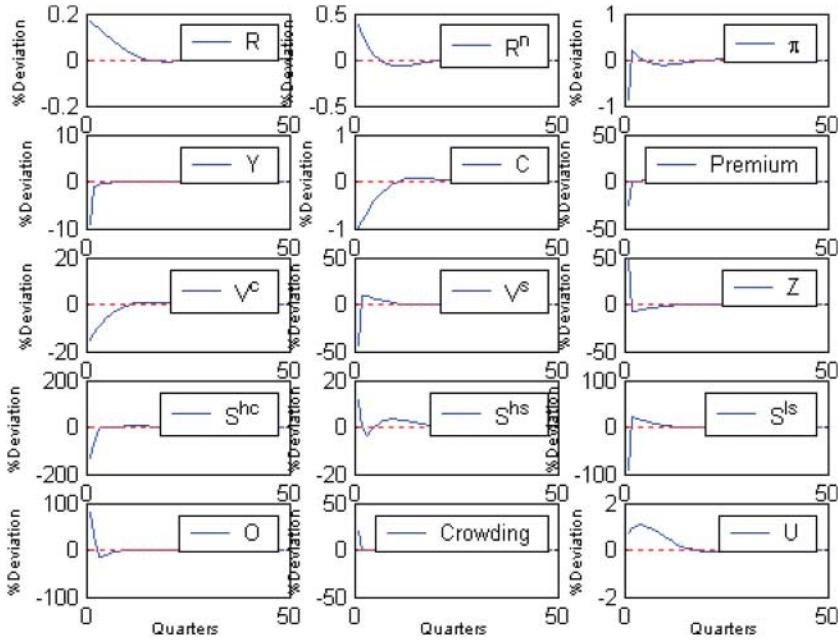
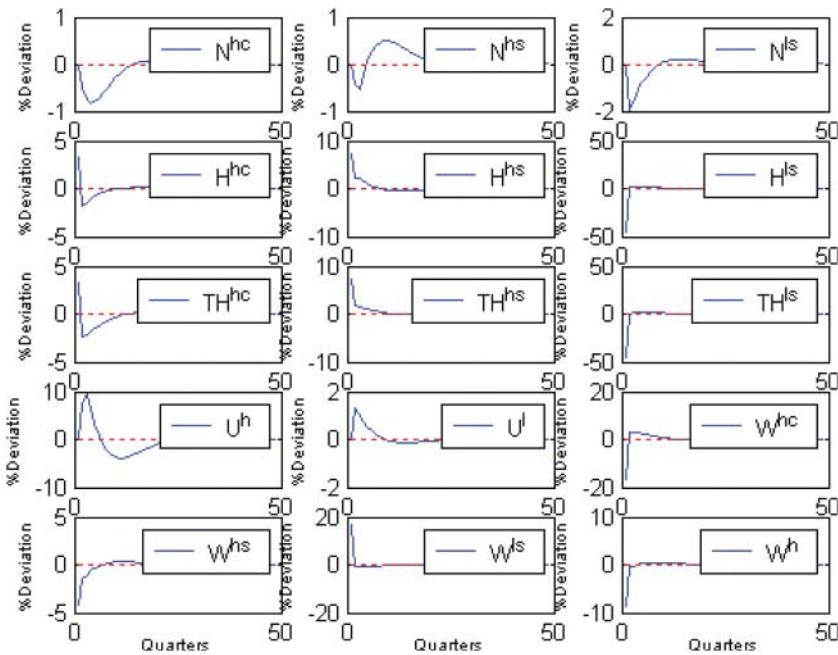**Figure 3.** Model impulse response functions to a 1% monetary policy shock.

Figure 4. Model impulse response functions to a 1% monetary policy shock.

reduces their current and future demand for intermediate goods, which they use as inputs for the final output. This consequently causes a decline in their production, which can only occur at declined marginal costs, and, because prices are set based on expected future real marginal cost, inflation declines.

Wholesalers, faced by a decline in the demand for their goods, reduce the posting of complex and simple vacancies. The low-educated unemployed faced with a decline in the proportion of simple vacancies directed to them, reduce their search intensity for this type of vacancy. Accordingly, the proportion of the low educated in simple occupations decline, while the proportion of the low educated unemployed increases, consistently with the VAR results. Similarly, as the complex vacancies decline, the high-educated unemployed decrease their search intensity for complex occupations. Thus, the proportion of the high educated in complex occupations decline and the unemployment of the high educated increases. As simple vacancies are cheaper to create, their recovery is faster than that of complex vacancies. This, along with the increase in the proportion of simple vacancies directed to the high educated, induce the high educated unemployed to increase their search intensity for this type of vacancy. This causes a lagged increase in the employment of the high educated in simple occupations. The total hours of the high educated in simple occupations increase, while that of the low educated in simple occupations decrease. This causes an increase in the crowding out process.

As the proportion of the low educated in simple occupations declines, the probability that a simple vacancy is filled by one declines as well, and the discounted expected value of an additional worker of that type to the firm increases, thus increasing the wage of this type. The wage of the high educated is a weighted average of the wages of the high educated in complex and in simple occupations, and the weights are given by the total hours of the two types. As the wage of the high educated in simple occupations declines, while their total hours increase, the weighted average wage of the high educated declines. This decline, along with the increase in the wage of the low educated in simple occupations, causes the skill premium to decline as well.

Table 7 presents the cross-correlation coefficients between the variables of interest in the model. These are consistent with the VAR results. For instance, the skill

Table 6. Model moments. standard errors in () calculated by bootstrapping

x	Cross correlations of output(t) and $x(t+i)$								
	$x(t-4)$	$x(t-3)$	$x(t-2)$	$x(t-1)$	$x(t)$	$x(t+1)$	$x(t+2)$	$x(t+3)$	$x(t+4)$
Premium	0.2320	0.2643	0.2715	0.2886	0.4485	0.7698	0.6696	0.5566	0.4788
	(0.0990)	(0.1081)	(0.1026)	(0.0987)	(0.0827)	(0.0404)	(0.0540)	(0.0764)	(0.0758)
U^h	−0.2288	−0.2644	−0.2812	−0.2937	−0.4090	−0.6398	−0.6716	−0.6101	−0.5309
	(0.1046)	(0.1024)	(0.1030)	(0.0976)	(0.0907)	(0.0598)	(0.0536)	(0.0683)	(0.0713)
U^l	−0.2169	−0.2551	−0.2702	−0.2895	−0.4360	−0.7216	−0.6961	−0.6002	−0.5106
	(0.1038)	(0.1065)	(0.1021)	(0.1031)	(0.0858)	(0.0464)	(0.0504)	(0.0690)	(0.0697)
U	−0.2285	−0.2641	−0.2809	−0.2936	−0.4101	−0.6430	−0.6727	−0.6099	−0.5303
	(0.0995)	(0.1015)	(0.1013)	(0.0994)	(0.0895)	(0.0609)	(0.0532)	(0.0689)	(0.0708)
Crowding	−0.2407	−0.2358	−0.2859	−0.5140	−0.9323	−0.6138	−0.4320	−0.3793	−0.3634
	(0.1121)	(0.1018)	(0.0966)	(0.0730)	(0.0113)	(0.0599)	(0.0923)	(0.0846)	(0.0991)

Table 7. Model cross correlation coefficients

	Premium	U^h	U^l	TH^{hc}	TH^{hs}	TH^{ls}	Crowding	Y	π	R^n
Premium	1									
U^h	0.0191	1								
U^l	0.0702	0.8556	1							
TH^{hc}	−0.6788	−0.5480	−0.7524	1						
TH^{hs}	−0.9008	0.2723	0.3378	0.2974	1					
TH^{ls}	0.9999	0.0235	0.0702	−0.6759	−0.9029	1				
Crowding	−0.9975	0.0209	−0.0094	0.6270	0.9289	−0.9979	1			
Y	0.9776	−0.1315	−0.1306	−0.5104	−0.9717	0.9784	−0.9897	1		
π	0.9020	0.3356	0.2620	−0.6807	−0.7903	0.9072	−0.9011	0.8645	1	
R^n	−0.6934	0.6628	0.6173	0.0500	0.8561	−0.6896	0.7233	−0.7970	−0.3925	1

Table 8. Unemployment serial correlations

	Variable	$\rho(x_t, x_{t-1})$	$\rho(x_t, x_{t-2})$	$\rho(x_t, x_{t-3})$	$\rho(x_t, x_{t-4})$	$\rho(x_t, x_{t-5})$
Data	U_t	0.870	0.695	0.492	0.299	0.101
Model1	U_t	0.964	0.892	0.796	0.687	0.574
Model2	U_t	0.922	0.834	0.747	0.664	0.585
Data	U_t^h	0.796	0.643	0.504	0.338	0.118
Model1	U_t^h	0.853	0.580	0.336	0.141	−0.008
Model2	U_t^h	0.923	0.835	0.748	0.665	0.586
Data	U_t^l	0.855	0.649	0.432	0.229	0.038
Model1	U_t^l	0.733	0.528	0.357	0.217	0.105
Model2	U_t^l	0.896	0.798	0.702	0.612	0.529

premium is negatively correlated with the nominal interest rate with a coefficient of −0.6934. The unemployment rates of the high and the low educated are positively correlated with the nominal interest rate, with coefficients of 0.6628 and 0.6173, respectively. The crowding out is positively correlated with the nominal interest rate with a coefficient of 0.7233. Finally, as is standard in the literature, the real gross domestic product and the inflation rate are negatively correlated with nominal interest rate, with correlation coefficients of −0.7970 and −0.3925, respectively.

The model also succeeds in reproducing the persistence of unemployment as shown in Table 8 under Model 1. For instance, the first lag serial correlation of the unemployment of the high educated is 0.796 in the data and 0.853 in the model. The second lag autocorrelation is 0.643 in the data and 0.580 in the model. Similarly, the first lag autocorrelation of the unemployment of the low educated is 0.855 in the data and 0.733 in the model. The second lag autocorrelation is 0.649 in the data and 0.528 in the model. For the remaining lagged serial correlations of the unemployment variables, the persistence is slightly lower in the model than that in the data. For the total unemployment rate, the model generates a higher persistence than that displayed in the data. This can be attributed to the observation that after the initial shock, the recovery of the economy is captured in a faster recovery of the hours of work, rather than in the employment levels.

This causes the unemployment, in the models with the endogenous choice of the hours of work, to exhibit higher persistence.

6.2 *Technological Shock*

The impulse responses in Figures 5 and 6 show the dynamic evolution of the variables of interest along with a deviation of output from its long run trend as a consequence of a negative aggregate technological shock. The adverse shock decreases the productivity of all types of workers. This reduces the discounted expected value of an additional worker of any type to the firm. The firm posts complex vacancies such that the expected marginal cost of posting a complex vacancy is equal to the discounted expected value for the firm of an additional high educated worker. Accordingly, the decrease in the marginal productivity of workers induces firms to decrease their posting of complex vacancies. On the other hand, firms post simple vacancies such that the expected marginal cost of posting a simple vacancy is equal to the discounted expected value of creating an occupation from this vacancy, whether it is filled by a high or a low educated worker. Even though the productivity of both types of workers declined, the probability that a simple vacancy is filled by a high educated increases. This causes an increase in the posting of simple vacancies directed to the high educated.

Accordingly, the search intensity for simple vacancies by the high educated increases, and that for complex vacancies decreases. This causes a decline in the employment of the high educated in complex occupations, and an increase in the
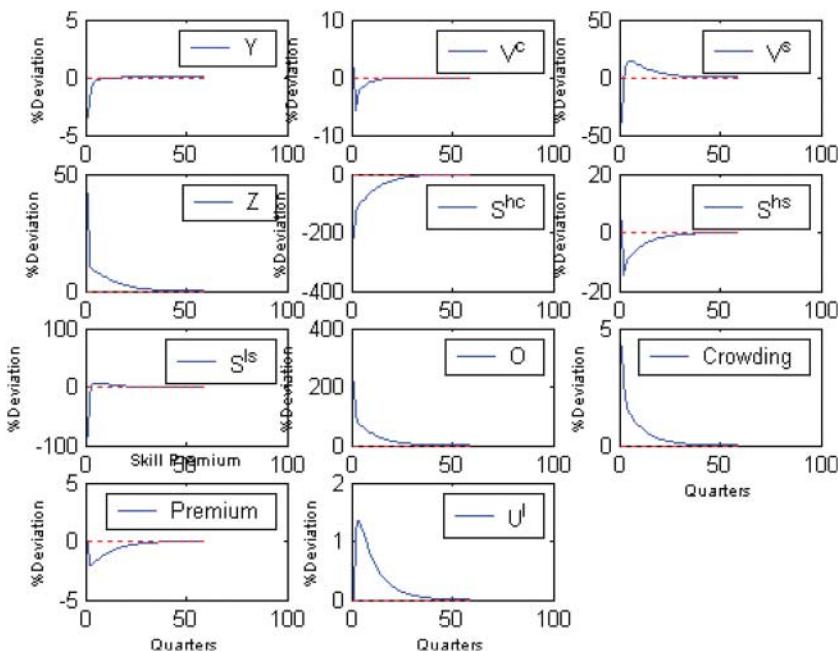

Figure 5. Model impulse response functions to a negative 1% aggregate technological shock.
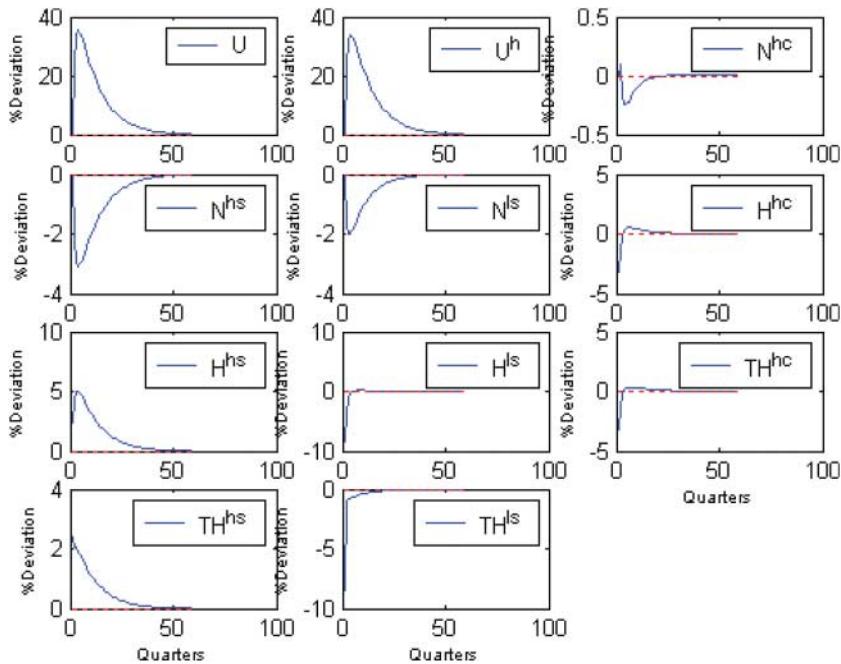
Figure 6. Model impulse response functions to a negative 1% aggregate technological shock.

employment of the high educated in simple occupations. As the decline in the former is smaller than the increase in the latter, the unemployment of the high educated increases.

On the other hand, the low-educated unemployed reduce their search intensity for simple occupations due to the decline in the proportion of simple vacancies directed to this type. This causes a decrease in the employment of the low educated in simple occupations and an increase in the unemployment of the low educated. The impulse responses show a high persistence of total unemployment, consistently with the observations. The model, however, produces a higher response of the unemployment of the high educated relative to that of the low educated, but the persistence of the former is lower, consistently with the observations.

The hours of work of any type are chosen such that the disutility of leisure from increasing the hours of work by one unit is offset by the increase in the marginal productivity due to an increase in hours by one unit. Figure 6 shows that the hours of work of the high educated in complex occupations and of the low educated in simple occupations decline. Due to the increase in the employment and the hours of the high educated in simple occupations, the total hours of this type increase. Therefore, the crowding out variable increases. This crowding out of the low educated by the high educated contributes to the persistence of unemployment.

The wage of the high educated is a weighted average of the wage of the high educated in complex and in simple occupations. The weights are given by the total hours of each type. The increase in the weight of the high educated in simple

occupations, combined with a decrease in their wages, causes the average wage of the high educated to decrease with a lag. This causes the skill premium to decrease as well.

The model succeeds in reproducing the cross-correlations coefficients as shown in Table 6. However, the total unemployment rate shows a lagged behavior that is not observed in the data, while the crowding out effect does not show the lag observed in the data. The model also succeeds in reproducing the persistence of unemployment as shown in Table 8 under Model 2. However, the persistence is higher with an aggregate technological shock compared with a contractionary monetary shock.

7.   Conclusion

This paper assumes the task of analyzing the impact of monetary policy on the skill premium, and the unemployment across skills. To analyze the effect of a monetary policy shock, a vector autoregressive analysis is undertaken. A positive shock to the Fed funds rate causes a decline in the inflation rate, in real gross domestic product and in the skill premium with a lag. The shock causes an increase in the crowding out of the unskilled by the skilled workers in occupying unskilled jobs. The shock also induces a highly persistent unemployment rate, and a more persistent increase in the unemployment rate of the unskilled relative to that of the skilled.

To account for these patterns, a framework characterized by search frictions is considered where workers are heterogeneous in terms of their education level. There are two types of firms: wholesalers and retailers. Wholesalers post two types of vacancies: the complex that can be filled by the high educated, and the simple that can be filled by the high and the low educated. High educated workers in a simple occupation can continue searching on-the-job for a complex occupation. The wholesalers produce intermediate goods using labor only, and sell their product to retailers in a perfectly competitive market. Retailers purchase these intermediate goods, differentiate and sell them to households in a monopolistically competitive market. Nominal rigidities are generated as only some of the retailers adjust their price every period. Monetary authority utilizes the nominal interest rate as the instrument for the conduct of monetary policy, and relies on a forward looking Taylor rule. A contractionary monetary policy induces the high educated unemployed to compete with the low educated, as they increase their search intensity for simple vacancies. As the high educated occupy simple vacancies, they crowd out the low educated into unemployment. This downgrading of jobs, or the increase in the labor input of the high educated in simple occupations, and the subsequent crowding out of the low educated into unemployment, provide a possible explanation to unemployment persistence and the cyclical pattern of the skill premium.

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Appendix

A.1   *Data*

The data set used is the Outgoing Rotation Group of the Current Population Survey. The Current Population Survey is a rotating panel. After the fourth month in the survey, the participants take an eight-month hiatus. Afterwards, they are interviewed for another four months, and after the eighth month in sample, they are completely dropped from the survey. The Outgoing Rotation series is a merged collection of the fourth and eighth month-in-sample groups from all 12 months. These two groups play a special role as they are given additional questions, the answers to which are collected in the Outgoing Rotation Group files. The data is monthly and covers the period from January 1979 until December 2004. At the end of each year, the 12 monthly files from January till December are concatenated into a single annual file. The variables extracted are as in Table 1.

Each annual file is divided into monthly files according to the variable MONTH. For each monthly file, participants in the labor force are split into those employed and those unemployed according to MLR. This variable distinguishes between the employed, the unemployed and those not in the labor force. Both the employed and the unemployed are further split into high educated and low educated workers, where the former are those who obtained some college education or higher. Table 2 shows the variables' ranges defining the high and the low educated

Each worker group, the high or the low educated, is further divided into two groups: those employed in complex occupations and those employed in simple occupations, where the former are jobs that require at least some college education. This mapping between occupations and educational requirements is based on judgment. In most cases, it is straightforward to determine whether an occupation requires college education. In the cases where it is not clear, the occupations are considered once as complex and another as simple.[12] The results did not

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[12]For instance, under the category of health practitioners: dentists, pharmacists, physicians and surgeons are considered complex occupations. On the other hand, therapists, clinical laboratory technicians are considered simple occupations. Finally, optometrists and opticians can be considered either as a complex or a simple occupation.

change in both cases. The complex and simple occupations are defined by the ranges of the variable OCC specified as shown in Table 3.

Therefore, we have four employed and two unemployed types: the high-educated employed in a complex occupation, the high-educated employed in a simple occupation, the high-educated unemployed, the low-educated employed in a complex occupation, the low-educated employed in a simple occupation, and the low-educated unemployed.

The weighted average of the weekly earnings and hours worked last week for each of the working groups are calculated using the proper weights ERNWGT. These weights are created for each month such that, when applied, the resulting counts are representative of the national counts. Thus, the proper application of weights enables the results to be presented in terms of the population of the United States as a whole, instead of just the participants in the survey. The hourly wage of each worker type is calculated as the ratio of the weighted average weekly earnings to the weighted average hours worked last week for each group. These derived wages are used to calculate the skill premium, which is defined as the ratio of the weighted average hourly wage of the two high educated types to that of the low educated in simple occupations. To calculate measures of employment and unemployment ratios, the variable MLR is used to distinguish the two groups. The unemployed are divided into high and low educated in the same manner as explained earlier. The employed are divided into four types as explained earlier. The ratios of the employed and the unemployed types to the total sample are calculated by summing over the weights in each type, and dividing by the sum of the weights of the total sample. The total hours are calculated by multiplying the level of employment in every type by the weighted average weekly hours of work for each type. A crowding out variable is calculated as the proportion of the total hours of the high educated amongst the total hours of all those employed in simple occupations. Finally, the variables compiled and used in the analysis are: (1) the skill premium; (2) the proportion and the hours of the high educated in complex occupations; (3) the total hours of the high educated employed in complex occupations; (4) the proportion and the hours of the high educated in simple occupations; (5) the total hours of the high educated employed in simple occupations; (6) the proportion and the hours of the low educated in simple occupations; (7) the total hours of the low educated employed in simple occupations; (8) the proportion of the high educated unemployed; (9) the proportion of the low educated unemployed; (10) the total unemployment rate; and (11) the crowding out. Finally, the Real Gross Domestic Product data (Chained Dollars, seasonally adjusted at annual rates) is extracted from the National Income and Product Accounts NIPA. The inflation rate is the percentage change of the consumer price index available from the Bureau of Labor Statistics. The interest rates are the monthly Federal funds rate from the Board of Governors of the Federal Reserve System. As the Gross Domestic Product data are quarterly, these monthly time series are transformed into quarterly ones by taking three months averages. All variables except the employment rates, the unemployment rates, and the inflation rate are logged. The data are seasonally adjusted or deseasonalized using a ratio to moving average multiplicative seasonal filter. All variables are detrended using the Hodrick Prescott filter with a smoothing parameter of 1600.

A.2   Derivations

A.2.1   The wage of high educated workers in complex occupations.
The wage of the high educated in a complex occupation is determined by

$$
W_t^{hc} = argmax \left[\frac{1}{\lambda_t} \frac{\partial \Gamma_t^H}{\partial N_t^{hc}} \right]^{1-\xi^{hc}} \left[\frac{\partial \Gamma_t^F}{\partial N_t^{hc}} \right]^{\xi^{hc}}
$$

Then the sharing rule implies $\xi^{hc} \left[\frac{\partial \Gamma_t^H}{\partial N_t^{hc}} \right] = (1 - \xi^{hc}) \lambda_t \left[\frac{\partial \Gamma_t^F}{\partial N_t^{hc}} \right]$. Substituting the

envelope conditions of the household $\frac{\partial \Gamma_t^H}{\partial N_t^{hc}}$ and of the firm $\frac{\partial \Gamma_t^F}{\partial N_t^{hc}}$, we have

$$
\xi^{hc} \frac{\beta}{\lambda_t} E_t \left[\frac{\partial \Gamma_{t+1}^H}{\partial N_{t+1}^{hc}} \right] = (1 - \xi^{hc}) \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \frac{\partial \Gamma_{t+1}^F}{\partial N_{t+1}^{hc}} \right] = (1 - \xi^{hc}) \frac{\omega^c}{q_t^{hc}}
$$

we have

$$
\xi^{hc} \left[\Omega^{hc} (1 - H_t^{hc}) - \Omega^h (1 - S_t^{hc} - S_t^{hs}) + \lambda_t W_t^{hc} H_t^{hc} \right.
$$

$$
+ (1 - \chi^{hc} - P_t^{hc} S_t^{hc}) \lambda_t \frac{1 - \xi^{hc}}{\xi^{hc}} \frac{\omega^c}{q_t^{hc}} - \beta P_t^{hs} S_t^{hs} \frac{\tau^h}{\beta P_t^{hs}} \left. \right]
$$

$$
= (1 - \xi^{hc}) \lambda_t \left[X_t \frac{\partial Y_t}{\partial N_t^{hc}} - H_t^{hc} W_t^{hc} + (1 - \chi^{hc}) \frac{\omega^c}{q_t^{hc}} \right]
$$

Simplifying yields

$$
\lambda_t W_t^{hc} H_t^{hc} = (1 - \xi^{hc}) \lambda_t \left[X_t \frac{\partial Y_t}{\partial N_t^{hc}} + (1 - \chi^{hc}) \frac{\omega^c}{q_t^{hc}} \right]
$$

$$
- (1 - \xi^{hc}) (1 - \chi^{hc} - P_t^{hc} S_t^{hc}) \lambda_t \frac{\omega^c}{q_t^{hc}}
$$

$$
+ \xi^{hc} [\Omega^h (1 - S_t^{hc} - S_t^{hs}) - \Omega^{hc} (1 - H_t^{hc}) + S_t^{hs} \tau^h]
$$

Solving for the equilibrium wage rule for the high educated workers in complex occupations yields equation (35).

A.2.2   The wage of high educated workers in simple occupations.
The wage of the high educated in a simple occupation is determined by

$$
W_t^{hs} = argmax \left[\frac{1}{\lambda_t} \frac{\partial \Gamma_t^H}{\partial N_t^{hs}} \right]^{1-\xi^{hs}} \left[\frac{\partial \Gamma_t^F}{\partial N_t^{hs}} \right]^{\xi^{hs}}
$$

Then the sharing rule implies $\xi^{hs}\left[\frac{\partial \Gamma_t^H}{\partial N_t^{hs}}\right] = (1 - \xi^{hs})\lambda_t\left[\frac{\partial \Gamma_t^F}{\partial N_t^{hs}}\right]$. Substituting the

envelope conditions of the household $\frac{\partial \Gamma_t^H}{\partial N_t^{hs}}$ and of the firm $\frac{\partial \Gamma_t^F}{\partial N_t^{hs}}$, in addition to

$$\xi^{hs}\frac{\beta}{\lambda_t}E_t\left[\frac{\partial \Gamma_{t+1}^H}{\partial N_{t+1}^{hs}}\right] = (1 - \xi^{hs})\beta E_t\left[\frac{\lambda_{t+1}}{\lambda_t}\frac{\partial \Gamma_{t+1}^F}{\partial N_{t+1}^{hs}}\right] = (1 - \xi^{hs})\frac{\omega^s}{q_t^{hs}}$$

from the first-order condition yields

$$\xi^{hs}\left[-\Omega^h(1 - S_t^{hc} - S_t^{hs}) + \Omega^{hs}(1 - H_t^{hs} - O_t) + \lambda_t W_t^{hs} H_t^{hs}\right.$$

$$+ \beta((1 - \chi^{hs})(1 - O_t P_t^{hc}) - P_t^{hs}S_t^{hs})\frac{1 - \xi^{hs}}{\xi^{hs}}\lambda_t\frac{\omega^s}{q_t^{hs}}$$

$$\left.+ \beta(P_t^{hc}O_t - P_t^{hc}S_t^{hc})\frac{\tau^h}{\beta P_t^{hc}}\right]$$

$$= (1 - \xi^{hs})\lambda_t\left[X_t\frac{\partial Y_t}{\partial N_t^{hs}} - H_t^{hs}W_t^{hs} + (1 - \chi^{hs})(1 - O_t P_t^{hc})\frac{\omega^s}{q_t^{hs}}\right]$$

Solving for the equilibrium wage rule for the high educated workers in simple occupations yields equation (36).

A.2.3 The wage of low educated workers in simple occupations.
The wage of the low educated in a simple occupation is determined by

$$W_t^{ls} = argmax\left[\frac{1}{\lambda_t}\frac{\partial \Gamma_t^H}{\partial N_t^{ls}}\right]^{1-\xi^{ls}}\left[\frac{\partial \Gamma_t^F}{\partial N_t^{ls}}\right]^{\xi^{ls}}$$

Then the sharing rule implies $\xi^{ls}\left[\frac{\partial \Gamma_t^H}{\partial N_t^{ls}}\right] = (1 - \xi^{ls})\lambda_t\left[\frac{\partial \Gamma_t^F}{\partial N_t^{ls}}\right]$. Substituting the

envelope conditions of the household $\frac{\partial \Gamma_t^H}{\partial N_t^{ls}}$ and of the firm $\frac{\partial \Gamma_t^F}{\partial N_t^{ls}}$, in addition to

$$\xi^{ls}\frac{\beta}{\lambda_t}E_t\left[\frac{\partial \Gamma_{t+1}^H}{\partial N_{t+1}^{ls}}\right] = (1 - \xi^{ls})\beta E_t\left[\frac{\lambda_{t+1}}{\lambda_t}\frac{\partial \Gamma_{t+1}^F}{\partial N_{t+1}^{ls}}\right] = (1 - \xi^{ls})\frac{\omega^s}{q_t^{ls}}$$

from the first-order condition yields

$$\xi^{ls}\left[-\Omega^l(1 - S_t^{ls}) + \Omega^{ls}(1 - H_t^{ls}) + \lambda_t W_t^{ls} + (1 - \chi^{ls} - P_t^{ls}S_t^{ls})\frac{1 - \xi^{ls}}{\xi^{ls}}\lambda_t\frac{\omega^s}{q_t^{ls}}\right]$$

$$= (1 - \xi^{ls})\lambda_t\left[X_t\frac{\partial Y_t}{\partial N_t^{ls}} - H_t^{ls}W_t^{ls} + (1 - \chi^{ls})\frac{\omega^s}{q_t^{ls}}\right]$$

Solving for the equilibrium wage for low educated workers in simple occupations yields equation (37).

A.2.4   *The hours of high educated workers in complex occupations.*

The hours of work of the high-educated workers in complex occupations are given by

$$H_t^{bc} = argmax \left[\left(\frac{1}{\lambda_t} \frac{\partial \Gamma_t^H}{\partial N_t^{bc}} \right) + \left(\frac{\partial \Gamma_t^F}{\partial N_t^{bc}} \right) \right]$$

Substituting the envelope conditions for $\frac{\partial \Gamma_t^H}{\partial N_t^{bc}}$ and $\frac{\partial \Gamma_t^F}{\partial N_t^{bc}}$ yields

$$H_t^{bc} = argmax \left[\begin{array}{c} \frac{1}{\lambda_t} \left(\begin{array}{c} \Omega^{bc}(1 - H_t^{bc}) - \Omega^b(1 - S_t^{bc} - S_t^{bs}) + \lambda_t W_t^{bc} H_t^{bc} \\ + \beta(1 - \chi^{bc} - P_t^c S_t^{bc}) E_t \left[\frac{\partial \Gamma_{t+1}^H}{\partial N_{t+1}^{bc}} \right] - \beta P_t^{bs} S_t^{bs} E_t \left[\frac{\partial \Gamma_{t+1}^H}{\partial N_{t+1}^{bs}} \right] \end{array} \right) \\ + \left(X_t \frac{\partial Y_t}{\partial N_t^{bc}} - H_t^{bc} W_t^{bc} + (1 - \chi^{bc}) \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \frac{\partial \Gamma_{t+1}^F}{\partial N_t^{bc}} \right] \right) \end{array} \right]$$

The hours are thus given by equation (39).

A.2.5   *The hours of high educated workers in simple occupations.*

The hours of work of the high-educated workers in simple occupations are given by

$$H_t^{bs} = argmax \left[\left(\frac{1}{\lambda_t} \frac{\partial \Gamma_t^H}{\partial N_t^{bs}} \right) + \left(\frac{\partial \Gamma_t^F}{\partial N_t^{bs}} \right) \right]$$

Substituting the envelope conditions for $\frac{\partial \Gamma_t^H}{\partial N_t^{bs}}$ and $\frac{\partial \Gamma_t^F}{\partial N_t^{bs}}$, the hours are thus given by equation (41).

A.2.6   *The hours of low educated workers in simple occupations.*

The hours of work of the low-educated workers in simple occupations are given by

$$H_t^{ls} = argmax \left[\left(\frac{1}{\lambda_t} \frac{\partial \Gamma_t^H}{\partial N_t^{ls}} \right) + \left(\frac{\partial \Gamma_t^F}{\partial N_t^{ls}} \right) \right]$$

Substituting the envelope conditions for $\frac{\partial \Gamma_t^H}{\partial N_t^{ls}}$ and $\frac{\partial \Gamma_t^F}{\partial N_t^{ls}}$, the hours are thus given by equation (41).

A.2.7   *The Phillips curve.*

To derive the Phillips curve, substitute the log linearized version of the price index into that of the optimal retail price equation. The price index can be written as

$$\rho_t = [(1 - \sigma)(\rho_t^*)^{1-\theta} + \sigma \rho_{t-1}{}^{1-\theta}]^{\frac{1}{1-\theta}}$$

To log linearize the price index, divide both sides by $(\rho_t)^{1-\theta}$. Log linearization yields after substituting the steady state condition $\rho = \rho^*$, and rearranging

$$\sigma \hat{\rho}_t + (1 - \sigma)\hat{\rho}_t = (1 - \sigma)\hat{\rho}_t^* + \sigma \hat{\rho}_{t-1}$$

This can be rewritten as

$$\hat{\rho}_t = (1 - \sigma)\hat{\rho}_t^* + \sigma \hat{\rho}_{t-1}$$

The steady state condition for the optimal retail price equation is given by

$$\rho^* = \frac{\theta}{\theta - 1}X$$

The log linearization of the optimal retail price equation yields after substituting the steady state, and rearranging can be written as

$$\hat{\rho}_t^* = (1 - \sigma\beta)E_t \sum_{s=0}^{\infty} \sigma^s \beta^s \hat{X}_{t+s}$$

This can be expanded, and arranged as

$$\hat{\rho}_t^* = (1 - \sigma\beta)\hat{X}_t + \sigma\beta E_t \hat{\rho}_{t+1}^*$$

From the log linearized version of the price index, we have

$$\hat{\pi}_t + (1 - \sigma)\hat{\rho}_{t-1} = (1 - \sigma)\hat{\rho}_t^*$$

and can be written as

$$\hat{\rho}_t^* = \frac{1}{1 - \sigma}\hat{\pi}_t + \hat{\rho}_{t-1}$$

leading by one period, and taking the expectation as per period t yields

$$E_t\hat{\rho}_{t+1}^* = \frac{1}{1 - \sigma}E_t\hat{\pi}_{t+1} + \hat{\rho}_t$$

Substituting both in both sides of the log linearized version of the optimal retail price equation yields

$$\frac{1}{1 - \sigma}\hat{\pi}_t + \hat{\rho}_{t-1} = (1 - \sigma\beta)\hat{X}_t + \sigma\beta \left(\frac{1}{1 - \sigma}E_t\hat{\pi}_{t+1} + \hat{\rho}_t \right)$$

This can be rearranged, after adding and subtracting $\hat{\rho}_t$ from the right-hand side, as

$$\frac{1}{1-\sigma}\hat{\pi}_t = (1-\sigma\beta)\hat{X}_t - \hat{\rho}_{t-1} + \frac{\sigma}{1-\sigma}\beta E_t\hat{\pi}_{t+1} + \sigma\beta\hat{\rho}_t + \hat{\rho}_t - \hat{\rho}_t$$

This can finally be arranged as

$$\left(\frac{1}{1-\sigma} - 1\right)\hat{\pi}_t = (1-\sigma\beta)(\hat{X}_t - \hat{\rho}_t) + \frac{\sigma}{1-\sigma}\beta E_t\hat{\pi}_{t+1}$$

Which gives us the following Phillips curve.