Equilibrium Labor Market Search and Health Insurance Reform*

Naoki Aizawa† Hanming Fang‡

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Abstract

We empirically implement an equilibrium labor market search model where both wages and health insurance provisions are endogenously determined and use it to predict the impact of the 2010 U.S. health insurance reform on health insurance coverage and labor market outcomes. In our model, employers make a health insurance coverage decision by taking into account health composition of their employees. By offering health insurance, they may attract unhealthy workers who both increase their health insurance costs and decrease their labor productivity, generating an adverse selection problem. On the other hand, because health insurance coverage can improve employees' future health status, the cost generated by the adverse selection will be reduced over time. In equilibrium, more productive employers benefit more from the latter channel, leading to a positive correlation among wage, health insurance coverage, and employer size, which is consistent with the data. We estimate the model using Survey of Income and Program Participation, Medical Expenditure Panel Survey, and Robert Wood Johnson Employer Health Insurance Survey. We use the model estimates to evaluate the equilibrium effects of several features of the health insurance reform.

Keywords: Health, health insurance, the 2010 U.S. health insurance reform, labor market equilibrium, job search.

JEL Classification Number: G22, I11, I13, J32.

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†Department of Economics, University of Pennsylvania, 3718 Locust Walk, Philadelphia, PA 19104. Email: naizawa@sas.upenn.edu

‡Department of Economics, University of Pennsylvania, 3718 Locust Walk, Philadelphia, PA 19104 and the NBER. Email: hanming.fang@econ.upenn.edu

1 Introduction

Health care accounts for about one sixth of the U.S. economy. The U.S. is also unique among industrialized nations in that it lacks a national health insurance system and that most of the working age populations obtain health insurance coverage through their employers. According to Kaiser Family Foundation and Health Research and Educational Trust (2009), more than 60 percent of the non-elderly population received their health insurance sponsored by their employers,[1] and about 10 percent of workers' total compensation was in the form of employer-sponsored health insurance premiums.

Given the importance of employer-sponsored health insurance in the U.S., and the importance of employer-sponsored health insurance premiums in workers' compensation, evaluating the U.S. health insurance system requires the better understanding of the interactions between the labor market and health insurance market. Indeed, several patterns have been well documented: firms that do not offer health insurance are more likely to be small firms, to offer low wage, and to experience high rate of worker turnover. While the average employee size of employers not offering health insurance is 8.83, it is 33.90 for employers offering health insurance. The average annual wage of employees at employers not offering health insurance is $20,560, while it is $29,077 for employers who do. Furthermore, annual separation rate of employers not offering health insurance is 28%, while it is 21% for employers who do.

Furthermore, understanding the interactions between the labor market and health insurance market is crucial to predict the general equilibrium effects of the Affordable Care Act (hereafter, ACA) enacted on March 2010. The ACA puts in place comprehensive health insurance reforms that will roll out over four years and beyond, with most changes taking place by 2014.

Among its many provisions, the ACA would establish state-based health insurance exchanges where the uninsured and self-employed can purchase insurance with subsidies available to individuals and families with income between the 133 percent and 400 percent of poverty level. Importantly, the premiums for individuals who purchase their insurance from the insurance exchanges will be pooled across participants; and all individuals will be mandated to hold health insurance by 2014 or else they will face a fine of $695or 2.5 percent of income, whichever is higher starting from 2016, the first year the fine will be fully in place. Separate exchanges would also be created for small businesses to purchase coverage in 2014.[2]

The ACA also would require that employers with more than 50 employees provide health insurance

[1] Among those with private coverage from any source, about 95% obtained employment-related health insurance (Selden and Gray 2006).

[2] The Affordable Care Act refers to the Patient Protection and Affordable Care Act (PPACA) signed into law by President Barack Obama on March 23, 2010, as well as the Amendment in the Health Care and Education Reconciliation Act of 2010.

or pay a fine of $2000 per worker each year if any worker receives federal subsidies to purchase health insurance, where the fines would apply to entire number of employees minus some allowances.

The goal of this paper is to understand how the health care reform will lead to changes in the health insurance and labor markets. Many important questions need to be addressed. Would more employers be offering health insurance to their employers? Would the reform reduce the distortions in workers' job mobility decisions? Would the health care reform improve workers' health and reduce the overall health care expenditure? How would workers' welfare and firms' productivity be affected? Also, can we identify reforms that may enhance welfare relative to the proposed reform?

To address these questions, we first construct and estimate an equilibrium labor market search model, where both the wages and health insurance provisions are endogenous determined, that can match the most salient features of the labor market and health care in the data. Our model is based on Burdett and Mortensen (1998) and Bontemps et al. (1999, 2000), but we depart from these standard models by incorporating health and health insurance.

In our model, workers owns their health status which evolves stochastically. Health status affects both their medical expenditures and their labor productivity. Health insurance insures their medical expenditure risks and affects the dynamics of health status. In the benchmark model, we assume that workers can obtain health insurance only through employers. Both unemployed and employed workers randomly meet firms and decide whether to accept their job offer, compensation package of which consists of wage and employer-sponsored health insurance.

Firms, which are heterogenous in their productivity, post compensation packages to attract workers. The cost of providing health insurance, i.e., premiums for employer-sponsored health insurance, is determined by both the health composition of employees of the firm and the fixed administrative load. When deciding the compensation packages, they anticipate that their choice of compensation packages will affect the composition of workers in terms of their health status, and will also affect their size in the steady state. Moreover, they take into account two institutional features. First, the premiums for employer-sponsored health insurance are exempt from income taxes. Second, the offer of compensation package cannot depend on workers' individual health status due to anti-discrimination laws. In the baseline model, we assume that employers are the only provider of health insurance.

We characterize the steady state equilibrium of the model in the spirit of Burdett and Mortensen (1998). We show that our baseline model can qualitatively and quantitatively explain the observed relationship between firms' health insurance coverage decisions and their other characteristics such as size, wages, turnover rates etc. In particular, we argue that the effect of health insurance on the dynamics of health status is critical to generate the relationship. If firms offer health insurance, they can benefit from the tax exemption of the insurance premium; on the other hand, by offering insurance they may attract unhealthy workers, generating adverse selection problem. Because firms cannot design a compensation package based on worker's health, the cost generated by this channel may offset the benefit. However, the dynamic effect of health insurance on health can reduce the costs generated by adverse selection. As health insurance improves health status, health insurance can decreases the average expected health costs and increase labor productivity over time. Firms that retain workers longer can capture this benefit more. Because these firms are more likely to offer high wage and become large in equilibrium, we have a positive correlation between wage, health insurance, and firm size. Moreover, it also helps explain why health status of employees covered by employer-sponsored health insurance does not differ much from uninsured employees' one in the data.

We estimate the model by using 1996 Panel of Survey of Income and Program Participation (SIPP), Medical Expenditure panel Survey (MEPS) 1996-1999, and 1997 Robert Wood Johnson Foundation Employer Health Insurance Survey (RWJ-EHIS). The estimation strategy is a three-step semiparametric estimation which is a modification of Bontemps et al. (1999, 2000) and Shephard (2011). In the first step, we estimate parameters characterizing worker's health status dynamics and health care distribution by using SIPP and MEPS. In the second step, we estimate parameters for worker's preference and labor market friction and offer distribution of compensation package using SIPP data. The estimation is by maximum likelihood. In the third step, we estimate the remaining parameters characterizing firm side parameter by matching moments on offer distribution recovered in the second step and on employer size distribution from the data. In particular, we nonparametically estimate firm productivity distribution.

The preliminary estimates show that the model reasonably fits well in terms of coverage rate, health, labor market dynamics, and wage distribution. We find that there is a quantitatively significant effect of health insurance on the dynamics of health status. In particular, the health insurance coverage positively affects the transition from less healthy to healthy.

We use the model estimates to evaluate the equilibrium effects of several feature of the ACA. The model allows to describe many important components of this reform, including: any uninsured workers and firms with less than 50 employees can participate into insurance exchange where premium is endogenously determined; the participants of the insurance exchange obtain subsidies; individuals are mandated to carry health insurance and large firms are mandated to offer health insurance. By conducting counterfactual policy experiments, we investigate the impact of the ACA on health insurance coverage, unemployment, job mobility, wage, employment, firm size distribution, and labor productivity.

The remainder of the paper is structured as follows. In Section 2, we review the related literature; in Section 3 we present the model of the labor market with endogenous determinations of wages and health insurance provisions; in Section 4 we describe the numerical algorithm to solve for the steady state equilibrium of the model, and present a qualitative assessment of the workings of the model; in Section 5 we describe the data sets used in our empirical analysis; in Section 6 we explain our estimation strategy; in Section 7 we present our estimation results and the goodness-of-fit; in Section 8 we describe the results from several counterfactual experiments; and finally in Section 9 we conclude.

2 Related Literature

This paper is related to two strands of the literature. First and mostly, it is related to a small literature that examines the relationship between health insurance and labor market. The seminal paper is Dey and Flinn (2005). They propose and estimate an equilibrium model of the labor market in which firms and workers bargain over both wages and health insurance offerings to examine the question of whether the employer-provided health insurance system leads to inefficiencies in workers' mobility decisions (which are often referred to as "job lock" or "job push" effects). Their model has the following important features. Workers are heterogenous in their preference for health insurance; firms are heterogeneous in their costs of offering health insurance which are exogenously given; and health insurance is productive in the sense that it reduces the probability of separation between worker sand firms. However, because a worker/vacancy match is the unit of analysis of Dey and Flinn (2005), their model is not designed to address the relationship between firm size and wage/health insurance provisions. More importantly, because the health insurance costs are exogenous, their model is not designed to assess general equilibrium effects through the interaction between labor and insurance markets, which is the main focus in our counterfactual policy experiments.

Bruegemann and Manovskii (2010) develop and calibrate a search and matching model with large firms to study the very similar research agenda. They allow employer size being a discrete, highlighting the effect of health composition of employees on the dynamics of firm's coverage decision and argue that small firms insurance markets suffer from adverse selection problem because those firms try to purchase health insurance when most of their employees are unhealthy. Complementary to theirs, our study provides an alternative channel which has been received less attention in the literature: small firms cannot overcome adverse selection problems because they cannot retain worker longer and cannot capture the benefit arising from the dynamic effect of health insurance on health. This channel arises in the environment with on-the-job search and the dynamic effect of health insurance on health, both of which are absent in their model.

The channel that worker turnover discourages employers providing health insurance coverage is related to the one emphasized in Fang and Gavazza (2011). They argue that health is a form of general human capital and labor turnover and labor-market frictions prevent an employer-employee pair from capturing the entire surplus from investment in an employee's health, generating underinvestment in health during working years and increasing medical expenditures during retirement. This paper instead argues that such a channel also helps explain why small firms cannot overcome the adverse selection problem.

Second, this paper is also related to a large literature estimating equilibrium labor market search models, initiated by Eckstein and Wolpin (1990). Van der Berg and Ridder (1998) and Bontemps et. al

(1999, 2000) empirically implement Burdett and Mortensen's (1998) model. Their empirical frameworks have been widely applied in the subsequent studies investigating the impact of various labor market policies on labor market outcomes. Among them, our studies are mostly related to Shephard (2011) and Meghir et al. (2011). As in our studies, they allow multi-dimensional job characteristics (e.g., wage and part-time/full time and wage and formal/informal sector job). However, worker's characteristics is modelled as permanent one. Therefore, we contribute to this literature by offering an empirical framework where job characteristics can affect the dynamics of worker's characteristics such as human capital[3].

3 An Equilibrium of Model of Wage Determination and Health Insurance Provision

3.1 The Environment

Consider a labor market with a continuum of firms with measure normalized to 1 and a continuum of workers with measure $M > 0$. They are randomly matched in a frictional labor market. Time is discrete, and indexed by $t = 0, 1, ...,$ and we use $\beta \in (0, 1)$ to denote the discount factor.

Workers have constant absolute risk aversion (CARA) preferences implying that for a given consumption c:

$$u(c) = -\frac{1}{\gamma} \exp(-\gamma c).$$

Workers' Health. Workers differ in their health status, denoted by h, and they can either be **H**ealthy (H) or **U**nhealthy (U) . In our model, a worker's health status has two effects. First, it affects the distribution of health expenditures. Specifically, we assume that the probability that a healthy worker experiences a bad health shock is given by q_B^H, and with the complementary probability $1 - q_B^H$ a healthy worker experiences a good health shock. For an unhealthy worker, the probability of experiencing a bad health shock is q_B^U, where $q_B^U > q_B^H$. In order to capture the idea that an individual's health expenditure may be affected by whether she has health insurance, we assume that the medical expenditure for an individual with health insurance status $x \in \{0, 1\}$ upon experiencing a bad health shock is m_B^x where $m_B^1 > m_B^0$; similarly, the medical expenditure for an individual with health insurance status $x \in \{0, 1\}$ upon experiencing a good health shock is m_G^x where $m_G^1 > m_G^0$. Moreover, we assume that $m_G^1 < m_B^0$.

Second, a worker's health status affects her productivity. Specifically, if an individual works for a firm with productivity p, she can produce p units of output if she is healthy, but she can produce only $d \times p$

[3]Another important difference is that we estimate the model by matching not only wage distribution but also employer size distribution, while most of the existing studies have rarely incorporate employer size distribution as a target. Postel-Vinay and Robin (2002) and Cahuc et al. (2006) are the only exception.

units of output if she is unhealthy where $1-d$ represents the productivity loss from being unhealthy.[4]

In each period, worker's health status changes stochastically and it follows Markov Process. The period-to-period transition of an individual's health status depends on her health insurance status. We use $\pi^x_{h'h}$ to denote the probability that a worker's health status changes from $h \in \{H,U\}$ to $h' \in \{H,U\}$ conditional on coverage status $x \in \{0,1\}$, where $x=1$ means that the worker owns insurance. The transition matrix is thus, for $x=0,1$,

$$\mathbf{\Pi}^x = \begin{pmatrix} \pi^x_{HH} & \pi^x_{UH} \\ \pi^x_{HU} & \pi^x_{UU} \end{pmatrix}, \text{ where } \pi^x_{UH} = 1-\pi^x_{HH} \text{ and } \pi^x_{HU} = 1-\pi^x_{UU}.$$

To capture the idea that health insurance has a higher marginal effect on health for a currently unhealthy worker than for a currently healthy worker, we hypothesize that $\pi^1_{HU}-\pi^0_{HU} > \pi^1_{HH}-\pi^0_{HH}$.

New-born workers have health status H with probability μ_H.

Firms. Firms are heterogeneous in terms of productivity and hiring technology. The distribution of productivity is denoted by $\Lambda(\cdot)$. We assume that Λ has an everywhere continuous and positive density function. The distribution of hiring technology is denoted by $H(\cdot)$. The hiring technology, k, affects visibility of firms in labor markets. That is, it affects the sampling probability of workers. We assume that the support of H is finite and $h(k)$ denotes the worker's sampling probability to firms with characteristics k. Moreover, at this stage, productivity p and hiring technology k is independent[5].

Firms, after observing their productivity, decide a package of wage and health insurance provision, denoted by (w,x) where $w \in R_+$ and $x \in \{0,1\}$. If a firm offers health insurance to its workers, we assume that it has to pay a fixed cost $F>0$ that captures the administrative loading factor. We assume that the health insurance charges a premium from the workers each period, but reimburses all the realized health expenditures.[6]

Moreover in the baseline model, we assume that workers can only receive employer-provided health insurance. In our counterfactual experiment, we will consider the case of competitive private insurance market.

[4]One can alternatively assume that the productivity loss only occurs to individuals who experience a bad health shock. Because an unhealthy worker is more likely to experience a bad health shock, such a formulation is equivalent to the one we adopt in the paper.

[5]The standard model assumes that $h(k)=h(k')$, for any k and k'. We incorporate the distribution of hiring technology in order to improve the model fit with respect to firm size distribution and wage. The similar idea is used in Postel-Vinay and Robin (2002)and Cahuc et al. (2006). One can provide micro foundation of this hiring technology by assuming that firms, having different costs of creating job positions, endogenously chooses recruiting intensity. We leave such an extension for a future work.

[6]In principle, firms should also be able to decide on the premium conditional on offering health insurance. However, as we show below, we will be requiring firms to be self-insured in our model. Thus, the insurance premium will be determined in equilibrium by the health distribution of workers for the firm in steady state.

Labor Market. Firms and workers are randomly matched in the labor market. In each period, an unemployed randomly meets a firm with probability $\lambda_u \in (0,1)$. She then decides whether to accept the offer or remain unemployed and search for jobs in next period. We assume that all new-born workers are unemployed.

If an individual is employed, she meets randomly with another firm with probability $\lambda_e \in (0,1)$ where $\lambda_e < \lambda_u$. If a currently employed worker receives an offer from another firm, she need to decide whether to accept such this outside offer or stay with the current firm. An employed worker can also decide to return to the unemployment pool.[7]Moreover, each match is destructed exogenously with probability $\delta \in (0,1)$. We allow that individual may experience both the exogenous job destruction and the arrival of the new job offer within in the same period[8].

Income Taxes and Unemployment Benefit. Workers' wages and unemployment benefits are subject to tax schedule denoted by $T(\cdot)$; but the premium for employer-provided health insurance is assumed to be tax exempt in the baseline model.

3.2 Timing in a Period

Now we describe the timing in a period. At the beginning of each period, we should imagine that individuals, who are heterogeneous in their health status, are either unemployed or working for firms offering different combinations of wage and health insurance packages.

1. Any individual, whether employed or unemployed, and regardless of her health status, may leave the labor market with probability $\rho \in (0,1)$;

2. If an employed individual stays in the market, then she produces output as described above, and firms pay wage and collects insurance premium from the current employees if health insurance is offered;

3. The medical expenditure shocks, whose distributions depend on the beginning-of-the-period health status, are realized;

4. The workers then observe the realization of the health status that will be applicable next period;

5. The current jobs will be terminated with probability $\delta \in (0,1)$;

[7]Returning to unemployment may be a better option for a currently employed worker if her heath status changed from when she accepted the current job offer, for example.

[8]This specification is used by Wolpin (1992) and more recently by Jolivet et al. (2006).

6. All job searchers, employed or unemployed, randomly meet with new employers with some probability. An unemployed individual decides whether to accept the offer, and an employed worker also decides whether to quit into unemployment;

7. Time moves to the next period.

3.3 Analysis of the Model

In this section, we characterize the steady state equilibrium of the model. The analysis here is similar to, but generalizes, that in Burdett and Mortensen (1998). We first consider the decision problem faced by a worker, for a postulated distribution of wage and insurance packages by the firms, denoted by $F(w,x)$; then derive the steady state distribution of workers of different health status among firms with different offers of wage and health insurance packages (w,x), as well as unemployment state; and finally provide the conditions for the postulated $F(w,x)$ to be consistent with equilibrium.

3.3.1 Value Functions

We first introduce the notation for several valuation functions. We use $v_h(y,x)$ to denote the expected flow utility of workers with health status h from per period income y and insurance status $x \in \{0,1\}$; and it is give by:

$$v_h(y,x) = \begin{cases} u\left(T\left(y\right)\right) & \text{if } x = 1 \\ q_B^h u\left(T(y) - m_B^0\right) + \left(1 - q_B^h\right) u\left(T(y) - m_G^0\right) & \text{if } x = 0, \end{cases} \tag{1}$$

where we recall that q_B^h is the probability of experiencing a bad health shock for an individual with health status h, m_B^0 (respectively, m_G^0) is the medical expenditures for an uninsured individual when there is a bad (respectively, good) health shock and $T(y)$ is after-tax income. Note that when an individual is insured, i.e., $x = 1$, her medical expenditures are fully covered by the insurance. The fact that m_B^0 and m_G^0 are positive, together with risk aversion, implies that $v_h(y,1) > v_h(y,0)$; i.e., regardless of workers' health, if wages are fixed, then all workers desire health insurance. Moreover, because $q_B^U > q_B^H$ and $m_B^0 > m_G^0$, it can be easily shown that $v_U(y,1) - v_U(y,0) > v_H(y,1) - v_H(y,0)$. This implies that if an unhealthy worker benefits

Now let U_h denote the value function for an unemployed worker with health status h at the beginning of a period; and let $V_h(w,x)$ denote the value function for an employed worker with health status h working for a job characterized by wage-insurance package (w,x) at the beginning of a period. U_h and $V_h(\cdot,\cdot)$ are of course related recursively. U_h is given by:

$$\frac{U_h}{1-\rho} = v_h(b,0) + \beta \mathbf{E}_{h'}\left[\lambda_u \int \max\{V_{h'}(w,x), U_{h'}\} dF(w,x) + (1-\lambda_e)U_{h'} \mid (h,0)\right], \tag{2}$$

where the expectation $\mathbf{E}_{h'}$ is taken with respect of the distribution of h' conditional on the current health status h and insurance status $x = 0$ because unemployed workers are assumed to be uninsured. Similarly, $V_h(w, x)$ is given by

$$\frac{V_h(w,x)}{1-\rho} = v_h(w,x) + \quad \beta(1-\delta)\left\{ \begin{array}{c} \lambda_e \mathbf{E}_{h'}\left[\int \max\{V_{h'}(\tilde{w},\tilde{x}), V_{h'}(w,x), U_{h'}\} dF(\tilde{w},\tilde{x}) \mid (h,x)\right] \\ (1-\lambda_e)\mathbf{E}_{h'}\left[\max\left\{U_{h'}, V_{h'}(w,x)\right\} \mid (h,x)\right] \end{array} \right\}$$
$$+ \quad \beta\delta\left\{(1-\lambda_e)\mathbf{E}_{h'}[U_{h'} \mid (h,x)] + \lambda_e \mathbf{E}_{h'}\left[\int \max\left\{U_{h'}, V_{h'}(\tilde{w},\tilde{x})\right\} dF(\tilde{w},\tilde{x}) \mid (h,x)\right]\right\} \tag{3}$$

Note that, due to our timing assumptions (see Section 3.2), a worker's health status next period depends on her insurance status this period even if she is separated from her job at the end of this period.

3.3.2 Workers' Optimal Strategies

Standard arguments can be used to show that worker's decision about whether to accept job offer is characterized by using reservation wages. Note that in our model, both unemployed and employed workers make decisions about whether to accept or reject an offer.

Optimal Strategies for Unemployed Workers. First, consider an unemployed worker. As the right hand side of (1) is increasing in w, $V_h(w, x)$ is increasing in w. On the other hand, U_h is independent of w. Therefore, the reservation wage for unemployed worker with health status h is defined as

$$U_h = V_h(\underline{w}_h^x, x), \tag{4}$$

so that if an unemployed worker meets a job with offer (w, x), he will accept the offer if $w \geq \underline{w}_h^x$ and reject otherwise. Because worker's flow the expected flow utility $v_h(w, x)$ and the law of motion depends on worker's current health and health insurance status, the reservation wage of unemployed can also differ across these status.

Optimal Strategies for Currently Employed Workers: Job to Job Transition. Similarly, one can define the reservation wage for employed worker. Let (w, x) be the wage-insurance package offered by his current employer. Let (w', x') be the one offered by his potential employer. Then, the reservation wage for the employed worker with health status h to switch, denoted by $\underline{s}_h^{x'}(w, x)$, is

$$V_h(w, x) = V_h(\underline{s}_h^{x'}(w, x), x'). \tag{5}$$

A worker with health status h on a current job (w, x) will switch to a job (w', x') if and only if $w' > \underline{s}_h^{x'}(w, x)$. It is straightforward from (3) that the following must be true:

$$\underline{s}_h^{x'}(w,x) \left\{ \begin{array}{c} = w \text{ if } x = x' \\ > w \text{ if } x = 1, x' = 0 \\ < w \text{ if } x = 0, x' = 1. \end{array} \right.$$

However, when $x \neq x'$, the exact value of $\underline{s}_h^{x'}(w,x)$ must be solved from (5); in particular, it will differ by worker's health and health insurance status.

Optimal Strategies for Currently Employed Workers: Quitting to Unemployment. Finally, a worker with health status h who is currently on a job (w,x) may choose to quit into unemployment. This may happen because of the changes in workers' health condition since she last accepted the current job offer and the assumption that the offer arrival probability is higher for unemployed worker than for an employed worker ($\lambda_e < \lambda_u$). Clearly a worker with health status h and health insurance status x will quit into unemployment only if the current wage w is below a threshold. Let us denote the threshold wages for quitting into unemployment by $\underline{q}_h^x$. Clearly, $\underline{q}_h^x$ must satisfy

$$V_h\left(\underline{q}_h^x, x\right) = U_h. \tag{6}$$

Comparing (6) with (4), it is clear that $\underline{q}_h^x = \underline{w}_h^x$. Thus we can conclude that employed workers will quit to unemployment only if his health status changed from when he first started on the job. Moreover, if $\underline{w}_H^x < \underline{w}_U^x$, then a currently unhealthy worker who accepted a job (w,x) with wage $w \in (\underline{w}_H^x, \underline{w}_U^x)$ when his health status was H may now quit into unemployment; if $\underline{w}_H^x > \underline{w}_U^x$ instead, then a currently healthy worker who accepted a job (w,x) with wage $w \in (\underline{w}_U^x, \underline{w}_H^x)$ when his health status was U may now quit into unemployment.

3.3.3 Steady State Condition

We will focus on the steady state of the dynamic equilibrium of the labor market described above. We first describe the steady state equilibrium objects that we need to characterize and then provide the steady state conditions.

In the steady state, we need to describe how the workers are allocated in their employment (w,x) and their health status h. Let u_h denote the measure of unemployed workers with health status $h \in \{U,H\}$; and let e_h^x denote the measure of employed workers with health insurance status $x \in \{0,1\}$ and health status is $h \in \{U,H\}$. Of course, we have

$$\sum_{h\in\{U,H\}} \left(u_h + e_h^0 + e_h^1\right) = M. \tag{7}$$

Let $G_h^x(w)$ the *fraction* of employed workers with health status h working on jobs with insurance status x and wage below w, and let $g_h^x(w)$ be the corresponding density of $G_h^x(w)$. Thus, $e_h^x g_h^x(w)$ is the density of employed workers with health status h in sector x whose compensation package is (w,x).

These objects would have to satisfy the steady state conditions for unemployment and firm size. First, let us consider the steady state condition for unemployment. The inflow into unemployment with health status h is given by

$$
\begin{aligned}
[u_h]^+ \quad \equiv \quad & \overbrace{(1-\rho)\left[\delta(1-\lambda_e)+\delta\lambda_e(F(\underline{w}_h^1,1)+F(\underline{w}_h^0,0))\right]\left[e_h^0\pi_{hh}^0+e_h^1\pi_{hh}^1+e_{h'}^0\pi_{hh'}^0+e_{h'}^1\pi_{hh'}^1\right]}^{\text{Term 1}} \\
& +\overbrace{(1-\rho)u_{h'}\pi_{hh'}^0[1-\lambda_u(1-F(\underline{w}_h^1,1)-F(\underline{w}_h^0,0))]}^{\text{Term 2}}+\overbrace{M\rho\mu_h}^{\text{Term 3}} \\
& +\overbrace{(1-\rho)(1-\delta)\int\pi_{hh'}^1e_{h'}^1g_{h'}^1(w)\left[1-\lambda_e(1-F(\underline{w}_h^1,1)-F(\underline{w}_h^0,0))\right]\mathbf{1}\{V_h(w,1)<U_h\}dw}^{\equiv Q_h^1} \\
& +\overbrace{(1-\rho)(1-\delta)\int\pi_{hh'}^0e_{h'}^0g_{h'}^0(w)\left[1-\lambda_e(1-F(\underline{w}_h^1,1)-F(\underline{w}_h^0,0))\right]\mathbf{1}\{V_h(w,0)<U_h\}dw}^{\equiv Q_h^0}. \quad (8)
\end{aligned}
$$

In the above expression, Term 1 is the measure of employed workers who has health status h this period who did not leave the labor market but whose job is terminated and cannot find a job which is better than being unemployed; Term 2 is the measure of workers whose health status was h' last period but transitioned to h this period and who did not leave for employment; Term 3 is the measure of new workers born into health status h; and finally Q_h^1 and Q_h^0 are respectively the measures of workers currently working on jobs with and and without health insurance respectively quitting into unemployment. To understand these expressions, consider Q_h^1. First, quitting into unemployment only applies to workers who did not die and whose job did not get terminated (i.e., $(1-\rho)(1-\delta)$ measure of them); second, note that quitting into unemployment at health status h this period is possible only if the worker's health status is h' in the previous period, because otherwise the worker would have quit already in the previous period; thus quitting into unemployment with health status h this period only comes from workers with health status h' last period and then transitioned to h this period, given by the term $\pi_{hh'}^1e_{h'}^1$; the rest of the term in the integrand is the accepted wage distribution of such workers.

The outflow from unemployment is given by:

$$[u_h]^- \equiv u_h\left\{\rho+(1-\rho)\left[\pi_{h'h}^0+\pi_{hh}^0\lambda_u(1-F(\underline{w}_h^1,1)-F(\underline{w}_h^0,0))\right]\right\}. \quad (9)$$

It states that a ρ fraction of the unemployed with health status h will die and the remainder $(1-\rho)$ will either change to health status h' (with probability $\pi_{h'h}^0$), or if their health does not change (with probability π_{hh}^0) they may become employed with probability $\lambda_u(1-F(\underline{w}_h^1,1)-F(\underline{w}_h^0,0))$. Then, in a steady-state we must have

$$[u_h]^+ = [u_h]^-, h\in\{U,H\}. \quad (10)$$

Now we provide the steady state equation for workers employed on jobs (w,x) with health status h. Note that the inflow of workers with health status h on jobs $(w,1)$, denoted by $\left[e_h^1(w)\right]^+$, is given by:

$$\left[e_h^1(w)\right]^+ \equiv (1-\rho)f(w,1)\left\{\begin{array}{c} \lambda_u\left(u_h\pi_{hh}^0+u_{h'}\pi_{hh'}^0\right)+(1-\delta)\lambda_e\left[\begin{array}{c}\pi_{hh}^0 e_h^0\int g_h^0(\tilde{w})\mathbf{1}(V_h(\tilde{w},0)<V_h(w,1))d\tilde{w}\\ +\pi_{hh'}^0 e_{h'}^0\int g_{h'}^0(\tilde{w})\mathbf{1}(V_h(\tilde{w},0)<V_h(w,1))d\tilde{w}\\ +\pi_{hh}^1 e_h^1 G_h^1(w)+\pi_{hh'}^1 e_{h'}^1 G_{h'}^1(w)\end{array}\right]\\ +\delta\lambda_e\left(\pi_{hh}^0 e_h^0+\pi_{hh'}^0 e_{h'}^0+\pi_{hh}^1 e_h^1+\pi_{hh'}^1 e_{h'}^1\right)\end{array}\right\}$$
$$+(1-\rho)(1-\delta)\pi_{hh'}^1 e_{h'}^1 g_{h'}^1(w)\left[1-\lambda_e\left(1-\tilde{F}_h(w,1)\right)\right], \tag{11}$$

where $h'\neq h$ and $\tilde{F}_h(w,1)$ is defined by

$$\tilde{F}_h(w,1)=F(w,1)+\int f(\tilde{w},0)\mathbf{1}(V_h(\tilde{w},0)<V_h(w,1))d\tilde{w}. \tag{12}$$

In expression (11), the first term presents the inflows from unemployed workers with health status h; the second term presents inflows from workers who were employed on other jobs to job $(w,1)$; and finally the third term is the inflow from workers who were employed on the same job but has experienced a health transition from h' to h and yet did not transition to other better jobs (with probability $\lambda_e\left(1-\tilde{F}_h(w,1)\right)$).

Denote the outflow of workers with health status h from jobs $(w,1)$ by $\left[e_h^1(w)\right]^-$, and it is given by

$$\left[e_h^1(w)\right]^- \equiv e_h^1 g_h^1(w)\left\{\rho+(1-\rho)\left[\pi_{h'h}^1+\pi_{hh}^1\left(\delta+\lambda_e(1-\delta)\left(1-\tilde{F}_h(w,1)\right)\right)\right]\right\}. \tag{13}$$

The outflows consists of job losses due to death and exogenous termination represented by the term $e_h^1 g_h^1(w)\left(\rho+(1-\rho)\pi_{hh}^1\delta\right)$; changes in current workers' health status represented by the term $e_h^1 g_h^1(w)(1-\rho)\pi_{h'h}^1$; and transitions to other jobs represented by the term $e_h^1 g_h^1(w)(1-\rho)\pi_{hh}^1\lambda_e(1-\delta)\left(1-\tilde{F}_h(w,1)\right)$.

The steady state condition requires that

$$\left[e_h^1(w)\right]^+=\left[e_h^1(w)\right]^- \text{ for } h\in\{U,H\} \text{ and for all } w \text{ in the support of } F(w,1). \tag{14}$$

Similarly, the inflows of workers with health status h into jobs $(w,0)$, denoted by $\left[e_h^0(w)\right]^+$, are given by

$$\left[e_h^0(w)\right]^+ = f(w,0)(1-\rho)\left\{\begin{array}{c} \lambda_u\left[u_h\pi_{hh}^0+u_{h'}\pi_{hh'}^0\right]+\lambda_e(1-\delta)\left[\begin{array}{c}\pi_{hh}^1 e_h^1\int g_h^1(\tilde{w})\mathbf{1}(V_h(\tilde{w},1)<V_h(w,0))d\tilde{w}\\ +\pi_{hh'}^1 e_{h'}^1\int g_{h'}^1(\tilde{w})\mathbf{1}(V_h(\tilde{w},1)<V_h(w,0))d\tilde{w}\\ \pi_{hh}^0 e_h^0 G_h^0(w)+\pi_{hh'}^0 e_{h'}^0 G_{h'}^0(w)\end{array}\right]\\ +\delta\lambda_e\left(\pi_{hh}^1 e_h^1+\pi_{hh'}^1 e_{h'}^1+\pi_{hh}^0 e_h^0+\pi_{hh'}^0 e_{h'}^0\right)\end{array}\right\}$$
$$+(1-\rho)(1-\delta)\pi_{hh'}^0 e_{h'}^0 g_{h'}^0(w)\left[1-\lambda_e\left(1-\tilde{F}_h(w,0)\right)\right], \tag{15}$$

where $h\neq h'$ and $\tilde{F}_h(w,0)$ is defined by

$$\tilde{F}_h(w,0)=F(w,0)+\int f(\tilde{w},1)\mathbf{1}(V_h(\tilde{w},1)<V_h(w,0))d\tilde{w}. \tag{16}$$

The outflows of workers with health status h from jobs $(w,0)$, denoted by $\left[e_h^0(w)\right]^-$, are given by:

$$\left[e_h^0(w)\right]^-=e_h^0 g_h^0(w)\left\{\rho+(1-\rho)\left[\pi_{h'h}^0+\pi_{hh}^0(\delta+(1-\delta)\lambda_e(1-\tilde{F}_h(w,0))\right]\right\}. \tag{17}$$

The steady state condition thus requires that

$$\left[e_h^0\left(w\right)\right]^+ = \left[e_h^0\left(w\right)\right]^- \text{ for } h \in \{H, U\} \text{ and for all } w \text{ in the support of } F\left(w, 0\right). \tag{18}$$

From the four employment densities, $\langle e_h^x g_h^x(w) : h \in \{U, H\}, x \in \{0, 1\}\rangle$, we can define a few important terms related to firm size. First, given $\langle e_h^x g_h^x(w) : h \in \{U, H\}, x \in \{0, 1\}\rangle$, the number of employees with health status h if a firm offers (w, x) per hiring intensity is simply given by

$$n_h(w, x) = \frac{e_h^x g_h^x(w)}{f(w, x)}, \tag{19}$$

where the numerator is the total measure of workers with health status h on the job (w, x) and the denominator is the total measure of firms offering compensation package (w, x). Of course, the total employee size if a firm offers compensation package (w, x) is

$$n\left(w, x\right) = \sum_{h \in \{U,H\}} n_h\left(w, x\right) = \sum_{h \in \{U,H\}} \frac{e_h^x g_h^x(w)}{f(w, x)}. \tag{20}$$

Expressions (19) and (20) allow us to connect the firm sizes in steady state as a function of the entire distribution of employed workers $\langle e_h^x g_h^x(w) : h \in \{U, H\}, x \in \{0, 1\}\rangle$.

3.3.4 Firm's Optimization Problem

Firms with a given productivity p and hiring technology k decides what compensation package (w, x) to offer, taken as given the aggregate distribution of compensation packages $F\left(w, x\right)$. We assume that that before a firm makes this decision, it draws choice-specific shocks $(\epsilon_{0p}, \epsilon_{1p})$ from i.i.d. Type-I extreme value distribution; and we assume that ϵ_{xp} is persistent over time and it is separable from firm profits[9]. Finally, there is a fixed cost of offering health insurance, denoted by C.

Given the realization of $(\epsilon_{0p}, \epsilon_{1p})$, each firm chooses (w, x) to maximize the steady-state flow profit inclusive of the shocks. It is useful to think of the firm's problem as a two-stage problem. First, it decides the wages that maximizes the deterministic part of the profits for a given insurance provision choice; and second, it maximizes over the insurance choices by comparing the shock-inclusive profits with or without offering health insurance. Specifically, the firm's problem is as follows:

$$\max\{\pi_0(p, k) + \epsilon_{0p}, \pi_1(p, k) + \epsilon_{1p}\}, \tag{21}$$

$$\text{where: } \quad \pi_0(p, k) = \max_{w_0} \pi\left(w_0, 0\right) \equiv \left(\left(p - w_0\right) n_H(w_0, 0) + \left(pd - w_0\right) n_U(w_0, 0)\right) h(k) \tag{22}$$

$$\text{and, } \pi_1(p, k) = \max_{w_1} \pi\left(w_1, 1\right) \equiv \left(\left(p - w_1 - y_H\right) n_H(w_1, 1) + \left(pd - w_1 - y_U\right) n_U(w_1, 1)\right) h(k) - C \tag{23}$$

[9] These shocks allow us to smooth the insurance provision decision of the firms. One can interpret this heterogeneity as employer's specific preference of offering health insurance, heterogeneity of insurance premium which is not explained by health composition of employees, and others.

where y_h is the expected medical expenditure of worker with health status h, i.e., $y_h = q_B^h m_B^1 + (1-q_B^h) m_G^1$; and $n_H(w_x, x)$ and $n_U(w_x, x)$ are the steady state sizes of healthy and unhealthy employees for firms offering compensation packages (w_x, x), as defined by (19). Denote the solutions to problems (22) and (23) respectively as $w_0(p)$ and $w_1(p)$. Note that we do not condition wage on k because the optimal wage is independent of k. The proof for this property is given by Lemma 2.

Due to the assumption that $(\epsilon_{1p}, \epsilon_{0p})$ from i.i.d. Type-I extreme value distribution, firms' optimization problem (21) thus implies that the fraction of firms offering health insurance among those with productivity (p, k) is

$$\Delta(p,k) = \frac{\exp(\pi_1(p,k))}{\exp(\pi_1(p,k)) + \exp(\pi_0(p,k))}, \tag{24}$$

where $\pi_0(p)$ and $\pi_1(p)$ are respectively defined in (22) and (23).

3.4 Steady State Equilibrium

A *steady state equilibrium* is a list $\left\langle \left(\underline{w}_h^x, \underline{s}_h^x(\cdot,\cdot), \underline{q}_h^x\right), (u_h, e_h^x, G_h^x(w)), (w_x(p), \Delta(p,k)), F(w,x) \right\rangle$ such that the following conditions hold:

- **(Worker Optimization)** Given $F(w,x)$, for each $(h,x) \in \{U,H\} \times \{0,1\}$,
  - $\underline{w}_h^x$ solves the unemployed workers' problem as described by (4);
  - $\underline{s}_h^x(\cdot,\cdot)$ solves the job-to-job switching problem for currently employed workers as described by (5);
  - $\underline{q}_h^x$ describes the optimal strategy for currently employed workers regarding whether to quit into unemployment as described by (6);
- **(Steady State Worker Distribution)** Given workers' optimizing behavior described by $\left(\underline{w}_h^x, \underline{s}_h^x(\cdot,\cdot), \underline{q}_h^x\right)$ and $F(w,x)$, $(u_h, e_h^x, G_h^x(w))$ satisfy the steady state conditions described by (7), (10), (14) and (18);
- **(Firm Optimization)** Given $F(w,x)$ and the steady state employee sizes implied by $(u_h, e_h^x, G_h^x(w))$, a firm with productivity p and hiring technology k chooses to offer health insurance, i.e., $x = 1$, with probability $\Delta(p,k)$ and chooses not to offer health insurance with probability $1 - \Delta(p,k)$, where $\Delta(p,k)$ is given by (24). Moreover, conditional on insurance choice x, the firm offers a wage $w_x(p)$ that solves (22) and (23) respectively for $x = 0$ and 1.
- **(Equilibrium Consistency)** The postulated distributions of offered compensation packages are consistent with the firms' optimizing behavior $(w_x(p), \Delta(p,k))$. Specifically, $F(w,x)$ must satisfy:

$$F(w,1) = \sum_k \int_{\underline{p}}^{\overline{p}} \mathbf{1}(w_x(p) < w) \Delta(p,\kappa) h(k) d\Gamma(p), \tag{25}$$

$$F(w,0) = \sum_k \int_{\underline{p}}^{\overline{p}} \mathbf{1}(w_0(p) < w) \left[1 - \Delta(p,\kappa)\right] h(k) d\Gamma(p), \tag{26}$$

where $\Gamma(\cdot)$ is the CDF of the firms' productivity and $h(k)$ is the sampling probability of firm with hiring technology k.

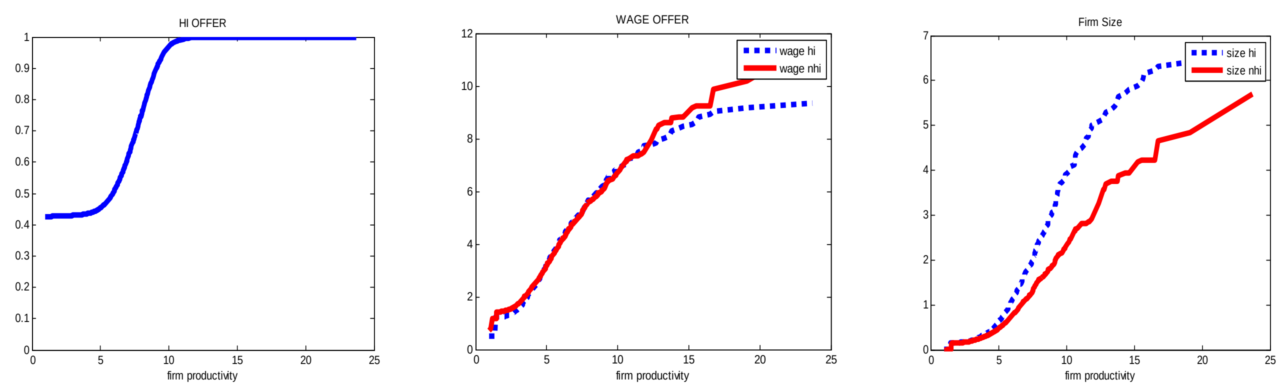
Due to the complexity of the model, we cannot solve the equilibrium analytically. We instead solve the equilibrium numerically. The numerical algorithm is provided in the Appendix. Although we do not have neither the existence nor uniqueness proof, we always find a unique equilibrium based on our algorithm.

4 Qualitative Assessment of the Model

4.1 Numerical Example

In this section, we provide numerical examples to show how our model can generate the positive correlation among wage, health insurance, and firm size. The numerical example is calculated based on parameter estimates. To highlight the main mechanism, we assume that $h(k) = h(k')$ for any $k = k'$. However, the main qualitative properties will not be unchanged in more generous cases.

First, figure 1 is the main patterns obtained from our benchmark model. In each figure, x-axis is firm productivity. The variables listed are (1) health insurance coverage; (2) wage offer; (3) firm size; (4) the average fraction of healthy workers in the firms; and (5) equilibrium profits. As clearly shown, the model predicts the positive correlation between health insurance coverage and productivity, wage and productivity, and firm size and productivity. As a result, it predicts the positive correlation among these four variables. the average health status of employees of employers offering health insurance is relatively better compared with employers not offering health insurance.



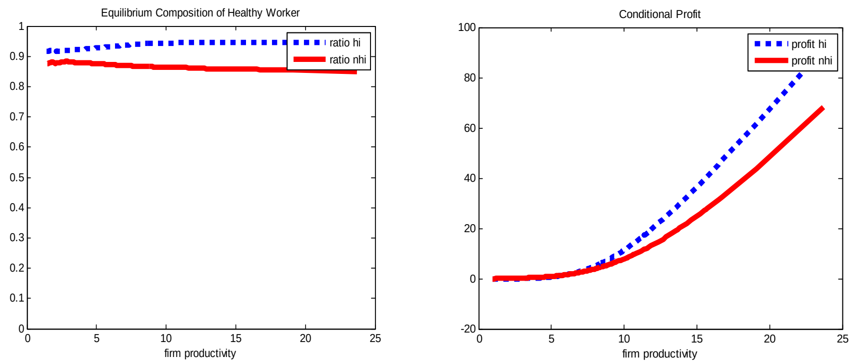


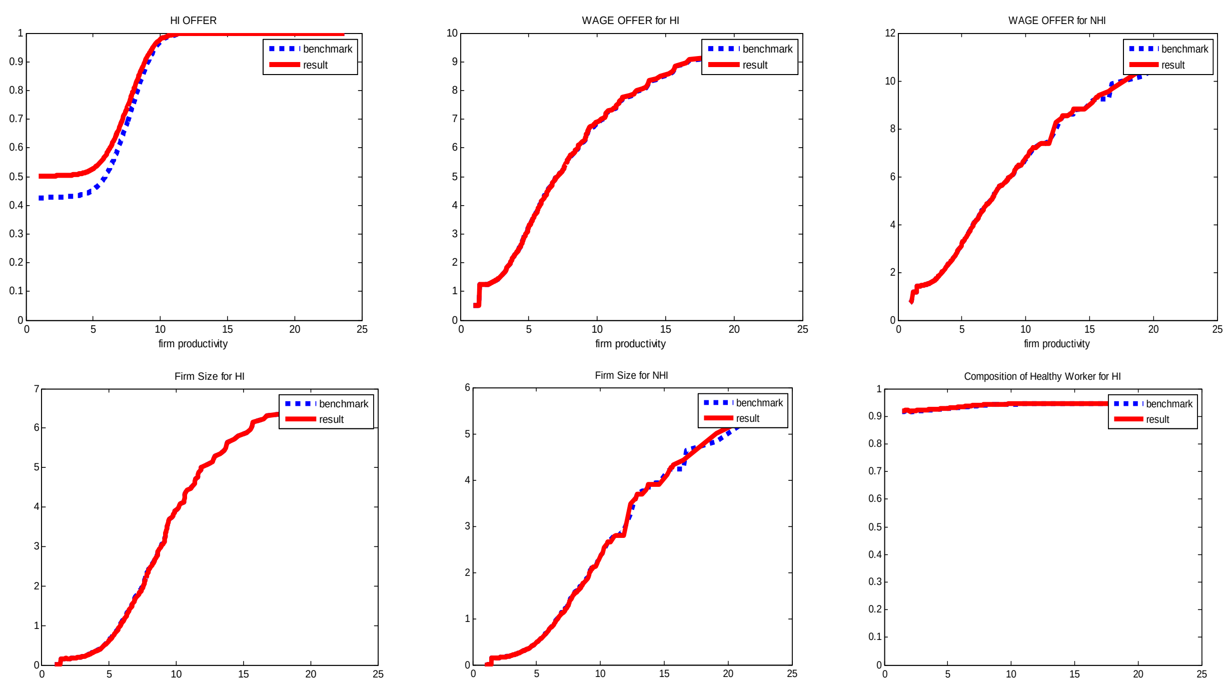
Figure 1: benchmark result

4.2 Comparative Statics

To understand which channels generating this pattern, we provide several comparative static results.

4.2.1 no loading factor

First, we investigate the effect of loading factor C on coverage rate. Figure 2 compares the benchmark case with the case where $C = 0$. In figure, "benchmark" means the outcome under benchmark case and "result" means the outcome under $C = 0$. It is clear from the figure that the loading factor only affects the coverage rate for small firms. Its effect for large firms is virtually zero. Moreover, it does not affect other outcomes. Although we still have a positive correlation between coverage and firm size, the coverage rate for small firms is around 50% if $C = 0$. Thus, in our model, it is important to have loading factors to flexibly generate the magnitude of coverage rate for small firms.



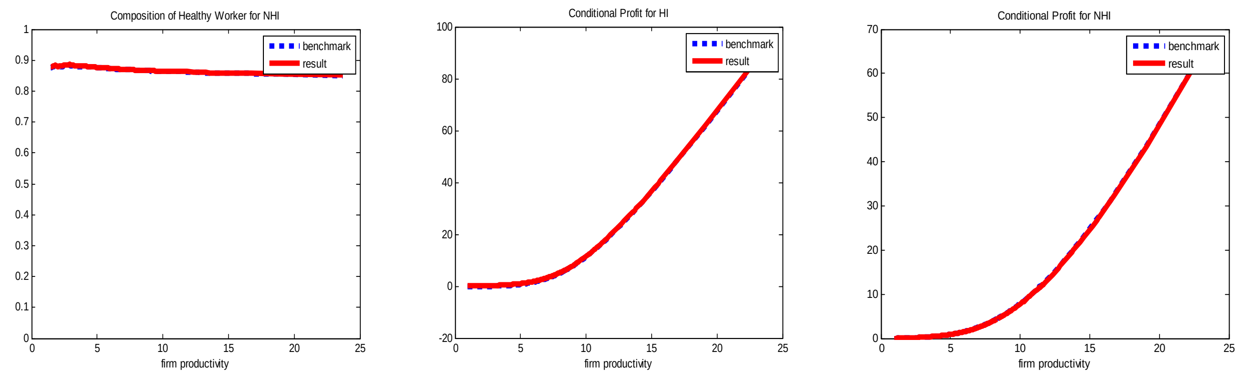
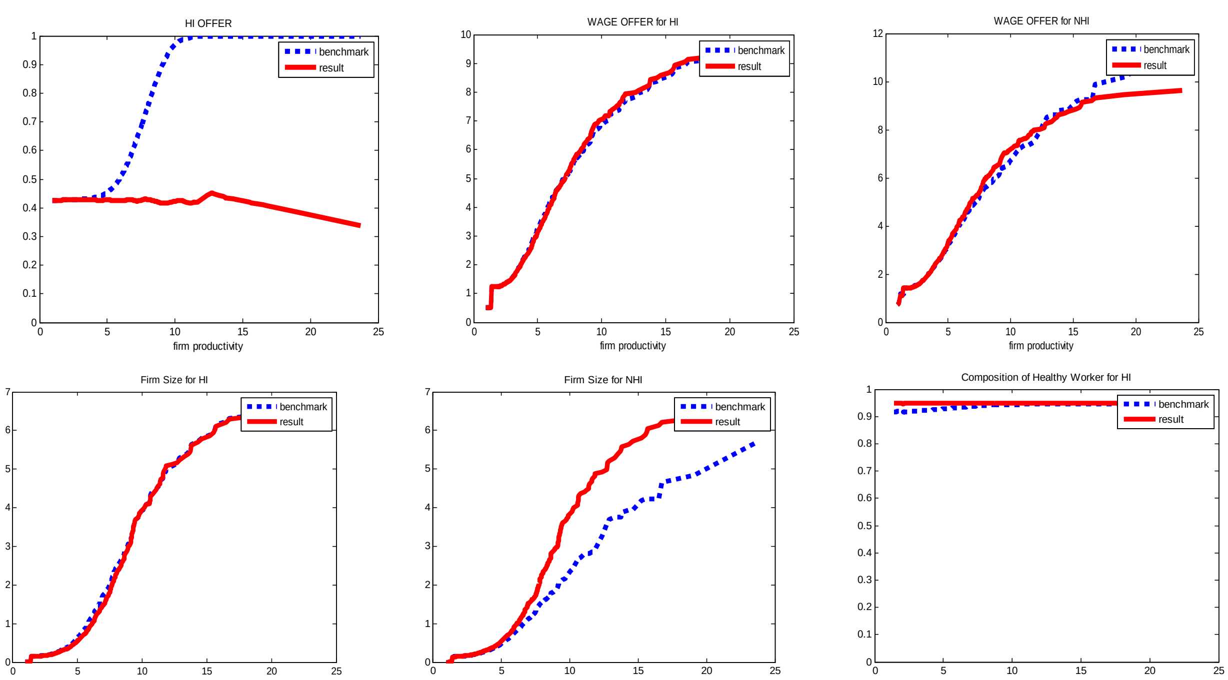


Figure 2: no loading factor

4.2.2 no health insurance effect on health ($\pi^0_{h'h} = \pi^1_{h'h}$)

Second, we shut down the effect that health insurance affects the dynamics of health status by assuming that health transition process for uninsured is the same as insured's one, implying that health composition of the economy must be higher than before[10]. Figure 3 shows the main result under this case. It is clear that the positive correlation between health insurance provision and firm productivity disappears. On the other hand, the positive correlation among wage, productivity, and firm size still exists. Therefore, the health insurance effect on health mainly influences the health insurance coverage decision.



[10]We can obtain the same qualitative result in the opposite scenario, where health transition of insured is equal to uninsured, one, implying that the health composition of the economy is worse than before.

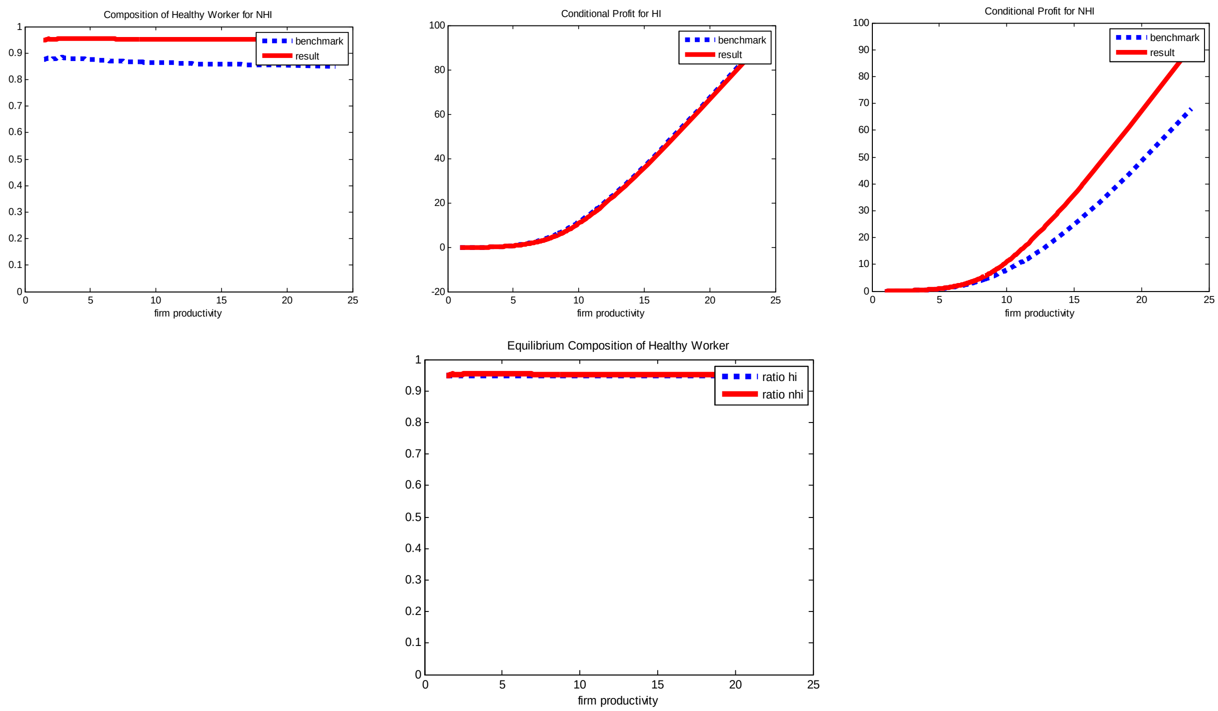


Figure 3: no health insurance effect on health

The reason why more productivity employers decide not to offer health insurance can be understood by considering their incentives. Because offering health insurance does not influence the dynamics of worker's health status, health composition is fully determined by worker's acceptance decision. Then, the bottom figure shows that health composition of employers offering health insurance is a little worse than that of employers who do not. This raises the health insurance costs and therefore reduces the incentive of offering health insurance.

4.2.3 low risk aversion

Another important margin affecting health insurance coverage decision is worker's risk aversion. If workers are less risk averse, they demand less on health insurance. Because of this, they can pay less risk premium to firms, who are risk neutral. This effect is confirmed in Figure 4, where we lower the value of CARA coefficient. It is clear that the coverage rate decline by high productivity firms. Another interesting effect is its effect on firms not offering health insurance. Because worker value health insurance less, they have more incentive to take jobs without health insurance. Because of this channel, those firms can reduce wage to attract workers, which is clearly shown in the figure for "wage offer for NHI".

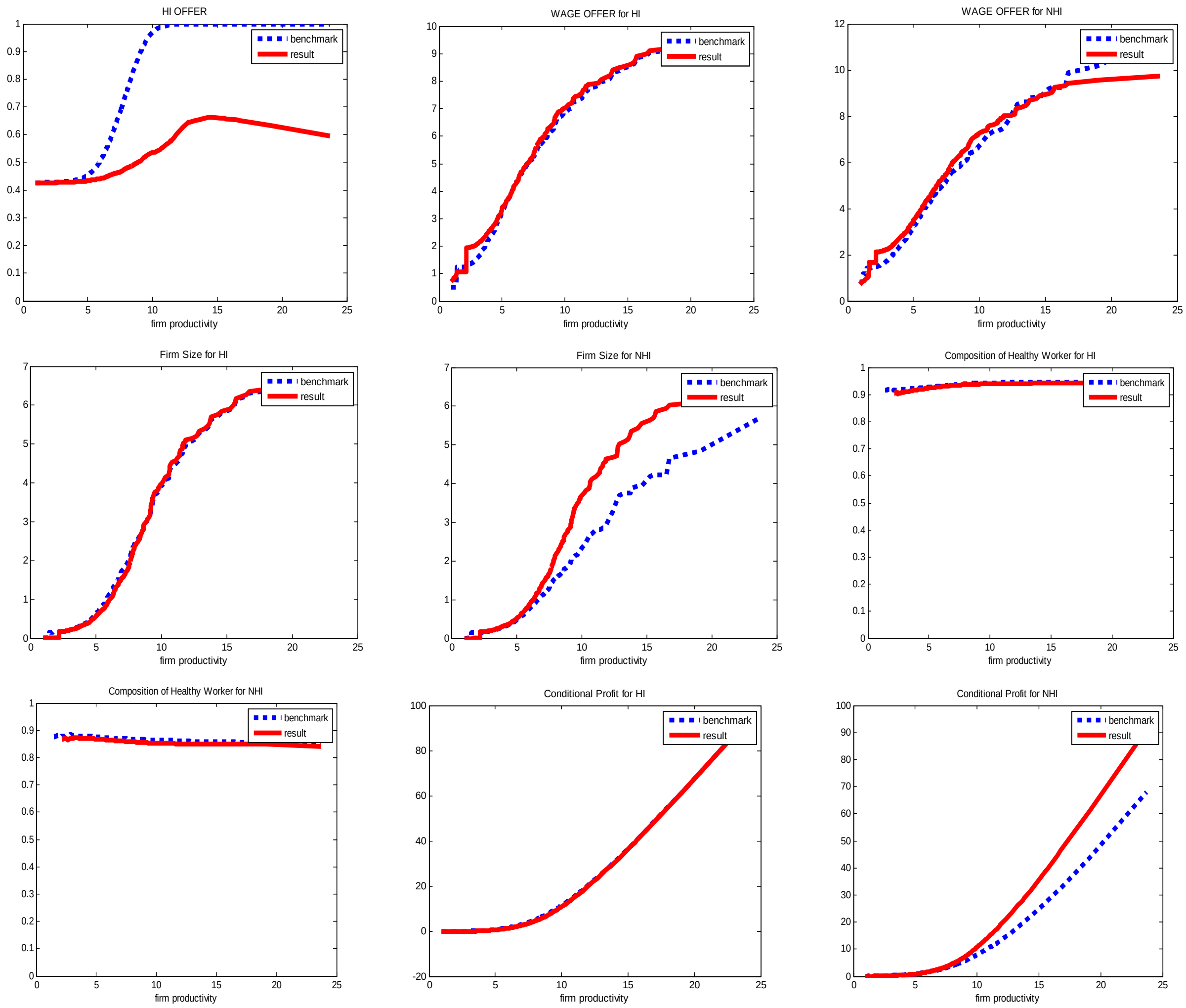


Figure 4: lower the risk aversion

4.2.4 low search friction ($\lambda_e = 0.25 \rightarrow 0.65$)

Next, we investigate the effect of search friction on coverage rate, by increasing λ_e. The result is in Figure 5. One interesting finding is that its impact on health insurance coverage provision is asymmetric between low and high productive firms. The coverage rate of low productivity firms slightly decreases, while it increases for high productivity firms. As a result, the overall impact of search friction on coverage rate in the economy is ambiguous. By reducing search frictions, low productivity firms are less able to retain workers. As a result, they cannot capture the surplus generated by the effect of health insurance on health.

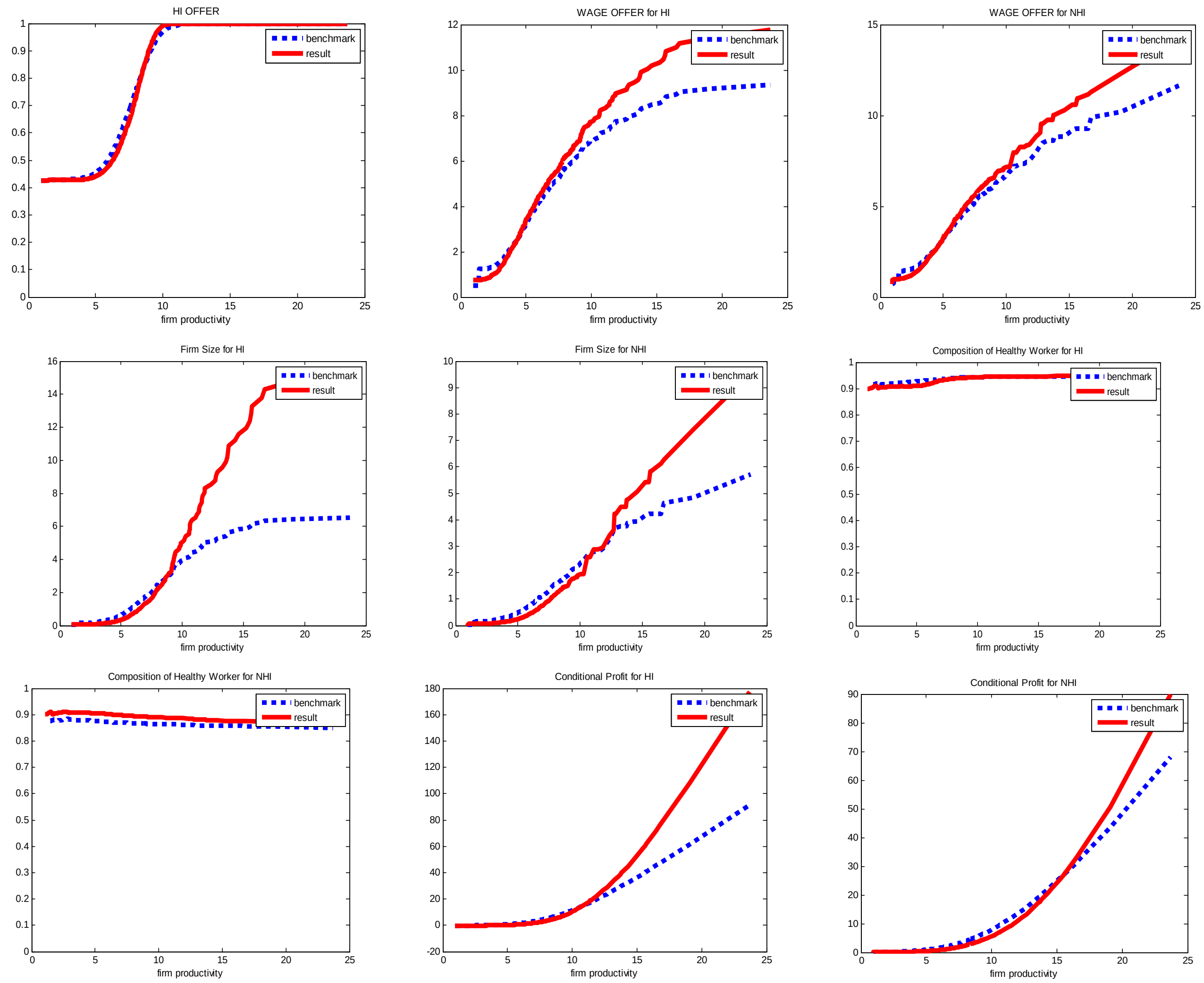
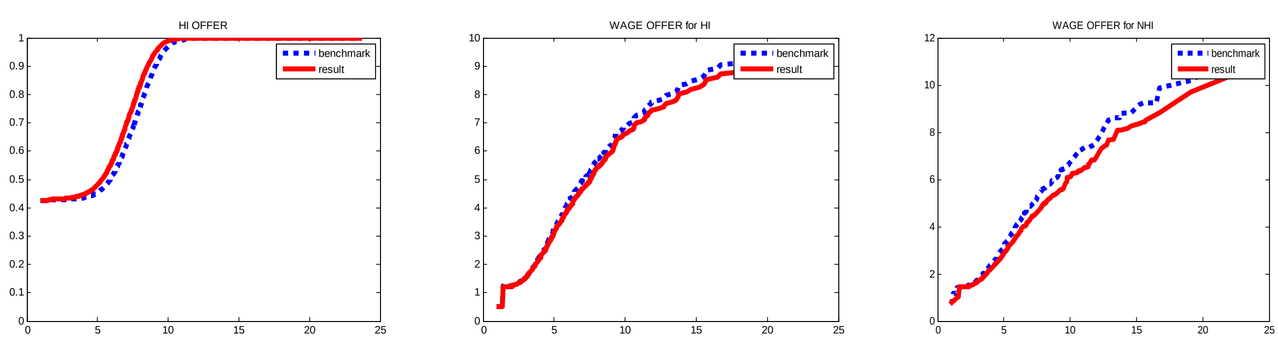


Figure 5: the effect of search friction

4.2.5 productivity effect of health ($d = 0.3$)

Finally, we investigate the productivity effect of health. To see this, we reduce d to 0.3 from 0.6. The main result is summarized in Figure 6. It shows that the coverage rate increases for small employers.



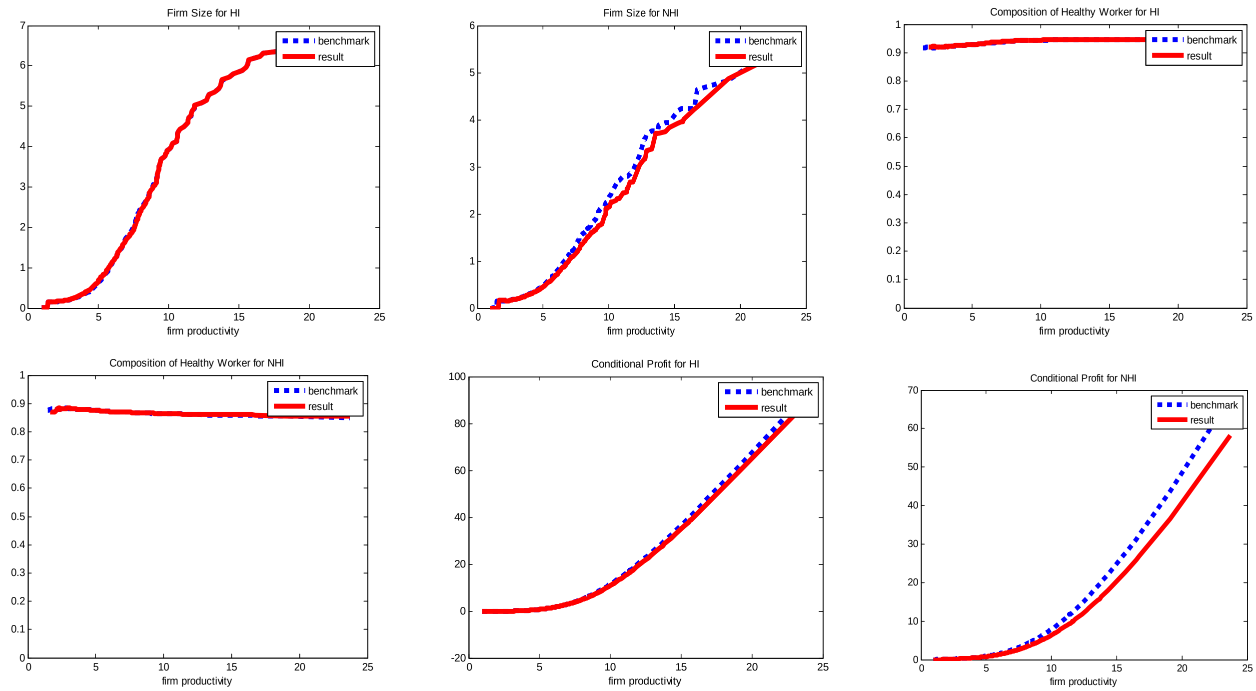


Figure 6: the productivity effect of health

5 Data Set

In this section, we describe the data set its sample selection. In order to estimate the model, it is ideal to use employee-employer matched data which contains information about worker's labor market outcome and its dynamics, health, medical expenditure, and health insurance, and employer's insurance coverage rate and size. Unfortunately, such a data set does not exist. Therefore, we combine three separate data set for our estimation: (1) Survey of Income and Program participation; (2) Medical Expenditure Panel Survey; and (3) Robert Wood Johnson Employer Health Insurance Survey.

5.1 Survey of Income and Program Participation

Our main dataset for individual labor market outcome, health, and health insurance is 1996 Panel of Survey of Income Program Participation (hereafter, SIPP 1996). SIPP 1996 interviews individuals for each four months up to twelve times, so that an individual will have been interviewed over a four year period. It consists of two parts: (1) core module, and (2) topical module. The core module, which is based on interviews in each wave, contains detailed monthly information regarding individuals' demographic characteristics and labor force activity, including earnings, number of weeks worked, average hours worked, employment status, as well as whether the individual changed jobs during each month included in the survey period. In addition, information for health insurance status is recorded once in each wave. It specifies the source of insurance such that (1) whether it is from employment based insurance, individual insurance, or Medicaid, and (2) whether it is obtained through individual name or the spouse's name. The topical module, which is based on interviews in each year, contains yearly information about worker and his family member's health status, out of pocket medical expenditure, insurance premium, and asset. Those information are collected in wave3, 6, 9, and 12. For my estimation, I match core module with topical module.

Sample Criterion The total sample size after matching topical module and core module is "115,981". We restrict sample to men (59,846 dropped) whose age is between 23-54 (33,651 dropped). Moreover, We drop the sample who enrolls in school, works as a self-employment (owns business), works in a public sector, or engages in military service. In addition, We only keep an individual who is not in school, does not work as a self-employment, does not work in a public sector, dose not engage in military service, and does not participate in any government welfare program (10,866 dropped). In addition, We keep the sample who is covered by employer based health insurance or is uninsured (2,884 dropped). Finally, We restrict the samples who are at most high school graduates (4,661 dropped) and top 99.5% salaried workers (236 dropped). As a result, the sample size is 7,548.

5.2 Medical Expenditure Panel Survey (MEPS)

The weakness of using SIPP data for my research is the lack of information for total medical expenditure. To obtain the information, we use Medical Expenditure Panel Survey (hereafter, MEPS) 1996-1999. MEPS is a set of large-scale annual rotating panel surveys. We use its Household Component (HC), which has information about individual demographic characteristics, health status, health insurance status, and medical expenditure[11]. We use the same sample selection criteria as SIPP 1996.

5.3 Robert Wood Johnson Foundation Employer Health Insurance Survey

In addition, I also need information for insurance premium across employers, which is not available from worker side data like SIPP. The data source I use is 1997 Robert Wood Johnson Foundation Employer Health Insurance Survey[12]. It is nationally representative survey of public and private establishments conducted in 1996 and 1997. It contains information about (1) employer's characteristics such as industry, firm size, and employees' demographics, and (2) health insurance such as whether their workers purchase health insurance from the employer, health insurance plans, employees' eligibility and enrollment in health plans, the plan type, and its premium.

[11] MEPS HC is publicly available from the following website:
http://www.meps.ahrq.gov/mepsweb/data_stats/download_data_files.jsp

[12] This microdata is publicly available. It is downloadable from
http://www.icpsr.umich.edu/icpsrweb/HMCA/studies/2935

To be consistent with worker side sample selection, I restrict the sample to establishments which belongs to private sectors. The final sample size is 21,545.

5.4 Summary Statistics

The summary statistics of key variables in SIPP 1996 is summarized as follows.

Variable Name	Mean	Standard Deviation
The fraction of healthy workers	0.919	0.273
The fraction of insured employed	0.741	0.438
4 month wage for employed worker	8.581	4.34
U-E transition rate	0.583	0.493
J-J transition rate	0.060	0.239
E-U transition rate	0.022	0.149

Table 1: Summary Statistics for 1996 SIPP

The comparison of summary statistics between MEPS 1997-1999 and SIPP 1996 are as follows.

Variable Name	MEPS	SIPP
The fraction of healthy workers	0.91 (0.31)	0.919 (0.27)
The fraction of insured among employed	0.67 (0.47)	0.741 (0.438)
annual medical expenditure	1.36 (5.49)	-
annual medical expenditure among insured and healthy	0.84 (2.35)	-
annual medical expenditure among uninsured and healthy	0.54 (5.33)	-
annual medical expenditure among insured and unhealthy	3.88 (6.91)	-
annual medical expenditure among uninsured and unhealthy	1.67 (4.69)	-

Table 2: Summary Statistics for 1996 SIPP and 1996-1999 MEPS

6 Estimation Strategy

This section discusses the structural estimation of our model using the dataset we described above. Our estimation procedure is a modification of semi-parametric procedure by Bontemps et al. (1999, 2000) and Shephard (2011). The estimation is based on three steps: in the first step, we estimate the parameters without using model; in the second step, we estimate the parameters for worker's preference and labor market frictions using the maximum likelihood; in the their step, we estimate firm side parameters by minimum distance estimator.

In our empirical application, we set the model period as four month, which is motivated by the fact that we can only observe the transition of health insurance status at four month frequency.

In this paper, we do not try to estimate β but set $\beta = 0.99$ so that annual interest rate is 4%. It is known from Flinn and Heckman (1983) that separately identifying the discount factor β from flow unemployed income b is difficult in the standard search model.

6.1 Step 1

Step 1 estimates parameters which are cleanly identified without explicitly using the model.

1. First, we estimate the parameters in medical expenditure distributions (q_B^H, q_B^U, m_B^0, m_G^0, m_B^1, m_G^1) by GMM using the MEPS. The sample target here is mean, variance, skewness, and kurtosis of medical expenditure conditional on health and health insurance status for those who health and health insurance status are unchanged over an year. The annual theoretical moments are constructed from parameters which are defined in a 4 month period model. Therefore, there are 16 moments and 6 parameters. I use weighting matrix as the diagonal matrix where each diagonal element is the inverse of variance of each sample moment.

2. Then, we estimate the parameters in health transition matrix, $\pi_{HH}^{HI}, \pi_{UU}^{HI}$, π_{HH}^{NHI}, and π_{UU}^{NHI}, using SIPP 1996 based on maximum likelihood. Let $x_t \in \{0, 1\}$ be worker's insurance status. Let the time period be 4 month. Although we can observe health insurance status for each period, we can observe health status for each 3 period. The log likelihood contribution for individual i whose $H_t = H$ is (I omit individual index):

$$\begin{aligned}\mathbf{1}(H_{t+3} &= H)\log(\Pr(H_{t+3} = 1|HI_t = x_t, HI_t = x_{t+1}, HI_t = x_{t+2}, H_t = H))\\ +\mathbf{1}(H_{t+3} &= U)\log(\Pr(H_{t+3} = 2|HI_t = x_t, HI_t = x_{t+1}, HI_t = x_{t+2}, H_t = H))\end{aligned}$$

where

$$\begin{aligned}\Pr(H_{t+3} &= H|HI_t = x_t, HI_t = x_{t+1}, HI_t = x_{t+2}, H_t = H) = \pi_{HH}^{x_t}\pi_{HH}^{x_{t+1}}\pi_{HH}^{x_{t+2}}\\ &+\pi_{HH}^{x_t}(1-\pi_{HH}^{x_{t+1}})(1-\pi_{UU}^{x_{t+2}}) + (1-\pi_{HH}^{x_t})(1-\pi_{UU}^{x_{t+1}})\pi + (1-\pi_{HH}^{x_t})\pi_{UU}^{x_{t+1}}(1-\pi_{UU}^{x_{t+2}})\end{aligned}$$

$$\begin{aligned}\Pr(H_{t+3} &= U|HI_t = x_t, HI_t = x_{t+1}, HI_t = x_{t+2}, H_t = U) = \pi_{HH}^{x_t}\pi_{HH}^{x_{t+1}}(1-\pi_{HH}^{x_{t+2}})\\ &+\pi_{HH}^{x_t}(1-\pi_{HH}^{x_{t+1}})\pi_{UU}^{x_{t+2}} + (1-\pi_{HH}^{x_t})(1-\pi_{UU}^{x_{t+1}})(1-\pi_{HH}^{x_{t+2}}) + (1-\pi_{HH}^{x_t})\pi_{UU}^{x_{t+1}}\pi_{UU}^{x_{t+2}}\end{aligned}$$

Similarly, the log likelihood contribution for individual i whose $H_t = U$ is

$$\begin{aligned}\mathbf{1}(H_{t+3} &= U)\log(\Pr(H_{t+3} = U|HI_t = x_t, HI_t = x_{t+1}, HI_t = x_{t+2}, H_t = U))\\ +\mathbf{1}(H_{t+3} &= U)\log(\Pr(H_{t+3} = U|HI_t = x_t, HI_t = x_{t+1}, HI_t = x_{t+2}, H_t = H))\end{aligned}$$

where

$$\Pr(H_{t+3} = H|HI_t = x_t, HI_t = x_{t+1}, HI_t = x_{t+2}, H_t = H) = (1-\pi_{UU}^{x_t})\pi_{HH}^{x_{t+1}}\pi_{HH}^{x_{t+2}}$$
$$+(1-\pi_{UU}^{x_t})(1-\pi_{HH}^{x_{t+1}})(1-\pi_{UU}^{x_{t+2}}) + \pi_{UU}^{x_t}(1-\pi_{UU}^{x_{t+1}})\pi_{HH}^{x_{t+2}} + \pi_{UU}^{x_t}\pi_{UU}^{x_{t+1}}(1-\pi_{UU}^{x_{t+2}})$$

$$\Pr(H_{t+3} = U|HI_t = x_t, HI_t = x_{t+1}, HI_t = x_{t+2}, H_t = H) = (1-\pi_{UU}^{x_t})\pi_{HH}^{x_{t+1}}(1-\pi_{HH}^{x_{t+2}})$$
$$+(1-\pi_{UU}^{x_t})(1-\pi_{HH}^{x_{t+1}})\pi_{UU}^{x_{t+2}} + \pi_{UU}^{x_t}(1-\pi_{UU}^{x_{t+1}})(1-\pi_{HH}^{x_{t+2}}) + \pi_{UU}^{x_t}\pi_{UU}^{x_{t+1}}\pi_{UU}^{x_{t+2}}$$

Then, one can obtain the log likelihood of transition function as a function of health transition parameters.

3. Finally, the exogenous retirement rate is set so that $\rho = 0.001$: the average length of being in a labor force is 40 years. Finally, the progressive income tax schedule is calculated based on the simulation in Kaplan (2011)[13].

6.2 Step 2

In the second step, we estimate transition parameters λ_u, λ_e, δ, CARA coefficient γ, the probability that initial health status is healthy, μ_h, and job offer distribution $F(w, x)$, and unemployed benefit b by using the maximum likelihood. The likelihood of each individual is defined as the probability that individual's observed first transition is generated from the model. We allow measurement error for accepted wage. To evaluate likelihood, we need information for offer distribution $F(w, x)$. To recover the offer distribution, we utilize the model's prediction about the relationship between offer distribution and employment distribution.

1. Nonparametrically estimate the distribution of employed workers, $\widehat{e_h^x g_h^x(w)}$. We use Gaussian kernel estimation with some bandwidth.

2. Guess $(\lambda_u, \lambda_e, \delta, \gamma, \mu_h)$.

3. Guess $\widehat{F(w, x)}$. Then, given parameters, solve worker's optimization problem by value function iteration. Once solving individual problem, solve worker's steady state distribution through the fixed point algorithm. Then, update $f(w, x)$ by using
$$f(w, x) = \frac{\sum_h e_h g_h^x(w)}{\sum_h n_h(w, x)}.$$
We replace the numerator by $\widehat{e_h^x g_h^x(w)}$ which is obtained in the previous step and we obtain $n_h(w, x)$ from the steady state condition in the model. Continue this process until converge. Then, obtain $F^*(w, x)$ which will be input of likelihood function.

[13]Robin and Roux (2002) are the first study investigating the role of progressive income tax within an equilibrium search model with on-the-job.

4. evaluate the likelihood function given the set of parameters. The likelihood contribution of unemployed worker with unemployment spells d whose initial health status is h is:

$$\overbrace{\frac{u_h}{M}}^{\substack{\text{the prob. unemployed} \\ \text{with } h \text{ is sampled}}} \qquad \overbrace{\Pi_{j=1}^{d}\sum_{h'}\Pr(h_{j+1}=h'|h_j)\Big((1-\lambda_u)+\lambda_u(F(\underline{w}^1_{h_j},1)+F(\underline{w}^0_{h_j},0)\Big)}^{\substack{\text{the prob. that individual experiences} \\ d \text{ periods of unemployment.}}}$$

$$\times\overbrace{\left(\sum_{h'}\Pr(h_{d+2}=h'|h_{d+1})\int_{\underline{w}^x_{h_{d+2}}}\lambda_u f(w,x)\Pr((\tilde{w},x)|(w,x))dw\right)^{UE}}^{\substack{\text{the prob. individual finds a job} \\ \text{with } (\tilde{w},x) \text{ at period } d+1}}.$$

where $UE\in\{0,1\}$ is an indicator whether we observe a transition to employment with (w,x) at period $d+1$. We assume that the initial condition of individuals is drawn from steady state worker distribution, implying that the probability that an unemployed worker with health status h is sampled is $\frac{u_h}{M}$.

Similarly, the likelihood contribution of employed workers with health status h whose employment status is (w,x):

$$\frac{\overbrace{(1-u_H-u_U)e^x_h g^x_h(w)}^{\text{the prob. employed with } (w,x) \text{ and health status } h \text{ is sampled.}}}{M}$$

$$\times\overbrace{\Pi_{j=1}^{d}\sum_{h'}\Pr(h_{j+1}=h'|h_j)(1-\delta)\Big((1-\lambda_e)+\lambda_e(F(w,x)+F(\underline{s}^{x'}_{h_j}(w,x),x'))\Big)}^{\text{the prob. that individual experiences of } d \text{ periods of employment.}}$$

$$\times\overbrace{\left(\delta(1-\lambda_e)+\delta\lambda_e\sum_x F(\underline{w}^x_h,x)\right)}^{\substack{\text{the prob. of job loss at } d+1 \\ loss}}$$

$$\times\overbrace{\sum_{h'}\Pr(h_{d+2}=h'|h_{d+1})\begin{pmatrix}\int_w(1-\delta)\lambda_e f(w',x)\Pr((\tilde{w},x)|(w',x))dw' \\ +\int_{\underline{w}^x_{h_{d+2}}}\delta\lambda_e\Pr((\tilde{w},x)|(w',x))f(w',x)dw'\end{pmatrix}}^{\substack{\text{the prob. of jj with } hi'=hi \\ jj,hi'=hi}}$$

$$\times\overbrace{\sum_{h'}\Pr(h_{d+2}=h'|h_{d+1})\begin{pmatrix}\int_{V_h(w,x)}(1-\delta)\lambda_e f(w',x')\Pr((\tilde{w},x)|(w',x'))dw' \\ +\int_{\underline{w}^{x'}_{h_{d+2}}}\delta\lambda_e\Pr((\tilde{w},x)|(w',x'))f(w',x')dw'\end{pmatrix}}^{\substack{\text{the prob. of jj with } hi'\neq hi \\ jj,hi'\neq hi}}$$

where $loss \in \{0,1\}$ is an indicator whether employed workers become unemployment, $(jj, hi = hi') \in \{0,1\}$ is an indicator whether employed workers change jobs while insurance status is the same, and $(jj, hi \neq hi') \in \{0,1\}$ is an indicator whether employed workers change jobs and switch the insurance status.

To write down the likelihood, we implicitly assume that there is no left censoring problem and instead assume that individuals begin their new employment status at interview round 3. The main reason for this choice is that we cannot obtain data for initial condition of individual health status, which is only available in interview wave 3,6, 9, and 12.

6.3 Step 3

In the third step, we estimate the remaining permeates $\gamma(p), h(k)$, d, F, and M by utilizing the estimates obtained from the previous steps. We assume that the number of firm specific hiring type is 3.

1. Guess d and F, M, and $h(k)$. We firstly recover the support of productivity distribution. To do so, we utilize the optimal condition for wage policy. Take first order condition with respect to wage in equations (22) and (23). By using estimated $\hat{f}(w,x)$ and other parameters, one can obtain the relationship between productivity and wage by

$$\begin{aligned} p_{NHI}(w) &= \frac{w(n'_H(w,0) + \tilde{n}'_U(w,0)) + \tilde{n}_H(w,0) + \tilde{n}_U(w,0)}{\tilde{n}'_H(w,0) + d\tilde{n}'_U(w,0)}, \\ p_{HI}(w) &= \frac{(w + y_H)\,\tilde{n}'_H(w,1) + (w_{HI} + y_U)\,\tilde{n}'_U(w,1) + \tilde{n}_H(w,1) + \tilde{n}_U(w,1)}{\tilde{n}'_H(w,1) + d\tilde{n}'_U(w,1)}, \end{aligned}$$

   where $\tilde{n}_H$ and $\tilde{n}_U$ are predicted firm size "per hiring effort". Given this, one can back out $[p^1_{NHI}, \ldots, p^{N_{NHI}}_{NHI}]$ and $[p^1_{HI}, \ldots, p^{N_{HI}}_{HI}]$. Due to the potential small sample problem, the support of p_{HI} and p_{NHI} may not coincide. Therefore, we take the union of these interval. Notice that $f(\widehat{w(p)},1) = \gamma(p)\pi(p)\sum_{k=1}^{N_K} h(k) = \gamma(p)x(p)$ and similarly $f(\widehat{w(p)},0) = \gamma(p)(1 - x(p))$. Thus, we obtain $\gamma(p)$ as $\gamma(p) = f(\widehat{w(p)},1) + f(\widehat{w(p)},0)$.

2. The remaining task to set some targets to pin down $h(k)$, d, F, and M given $\gamma(p)$. First, notice that, because $f(w,1) = \gamma(p)\sum_k \Delta(p,k)h(k)$ and $f(w,0) = \gamma(p)(1 - \sum_k \Delta(p,k)h(k))$, by taking the ratio $\frac{\gamma(p)\sum_k \Delta(p,k)h(k)}{\gamma(p)(1-\sum_k \Delta(p,k)h(k))}$, we have $\frac{\sum_k \Delta(p,k)h(k)}{(1-\sum_k \Delta(p,k)h(k))} = \frac{f(w,1)}{f(w,0)}$. Therefore, we can pin down $\sum_k \Delta(p,k)h(k)$ as

$$\sum_k \Delta(p,k)h(k) = \frac{f(w(p),1)}{f(w(p),1) + f(w(p),0)}.$$

   Given the initial guess d and F, M, and $h(k)$, we can also calculate $\pi(p)$ as

$$\sum_k \widehat{\Delta(p,k)}h(k) = \sum_k \frac{\exp(\pi_1(p,k))}{\exp(\pi_1(p,k)) + \exp(\pi_0(p,k))} h(k),$$

   where $\pi_{HI}(p)$ and $\pi_{NHI}(p)$ are equilibrium profits calculated based on the parameters. it gives us the first moment (1) criteria $1 = \sum_p |\sum_k \Delta(p,k)h(k) - \sum_k \widehat{\Delta(p,k)}h(k)|$. Moreover, from employer size data, construct empirical firm size moments, which consist of (1) mean firm size and (2) firm size distribution (say, quantile). From the model, we can also predict model based firm size moments. Let's call this moments as criteria 2. Then, search for parameters $\gamma(p), h(k)$, d, F, and M to minimize criteria 1+criteria 2.

Calculation of standard error In order to avoid a cumbersome derivation of asymptotics for our nonstandard estimation method, we obtain consistent standard errors by bootstrapping the last two step estimation procedure.

7 Estimation Results

7.1 Parameter Estimates

7.1.1 First Step

Table 3 reports the parameter estimates from step 1. One important finding is that there is a significant difference between π_{UU}^{HI} and π_{UU}^{NHI}, implying that the lack of health insurance delays the recovery from unhealthy. We can also see $\pi_{HH}^{HI} > \pi_{HH}^{NHI}$, although the difference of the magnitude is quite small.

Parameter	Estimates
q_B^H	0.03
q_B^U	0.1746
m_B^{HI}	0.801
m_B^{NHI}	0.43
m_G^{HI}	0.010
m_G^{NHI}	0.001
π_{HH}^{HI}	0.9803 (0.0015)
π_{HH}^{NHI}	0.9715 (0.0032)
π_{UU}^{HI}	0.7129 (0.0200)
π_{UU}^{NHI}	0.7982 (0.0163)

Table 3: Parameter estimates in step 1

(Standard error is in parenthesis. The unit of medical expenditure is $10,000.)

7.1.2 Second Step and third step (Work in Progress)

At this stage, we do not complete the estimation of second and third step. We are sure that we obtain the estimation result within a month. Instead, we provide the estimate based on the simulated method of moments (hereafter, SMM) where we specify Γ as a log normal distribution with mean μ_p and standard deviation σ_p. We will use these estimates as an initial guess for our semi parametric estimation procedure. The below is a list of moments. The associated parenthesis is a parameter that the corresponding moment is informative to identify it.

1. transition rate from unemployment to employment rate (λ_u)
2. job-to-job transition rate (λ_e)
3. employment to unemployment transition rate (δ)
4. the fraction of uninsured employed workers (C, d)
5. the fraction of employers offering health insurance (C, d)
6. the fraction of healthy workers
7. the mean wage of employed worker (μ_p)
8. the variance of wage of employed worker (σ_p)
9. the mean of accepted wage by previously unemployed worker (μ_p)
10. the variance of accepted wage by previously unemployed worker (σ_p)
11. the fraction of wage drop through JJ with HI gain (γ)
12. the fraction of wage up through JJ with HI loss (γ)

The objective function is defined by

$$\min_{\theta}(\hat{X} - S(\theta))W(\hat{X} - S(\theta))$$

where $\hat{X}$ is sample moments and $S(\theta)$ is simulated moments. We use W as diagonal matrix where each diagonal element is the inverse of variance of corresponding sample moment.

Table 4 shows the parameter estimates.

Parameter	Estimates
γ	1.32
d	0.60
b	0.17
λ_u	0.64
λ_e	0.34
δ	0.20
F	0.05
μ_H	0.98
μ_p	0.099
σ_p	0.15

Table 4: Parameter estimates from Simulated Method of Moments

7.2 Goodness of Fit

7.2.1 Within Model Fit

Here, we provide a within model fit based on estimates by SMM.

Definition of Moments	Data	Simulated
UE Transition	0.60	0.63
EU Transition	0.021	0.02
JJ Transition	0.060	0.06
The fraction of insured among employed	0.74	0.70
the fraction of firms offering health insurance	0.46	0.48
the fraction of healthy workers	0.92	0.89
mean of wages among employed	0.862	1.07
variance of wages among employed	0.1874	0.13
mean of wages by previously unemployed	0.580	0.70
variance of wages by previously unemployed	0.1500	0.10
the fraction of wage drop through JJ with HI gain	0.35	0.26
the fraction of wage up through JJ with HI loss	0.55	0.53

Table 5: Model Fits

Overall, the model fits for targeted moments are reasonably well.

8 Counterfactual Experiments (Work in Progress)

The main objective of our paper is to conduct counterfactual policy experiments to evaluate the impact of health insurance reforms. The below is the subset of the list of counterfactual experiments which we plan to implement.

8.1 Affordable Care Act (Work in Progress)

First, we evaluate several important components of the Affordable Care Act (ACA). Among its many components, we address (1) health insurance exchange; (2) subsidies to the participants in health insurance exchange; (3) health insurance mandate to large employers; (4) health insurance mandate to individuals. To capture these effects, we modify the benchmark model in the following way:

1. Health insurance exchange: we assume there are two separate exchange markets where one is for small employers (up to 50) and the other one is for individuals. The premium in the insurance exchange is determined as community rated. In the model, we allow that small employers will choose (1) not offer health insurance; (2) offer health insurance whose premium is determined as the same pricing rule as before; (3) offer health insurance which is purchased from health insurance exchange. In addition, uninsured workers can decide whether to purchase individual insurance from insurance exchange.

2. Subsidies to the participants in health insurance exchange: we assume that individual workers obtain income based subsidies if they purchase health insurance from insurance exchange. Moreover, employers participating insurance exchange can also obtain subsidies.

3. Insurance mandate on employer whose size is more than 50: we assume that employers with more than 50 employees must offer health insurance. Otherwise, they need to pay penalty which amounts to $2,000 per worker in each year.

4. health insurance mandate to workers: similarly, we assume that all workers must carry health insurance. Otherwise, they need to penalty.

The key extension of the model is to allow both uninsured workers and small employers participating in health insurance markets where the premium is community rated.

8.2 Employer Mandates Only (Work in Progress)

8.3 Health Insurance Exchange Only (Work in Progress)

8.4 Eliminating the Tax Preference for Employer-Sponsored Health Insurance Premium (Work in Progress)

9 Conclusion (Work in Progress)

In this paper, we constructed and estimated an equilibrium labor market search model where both the wages and health insurance provisions are endogenous determined to evaluate the 2010 U.S. health insurance reform. In our model, employers decide whether to offer health insurance by taking into account two channels. First, by offering health insurance, they may attract unhealthy workers who both increase the health insurance costs and decrease labor productivity, generating an adverse selection problem. Second, because health insurance coverage can improve employees' future health status, employers can reduce the cost generated by the adverse selection over time. We showed that the resulting equilibrium is one in which more productive employers benefit more from the latter channel, leading to a positive correlation among wage, health insurance coverage, and employer size, which is consistent with the data. We then estimated the model by combining several data sources. We found that the dynamics effect of health insurance on health is significant. Moreover, the model could reasonably fit the many aspects of the data.

Appendix

Numerical Algorithm to Solve the Equilibrium of the Model

We sketch the numerical algorithm that we use to solve for the steady-state equilibrium in section 4.

1. Given the productivity distribution Γ, simulate a large number of productivity p and construct an approximated productivity distribution $\tilde{\Gamma}$ with support $[\underline{p}, \overline{p}]$. Moreover, assign k and corresponding $h(\cdot)$ for each firm.

2. Provide an initial guess of the wage policy function and the health insurance offer probability $(w_0^0(p), w_1^0(p), \Delta^0(p,k))$ for all p on support $[\underline{p}, \overline{p}]$ and for all k.

3. Given the current guess of the wage policy function and the health insurance offer probability $(w_0^t(p), w_1^t(p), \Delta^t(p,k))$, construct the offer distribution $F^t(w,x)$ by using (26) and (25).

4. By using $F^t(w,x)$, numerically solve worker's optimal strategy $\left(\underline{w}_h^x, \underline{s}_h^x(\cdot,\cdot), \underline{q}_h^x\right)$ and calculate U_h and $V_h(w_x^t(p), x)$ for $h \in \{U, H\}$, $x \in \{0,1\}$, and p on on support $[\underline{p}, \overline{p}]$. Moreover, calculate $V_h(w,x)$

for $w \in \mathcal{W}$, where $\mathcal{W}$ is the discrete set of potential wage choices[14].

5. Calculate unemployment u_h^t and employment distribution $e_h^{x,t} G_h^{x,t}(w_x^t(p))$ for all p on support $[\underline{p}, \overline{p}]$ by solving functional fixed point equations (7), (10), (14) and (18)[15].

6. Calculate $n^t\left(w^t(p), x\right)$ for all p by using (20). Moreover, calculate $n^t(w, x)$ for $w \in \mathcal{W}$[16].

7. Update the firm's optimal policy $(w_0^{t+1}(p), w_1^{t+1}(p), \Delta^{t+1}(p,k))$ for all p and k. First, fix k. Starting from the lowest productivity $\underline{p}$, solve $w_0^*(p)$ and $w_1^*(p)$ by using (22) and (23). If we find threshold productivity p_0^* and p_1^* such that $n_H(w_x^{t+1}(p_x^*), x) > 0$ and $n_U(w_x^{t+1}(p_x^*), x) > 0$, calculate $w_x^*(p)$ for $p > p_x^*$ by utilizing envelope condition, which is discussed in Lemma 2:

$$w_1^*(p) = \frac{\left\{\begin{array}{c} [p - cy_H]\, n_H(w_1^t(p), 1) + [pd - cy_U]\, n_U(w_1^t(p), 1) \\ - \int_{p_1^*}^{p} \left(n_H(w_1^t(\tilde{p}), 1) + d n_U(w_1^t(\tilde{p}), 1)\right) d\tilde{p} - \tilde{\pi}_1(p_1^*) \end{array}\right\}}{n_H(w_1^t(p), 1) + n_U(w_1^t(p), 1)}$$

and

$$w_0^*(p) = \frac{\left\{\begin{array}{c} p n_H(w_0^t(p), 0) + p d n_U(w_0^t(p), 0) \\ - \int_{p_0^*}^{p} \left(n_H(w_0^t(\tilde{p}), 0) + d n_U(w_0^t(\tilde{p}), 0)\right) d\tilde{p} - \tilde{\pi}_0(p_0^*) \end{array}\right\}}{n_H(w_0^t(p), 0) + n_U(w_0^t(p), 0)}$$

where

$$\begin{aligned} \tilde{\pi}_1(p_1^*) &= (p_1^* - w_1^*(p_1^*) - y_H)\, n_H(w_1^t(p_1^*), 1) + (p_1^* d - w_1(p_1^*) - y_U)\, n_U(w_1^t(p_1^*), 1), \\ \tilde{\pi}_0(p_0^*) &= (p_0^* - w_0(p_0^*))\, n_H(w_0(p_0^*), 0) + (p_0^* d - w_0(p_0^*))\, n_U(w_0(p_0^*), 0). \end{aligned}$$

Given $(w_0^*(p),\ w_1^*(p))$, calculate $\pi_0^*(p)$ and $\pi_1^*(p)$ from (22) and (23) and obtain $\Delta^*(p,k)$ by using (24). Repeat this for all k.

8. If $(w_0^*(p), w_1^*(p), \Delta^*(p,k))$ satisfies $d(w_0^*(p), w_0^t(p)) < \epsilon_{tol}$, $d(w_1^*(p), w_1^t(p)) < \epsilon_{tol}$ and $d(\Delta^*(p,k), \Delta^t(p,k)) < \epsilon_{tol}$ for some distance metric, then firm's optimal policy converges and we have an equilibrium. Otherwise, update $(w_0^{t+1}(p), w_1^{t+1}(p), \Delta^{t+1}(p,k))$ so that

$$\begin{aligned} w_0^{t+1}(p) &= \omega w_0^t(p) + (1-\omega) w_0^*(p), \\ w_1^{t+1}(p) &= \omega w_1^t(p) + (1-\omega) w_1^*(p), \\ \Delta^{t+1}(p) &= \omega \Delta^t(p,k) + (1-\omega)\Delta^*(p,k), \end{aligned}$$

[14] I specify that $\mathcal{W} = \{b - p_u, \ldots, \overline{p}\}$ as the optimal wage must lies in $[b - p_u,\, \overline{p}]$. This value function will be used when we calculate firm's profit if it offers wage w given $F^t(w, x)$.

[15] Although we do not have a proof that the unique fixed point exists, we always find the unique solution regardless of initial guess of u_h and $e_h^x G_h^x(w(p))$.

[16] $n^t(w, x)$ is used when we evaluate the firm size if the firm offers wage w given $F^t(w, x)$.

for $\omega \in (0,1)$. Then go to step 3 and repeat the same process.

Lemma

Lemma 1 *For any wage distribution $F(w,x)$, $w_x(p)$ is increasing in p for each x.*

Proof. The proof is based on revealed preference argument. First, fix k. Choose any p and p' in $[\underline{p}, \overline{p}]$ such that $p > p'$ and fix $x \in \{0,1\}$. Notice that

$$\begin{aligned}
\pi_x(p,k) &= ((p - w_x(p) - xy_H)\, n_H(w_x(p),x) + (pd - w_x(p) - xy_U)\, n_U(w_x(p),x))\, h(k) - xC \\
&\geq \big((p - w_x(p') - xy_H\big)\, n_H(w_x(p'),x) + \big(pd - w_x(p') - xy_U\big)\, n_U(w_x(p'),x)\big)\, h(k) - xC \\
&\geq \big((p' - w_x(p') - xy_H\big)\, n_H(w_x(p'),x) + \big(p'd - w_x(p') - xy_U\big)\, n_U(w_x(p'),x)\big)\, h(k) - xC \\
&= \pi_x\left(p',k\right) \\
&\geq \big((p' - w_x(p) - xy_H\big)\, n_H(w_x(p),x) + \big(p'd - w_x(p) - xy_U\big)\, n_U(w_x(p),x)\big)\, h(k) - xC,
\end{aligned}$$

where the second line comes from the fact that $w_x(p)$ is the optimal wage policy for a firm with productivity p and third line is implied by the assumption that $p > p'$. The fifth line is implied by the fact that $w_x(p)$ is the optimal policy for a firm with productivity p, not p'. Therefore, we have

$$(p - p')(n_H(w_x(p),x) + n_U(w_x(p),x)) \geq (p - p')(n_H(w_x(p'),x) + n_U(w_x(p'),x)).$$

Since $n_h(w,x)$ is increasing in w, this inequality holds if and only if $w_x(p) \geq w_x(p')$. ■

Lemma 2 *Fix k. For each p, optimal wage policy must satisfy*

$$w_1(p) = \frac{\left\{\begin{array}{c} [p - cy_H]\, n_H(w_1(p),1) + [pd - cy_U]\, n_U(w_1(p),1) \\ -\int_{p_1^*}^{p} \left(n_H(w_1(\tilde{p}),1) + dn_U(w_1(\tilde{p}),1)\right) d\tilde{p} - \pi_1(p_1^*) \end{array}\right\}}{n_H(w_1(p),1) + n_U(w_1(p),1)}$$

$$w_0(p) = \frac{\left\{\begin{array}{c} pn_H(w_0(p),0) + pdn_U(w_0(p),0) \\ -\int_{p_0^*}^{p} \left(n_H(w_0(\tilde{p}),0) + dn_U(w_0(\tilde{p}),0)\right) d\tilde{p} - \pi_0(p_0^*) \end{array}\right\}}{n_H(w_0(p),0) + n_U(w_0(p),0)}$$

where p_x^* =inf$\{p \in [\underline{p},\overline{p}] : n_H(w_x(p),x) > 0$ and $n_U(w_x(p),x) > 0\}$ and

$$\pi_1(p_1^*) = (p_1^* - w_1^*(p_1^*) - y_H)\, n_H(w_1^t(p_1^*),1) + (p_1^* d - w_1(p_1^*) - y_U)\, n_U(w_1^t(p_1^*),1)$$

$$\pi_0(p_0^*) = (p_0^* - w_0(p_0^*))\, n_H(w_0(p_0^*),0) + (p_0^* d - w_0(p_0^*))\, n_U(w_0(p_0^*),0).$$

Proof. Define p_x^* =inf$\{p \in [\underline{p},\overline{p}] : n_H(w_x(p),x) > 0$ and $n_U(w_x(p),x) > 0\}$ for $x = 0,1$. Because $w_x(p)$ is increasing in p and $n_h(w,x)$ is increasing in w, we have $n_H(w_x(p),x) > 0$ and $n_U(w_x(p),x) > 0$ for $p > p_x^*$. Then, by applying envelope condition, we have

$$\pi_x'(p,k) = (n_H(w_x(p),x) + dn_U(w_x(p),x))\, h(k)$$

for $p > p_x^*$. By taking integral over $[p_x^*, p]$, we then obtain

$$\pi_x(p,k) = \int_{p_x^*}^{p} \left(n_H(w_x(\tilde{p}),x) + dn_U(w_x(\tilde{p}),x)\right) h(k) d\tilde{p} + \pi_x(p_x^*)h(k) + C.$$

By equating it with (22) and (23), we obtain

$$w_1(p) = \frac{\left\{ \begin{array}{c} [p - cy_H]\, n_H(w_1(p),1) + [pd - cy_U]\, n_U(w_1(p),1) \\ - \int_{p_1^*}^{p} \left(n_H(w_1(\tilde{p}),1) + dn_U(w_1(\tilde{p}),1)\right) d\tilde{p} - \pi_1(p_1^*) \end{array} \right\}}{n_H(w_1(p),1) + n_U(w_1(p),1)}$$

and

$$w_0(p) = \frac{\left\{ \begin{array}{c} pn_H(w_0(p),0) + pdn_U(w_0(p),0) \\ - \int_{p_0^*}^{p} \left(n_H(w_0(\tilde{p}),0) + dn_U(w_0(\tilde{p}),0)\right) d\tilde{p} - \pi_0(p_0^*) \end{array} \right\}}{n_H(w_0(p),0) + n_U(w_0(p),0)}$$

Notice that wage policy does not depend on $h(k)$ and C. This is a form of wage policy which we utilize in our numerical algorithm. ■

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