

# Can Employer Credit Checks Create Poverty Traps?

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## Abstract

According to a Survey by the Society for Human Resource Management (2010), 60% of human resource representatives interviewed in 2009 indicated that the companies they worked for ran credit checks on potential employees. In this paper, we explore how credit checks (observable signals based on an agent's unobservable type) may affect outcomes in a matching model of the labor market. We show that it may be individually optimal for employers to use such signals to make hiring/firing/compensation decisions. Such decisions however may have important implications for household welfare inducing a poverty trap. The analysis can shed light on the consequences of a law (the Equal Employment for All Act (H.R. 3149)) prohibiting the use of credit information in employment decisions which currently sits before Congress.

**Very preliminary, comments welcome.**

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# 1 Introduction

According to a Survey by the Society for Human Resource Management (2010), 60% of human resource representatives who were interviewed in 2009 indicated that the companies they worked for ran credit checks on potential employees.<sup>1</sup> The three primary consumer credit reports provided by (Equifax Persona, Experian Employment Insight, and TransUnion PEER) include not only personal information (such as addresses and social security numbers) and previous employment history but also any public record (such as bankruptcy, liens and judgments) as well as credit history. The Federal Trade Commission<sup>2</sup> published a consumer alert in May 2006 entitled “Negative Credit Can Squeeze a Job Search” warning consumers about the possibility of adverse employment actions due to a bad credit history. Further, the FTC writes “As an employer, you may use consumer reports when you hire new employees and when you evaluate employees for promotion, reassignment, and retention as long as you comply with the Fair Credit Reporting Act (FCRA).”<sup>3</sup>

In the survey, the most cited primary reason for credit checks in Table 1 is to reduce or prevent theft and embezzlement, which indicates that the employers control unwanted actions by means of monitoring credit market decisions. Table 2 summarizes the reasons why companies do not extend a job offer after a credit check, and it is clear that the credit market decisions are important when companies make hiring decisions even if the credit report includes other information as mentioned previously.

The actual practice of credit checks on employees has invoked debates of whether laws should prohibit it. Currently consumer reports may be used when firms hire new employees or evaluate employees for promotion, reassignment, and retention as long as the Fair Credit Reporting Act is complied.

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<sup>1</sup>While we do not address it in this paper, earlier surveys show that the fraction of firms undertaking credit checks has steadily been growing. In particular, 25% of human resource representatives who were interviewed in 1998 indicated that the companies they worked for ran credit checks on potential employees while the fraction increased to 43% in 2004.

<sup>2</sup><http://www.ftc.gov/bcp/edu/pubs/consumer/alerts/alt053.shtm>

<sup>3</sup><http://www.ftc.gov/bcp/edu/pubs/business/credit/bus08.shtm>

|                                             |     |
|---------------------------------------------|-----|
| Reduce/prevent theft and embezzlement       | 54% |
| Reduce level liability for negligent hiring | 27% |
| Assess overall trustworthiness              | 12% |
| Comply with applicable state law            | 7%  |

Table 1: Primary reasons for credit check

|                               |     |
|-------------------------------|-----|
| Current outstanding judgement | 64% |
| Accounts in debt collection   | 49% |
| Bankruptcy                    | 25% |
| High debt-to-income ratio     | 18% |
| Foreclosure                   | 11% |

Table 2: Top cited reasons for not extending a job offer

Although only written authorization from the consumer is required before credit checks in most states, some states set additional laws to regulate this practice. For instance, Washington, Hawaii, and Oregon actually prohibit any credit checks for employment screening. Furthermore, the Equal Employment for All Act<sup>4</sup> (currently in committee) would prohibit the use of any consumer credit checks for the purpose of making employment decisions if passed. Our model can be used to evaluate the welfare consequences of such a law.

Given that employers are increasingly turning to credit checks in hiring and retention decisions, we lay out a simple labor matching model with unobservable types of workers. The project is in two parts. First, we take credit checks simply to be exogenous signals about an individual’s unobservable type. We choose these signals to be consistent with default frequencies in the U. S. data. After calibrating the model to match labor market statistics, we show that workers are worse off when the economy moves from an environment where firms do not use credit checks to one where they do (which is individually rational for the firm). This provides a framework to

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<sup>4</sup>Details of the Equal Employment for All Act (HR 3149 IH) can be downloaded at [http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=111\\_cong\\_bills&docid=f:h3149ih.txt.pdf](http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=111_cong_bills&docid=f:h3149ih.txt.pdf)

understand why there may be legislation mentioned above to prevent employers from using credit checks. Second, we intend to endogenize the signals by embedding the model into an incomplete markets framework with debt and default.

## 2 Static Environment

We begin with a simple static environment which illustrates some important properties of the model analytically. There are two subperiods, which might be considered the beginning and end of a month. In the first subperiod, households send a worker to a frictional labor market as in Mortensen-Pissarides [8], with two key differences. First, a worker's productivity is private information. Second, firms receive exogenous signals about the worker's productivity. Due to this information asymmetry, wages are determined through a game of probabilistic one-time take-it-or-leave-it offers. While the wage is determined at the beginning of the period, production and payment occur in the second subperiod.

Since workers have to consume in the first subperiod as well as the second, they take short term loans in order to do so. Because there is no commitment to repay in the second subperiod, this debt is priced competitively (as in Chatterjee, et. al. [4]). Before the loan has to be repaid in the second period, workers receive two shocks. The first determines their productivity in the second subperiod and the other is a non-discretionary-spending shock (e.g. medical expenses). Upon realizing these two shocks, the household decides how many hours to work in the second subperiod as well as whether or not to default on their debt from the first subperiod. As in Lagos-Wright [?] we assume quasi-linear preferences in the second subperiod, which greatly simplifies the default decision. These two decisions determine consumption in the second subperiod.

## 2.1 Agents

The economy is populated by a unit measure of workers. These workers differ ex-ante and are one of two types  $i \in g, b$ . Their shares of the population are  $\pi_g$  and  $\pi_b$ . An agent's type can change between the first and second subperiod. The probability that an agent of type  $i$  changes to type  $i'$  is given by  $\delta_{ii'}$ . There is a large measure of entrepreneurs.

## 2.2 Preferences

Workers value three commodities: subperiod 1 consumption, subperiod 2 consumption, and subperiod 2 labor. Preferences are represented by a utility function that is strictly increasing in all three, strictly concave and separable in consumption in the two subperiods and linear in labor:

$$U(c_1, c_2, h) = u(c_1) + u(c_2) - h \quad (1)$$

## 2.3 Matching

The labor market in the first subperiod is subject to search frictions. A worker and an entrepreneur can only produce if they are matched, which is done via a matching function of the form:

$$M(u, v) = \mu u^\alpha v^{1-\alpha} \quad (2)$$

where  $u$  is the fraction of unemployed workers (one in the static model) and  $v$  is the number of job vacancies created. An entrepreneur can post a vacancy at cost  $\kappa$  and be matched with a worker with probability  $q \equiv M(u, v)/v$ . An unemployed worker meets a potential employer with probability  $f \equiv M(u, v)/u$ . Labor market tightness is defined as  $\theta \equiv \frac{v}{u}$ . If a worker and entrepreneur match, then an exogenous signal of the worker's productivity is revealed (described below). Upon observing this signal, the entrepreneur decides whether to employ the worker and, if they do so, the worker and entrepreneur play a bargaining game to determine the wage (described below). An unmatched entrepreneur earns zero.

## 2.4 Production Technology

There is a production technology for each subperiod. An employed worker of type  $i$  produces  $y_i$ , with  $y_g > y_b \geq 0$  at the beginning of the second subperiod. An unemployed worker of type  $i$  receives  $k$  from an outside option. Entrepreneurs pay their workers the negotiated wage at that time.

In the second subperiod, a worker can undertake home production after the realization of the type shock  $i'$ . The worker has one unit of time, so undertaking home production is costly (i.e.  $1 = l + h$ ). In the event of home production, the agent produces  $A_i h$  units of a marketable good.

## 2.5 Information

A worker's initial type is private information, but before matching with an entrepreneur in the early labor market the household receives a signal  $\tilde{d} \in \{0, 1\}$ . The probability of receiving a signal  $\tilde{d} = 1$  is a function of the household's type and is given by  $\psi_i$  with  $\psi_g \leq \psi_b$ . We will consider two labor market arrangements and two credit market arrangements. We will start by assuming that workers search in the same labor market independently of their signal and that types are fully observable in the credit market. We will then allow for labor markets to be segmented by the observable signals. Finally, we will consider a model in which lenders can only observe a household's signal (again, under the two labor market assumptions).

## 2.6 Wage Determination

If an entrepreneur decides to hire a worker with signal  $\tilde{d}$  (and the worker accepts), then the revenues are split via a probabilistic dictatorship game. That is, with probability  $\chi$ , the worker gets to make a one-time-take-it-or-leave-it offer and with probability  $1 - \chi$  the firm gets to make the offer.

## 2.7 Debt Contracts and Bankruptcy

Since workers are not paid until the second subperiod but need to consume throughout both subperiods, the worker takes out a loan from a financial

intermediary. This loan specifies receipts from the bank during the first subperiod and the amount that the household must repay in the second subperiod if they are solvent. However, the household can choose to file for bankruptcy in the second period, in which case the lender receives nothing. Default carries a utility cost,  $\lambda_{i'}$ , which depends on the  $i'$  shock. We will assume that  $\lambda_g > \lambda_b$ .

## 2.8 Timing of Events

| Early |                                                                                                                                                                                                  |
|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1     | Household $i$ assigned signal $\tilde{d} \in \{0, 1\}$ ,<br>with probabilities $\Pr(\tilde{d} = 1 i) = \psi_i$                                                                                   |
| 2     | Entrepreneur posts vacancy at cost $\kappa$                                                                                                                                                      |
| 3     | Workers search for jobs                                                                                                                                                                          |
| 4     | Matching occurs via $M(u, v)$ . Entrepreneurs observe $\tilde{d}$ , choose whether to hire                                                                                                       |
| 5     | If hired, workers and firms play wage game to determine $x$                                                                                                                                      |
| 6     | Workers choose debt contract $(\tilde{d}, Q, b)$ , then consume.                                                                                                                                 |
| Late  |                                                                                                                                                                                                  |
| 1     | Workers are paid earnings $x$                                                                                                                                                                    |
| 2     | Night productivity, $A \in \{A_g, A_b\}$ and expenditure shock $\tau \in \{0, \bar{\tau}\}$ realized<br>with probabilities $\Pr(A = A_g i) = \delta_{ig}$ and $\Pr(\tau = \bar{\tau} i) = \zeta$ |
| 3     | Night hours, $h$ , and default decision, $d$ , made                                                                                                                                              |
| 4     | Households consume nighttime goods, suffer stigma if bankrupt: $\lambda(A)$                                                                                                                      |

## 3 Equilibrium in the static economy

In this section we characterize the equilibrium of the static model completely and evaluate the welfare effects of a policy that forces firms to ignore the signal  $\tilde{d}$ . We begin by solving for the household's problem. This gives us the

reservation wages. We then use the entrepreneur's profit function to solve for their maximum willingness to pay, which then allows us to solve for the equilibrium wages and market tightness.

### 3.1 Worker's Maximization Problem

We solve the household's problem backwards, beginning in the late subperiod.

#### 3.1.1 Default and Labor in the Late Subperiod

For a given level of earnings,  $x$ , and debt,  $b$ , we define the indirect utility functions conditional on realized shocks  $i'$  and  $\tau$ :

$$\mathcal{E}_{i',\tau}(x, b) = \max_{0 \leq h \leq 1, d \in \{0,1\}} u(x + A_{i'}h - (1-d)(b + \tau)) - h - d\lambda_{i'} \quad (3)$$

This is a concave programming problem, so we can characterize the (interior) solution via the first order condition on  $h$  for a given value of  $d \in \{0, 1\}$  and then taking the maximal value of  $d = 0$  and  $d = 1$ :

$$h(d) = A^{-1} [u'^{-1}(A^{-1}) + (1-d)(b + \tau) - x] \quad (4)$$

And then we get that  $d = 1$  if and only if:

$$b + \tau > A\lambda \quad (5)$$

Substituting these into the utility function we get:

$$\mathcal{E}_{i',\tau}(x, b) = \begin{cases} u(u'^{-1}(A_{i'}^{-1})) - A^{-1}(u'^{-1}(A_{i'}^{-1}) + b + \tau - x), & b + \tau \leq A_{i'}\lambda_{i'} \\ u(u'^{-1}(A_{i'}^{-1})) - A^{-1}(u'^{-1}(A_{i'}^{-1}) - x) - \lambda_{i'}, & b + \tau > A_{i'}\lambda_{i'} \end{cases}$$

#### 3.1.2 Debt Pricing and Borrowing

In order to solve for the level of debt, we must posit a market structure for unsecured credit. We start with the assumption that an agent's type is



observable and then assume that only the signal  $\tilde{d}$  is observable. In both cases, we will assume that the recovery rate is zero and that  $\lambda_g > \lambda_b$ . Since we have already assumed that  $A_g > A_b$ , this means that a household is (weakly) more likely to default when they receive  $i' = b$  (for a given value of  $\tau$ ). We will also assume that  $\tau \in \{0, \bar{\tau}\}$  with the probability of  $\tau = \bar{\tau}$  given by  $\zeta$ , which is independent of  $i'$  and constant across households.

First, when creditors can observe a household's type (and therefore their default probability) perfectly, we use the zero profit pricing condition as is standard in unsecured credit models. This means that the pricing function is given by:

$$q(b; i) = \begin{cases} 1 & \text{if } b + \bar{\tau} \leq A_b \lambda_b \\ \delta_{ig} + \delta_{ib}(1 - \zeta) & \text{if } b \leq A_b \lambda_b < b + \bar{\tau} \leq A_g \lambda_b \\ \delta_{ig} & \text{if } A_b \lambda_b < b < b + \bar{\tau} \leq A_g \lambda_g \\ \delta_{ig}(1 - \zeta) & \text{if } A_b \lambda_b < b \leq A_g \lambda_g < b + \bar{\tau} \\ 0 & \text{if } b > A_g \lambda_g \end{cases}$$

Notice, importantly, that the pricing function is piecewise linear in the debt level. Therefore, as long as the household's debt decision is not at one of the kinks we can solve via the first order condition:

$$\max_b u(q_i(b)b) + \sum_{i' \in \{b, g\}} \delta_{ii'} [(1 - \zeta)\mathcal{E}_{i', 0}(x, b) + \zeta\mathcal{E}_{i', \bar{\tau}}(x, b)] \quad (6)$$

Which gives the solution:

$$b_i = \begin{cases} u'^{-1}(\mathbb{E}_{i'|i} A_{i'}^{-1}) & \text{if } b_i + \bar{\tau} < A_b \lambda_b \\ (\delta_{ig} + \delta_{ib}(1 - \zeta))^{-1} u'^{-1} \left( \frac{\delta_{ig} A_g^{-1} + \delta_{ib}(1 - \zeta) A_b^{-1}}{\delta_{ig} + \delta_{ib}(1 - \zeta)} \right) & \text{if } b_i \leq A_b \lambda_b < b_i + \bar{\tau} < A_g \lambda_b \\ \delta_{ig}^{-1} u'^{-1}(A_g^{-1}) & \text{if } A_b \lambda_b < b_i < b_i + \bar{\tau} < A_g \lambda_g \\ (\delta_{ig}(1 - \zeta))^{-1} u'^{-1}(A_g^{-1}) & \text{if } A_b \lambda_b < b_i < A_g \lambda_g < b_i + \bar{\tau} \end{cases}$$

It is clear that these debt levels are increasing from top to bottom, so we can make restrictions on parameters to make sure that the debt choice is

in a given region. Under the assumption that default occurs when agents transition to the bad state or when they get the expenditure shock then we get an optimal debt level of  $b_i^* = (\delta_{ig}(1 - \zeta))^{-1} u'^{-1}(A_g^{-1})$  and we can write the indirect utility function over earnings as simply:

$$\mathcal{B}_i(x) = x\mathbb{E}_{i'|i} + u(\delta_{ig}(1 - \zeta)b_i^*) + \sum_{i' \in \{b, g\}} \delta_{ii'} [(1 - \zeta)\mathcal{E}_{i',0}(0, b_i^*) + \zeta\mathcal{E}_{i',\bar{\tau}}(0, b_i^*)] \quad (7)$$

If, on the other hand, we believe that household type is not observable by the lender then the contract need not be linear and so we define preferences over receipts from the lender and payments (conditional on solvency):

$$\mathcal{U}_i(Q, b) = u(Q) - \begin{cases} \mathbb{E}_{i'|i} A_{i'}^{-1} b + \Gamma_{0,i} & \text{if } b + \bar{\tau} < A_b \lambda_b \\ (\delta_{ig} A_g^{-1} + \delta_{ib}(1 - \zeta) A_b^{-1}) b + \Gamma_{1,i} & \text{if } b \leq A_b \lambda_b < b + \bar{\tau} \leq A_g \lambda_b \\ \delta_{ig} A_g^{-1} b + \Gamma_{2,i} & \text{if } A_b \lambda_b < b_i < b_i + \bar{\tau} < A_g \lambda_g \\ \delta_{ig}(1 - \zeta) A_g^{-1} b + \Gamma_{3,i} & \text{if } A_b \lambda_b < b_i < A_g \lambda_g < b_i + \bar{\tau} \\ \Gamma_{4,i} & \text{if } b > A_g \lambda_g \end{cases} \quad (8)$$

where the  $\Gamma_{j,i}$  terms are constants depending on the default decision and are independent of  $b$ . From this we can calculate the marginal rate of substitution between  $b$  and  $Q$  for  $b$  levels within each region:

$$\frac{\frac{\partial \mathcal{U}_i}{\partial Q}}{\frac{\partial \mathcal{U}_i}{\partial b}} = \begin{cases} \frac{u'(Q)}{\mathbb{E}_{i'|i} A_{i'}^{-1}} & \text{if } b + \bar{\tau} < A_b \lambda_b \\ \frac{u'(Q)}{\delta_{ig} A_g^{-1} + \delta_{ib}(1 - \zeta) A_b^{-1}} & \text{if } b \leq A_b \lambda_b < b + \bar{\tau} \leq A_g \lambda_b \\ \frac{u'(Q)}{\delta_{ig} A_g^{-1}} & \text{if } A_b \lambda_b < b_i < b_i + \bar{\tau} < A_g \lambda_g \\ \frac{u'(Q)}{\delta_{ig}(1 - \zeta) A_g^{-1}} & \text{if } A_b \lambda_b < b_i < A_g \lambda_g < b_i + \bar{\tau} \\ \infty & \text{if } b > A_g \lambda_g \end{cases} \quad (9)$$

Notice that, while the two household types never have the same marginal rate of substitution within a region, the first two regions feature a larger MRS for the good types than for the bad types while the second two regions are just the opposite. For levels of debt where everyone repays, the good

household has a steeper indifference curve in  $Q - b$  space since they are more likely to arrive in the high  $A$  (low marginal utility) state. Relative to the bad household, they require a smaller increment of early consumption,  $Q$ , for a given increment of repayment  $b$ . In the region where default occurs when  $A = A_b$  the slopes of these indifference curves reverse, so that good households have a flatter indifference curve. This is because they are more likely to repay the debt and therefore, relative to bad households, require a larger increment in early consumption for a given increment in repayment.

### 3.1.3 Reservation and Maximal Wages

If we study the expression for  $\mathcal{B}_i(x)$  we can immediately find the reservations wage,  $\underline{w}_i$ , by solving for  $\mathcal{B}_i(\underline{w}_i) = \mathcal{B}_i(\kappa)$ . Since earnings only enter linearly in this expression along with an  $i$ -dependent constant, we get that  $\underline{w}_i = \kappa$  for  $i = g, b$ .

We can also solve for the maximal wage that a firm would be willing to pay an agent with signal  $\tilde{d}$ , call it  $\bar{w}(\tilde{d}) = y_g \Pr(i = g|\tilde{d}) + y_b(1 - \Pr(i = g|\tilde{d}))$ . We just need to find those probabilities. Since we assumed that the probability of getting  $\tilde{d} = 1$  was  $\psi_i$ , Bayes' rule gives:

$$\Pr(i = g|\tilde{d} = 1) = \frac{\psi_g \pi_g}{\psi_g \pi_g + \psi_b \pi_b}$$

$$\Pr(i = g|\tilde{d} = 0) = \frac{(1 - \psi_g) \pi_g}{(1 - \psi_g) \pi_g + (1 - \psi_b) \pi_b}$$

Thus the maximal wages are:

$$\bar{w}(1) = \frac{\psi_g \pi_g}{\psi_g \pi_g + \psi_b \pi_b} y_g + \frac{\psi_b \pi_b}{\psi_g \pi_g + \psi_b \pi_b} y_b$$

$$\bar{w}(0) = \frac{(1 - \psi_g) \pi_g}{(1 - \psi_g) \pi_g + (1 - \psi_b) \pi_b} y_g + \frac{(1 - \psi_b) \pi_b}{(1 - \psi_g) \pi_g + (1 - \psi_b) \pi_b} y_b$$

### 3.1.4 Wage Game

Our game leads to a stochastic wage. With probability  $1 - \chi$  the firm gets to make an offer. Since the reservation wages are the same here, the only

possibility is to make a pooling offer. They will find it optimal to hire the worker at this pooling offer if  $\bar{w}(\tilde{d}) > \kappa$  and they will offer the worker  $\kappa$  since that is the worker's reservation. If the worker makes a wage demand, which occurs with probability  $\chi$ , there are technically many equilibria because of the freedom of assigning beliefs to the firm. We will assume that the firm has beliefs that support the worker extracting the full surplus (this seems reasonable since the workers have the same reservation wages). Thus, the worker demands  $\bar{w}(\tilde{d})$  so long as it is above  $\kappa$ , otherwise they are not hired. Let  $\sigma \in \{0, 1\}$  designate nature's choice of who gets to make the offer (0 for workers) then:

$$w(\tilde{d}) = \begin{cases} \bar{w}(\tilde{d}) & \text{if } \bar{w}(\tilde{d}) \geq \kappa \text{ and } \sigma = 0 \\ \kappa & \text{if } \bar{w}(\tilde{d}) \geq \kappa \text{ and } \sigma = 1 \\ 0 & \text{if } \bar{w}(\tilde{d}) < \kappa \end{cases} \quad (10)$$

This allows us to write the worker's expected utility (assuming that  $\bar{w}(1) < \bar{w}(0)$  for simplicity):

$$\mathcal{V}_i = \begin{cases} (1 - f(\theta) + f(\theta)(1 - \chi))\mathcal{B}_i(\kappa) + f(\theta)\chi(\psi_i\mathcal{B}_i(\bar{w}(1)) + (1 - \psi_i)\mathcal{B}_i(\bar{w}(0))) & \text{if } \bar{w}(1) \geq \kappa \\ (1 - f(\theta) + f(\theta)(1 - \chi + \chi\psi_i))\mathcal{B}_i(\kappa) + f(\theta)\chi(1 - \psi_i)\mathcal{B}_i(\bar{w}(0)) & \text{if } \bar{w}(1) < \kappa \leq \bar{w}(0) \\ \mathcal{B}_i(\kappa) & \text{if } \bar{w}(0) < \kappa \end{cases}$$

And the entrepreneur's expected profits from posting a vacancy is given by:

$$\Pi = \begin{cases} q(\theta)(1 - \chi)(\pi_g y_g + \pi_b y_b - \kappa) - k & \text{if } \bar{w}(1) \geq \kappa \\ q(\theta)(1 - \chi)(\pi_g(1 - \psi_g) + \pi_b(1 - \psi_b))(\bar{w}(0) - \kappa) - k & \text{if } \bar{w}(1) < \kappa \leq \bar{w}(0) \\ -k & \text{if } \bar{w}(0) < \kappa \end{cases} \quad (12)$$

### 3.1.5 Determination of Market Tightness

Free entry means that firms make zero profits, so we can solve for the market tightness as:

$$\theta = \begin{cases} q^{-1} \left( \frac{k}{(1-\chi)(\pi_g y_g + \pi_b y_b - \kappa)} \right) & \text{if } \bar{w}(1) \geq \kappa \\ q^{-1} \left( \frac{k}{(1-\chi)(\pi_g(1-\psi_g) + \pi_b(1-\psi_b))(\bar{w}(0) - \kappa)} \right) & \text{if } \bar{w}(1) < \kappa \leq \bar{w}(0) \\ 0 & \text{if } \bar{w}(0) < \kappa \end{cases} \quad (13)$$

### 3.2 Welfare Consequences of Eliminating Signal

We now want to consider what happens when the signals are eliminated. For a variable  $x$ , we will denote the equilibrium value in the economy with signals as  $x_s$ . We assume that getting  $\tilde{d} = 0$  is a good signal, so that the posterior on the agent being good given  $\tilde{d} = 0$  is no less than the population share. Then we can take the difference of the ex-ante utility of a household of type  $i$  in the economy without signals and the one with signals. After some simple manipulation, the difference is easy to express. We list just the case that  $\bar{w}(1) < \kappa \leq \bar{w}(0)$  since that is the one of interest:

$$\mathcal{V}_i - \mathcal{V}_{i,s} = \chi \mathbb{E}_{i'|i} A_{i'}^{-1} [f(\theta)(\mathbb{E}y - \kappa) - (1 - \psi_i)f(\theta_s)(\bar{w}(0) - \kappa)] \quad (14)$$

This equation is easy to interpret. Since the household only gets a surplus above and beyond  $\kappa$ , and that occurs with probability  $\chi$  regardless of the signal, the entire difference is multiplied by  $\chi$ . Due to the quasi-linear preferences in the second sub-period, the term  $\mathbb{E}_{i'|i} A_{i'}^{-1}$  represents the average marginal utility in the second period given that the household begins as an  $i$ -type. The next two terms represent the difference in expected surpluses. The first is the expected surplus without signals. Here, conditional on matching, the household will always get a wage equal to the unconditional average productivity. This is lower than  $\bar{w}(0)$ , which is received in the economy with signals, but the household only gets that higher wage if they receive  $\tilde{d} = 0$ , which occurs with probability  $1 - \psi_i$ . This appears in the surplus from the economy with signals. Furthermore, since the aggregate

vacancies may differ in the two economies, and the expected surplus is what matters for utility, each of these surpluses is multiplied by the probability of the worker finding a job in the two economies.

We can now consider when each agent will gain from the policy of eliminating signals. Assume that  $\psi_b = 1$  so that the bad type always gets the signal  $\tilde{d} = 1$ . Then the policy will immediately improve the welfare of the bad type. This is intuitive- before they always received  $\kappa$  because they were never pooled with the good type, but without signals they will be pooled and receive an average wage strictly higher than  $\kappa$ . Now imagine that  $k \rightarrow 0$  so that the job finding rate is essentially 100% in each economy. Also note that if  $\psi_b = 1$  then  $\bar{w}(0) = y_g$ . Then the utility difference for the good type is:

$$\mathcal{V}_i - \mathcal{V}_{i,s} = \chi \mathbb{E}_{i'|i} A_{i'}^{-1} [\mathbb{E}y - y_g + \psi_g(y_g - \kappa)] \quad (15)$$

To take an extreme example, suppose that  $\pi_g = 0.99, \psi_g = 0.1, y_g = 1, y_b = 0, \kappa = 0.1$ . Then this difference becomes:

$$\mathcal{V}_i - \mathcal{V}_{i,s} = \chi \mathbb{E}_{i'|i} A_{i'}^{-1} [0.1 + 0.99 - 1 - (0.1)(0.1)] = 0.8 \chi \mathbb{E}_{i'|i} A_{i'}^{-1} > 0 \quad (16)$$

All that is left is to check that  $w(1) < \kappa$ , which is true here since  $w(1) = \frac{(0.1)(0.99)}{(0.1)(0.99)+0.01} =$

### 3.3 Entrepreneur Value Functions

When an entrepreneur posts a vacancy at the cost of  $\kappa$ , he will be randomly matched with a worker from the unemployment pool with probability  $\psi$  at the beginning of the next period. He will observe the worker's signal  $d'$  but not his type  $i'$

$$P = -\kappa + \frac{1}{1+r} \left[ \psi \sum_{d'} \gamma^{d'} H^{d'} + (1-\psi)P \right] \quad (17)$$

where  $\gamma^{d'}$  is the probability of matching with an unemployed worker with signal  $d'$  given by

$$\gamma^{d'} = \frac{\sum_i [\mu_i^0 \sum_{i'} \delta_{ii'} \rho_{i'}^{d'}]}{\sum_i \mu_i^0}. \quad (18)$$

Free entry implies that in equilibrium,

$$P = 0. \quad (19)$$

The (hiring) value function for an entrepreneur who has just been matched with an unemployed worker with information set  $I = (\cdot, d)$  is denoted  $H(I)$ . It is given by

$$H(\cdot, d) = \max \left\{ P, \tilde{H}(\cdot, d) \right\} \quad (20)$$

where

$$\tilde{H}(\cdot, d) = \sum_i p(i|\cdot, d) \left\{ \begin{array}{l} 1_{\{w(\cdot, d) \geq \underline{w}_i\}} \left[ -w(\cdot, d) + \frac{1}{1+r} \left( y_i + \sum_{i', d'} \delta_{ii'} \rho_{i'}^{d'} R(i, d') \right) \right] \\ + 1_{\{w(\cdot, d) < \underline{w}_i\}} P \end{array} \right\} \quad (21)$$

is the value of making a take-it-or-leave-it wage offer  $w(\cdot, d)$  given the newly matched worker's reservation wage  $\underline{w}_i$  (to be described in section 5.4). The higher the entrepreneur's belief that he is matched with a type  $g$  worker (i.e. the higher  $p(g|\cdot, d)$ ), the more likely the entrepreneur will hire the worker. If the value to hire this worker is lower than the value of vacancy, the entrepreneur will not extend a wage offer that exceeds any type's reservation wage and the job will remain vacant. Otherwise the entrepreneur will offer  $w(\cdot, d)$  based on the signal received.

The (retention) value function for an entrepreneur in an existing match with information set  $I = (i^-, d)$  is denoted  $R(I)$ . It is given by

$$R(i^-, d) = \max \left\{ P, \tilde{R}(i^-, d) \right\} \quad (22)$$

where

$$\tilde{R}(i^-, d) = \sum_i p(i|i^-, d) \left\{ \begin{aligned} &1_{\{w(i^-, d) \geq \underline{w}_i\}} \left[ -w(i^-, d) + \frac{1}{1+r} \left( y_i + \sum_{i', d'} \delta_{ii'} \rho_{i'}^{d'} R(i, d') \right) \right] \\ &+ 1_{\{w(i^-, d) < \underline{w}_i\}} P \end{aligned} \right\}. \quad (23)$$

Again, the higher the entrepreneur's belief that he is matched with a type  $g$  worker, the more likely the entrepreneur will retain the worker.

### 3.4 Worker Value Functions

The value function for unemployed type  $i$  workers is given by

$$U_i = u(k_i) + \beta \sum_{i'} \delta_{i,i'} \left[ \sum_{d'} \rho_{i'}^{d'} (\phi N_{i'}(\cdot, d') + (1 - \phi) U_{i'}) \right]. \quad (24)$$

The value function for a type  $i$  worker with signal  $d$  who is newly matched with an entrepreneur and is offered a wage  $w(\cdot, d)$  is given by

$$N_i(\cdot, d) = \max \left\{ U_i, u(w(\cdot, d)) + \beta \sum_{i'} \delta_{i,i'} \left[ \sum_{d'} \rho_{i'}^{d'} Z_{i'}(i, d') \right] \right\}. \quad (25)$$

As will be discussed in section 5.4, if the worker receives too low a wage offer  $w(\cdot, d)$ , he can reject it and remain unemployed receiving  $U_i$ . Similarly, the value function for a type  $i$  worker with past type  $i^-$  and signal  $d$  who receives a “retention” wage offer  $w(i^-, d)$  is given by

$$Z_i(i^-, d) = \max \left\{ U_i, u(w(i^-, d)) + \beta \sum_{i'} \delta_{i,i'} \left[ \sum_{d'} \rho_{i'}^{d'} Z_{i'}(i, d') \right] \right\}. \quad (26)$$

It is clear that the Markov structure of type shocks implies continuation values are the same for newly hired workers and retained workers with identical  $i$  and  $d$ . The only difference is the utility stemming from their current wage offer  $u(w(\cdot, d))$  or  $u(w(i^-, d))$ .



### 3.5 Wage Determination

As in Brugemann and Moscarini (2010) and Kennan (2010), here we implement Myerson's (1984) Neutral Bargaining Solution, which is a generalization of the Nash Bargaining Solution to a setting with incomplete information. Let  $E_i(\omega)$  be the value for a type  $i$  worker from accepting any given wage offer  $\omega$ :

$$E_i(\omega) = u(\omega) + \beta \sum_{i'} \delta_{i,i'} \left[ \sum_{d'} \rho_{i'}^{d'} Z_{i'}(i, d') \right].$$

Notice that given the wage offer  $\omega$ , the value of accepting  $E_i(\omega)$  is independent of past type  $i^-$  and signal  $d$ . It is independent of  $i^-$  because by the end of the period, current output perfectly reveals the worker's type so past output provides no extra information. It is independent of  $d$  because the signal is iid across time conditional on type.

Since  $E_i(\omega)$  is strictly increasing in  $\omega$  and  $U_i$  is independent of  $\omega$ , we know there exists a unique reservation wage  $\underline{w}_i$  for a type  $i$  worker which solves

$$E_i(\underline{w}_i) = U_i. \quad (27)$$

This is the lowest wage offer that a type  $i$  worker has to receive in order to accept. Since only the continuation value matters for a worker and  $U_i$  is independent of signals, the reservation wage for a type  $i$  unemployed who just got matched and a type  $i$  employed worker who is in an existing match is the same, independent of the entrepreneur's set  $I$ .

Whether or not a worker is hired or retained and what wage offer he receives, however, does depend on the entrepreneur's information set  $I$ . If the entrepreneur offers  $\omega < \underline{w}_b$ , neither type worker will accept. If  $\omega \in [\underline{w}_b, \underline{w}_g)$ , then the worker will accept only if he is type  $b$  and the entrepreneur will receive  $y_b$  for sure. If  $\omega \geq \underline{w}_g$ , then both type workers will accept and the entrepreneur will get an output of  $y_g$  with probability  $p(g|i^-, d)$  or an output of  $y_b$  and with probability  $p(b|i^-, d)$ .

Since the entrepreneur can make a take-it-or-leave-it wage offer, he max-

imizes the expected value of hiring an unemployed worker with signal  $d$  by choosing

$$w(\cdot, d) = \arg \max_{\omega} \sum_i p(i|\cdot, d) \left\{ \begin{array}{l} 1_{\{\omega \geq \underline{w}_i\}} \left[ -\omega + \frac{1}{1+r} \left( y_i + \sum_{i', d'} \delta_{ii'} \rho_{i'}^{d'} R(i, d') \right) \right] \\ + 1_{\{\omega < \underline{w}_i\}} P \end{array} \right\}. \quad (28)$$

Equation (46) is the analogue of equation (10) in Brugemann and Moscarini (2010). Notice that while the entrepreneur's costs are increasing in  $\omega$ , the probability of worker acceptance (and hence revenue creation) is also increasing in  $\omega$ . Given  $w(\cdot, d)$ , the entrepreneur will make the offer if  $\tilde{H}(\cdot, d) \geq P$  as in (38).

Similarly, an entrepreneur chooses the retention wage offer conditional on information  $I = (i^-, d)$  by choosing

$$w(i^-, d) = \arg \max_{\omega} \sum_i p(i|i^-, d) \left\{ \begin{array}{l} 1_{\{\omega \geq \underline{w}_i\}} \left[ -\omega + \frac{1}{1+r} \left( y_i + \sum_{i', d'} \delta_{ii'} \rho_{i'}^{d'} R(i, d') \right) \right] \\ + 1_{\{\omega < \underline{w}_i\}} P \end{array} \right\}. \quad (29)$$

Given  $w(i^-, d)$ , the entrepreneur will make the offer if  $\tilde{R}(i^-, d) \geq P$  as in (40).

### 3.6 Population Proportions

We next describe the transition equations for the population of employed and unemployed agents of both types. Let  $\mu_i^e$  be the measure of type  $i$  who are in employment status  $e \in \{0, 1\}$  where  $e = 1$  implies employment.

$$\mu_{i'}^1 = \sum_i \left[ \mu_i^1 \delta_{ii'} \sum_{d'} \rho_{i'}^{d'} 1_{\{w(i, d') \geq \underline{w}_{i'}\}} 1_{\{R^{d'}(i) \geq P\}} + \mu_i^0 \delta_{ii'} \sum_{d'} \rho_{i'}^{d'} \phi 1_{\{w(i, d') \geq \underline{w}_{i'}\}} 1_{\{H^{d'} \geq P\}} \right] \quad (30)$$

$$\mu_{i'}^0 = \sum_i \left[ \mu_i^1 \delta_{ii'} \sum_{d'} \rho_{i'}^{d'} \left( 1 - 1_{\{w(i, d') \geq \underline{w}_{i'}\}} 1_{\{R^{d'}(i) \geq P\}} \right) + \mu_i^0 \delta_{ii'} \sum_{d'} \rho_{i'}^{d'} \left( 1 - \phi 1_{\{w(i, d') \geq \underline{w}_{i'}\}} 1_{\{H^{d'} \geq P\}} \right) \right] \quad (31)$$

### 3.7 Definition of Equilibrium

A *Bayesian steady state equilibrium* is a list of:

1. worker value functions when unemployed, newly hired, and retained  $\{U_i, N_i(\cdot, d), Z_i(i^-, d), \forall(i^-, i, d)\}$ ,
2. entrepreneur value functions when posting a vacancy and when making hiring and retention decisions  $\{P, H(\cdot, d), R(i^-, d), \forall(i^-, d)\}$ ,
3. wage offers to new and existing workers  $\{w(\cdot, d), w(i^-, d), \forall(i^-, d)\}$
4. population proportions of unemployed and employed workers  $\{\mu_i^e, \forall(i, e)\}$
5. beliefs about new hires and retained workers  $\{p(i|\cdot, d), p(i|i^-, d), \forall(i^-, i, d)\}$  which satisfy Bayes rule whenever possible.

## 4 Simple Environment

The environment is based on a discrete time version of the Mortensen-Pissarides (1994) labor matching model with two key differences. First, a worker's type affects productivity but is unobservable and follows a Markov Process. Second, there are signals about a workers type.

### 4.1 Agents

The economy is populated by a unit measure of workers (who may be employed or unemployed). Workers can be of two types  $i_t \in \{g, b\}$ . In each period, agents may switch from type  $i_t = i$  to type  $i_{t+1} = i'$  with probability  $\delta_{ii'}$ . The switching probability implies that the unconditional fraction of type  $g$  agents in a stationary economy is

$$\gamma = \frac{\delta_{bg}}{\delta_{gb} + \delta_{bg}}.$$

There is also a continuum of entrepreneurs (or firms).

## 4.2 Preferences

Workers are risk averse with utility function  $u(c_t)$  which is strictly increasing and strictly concave in consumption  $c_t$ . Entrepreneurs are risk neutral and can have negative consumption. Workers discount the future at rate  $\beta$  and entrepreneurs discount the future at rate  $1/(1+r)$ , both strictly less than one.

## 4.3 Matching

The matching function is assumed to be:

$$M(u_t, v_t) = \chi u_t^\alpha v_t^{1-\alpha} \quad (32)$$

where  $u_t$  is the fraction of unemployed workers and  $v_t$  is the number of job vacancies. An entrepreneur can post a vacancy at cost  $\kappa$  and be matched with a worker with probability  $\psi_t \equiv M(u_t, v_t)/v_t$ . An unemployed worker meets a potential employer with probability  $\phi_t \equiv M(u_t, v_t)/u_t$ . Labor market tightness is defined as  $\theta_t \equiv v_t/u_t$ . A simple special case without aggregate uncertainty considered by a large body of literature assumes  $\theta_t = 1$  in which case the matching probabilities are simply  $\psi_t = \phi_t = \chi$ . After matching, the entrepreneur decides whether to employ the worker and the worker decides whether to accept the job.

## 4.4 Production Technology

An employed worker of type  $i_t$  produces  $y_{i_t}$  at the end of the period where  $y_g > y_b \geq 0$ . An unemployed worker of type  $i_t$  receives  $k_{i_t}$  where  $k_g \geq k_b$ . To give meaning to the tags “good” and “bad” type, we assume that type  $b$  workers are more productive at home than at the office and type  $g$  workers are more productive at the office than at home (i.e.  $y_g > k_g$  and  $y_b < k_b$ ). Entrepreneurs must pay their workers at the beginning of the period. An unmatched entrepreneur earns zero. Entrepreneurs have deep pockets (i.e. there are no borrowing constraints).

## 4.5 Information

A worker's type is private information (unknown by the entrepreneur). However, after the type shock is realized an entrepreneur can costlessly receive a signal  $d_t \in \{0, 1\}$  of the agent's type with probability  $\rho_{i_t}^{d_t}$ . We assume  $\rho_g^0 \geq \rho_b^0$  with the interpretation that  $d_t = 1$  represents an adverse event (such as a default) on the worker's credit record  $d_t = 0$  represents no adverse events on one's record. Within a match output is observable, but after a match is dissolved, the past history of a worker's output is unobservable.

Note that upon production, the entrepreneur knows the worker's current type but the type switching probability means the entrepreneur does not know the worker's type at the beginning of next period with certainty. Given the markov structure of type change, in the case where  $\delta_{gb}$  and  $\delta_{bg}$  are not  $1/2$ , the worker's current output  $y_t$  is informative about his future type.

When a worker first meets an entrepreneur, the information set at the beginning of the period is thus  $I_t = d_t$ . After being in the relationship for at least one period, the information set is  $I_t = (i_{t-1}, d_t)$ . Given the markov nature of type change and the fact that there is not randomness in the production technology, information on  $i_{t-1}$  in the information set  $I_t$  is sufficient to capture all history.

## 4.6 Wage Determination

Employed workers and entrepreneurs bargain over wages conditional on  $I_t$ . The employer makes a take-it-or-leave-it offer  $w(I_t)$  to the worker. If the worker accepts, he produces  $y(i_t)$ . If the worker rejects, the match is dissolved and the worker receives home production  $k(i_t)$  while the producer receives 0.

## 4.7 Timing of Events

1. Any unmatched entrepreneur posts a vacancy at cost  $\kappa$  and becomes matched with a worker from the unemployment pool with probability  $\psi_t$  at the beginning of period  $t + 1$ .

2. Any unemployed worker searches and becomes matched with a job vacancy with probability  $\phi_t$  at the beginning of period  $t + 1$ .
3. Upon becoming matched at the beginning of period  $t$ , workers and entrepreneurs decide whether to stay matched.
4. In any match, the entrepreneur makes a take-it-or-leave-it wage offer  $w(I_t)$  where  $I_t$  depends on whether it is a new hire or retention wage offer.
5. Workers decide whether or not to accept the wage offer.
6. Output  $y(i_t)$  is realized at the end of the period.
7. Workers (whether employed or unemployed) receive their type shock  $i_{t+1}$  and signal  $d_{t+1}$ .

In matches that break up either in step (4) or step (6), the worker becomes unemployed and receives home production  $k(i_t)$  while the entrepreneur has a vacancy.

## 5 Equilibrium in the simple economy

In this section, we study steady state equilibria which depend on the informativeness of signals. In particular, signals may be completely uninformative (i.e. where  $\rho_g^{d_t} = \rho_b^{d_t}$ ), fully informative (i.e. where  $\rho_g^0 = 1$  and  $\rho_b^1 = 1$ ), and an intermediate case where they are partially informative (i.e. where  $\rho_g^0 > \rho_b^0$ ). An entrepreneur must make hiring and retention decisions solely based upon  $I_t$  which contains the signal and may contain other information.

### 5.1 Posterior Functions

Let  $p(i_t|I_t)$  be the entrepreneur's posterior of the probability of being matched with a type  $i_t$  worker given his information  $I_t$ . Since we will be using recursive methods, let  $x \equiv x_t$ ,  $x^- \equiv x_{t-1}$ , and  $x' \equiv x_{t+1}$ .

In the case where an entrepreneur and worker first match, the entrepreneur's match specific information set simply contains the signal  $d$ . In this case, the entrepreneur also uses the distribution of types in the unemployment pool to infer the type of the worker. The entrepreneur's posterior in this case is given by:

$$p(i|\cdot, d) = \frac{\sum_{i^-} \mu_{i^-}^0 \delta_{i^-i} \rho_i^d}{\sum_{(i^-, \iota)} \mu_{i^-}^0 \delta_{i^- \iota} \rho_\iota^d} \quad (33)$$

where  $\mu_i^e$  denotes the fraction of the population of type  $i$  in employment state  $e \in \{0, 1\}$  where  $e = 0$  denotes unemployment (the determination of these population measures is described in section 5.5). In particular,  $\mu_{i^-}^0$  denotes the fraction of type  $i$  at time  $t - 1$  who are unemployed. Thus  $\mu_{i^-}^0 \delta_{i^-i} \rho_i^d$  is the fraction of unemployed who were type  $i^-$  at  $t - 1$ , became type  $i$  at the beginning of  $t$  and received a signal  $d$ .

Within an existing relationship, the entrepreneur *knows* the type of a worker from the previous output realization, and he takes the type switching probability into account when he calculates the posterior:

$$p(i|i^-, d) = \frac{\delta_{i^-i} \rho_i^d}{\sum_{\iota} \delta_{i^- \iota} \rho_\iota^d} \quad (34)$$

This makes clear the simplifying assumption that the degenerate output distribution buys us; a simple prior and no need to keep track of an endogenous prior.<sup>5</sup>

## 5.2 Entrepreneur Value Functions

When an entrepreneur posts a vacancy at the cost of  $\kappa$ , he will be randomly matched with a worker from the unemployment pool with probability  $\psi$  at the beginning of the next period. He will observe the worker's signal  $d'$  but not his type  $i'$

$$P = -\kappa + \frac{1}{1+r} \left[ \psi \sum_{d'} \gamma^{d'} H^{d'} + (1-\psi)P \right] \quad (35)$$

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<sup>5</sup> A similar simplifying assumption was used in Athreya, et. al. (2011).

where  $\gamma^{d'}$  is the probability of matching with an unemployed worker with signal  $d'$  given by

$$\gamma^{d'} = \frac{\sum_i \left[ \mu_i^0 \sum_{i'} \delta_{ii'} \rho_{i'}^{d'} \right]}{\sum_i \mu_i^0}. \quad (36)$$

Free entry implies that in equilibrium,

$$P = 0. \quad (37)$$

The (hiring) value function for an entrepreneur who has just been matched with an unemployed worker with information set  $I = (\cdot, d)$  is denoted  $H(I)$ . It is given by

$$H(\cdot, d) = \max \left\{ P, \tilde{H}(\cdot, d) \right\} \quad (38)$$

where

$$\tilde{H}(\cdot, d) = \sum_i p(i|\cdot, d) \left\{ \begin{array}{l} 1_{\{w(\cdot, d) \geq \underline{w}_i\}} \left[ -w(\cdot, d) + \frac{1}{1+r} \left( y_i + \sum_{i', d'} \delta_{ii'} \rho_{i'}^{d'} R(i, d') \right) \right] \\ + 1_{\{w(\cdot, d) < \underline{w}_i\}} P \end{array} \right\} \quad (39)$$

is the value of making a take-it-or-leave-it wage offer  $w(\cdot, d)$  given the newly matched worker's reservation wage  $\underline{w}_i$  (to be described in section 5.4). The higher the entrepreneur's belief that he is matched with a type  $g$  worker (i.e. the higher  $p(g|\cdot, d)$ ), the more likely the entrepreneur will hire the worker. If the value to hire this worker is lower than the value of vacancy, the entrepreneur will not extend a wage offer that exceeds any type's reservation wage and the job will remain vacant. Otherwise the entrepreneur will offer  $w(\cdot, d)$  based on the signal received.

The (retention) value function for an entrepreneur in an existing match with information set  $I = (i^-, d)$  is denoted  $R(I)$ . It is given by

$$R(i^-, d) = \max \left\{ P, \tilde{R}(i^-, d) \right\} \quad (40)$$



where

$$\tilde{R}(i^-, d) = \sum_i p(i|i^-, d) \left\{ \begin{aligned} &1_{\{w(i^-, d) \geq \underline{w}_i\}} \left[ -w(i^-, d) + \frac{1}{1+r} \left( y_i + \sum_{i', d'} \delta_{ii'} \rho_{i'}^{d'} R(i, d') \right) \right] \\ &+ 1_{\{w(i^-, d) < \underline{w}_i\}} P \end{aligned} \right\}. \quad (41)$$

Again, the higher the entrepreneur's belief that he is matched with a type  $g$  worker, the more likely the entrepreneur will retain the worker.

### 5.3 Worker Value Functions

The value function for unemployed type  $i$  workers is given by

$$U_i = u(k_i) + \beta \sum_{i'} \delta_{i,i'} \left[ \sum_{d'} \rho_{i'}^{d'} (\phi N_{i'}(\cdot, d') + (1 - \phi) U_{i'}) \right]. \quad (42)$$

The value function for a type  $i$  worker with signal  $d$  who is newly matched with an entrepreneur and is offered a wage  $w(\cdot, d)$  is given by

$$N_i(\cdot, d) = \max \left\{ U_i, u(w(\cdot, d)) + \beta \sum_{i'} \delta_{i,i'} \left[ \sum_{d'} \rho_{i'}^{d'} Z_{i'}(i, d') \right] \right\}. \quad (43)$$

As will be discussed in section 5.4, if the worker receives too low a wage offer  $w(\cdot, d)$ , he can reject it and remain unemployed receiving  $U_i$ . Similarly, the value function for a type  $i$  worker with past type  $i^-$  and signal  $d$  who receives a “retention” wage offer  $w(i^-, d)$  is given by

$$Z_i(i^-, d) = \max \left\{ U_i, u(w(i^-, d)) + \beta \sum_{i'} \delta_{i,i'} \left[ \sum_{d'} \rho_{i'}^{d'} Z_{i'}(i, d') \right] \right\}. \quad (44)$$

It is clear that the Markov structure of type shocks implies continuation values are the same for newly hired workers and retained workers with identical  $i$  and  $d$ . The only difference is the utility stemming from their current wage offer  $u(w(\cdot, d))$  or  $u(w(i^-, d))$ .

## 5.4 Wage Determination

As in Brugemann and Moscarini (2010) and Kennan (2010), here we implement Myerson's (1984) Neutral Bargaining Solution, which is a generalization of the Nash Bargaining Solution to a setting with incomplete information. Let  $E_i(\omega)$  be the value for a type  $i$  worker from accepting any given wage offer  $\omega$ :

$$E_i(\omega) = u(\omega) + \beta \sum_{i'} \delta_{i,i'} \left[ \sum_{d'} \rho_{i'}^{d'} Z_{i'}(i, d') \right].$$

Notice that given the wage offer  $\omega$ , the value of accepting  $E_i(\omega)$  is independent of past type  $i^-$  and signal  $d$ . It is independent of  $i^-$  because by the end of the period, current output perfectly reveals the worker's type so past output provides no extra information. It is independent of  $d$  because the signal is iid across time conditional on type.

Since  $E_i(\omega)$  is strictly increasing in  $\omega$  and  $U_i$  is independent of  $\omega$ , we know there exists a unique reservation wage  $\underline{w}_i$  for a type  $i$  worker which solves

$$E_i(\underline{w}_i) = U_i. \quad (45)$$

This is the lowest wage offer that a type  $i$  worker has to receive in order to accept. Since only the continuation value matters for a worker and  $U_i$  is independent of signals, the reservation wage for a type  $i$  unemployed who just got matched and a type  $i$  employed worker who is in an existing match is the same, independent of the entrepreneur's set  $I$ .

Whether or not a worker is hired or retained and what wage offer he receives, however, does depend on the entrepreneur's information set  $I$ . If the entrepreneur offers  $\omega < \underline{w}_b$ , neither type worker will accept. If  $\omega \in [\underline{w}_b, \underline{w}_g)$ , then the worker will accept only if he is type  $b$  and the entrepreneur will receive  $y_b$  for sure. If  $\omega \geq \underline{w}_g$ , then both type workers will accept and the entrepreneur will get an output of  $y_g$  with probability  $p(g|i^-, d)$  or an output of  $y_b$  and with probability  $p(b|i^-, d)$ .

Since the entrepreneur can make a take-it-or-leave-it wage offer, he max-

imizes the expected value of hiring an unemployed worker with signal  $d$  by choosing

$$w(\cdot, d) = \arg \max_{\omega} \sum_i p(i|\cdot, d) \left\{ \begin{array}{l} 1_{\{\omega \geq \underline{w}_i\}} \left[ -\omega + \frac{1}{1+r} \left( y_i + \sum_{i', d'} \delta_{ii'} \rho_{i'}^{d'} R(i, d') \right) \right] \\ + 1_{\{\omega < \underline{w}_i\}} P \end{array} \right\}. \quad (46)$$

Equation (46) is the analogue of equation (10) in Brugemann and Moscarini (2010). Notice that while the entrepreneur's costs are increasing in  $\omega$ , the probability of worker acceptance (and hence revenue creation) is also increasing in  $\omega$ . Given  $w(\cdot, d)$ , the entrepreneur will make the offer if  $\tilde{H}(\cdot, d) \geq P$  as in (38).

Similarly, an entrepreneur chooses the retention wage offer conditional on information  $I = (i^-, d)$  by choosing

$$w(i^-, d) = \arg \max_{\omega} \sum_i p(i|i^-, d) \left\{ \begin{array}{l} 1_{\{\omega \geq \underline{w}_i\}} \left[ -\omega + \frac{1}{1+r} \left( y_i + \sum_{i', d'} \delta_{ii'} \rho_{i'}^{d'} R(i, d') \right) \right] \\ + 1_{\{\omega < \underline{w}_i\}} P \end{array} \right\}. \quad (47)$$

Given  $w(i^-, d)$ , the entrepreneur will make the offer if  $\tilde{R}(i^-, d) \geq P$  as in (40).

## 5.5 Population Proportions

We next describe the transition equations for the population of employed and unemployed agents of both types. Let  $\mu_i^e$  be the measure of type  $i$  who are in employment status  $e \in \{0, 1\}$  where  $e = 1$  implies employment.

$$\mu_{i'}^1 = \sum_i \left[ \mu_i^1 \delta_{ii'} \sum_{d'} \rho_{i'}^{d'} 1_{\{w(i, d') \geq \underline{w}_{i'}\}} 1_{\{R^{d'}(i) \geq P\}} + \mu_i^0 \delta_{ii'} \sum_{d'} \rho_{i'}^{d'} \phi 1_{\{w(i, d') \geq \underline{w}_{i'}\}} 1_{\{H^{d'} \geq P\}} \right] \quad (48)$$

$$\mu_{i'}^0 = \sum_i \left[ \mu_i^1 \delta_{ii'} \sum_{d'} \rho_{i'}^{d'} \left( 1 - 1_{\{w(i, d') \geq \underline{w}_{i'}\}} 1_{\{R^{d'}(i) \geq P\}} \right) + \mu_i^0 \delta_{ii'} \sum_{d'} \rho_{i'}^{d'} \left( 1 - \phi 1_{\{w(i, d') \geq \underline{w}_{i'}\}} 1_{\{H^{d'} \geq P\}} \right) \right] \quad (49)$$

## 5.6 Definition of Equilibrium

A *Bayesian steady state equilibrium* is a list of:

1. worker value functions when unemployed, newly hired, and retained  $\{U_i, N_i(\cdot, d), Z_i(i^-, d), \forall(i^-, i, d)\}$ ,
2. entrepreneur value functions when posting a vacancy and when making hiring and retention decisions  $\{P, H(\cdot, d), R(i^-, d), \forall(i^-, d)\}$ ,
3. wage offers to new and existing workers  $\{w(\cdot, d), w(i^-, d), \forall(i^-, d)\}$
4. population proportions of unemployed and employed workers  $\{\mu_i^e, \forall(i, e)\}$
5. beliefs about new hires and retained workers  $\{p(i|\cdot, d), p(i|i^-, d), \forall(i^-, i, d)\}$  which satisfy Bayes rule whenever possible.

## 6 Calibration of the simple economy

We calibrate our simple benchmark to an economy with private information where signals are uninformative. We think of the benchmark as the time period before credit checks were extensively used and label it PI(1). The set of parameters includes those we take as given outside the model  $\{u(\cdot), \beta, r, k_g, \alpha\}$  and those we choose within the model  $\{\delta_{gb}, \delta_{bg}, \chi, y_g, y_b, k_b, \kappa\}$ .

The model period is one month. The discount rate  $\beta$  is set to be 0.9966 to have an annual rate of 0.96. The risk free is set to be 0.0034 such that  $\beta(1 + r) = 1$ . Workers have log preferences  $u(c) = \log(c)$  where  $c$  is consumption.

The equilibrium of our economy is consistent with the following hiring and retention decisions: When an entrepreneur meets a worker, he makes a hiring wage offer to start a relationship. When an entrepreneur makes the retention decision, it is based on the past output realization which reveals the worker's past type perfectly. In particular, he makes a retention wage offer if the worker was a type  $g$  last period otherwise he fires the worker.

To keep the model consistent with many matching models (e.g. Shimer (2005)), we start by setting market tightness to be 1, which then implies that  $\phi = \psi = \chi$  (when we consider alternative economies, market tightness

| Parameter | Description              | Values |
|-----------|--------------------------|--------|
| $\beta$   | Discount rate            | 0.9966 |
| $r$       | Risk free rate           | 0.0034 |
| $k_g$     | Type $g$ outside option  | 1      |
| $\alpha$  | Matching power parameter | 0.5    |

Table 3: Model Exogenous Parameters

| Parameter     | Description                                | Value  |
|---------------|--------------------------------------------|--------|
| $\delta_{bg}$ | Type switching probability from $b$ to $g$ | 0.046  |
| $\delta_{gb}$ | Type switching probability from $g$ to $b$ | 0.004  |
| $\chi$        | Coefficient on matching technology         | 0.31   |
| $y_g$         | Type $g$ output                            | 1.05   |
| $y_b$         | Type $b$ output                            | 0.7    |
| $k_b$         | Type $b$ outside option                    | 0.56   |
| $\kappa$      | Vacancy posting cost (solved)              | 0.2503 |

Table 4: Model Parameters Calibrated in PI(1) Equilibrium

responds endogenously so that we must solve for  $(\theta, \phi, \psi)$  and in this case we take  $\alpha = 0.5$  as in Bils et al. (2010)). In PI(1), we choose the matching probability  $\chi$  together with the type switching probabilities  $\delta_{gb}$  and  $\delta_{bg}$  such that the equilibrium distribution given the above hiring and retention decisions roughly match labor market statistics. Bils et al. (2011) estimate a monthly separation rate of 2% and an unemployment rate of 6% from the Job Openings and Labor Turnover Survey (JOLTS) data. This implies that the probability of being matched with a firm is 0.31 for an average worker in the steady state.<sup>6</sup> Our calibrated matching function elasticity parameter  $\chi$  is 0.31, and the type switching probabilities are  $\delta_{gb} = 0.4\%$  and  $\delta_{bg} = 4.6\%$ , which generate an unemployment rate of 7%, an endogenous separation rate of 2%, and a job finding rate of 31%. We note that these values of  $\delta_{gb}$  and  $\delta_{bg}$  imply that the population of good types is 92%.

<sup>6</sup>To see this, from the law of motion for unemployment, we know  $u = s(1-u) + (1-f)u$  in the steady state where  $s$  is the job separation rate and  $f$  is the job finding rate. Since  $s$  is 2% and  $u$  is 6%, this implies a job finding rate of  $f = 2\%(1-6\%)/6\% = 31\%$  in their paper.

| Statistics                                       | Data  | PI(1) |
|--------------------------------------------------|-------|-------|
| Unemployment rate                                | 0.06  | 0.07  |
| Job separation rate                              | 0.02  | 0.02  |
| Job finding rate                                 | 0.31  | 0.31  |
| Average consumption for employed over unemployed | 1.51  | 1.62  |
| Mean profit margin                               | 0.044 | 0.037 |
| Standard deviation of profit margin              | 0.068 | 0.070 |

Table 5: Data and Model Moments

The outside option for a type  $i = g$  agent is normalized so that  $k_g = 1$ . The outside option for a type  $i = b$  worker is chosen to match the average consumption for employed workers over average consumption for unemployed workers of 1.51 calculated from the 1996 PSID. In this equilibrium, the wage for all workers is given by the reservation wage of the good type (i.e.  $w(\cdot, d) = w(g, d) = \underline{w}_g$ ). An outside option  $k_b = 0.56$  generates the relative consumption statistic of 1.62.<sup>7</sup> The output level is chosen to be 1.05 for a type  $g$  worker and 0.7 for a type  $b$  worker to match the mean and standard deviation of the net profit margin.<sup>8</sup> The vacancy posting cost  $\kappa$  is set so that  $P = 0$ . This implies  $\kappa = 0.25$ .

Since PI(1) is the uninformative signals case, we are free to choose any signal probability provided they are equal for good and bad types. Here we choose  $\rho_i^1 = 0.001$ ,  $\forall i$ , which will yield an annual default frequency of 1.2% which is in line with the 2004 SCF data.

## 7 Variation in Information

In our benchmark where signals are uninformative PI(1), the decision to hire (38) and fire (40) depends on the entrepreneur's beliefs about what type of worker he is matched with (appearing in equations (39) and (41)). Given that  $\delta_{bg}$  and  $\delta_{gb}$  imply there is a large proportion of good types in

<sup>7</sup>The average consumption for employed workers is given by  $\underline{w}_g$ , while the average consumption for unemployed worker is given by  $\left(\frac{1}{\mu_g^0 + \mu_b^0}\right) \cdot (\mu_g^0 k_g + \mu_b^0 k_b)$

<sup>8</sup>Net profit margin is calculated by taking  $\frac{\bar{y} - \underline{w}_g}{\bar{y}}$  where  $\bar{y} = \mu_g^1 y_g + \mu_b^1 y_b$

the economy (specifically 92%), the entrepreneur rationally believes that the chance that he is matched with a good type when he must make a hiring decision is not too low (i.e.  $p(g|\cdot, \cdot) = 0.1729$ ). On the other hand, persistence for the bad type  $\delta_{bb} = 0.954$  implies that when the entrepreneur witnesses low production it is likely that the same worker will produce low output next period if he remains with that worker. Hence, he fires the worker. He could try to offer the worker a lower wage next period, but since the outside option for good types following such a deviation from the equilibrium path is greater than that wage, all the entrepreneur would retain is the bad type and that is unprofitable.

In this subsection, we keep all parameters the same except for signal probabilities (thereby varying information sets). In particular, we consider the full information case (which we call FI) where  $\rho_g^0 = 1$  and  $\rho_b^1 = 1$  in order to see the impact of the information problem. Then we consider the case where signals are partially informative (which we call PI(2)). We choose  $\rho_g^0 > \rho_b^0$  to be roughly consistent with data on the fraction of unemployed with a default on their record. We think of this case as the current practice by human resource managers of using adverse credit record information as a way to screen new hires and make retention/promotion decisions. Specifically, we choose  $\rho_g^1 = 0.08\%$  and  $\rho_b^1 = 0.35\%$  such that the average annual bankruptcy rate is 1.2% and the average annual bankruptcy rate given unemployment is 3.8% consistent with the 2004 SCF data.

| $(i_-, d)$   | PI(1)  | PI(2)  | FI |
|--------------|--------|--------|----|
| $(\cdot, 0)$ | 0.1729 | 0.1732 | 1  |
| $(\cdot, 1)$ | 0.1729 | 0.0456 | 0  |
| $(g, 0)$     | 0.9960 | 0.9960 | 1  |
| $(g, 1)$     | 0.9960 | 0.9827 | 0  |
| $(b, 0)$     | 0.0460 | 0.0461 | 1  |
| $(b, 1)$     | 0.0460 | 0.0109 | 0  |

Table 6: Equilibrium Posterior Functions  $p(g|i_-, d)$

Table 6 summarizes the equilibrium posterior function. If the signal is

uninformative as in PI(1), when an entrepreneur meets a worker from the unemployment pool, he believes that there is a 17.29% chance that he is a type  $g$  worker. However, when the signal is partially informative, when he meets a worker with  $d = 0$ , his belief will increase to 0.1732 (i.e. a rise of beliefs of 2/10 of one percent). On the other hand, if the signal turns from uninformative to partially informative, when the entrepreneur meets with a worker with signal  $d = 1$ , his belief that the worker is type  $g$  drops from 0.1729 in PI(1) to 0.0456 in PI(2) (i.e. a drop of beliefs of 74 percent). The large change in beliefs associated with a bad credit report is because  $\rho_b^1$  is over 4 times more informative about a bad type than  $\rho_g^1$ .

| $(i, d)$     | PI(1) | PI(2) | FI |
|--------------|-------|-------|----|
| $(\cdot, 0)$ | 1     | 1     | 1  |
| $(\cdot, 1)$ | 1     | 0     | 0  |
| $(g, 0)$     | 1     | 1     | 1  |
| $(g, 1)$     | 1     | 1     | 0  |
| $(b, 0)$     | 0     | 0     | 1  |
| $(b, 1)$     | 0     | 0     | 0  |

Table 7: Equilibrium Hiring/Retention Decisions

Given the changes in posteriors, the hiring/retention decisions differ across the three equilibria as evident in Table 7. In PI(2), although the retention decision does not depend on signals (as in PI(1)), the hiring decisions depend on signals. The entrepreneur hires only if the unemployed worker has a signal  $d = 0$ . This is because there is not sufficient variation in retention posteriors, but there is a big difference in hiring posteriors. Of course, with perfectly informative signals (i.e. in FI), *both* hiring and retention decisions depend and only depend on signals.

Table 8 summarizes the equilibrium distribution  $\mu_i^e$ . The unemployment rate drops slightly for type  $g$  workers and rises slightly for type  $b$  workers when signals become more informative (and all type  $b$  workers are unemployed in FI). Since the signal probabilities  $\rho_g^1 = 0.08\%$  and  $\rho_b^1 = 0.35\%$  in PI(2) are so low, there are not large differences in the distribution between PI(1) and PI(2) with an unemployment rate around 7%. When signals be-



|           | PI(1)  | PI(2)  | FI     |
|-----------|--------|--------|--------|
| $\mu_g^1$ | 0.9109 | 0.9109 | 0.9119 |
| $\mu_g^0$ | 0.0091 | 0.0091 | 0.0081 |
| $\mu_b^1$ | 0.0211 | 0.0210 | 0      |
| $\mu_b^0$ | 0.0589 | 0.0590 | 0.0800 |

Table 8: Equilibrium Distribution

come perfectly informative in FI, the unemployment rate increases to 8.8%.

|                      | PI(1)  | PI(2)  | FI     |
|----------------------|--------|--------|--------|
| $\theta$             | 1      | 1.0002 | 1.0428 |
| $\phi$               | 0.31   | 0.3101 | 0.3166 |
| $\psi$               | 0.31   | 0.3099 | 0.3036 |
| $\underline{w}_g$    | 0.9918 | 0.9918 | 1      |
| $\kappa _{\theta=1}$ | 0.2520 | 0.2521 | 0.2587 |

Table 9: Job Market Tightness, Wages, and Vacancy Cost

Equilibrium job market tightness increases when signals becomes more informative as apparent in Table 9. This is because at the same vacancy posting cost, more information allows firms to avoid hiring some bad type workers in PI(2) and retaining bad type workers in FI resulting in higher profits. As profits rise for firms, with a constant vacancy cost, the measure of vacancy postings increases. This results in an increase in job tightness of 2/100 of one percent in PI(2) and 4.3% in FI relative to PI(1). The general equilibrium consequence of an increase in job market tightness is a decrease in the probability of matching with a worker (i.e.  $\psi$ ) from 0.31 in PI(1) to 0.3099 in PI(2) and 0.3036 in FI.

A particular firm however does not internalize the effect of using this information because it is of measure zero. If we hold the job market tightness constant at 1 across the three environments (i.e. we take a partial equilibrium approach), then to satisfy the free entry condition, it must be the case that the vacancy posting cost increases when the entrepreneur becomes more informative to offset the increased profits earned by the firm

from better screening (from 0.2520 in PI(1) and 0.2521 in PI(2) to 0.2587 in FI). This provides a measure of the ex-ante private benefit to firms of using credit checks. In particular, there is a small rise in  $\kappa$  by 4/100 of one percent from PI(1) to PI(2) and a rise of 2.7% from PI(2) to FI as can be seen in Table 9.

To evaluate the welfare consequence of a change in the informativeness of signals on workers, we calculate the percentage increase in consumption each worker would be willing to pay (or need to be paid) in all future periods and contingencies so that the expected utility from the current PI(1) equilibrium equals that of the PI(2) or FI equilibria. Because of log preferences, the consumption equivalent welfare gain for an individual in state  $(i, i^-, d)$  can be computed as follows.

$$\lambda(i, \cdot, \cdot) = e^{(1-\beta)(\tilde{U}_i - U_i)} - 1 \quad (50)$$

$$\lambda(i, \cdot, d) = e^{(1-\beta)(\tilde{N}_i(\cdot, d) - N_i(\cdot, d))} - 1 \quad (51)$$

$$\lambda(i, i^-, d) = e^{(1-\beta)(\tilde{Z}_i(i^-, d) - Z_i(i^-, d))} - 1 \quad (52)$$

where  $\{\tilde{U}_i, \tilde{N}_i(\cdot, d), \tilde{Z}_i(i^-, d)\}$  are the equilibrium values under the new policies (PI(2) or FI).

| State $(i, e)$  | PI(2)      | FI      |
|-----------------|------------|---------|
| $(g, 0)$        | -0.4035e-4 | -0.0216 |
| $(g, 1)$        | -0.3944e-4 | -0.0212 |
| $(b, 0)$        | -0.7279e-4 | -0.0391 |
| $(b, 1)$        | -0.0160e-4 | 0       |
| $\bar{\lambda}$ | -0.4062e-4 | -0.0226 |

Table 10: Equilibrium Consumption Equivalents

As Table 10 makes clear, all workers are worse off as signals become more informative, with type  $b$  workers receiving higher welfare losses than type  $g$  workers. Unemployed type  $b$  workers have the biggest welfare loss from PI(1) to PI(2) or to FI, because they are less likely to receive a wage offer.

The average welfare gain in the economy is calculated as follows:

$$\bar{\lambda} = \sum_{i'} \left\{ \begin{aligned} & \sum_i \left[ \mu_i^1 \delta_{ii'} \sum_{d'} \rho_{i'}^{d'} 1_{\{w(i,d') \geq \underline{w}_{i'}\}} 1_{\{R^{d'}(i) \geq P\}} \lambda(i', \cdot, \cdot) \right] \\ & + \sum_i \left[ \mu_i^0 \delta_{ii'} \sum_{d'} \rho_{i'}^{d'} \phi 1_{\{w(i,d') \geq \underline{w}_{i'}\}} 1_{\{H^{d'} \geq P\}} \lambda(i', \cdot, \cdot) \right] \\ & + \sum_i \left[ \mu_i^1 \delta_{ii'} \sum_{d'} \rho_{i'}^{d'} 1_{\{w(i,d') \geq \underline{w}_{i'}\}} 1_{\{R^{d'}(i) \geq P\}} \lambda(i', i, d') \right] \\ & + \sum_i \left[ \mu_i^0 \delta_{ii'} \sum_{d'} \rho_{i'}^{d'} \phi 1_{\{w(i,d') \geq \underline{w}_{i'}\}} 1_{\{H^{d'} \geq P\}} \lambda(i', \cdot, d') \right] \end{aligned} \right\}$$

where the distribution  $\mu_i^e$  corresponds to the PI(1) equilibrium. The average welfare loss measured as consumption equivalents is 0.4062e-4 from PI(1) to PI(2), while it increases to 0.0226 from PI(1) to FI. This provides a rationale for why the government might actually choose to make the use of credit checks illegal.

## 8 Extended Environment

In this section, we add noncontingent debt and allow a default to be on a worker's credit record. This turns the exogenous signal  $\rho_i^d$  into an endogenous signal. In this case, when a worker chooses to default, there is potentially a harsh punishment beyond the standard exclusion from credit markets or exogenous losses in income. In particular, the earnings loss becomes endogenous which is different from most models of bankruptcy (e.g. Chatterjee, et. al. (2007)). In those models with endogenous default, agents default when they have lots of debt and a low income realization. The pattern of earnings implied in our matching model is consistent with that behavior, so we expect to be able to construct such equilibria.

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