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Heterogenous match efficiency

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Abstract

In this paper, we show a model with one-sided endogenous match efficiency. It is assumed that schooling can enhance match efficiency, and people will choose the schooling level optimally to balance its costs and benefits of enhanced match efficiency. Assuming a financial market imperfection which limits individuals to borrow, we showed that, in equilibrium, when educational achievements can be characterised by dicohotomy (secondary vs. tertiary), tertiary education gives higher wages even it only has pure match efficiency (signalling) value with no human capital value. We also showed that relative match efficiency vis-a-vis its mean matters in wage levels.

Keywords: job search, signaling, match efficiency

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Heterogenous match efficiency[§]

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1 Introduction

In South Africa, it is casually observed that many individuals do not know where to search for the jobs. In the qualitative interviews undertaken by one of the authors, some respondents in low income areas reveal that they do not make use of the job creation centres nor employment agencies, they do not plan ahead to enquire about the job opening over the phone, but they simply go to the workplace and enquire directly. Majority of low income individuals cannot afford the internet usage, so they do not search over the web.[*1] The most cost-effective, active search method can be newspaper advertisement, which may be subject to a limited employer base. Many individuals rely on word of mouth to get the job opening information. The quality of job information through word of mouth then may depend on the size and quality of network characterised by weak ties (Granovetter, 1983, 2005), which may be positively correlated with job searcher's own wealth levels.

This points to the questions of search efficiency impacts on labour market outcomes. A job search can be strategised to increase the rate of job match. A capacity to strategise may depend on schooling. First, strategisation requires careful thinking and planning, and schools are meant to capacitate the students in doing so. Second, alum networks of top schools can be of high quality due to its size and informational contents. The better your school friends do, the better your chances of getting the information will be.

We consider a model with heterogenous search efficiency in an equilibrium search framework of Pissarides (1985). The model treates "educational investments" (signal) as search efficiency. It derives steady state unemployment and vacancy under heterogeneity. The educational investments are assumed to carry no human capital value, and are optimally chosen by balancing the current costs and future benefits. Heterogeneity is introduced by heterogenous marginal costs of educational investments. In the search equilibrium, we naturaly see the job matching rate is greater with a greater

§ This paper was written when Seiro Ito visited the Faculty of Managerial and Economic Sciences, Stellenbosch Univeristy. He would like to thank deeply for their hospitality and the opportunities provided.

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*1 Not using phones and internet may sound irrational, but their non-use makes a perfect sense, given the price plans and complexity of services offered. In February 2015, with a leading carrier, data costs about monthly R.29 for 100 Mb (but pay a prohibitive, a seven times higher rate of R.2 per Mb after using 100 Mb allocation), so it is not just expensive but also tremendously difficult for low income earners to plan the megabytes and use, even if you have a smart phone. A phone call costs R. 1.20 per minute, so it is about 4.8 times of cashier minimum wage (R.14.98 per hour) per minute. Phone calls, too, are expensive for low income earners.

value of educational investments.

Greater values of educational investments e can be considered to lead to a labour market advantage beyond traditional signaling function: More accurate revealation of individual traits. This is assumed to be achieved through better presentation skills and acquiring access to a better quality network which transmits information more efficiently and precisely. If $e_1 > e_2$, job matching rate is higher for individual 1 than individual 2.

Inspired by Acemoglu (2001); Navarro (2007), the model treats heterogenous individuals but do not assume sector specific employability. In fact, there is only one sector in the economy.

2 Setup

2.1 Standard matching

Under the standard matching, it is assumed that an individual spends a unit time to search the jobs when unemployed, but not during employed. So the total number of job searchers in an economy is the number of unemployed uL where L is population size. There are vL vacancies in the economy. The employers and job searchers meet and examine the match of traits between individuals have and jobs require. The match of traits is "produced" in a production function-like process called a matching function. Following the previous works, the matching function is assumed to take arguments of u, v, and is homogenous of degree 1. The number of job matches x with the people under unemployment uL and vacancies vL is given by $x(uL, vL)$. We normalize the population size L to 1. Then x is considered as the rate of job match per individual given unemployment rate u and vacancy rate v:

$$x = \tilde{x}(u, v) = \tilde{x}\left(\frac{u}{v}, 1\right) v = \tilde{x}\left(\theta^{-1}, 1\right) v \overset{\text{def}}{=} \tilde{q}(\theta) v, \tag{1}$$

where

$$\theta \overset{\text{def}}{=} \frac{v}{u}, \quad \tilde{q}' < 0.$$

Match arrival rates for vacancy position and the unemployed are expressed as:

$$\frac{\tilde{x}}{v} = \tilde{q}(\theta), \quad \frac{\tilde{x}}{u} = \frac{v}{u}\frac{\tilde{x}}{v} = \theta\tilde{q}(\theta). \tag{2}$$

2.2 Match efficiency

The above matching function has a microeconomic basis known as urn-ball matching (Petrongolo and Pissarides, 2001). Assuming that a vacancy is public knowledge and each unemployed sends one application, the probability that a vacancy receives at least one application is $1-(1-\frac{1}{vL})^{uL}$. Then the number of match is given by multiplying with total number of vacancies, or $vL\{1-(1-\frac{1}{vL})^{uL}\}$.

Taking $L \to \infty$ while holding u, v fixed, $(1 - \frac{1}{vL})^{uL}$ approaches to $\exp\left(\frac{u}{v}\right)$. Hence urn-ball matching function has a form

$$X(uL, vL) = vL\left\{1 - \exp\left(\frac{u}{v}\right)\right\}.$$

This function is homogenous of degree one. One way to define the efficiency in matching, from the job searcher's point of view, is to make vacancies vL variable. We can assume that the matching can incoporate efficiency by introducing $e \in [1, \infty)$ to be multiplied with the number of vancancies, giving evL. Then we have:

$$eX(uL, vL) = evL\left\{1 - \exp\left(\frac{u}{v}\right)\right\},$$

or its proportion form:

$$\frac{eX(uL, vL)}{L} \stackrel{\text{def}}{=} ex(u, v) = ev\left\{1 - \exp\left(\frac{u}{v}\right)\right\}. \tag{3}$$

We see that $x(u, v)$ is homogeneous of degree one, so is $ex(u, v)$.

2.3 Individuals

An individual is forward looking, infinitely lived, and maximizes the lifetime utility by choosing the labour market status and by choosing the education levels in childhood. An individual is assumed to be risk neutral, and invests in schooling e in childhood (time 0) to enhance the matching efficiency. In childhood, there is no consumption but there is a nonpecuninary cost for education.

After invested in e, an individual will search for the job and receives an offer if a firm decides to do so. An individual decides whether to accept the job. An individual will accept the offer only if it increases the expected lifetime utility. After observing the match, the matched individual and firm will enter a generalized Nash-bargaining process where the threat points are unemployment and no production, respectively. The bargaining power for an individual is assumed to be unique and fixed at $\beta \in (0, 1)$.

The individuals receive the unemployment benefits $b > 0$ during unemployment, and firms will receive nothing if not producing. In each period, there is a fixed chance $s \in [0, 1]$ of job loss which hurts both the worker and the firm as they take away employment/production opportunities. Job loss is a random event that is not correlated with any parameters of the model. An individual will quit the job if doing so increases the expected lifetime utility. The problem that an individual faces at t under the discount rate r can be stated as maximizing the following function:

$$V(t) = \int_t^\infty \exp(-r\tau) y\{edu, m(\tau)\} d\tau$$

where $y\{edu, m(\tau)\}$ is net income in time τ with labour market status $m(\tau)$ a chosen education level edu.

We assume that matching becomes more efficient if an individual attains higher educational qualification. This is because of two related but potentially separate reasons. First, with better schooling comes with better presentation and a more matched focus, employers see the job candidate's traits more accurately, which makes them easier to hire. Secondly, higher educational qualification can grant access to higher quality networks. A network is of superior quality if it shares the information at a greater scale and speed, or with higher precision without much decay in informational contents. Or one can expect that, with better educational qualification, one can expect the peer to be closer to decision making positions of job applicants. This should give search efforts an extra efficiency in getting more offers. Thus even with the same information one sees between 1 and 2 except for e, employability of 1 is greater with the larger signaling value $e_1 > e_2$.

We assume there are $I > 0$ types of individuals. Types differ in their match efficiency $e_i \neq e_{i'}$ for $i' \neq i, \forall\, i' \in \mathbb{I}$. With match efficiency e_i, we redefine the matching function $\tilde{x}(\cdot) = ex(\cdot)$ as in (3):

$$\tilde{x}(u_i, v_i) = e_i x(u_i, v_i) = e_i x\left(\tfrac{u_i}{v_i}, 1\right) v = e_i x\left(\theta_i^{-1}, 1\right) v_i \stackrel{\text{def}}{=} e_i q(\theta_i) v_i, \quad q' < 0. \tag{4}$$

Note that now all u and v are indexed with the type i, because different level of educational investments distinguishes different types of individuals.[*2] Naturally, different values of e will result in different values of θ. Note also that an (exogenous) increase in e_i is purely welfare improving, better for both individuals and firms.

2.4 Firms

In production, a worker contributes one unit of labour which gives an output of y. We assume linear production technology, and each firm employs only one labourer. A firm can create a job to enjoy the profit opportunities, and can keep the worker as long as it wishes and fire at will. But the firms will keep on employing the same worker as much as they can, because we assume homogeneity in worker productivity and there is a fixed cost $\gamma > 0$ of creating a job which they must incurr had they decided to switch to a new worker. This fixed cost acts like an entry barrier and leads to a subsequent rent to be enjoyed.

The overall match for all firms becomes:

$$\overline{eq} = \sum_{i \in \mathcal{I}} \phi_i e_i q(\theta_i), \quad \sum_{i \in \mathcal{I}} \phi_i = 1,$$

where ϕ_i is proportion of type i workers.

[*2] So the number of matches x should also be indexed by i as well, but we do not do so as we use x for a function $x(\cdot)$, and it may conflate with the notion that the functional form is also different.

2.5 Contrasts with search intensity model

Note that there is a close parallel with Pissarides (2000, Chapter 5)'s model with endogenous search intensity. In his model, an individual i can choose the "search units" s_i, which gives the search volume of $s_i u$. The matching function then becomes:

$$\ddot{x}(su, v) = \ddot{x}\left(s\frac{u}{v}, 1\right) v \stackrel{\text{def}}{=} \ddot{q}\left(\frac{\theta}{s}\right) v.$$

$$\theta \stackrel{\text{def}}{=} \frac{v}{u}, \ \ddot{q}' < 0.$$

Under variable search intensity, the match arrival rate for the unemployed shows negative externality of s, while it has positive impacts for match per vacancy.

$$\frac{\ddot{x}}{v} = \ddot{q}\left(\frac{\theta}{s}\right), \quad \frac{\ddot{x}}{su} = \ddot{q}\left(\frac{\theta}{s}\right)\frac{\theta}{s}.$$

This captures that searching with more search units has negative externality. An increase in s is good for firms but may not be good for individuals.

Contrasting two models may indicate:

- What changes: volume vs. efficiency.
- Notion: wander more vs. communicate better.
- Welfare: umbiguous vs. no worse.
- Choice variables: flow vs. stock.
- Timing: Contemporaneous vs. childhood.
- u: umbiguous vs. reduces.
- w: reduces (?) vs. increases.

3 Equilibrium

3.1 Equilibrium Bellman equations

Individuals and firms have two potential states, respectively. Namely, employed or unemployed, and having a vacancy or a nonvacancy. These states have on going values represented by the following four Bellman equations. Following the literature, we assume firms incurr a fixed hiring cost $\gamma > 0$, there is a $s \in [0, 1]$ chance of a job being destroyed (job destruction rate), the unemployed receive unemployment benefits $z > 0$, firms produce y while paying a wage w_i to the worker which results in a profit $y - w_i$, and individuals and firms discount the future with the factor $r > 0$.

Vacancy value J^V:

$$rJ^V = -\gamma + \overline{eq}\left(rJ^F - rJ^V\right). \tag{5}$$

Filled position value J^F:[*3]

$$rJ^F = y - w_i + (s + \delta_i)\left(rJ^V - rJ^F\right), \tag{6}$$

Note that e does not enter, because we assume that education has no productivity impact.[*4]Unemployment value J^U:

$$rJ_i^U = z + \theta_i e_i q(\theta_i)\left(rJ_i^E - rJ_i^U\right). \tag{7}$$

Employment value J^E:

$$rJ_i^E = w_i + (s + \delta_i)\left(rJ_i^U - rJ_i^E\right). \tag{8}$$

A firm may not need to differentiate wages across types, because they have the same productivity. However, it is assumed that a firm bargains wages to all workers. This can differentiate the wages due to different relative bargaining positions. The population increases by δ_i for each type. We assume δ_i differs across types. At each moment there will be δ_i more workers, hence matches, for type i. It reduces the value of filled positions by δ_i. Firms can offer lower wages by citing the larger number of applicants of the same type.[*5]

3.2 Individual choices in equilibrium

From (7) and (8):

$$rJ_i^E = \frac{(s + \delta_i)z + \{r + \theta_i e_i q(\theta_i)\}\, w_i}{r + s + \delta_i + \theta_i e_i q(\theta_i)}, \tag{9}$$

$$rJ_i^U = \frac{(r + s + \delta_i)z + \theta_i e_i q(\theta_i) w_i}{r + s + \delta_i + \theta_i e_i q(\theta_i)}. \tag{10}$$

Difference is proportional to relative benefits of employment:

$$J_i^E - J_i^U = \frac{w_i - z}{r + s + \delta_i + \theta_i e_i q(\theta_i)} \propto w_i - z. \tag{11}$$

[*3] δ_i is the rate of new labor market entries which reduces the asset value by δ_i because of more filled positions.

[*4]

[*5] A note on filled position value (6). I could have set $\delta_i = 0$ to keep things simpler.

Note (9) and (10) can be written as:

$$rJ_i^E = a_{i1}z + (1 - a_{i1})w_i, \tag{12}$$

$$rJ_i^U = a_{i2}z + (1 - a_{i2})w_i. \tag{13}$$

with

$$a_{i1} = \frac{s + \delta_i}{r + s + \delta_i + \theta_i e_i q(\theta_i)} < \frac{r + s + \delta_i}{r + s + \delta_i + \theta_i e_i q(\theta_i)} = a_{i2}.$$

$w_i > z$ shows that $rJ_i^E > rJ_i^U$ as it gives a larger weight on w_i.

3.3 Educational investments

A rational student will invest up to e^* that maximizes net expected values when initial employment probability is p:

$$\begin{aligned} e_i^* &= \text{argmax}\{pJ_i^E + (1-p)J_i^U - c(e_i)\}, \\ &= \text{argmax}\,\{(r+s+\delta_i)z + \theta_i e_i q(\theta_i)w_i + p(w_i - z) \\ &\qquad - \{r+s+\delta_i+\theta_i e_i q(\theta_i)\}\,c(e_i)\}, \\ &= \text{argmax}\,\{\theta_i e_i q(\theta_i)w_i - \{r+s+\delta_i+\theta_i e_i q(\theta_i)\}\,c(e_i)\}. \end{aligned} \tag{14}$$

We assume that $c(e_i)$ is a convex cost function. FOC is:

$$\theta_i q(\theta_i)\{w_i - c(e_i)\} - \{r+s+\delta_i+\theta_i e_i q(\theta_i)\}\,c'(e_i) = 0 \tag{15}$$

If $p = p(e_i)$ with $p' > 0$, e_i^* increases (with $c(\cdot)$ convex):

$$\theta_i q(\theta_i)\{w_i - c(e_i)\} + p'(e_i)(w_i - z) - \{r+s+\delta_i+\theta_i e_i q(\theta_i)\}\,c'(e_i) = 0 \tag{16}$$

In either case, e_i^* is increasing in w_i, which is considered as an expected wage rate. It implies that the higher the reservation wage, the longer the schooling they should acquire.

If $c(e) = c(e, \omega)$ with $\frac{\partial^2 c}{\partial e \partial \omega} < 0$, where ω is wealth, we get:

$$e^* = g(\omega), \quad g' > 0.$$

This assumption can be justified by the presence of a credit constraint, school (signal) quality $\propto \omega$, geographical sorting: distance to jobs $\propto \frac{1}{\omega}$[*6], network costs when e is a referral.

Usually, schooling is a discrete variable. Here, we assume $e = e_1, e_2$ with e_1 is a matriculation degree and e_2 is an advanced degree. Then

$$^{\exists}\ \omega^* \in \mathbb{R}_{++} \quad \text{s.t.} \quad \omega \left\{ \begin{array}{c} \leqslant \\ > \end{array} \right. \omega^* \Leftrightarrow \quad e^* = \left\{ \begin{array}{l} e_1 \\ e_2 \end{array} \right.$$

[*6] This is not true in the US.

3.4 Firm choices in equilibrium

Free entry of firms imply:

$$rJ^V = 0. \tag{17}$$

We assume the generalized Nash barganing over matched rents. Given the bargaining power $\beta \in (0, 1)$ of the individuals, this results in:

$$J_i^E - J_i^U = \frac{\beta}{1-\beta}\left(J^F - J^V\right). \tag{18}$$

Filled position value (6) can be writtenn as:

$$J^F = \frac{y - w_i}{r + s + \delta_i}.$$

Vacancy value (5) and free entry (17) give:

$$J^F = \frac{\gamma}{\overline{eq}}, \tag{19}$$

So

$$y - w_i - \gamma\frac{r + s + \delta_i}{\overline{eq}} = 0. \tag{20}$$

Job creation under free entry must yield a positive rent $y - w_i > 0$ to recover the cost γ. w_i is lower if there are more new entrants δ_i.

(9), (10), (23) give:

$$rJ_i^E = \frac{(s + \delta_i)z + \{r + \theta_i e_i q(\theta_i)\}\left\{\beta\left(y + \gamma\theta_i\frac{e_i q_i}{\overline{eq}}\right) + (1-\beta)z\right\}}{r + s + \delta_i + \theta_i e_i q(\theta_i)}, \tag{21}$$

$$rJ_i^U = \frac{(r + s + \delta_i)z + \theta_i e_i q(\theta_i)\left\{\beta\left(y + \gamma\theta_i\frac{e_i q_i}{\overline{eq}}\right) + (1-\beta)z\right\}}{r + s + \delta_i + \theta_i e_i q(\theta_i)}. \tag{22}$$

Note $\overline{eq} = \sum_j \phi_j\theta_j q(\theta_j)$. At $\theta_j = 0$ for $\forall j \neq i$, rJ_i^E is positve:

$$rJ_i^E\Big|_{\theta_j=0} = \frac{(s + \delta_i)z + \{r + \theta_i e_i q(\theta_i)\}\{\beta(y + \gamma\theta_i) + (1-\beta)z\}}{r + s + \delta_i + \theta_i e_i q(\theta_i)}.$$

It can also be seen that:

$$\frac{\partial rJ_i^E}{\partial\theta_i} > 0.$$

We see if $\theta_2 > \theta_1$

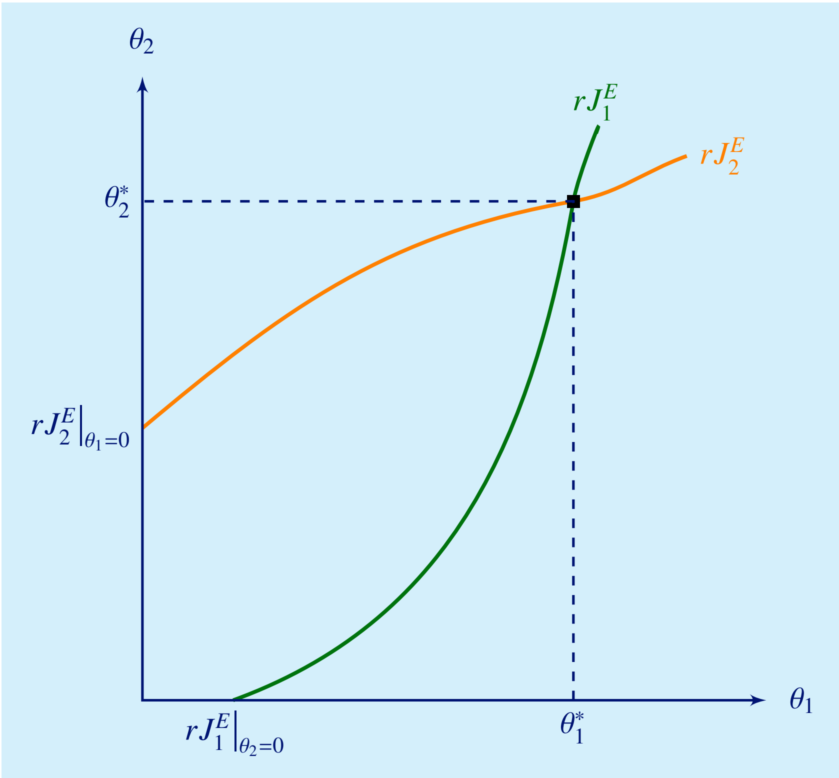
$$rJ_1^E\Big|_{\theta_2=0} \gtrless rJ_2^E\Big|_{\theta_1=0}, \quad \frac{\partial\, rJ_2^E\Big|_{\theta_1=0}}{\partial\theta_2} < \frac{\partial\, rJ_1^E\Big|_{\theta_2=0}}{\partial\theta_1}.$$

Use a short hand $dq = q(\theta_i) + \theta_i q'(\theta_i)$:

$$\frac{\partial r J_i^E}{\partial \theta_i} = -\frac{\{num\}}{(denom)^2} e_i dq + \frac{e_i}{(denom)} \Bigg[\{wage\}\, dq + \{r + \theta_i e_i q(\theta_i)\}\beta\gamma \left\{ dq - \frac{\theta_i q(\theta_i)\phi_i e_i q'(\theta_i)}{\overline{eq}^2} \right\} \Bigg]$$
$$= \frac{e_i dq}{(denom)^2} \Bigg[-\{num\} + (denom)\{wage\} + (denom)\{r + \theta_i e_i q(\theta_i)\}\beta\gamma \left\{ 1 - \phi_i \theta_i \frac{e_i q(\theta_i)}{\overline{eq}^2} \frac{q'(\theta_i)}{dq} \right\} \Bigg].$$

The last term is positive. Comparing the 1st and 2nd terms and one can show:

$$-\{num\} + (denom)\{wage\} = (s + \delta_i)\beta \left(y + \gamma\theta_i \frac{e_i q_i}{\overline{eq}} - z \right) > 0.$$



3.5 Steady state

(5), (6), (7), (8) and (17), (18) give:

$$w_i = \beta \left(y + \gamma\theta_i \frac{e_i q_i}{\overline{eq}} \right) + (1 - \beta) z. \tag{23}$$

So the higher the relative match efficiency $\frac{e_i q_i}{\overline{eq}}$, the higher the rent share. Looking at FOC in (15), $\frac{de_i}{dw_i} > 0$ and an increase in w_i encourages investments in e_i.

$$\theta_i q(\theta_i)\left\{w_i - c(e_i)\right\} - \left\{r + s + \delta_i + \theta_i e_i q(\theta_i)\right\} c'(e_i) = 0 \tag{15}$$

Note the externality: If $j \neq i$ invests more in e_j, i's rent share falls.

(7), (8) and (17), (18) give:

$$\begin{aligned}(r + s + \delta_i)(J_i^E - J_i^U) &= w_i - rJ_i^U,\\ J_i^E - J_i^U &= \tfrac{\beta}{1-\beta} J^F,\\ J^F &= \tfrac{1}{r+s+\delta_i}(y - w_i)\end{aligned}$$

So

$$w_i = \beta y + (1 - \beta) r J_i^U. \tag{24}$$

(7), (18), (19) give:

$$\begin{aligned}yJ_i^U &= z + \theta_i e_i q(\theta_i)\left(rJ_i^E - rJ_i^U\right),\\ &= z + \theta_i e_i q(\theta_i)\tfrac{\beta}{1-\beta} J^F,\\ &= z + \tfrac{\beta}{1-\beta}\gamma\theta_i \tfrac{e_i q_i}{\overline{eq}}.\end{aligned} \tag{25}$$

(24) and (25) give (23).

The steady state is characterised by the following equations. For signals:

$$\theta_i q(\theta_i)\left\{w_i - c(e_i)\right\} - \left\{r + s + \delta_i + \theta_i e_i q(\theta_i)\right\} c'(e_i) = 0 \tag{15}$$

Job creation:

$$y - w_i - \gamma\frac{r + s + \delta_i}{\overline{eq}} = 0. \tag{20}$$

Wage:

$$w_i = \beta\left(y + \gamma\theta_i \frac{e_i q_i}{\overline{eq}}\right) + (1 - \beta) z. \tag{23}$$

Beveridge curve:

$$u_i = \frac{s + \delta_i}{s + \delta_i + \theta_i e_i q(\theta_i)} \tag{26}$$

Again, $\overline{eq}$ is a function of all θ_i's, so $4 \times I$ equations must be solved simultaneously.

Alternatively, the steady state is $\{u_i, v_i, e_i\}$ determined by:

$$\begin{aligned}&\theta_i q(\theta_i)\left\{\beta\left(y + \gamma\theta_i \frac{e_i q_i}{\overline{eq}}\right) + (1 - \beta) z - c(e_i)\right\}\\ &- \left\{r + s + \delta_i + \theta_i e_i q(\theta_i)\right\} c'(e_i) = 0\end{aligned} \tag{16}$$

$$(1 - \beta)(y - z) - \frac{\gamma}{\overline{eq}}\left\{r + s + \delta_i - \beta\theta_i e_i q(\theta_i)\right\} = 0. \tag{27}$$

$$u_i = \frac{s + \delta_i}{s + \delta_i + \theta_i e_i q(\theta_i)} \tag{28}$$

Three unknowns u_i, v_i (or $\theta_i = \frac{v_i}{u_i}$), e_i are solved with three equations provided that other types are in an equlibrium.

For $i = 1, 2$, (23) and (20) give:

$$(1 - \beta)(y - z) - \frac{\gamma}{eq} \{r + s + \delta_i - \beta\theta_i e_i q(\theta_i)\} = 0. \tag{29}$$

This gives θ_i. An equilibrium requires θ_1 and θ_2 to be determined simultaneously. (28), (29) give u_i, θ_i (or v_i). For $i = 1, 2$, it gives unique $\theta_1^* < \theta_2^*$.

4 Concluding remarks

In this paper, we showed a model with one-sided endogenous match efficiency. It is assumed that schooling can enhance match efficiency, and people will choose the schooling level optimally to balance its costs and benefits of enhanced match efficiency. Assuming a financial market imperfection which limits individuals to borrow, we showed that, in equilibrium, when educational achievements can be characterised by dicohotomy (secondary vs. tertiary), tertiary education gives higher wages even it only has pure match efficiency (signalling) value with no human capital value. We also showed that relative match efficiency *vis-à-vis* its mean matters in wage levels.

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