Hedonic Wages with Search Frictions: Reconsidering Employer Heterogeneity

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Abstract

Recent work has shown that in a labor market with search frictions and wage dispersion, the relationship between wages and amenities may be much different than in the classical compensating wage model. This paper generalizes their work, revealing the full range of potential relationships between wages and amenities possible in a labor market with frictions and clarifying the key role of the nature of firms' productive heterogeneity in determining which one is realized. An equal profits baseline for firms' heterogeneity is proposed that implies wage differentials will typically not be fully compensating, with higher amenity jobs tending to give more utility to workers.

1 Introduction

In a labor market with perfect information, jobs with worse characteristics from the perspective of the worker (working conditions, safety risks, and so on) must have a fully compensating wage differential to attract any workers, as first theorized by Adam Smith. Rosen (1974) formalized the relationship between job amenities (good characteristics) and wages, showing that the wage is a function of job amenities, the slope of which must at each point equal the worker's marginal rate of substitution between consumption and job amenity and the firm's technical rate of substitution. This wage function is commonly referred to as a hedonic wage and can be understood as a fixed base wage minus an implicit price charged to the worker for job amenities.

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In a survey article, Rosen (1986) acknowledges that the classic theory of compensating wage differentials assumes perfect information while at the same time noting that search and information costs "sustain significant wage variability among measurably identical jobs and workers" (fn. 2, p. 643). He argues that a model with search frictions will nevertheless tend toward the same relationship between amenities and wages in equilibrium as the perfect information outcome.

> The search for a job and investment in information is in many ways a search for the type of allocations described here. Hence the theory must be considered as one of longer run tendencies and of equilibrium behavior in the steady state of a more complex dynamic process. (p. 643)

However, recent papers have shown that search frictions can plausibly lead to labor market equilibria with very different configurations of wages and amenities, in which the slope of the wage-amenity relationship need not equal the slope of the worker's indifference curve. These papers adapt equilibrium search models such as (Burdett and Mortensen, 1998) in which there is wage dispersion in equilibrium, even with homogeneous workers. Firms face a tradeoff between the cost of offering a higher wage to workers and the difficulty of finding and retaining workers with a low wage. In equilibrium firms each maximize profit at different wage choices. For each, the gain from lowering their wage offer would be exactly offset by the resulting increase in costs of hiring and turnover. It is straightforward conceptually to extend this idea to multi-dimensional compensation, a model in which the worker values characteristics of jobs as well as the wage. Workers search for jobs based on the total utility they would get, accounting for both the wage and amenities. Their optimal acceptance strategies will involve reservation utility levels rather than reservation wages, for instance. And by the same reasoning as in the single-dimensional compensation case, there will be a dispersion of utilities offered to workers in equilibrium.

Lang and Majumdar (2004) consider the case of homogenous firms, as well as identical workers. In a frictionless labor market, the equilibrium would consist of a single wage-amenity pair at a point of tangency between the workers' indifference curves and firms' isoprofit curves. With utility dispersion, however, there are a range of wage-amenity pairs in equilibrium with a positive relationship between wages and amenities. This is because each firm will provide utility to workers in the most cost effective way, trading off between using higher wages or better amenities to make their jobs attractive. Under the standard assumptions (job amenities are normal goods for workers and firms have increasing marginal costs of providing amenities), firms offering higher utility to workers will thus offer both a higher wage and better amenities than the lower utility firms, leading to the positive relationship in equilibrium, the opposite of a compensating wage differential. This is analogous to the well known potential for bias in estimating hedonic wage functions that can result from unobserved heterogeneity in worker ability, which is cited by Rosen (1986) as "the fundamental reason why low paying jobs tend to be the 'worst' jobs" (p. 671). However, in this model, workers are of identical ability, and the only difference between workers is in how lucky they are when searching for jobs.

Hwang et al. (1998) explore the implications of firm heterogeneity for the equilibrium distribution of wages and amenities. Now, in a frictionless labor market with homogeneous workers and multiple types of firms offering different levels of an amenity, the hedonic wage function will trace out an indifference curve of the workers. This is a best case scenario from the perspective of estimating the preferences of the workers for job characteristics. In an equilibrium with utility dispersion, however, wage-amenity pairs are spread among a range of the workers' indifference curves, rather than tracing out a single utility level. In the special case considered by Hwang et al. (1998), the firm types that offer the higher levels of amenity also offer discretely higher utility jobs overall, which means that wage differentials between jobs are not fully compensating. The slope of the relationship between wages and amenity will tend toward zero, less steep than the workers' indifference curves, and may even become positive.

Concern about search frictions as a potential source of significant bias when estimating worker preferences using the traditional hedonic wage model led Gronberg and Reed (1994) to propose an alternative approach to estimating worker preferences based on job duration data rather than the relationship between wages and amenities. Although compensating wage differentials can be distorted in a market with search frictions, the on-the-job search model itself predicts a systematic relationship between the utility of a job and how long a worker will stay at the job that can be used instead to estimate worker preferences. Gronberg and Reed (1994) apply their method to working conditions such as whether the job requires kneeling/stooping. It has also been applied to commuting time(van Ommeren et al., 2000), night shift work (Manning, 2003), and risk of injury (Dale-Olsen, 2006). In each case, the workers' marginal willingness to pay (MWP) for job amenities are estimated to be higher by the job durations method than by the traditional hedonic wage method, which has been interpreted as confirmation of the claim of Hwang et al. (1998) that search frictions always cause the observed slope of the hedonic wage relationship to be less than the true slope of workers' indifference curves, that is, their MWP. However, it is as yet unclear whether these estimates should be considered more accurate than the traditional method,[1] as various objections can be raised to the basic job durations method.

Another approach to estimating worker preferences that is not new but has been given renewed attention in light of the challenge of search frictions to traditional hedonic wage regressions is the method of estimating preferences of workers by looking directly at their choices between jobs, as seen in their voluntary job transitions. Each instance of a worker voluntarily changing jobs gives unambiguous information about the worker's preferences between them. (Bonhomme and Jolivet, 2006) is an innovative recent application of this approach based on moving costs rather than search frictions. It may be the first empirical analysis of the difference between the performance of the cross-sectional hedonic wage approach and an alternative method for estimating preferences within a single modelling framework. My hope is that this paper could be a step toward a similar empirical analysis in which the job durations method could be compared to the standard approach in a common framework.

In this paper, I adapt the models of Hwang et al. (1998) and Lang and Majumdar (2004) and allow for a more general form of firm heterogeneity, retaining the assumption of homogeneous workers for clarity and tractability.[2] The theoretical contribution here is characterizing in full generality which firm types will offer higher utility jobs in equilibrium. I also extend the model to allow for a continuous distribution of firm types, following the model of (Burdett and Mortensen, 1998) for the single-dimensional compensation case. However, in the case of multi-dimensional compensation, allowing a continuum of firm types makes for a qualitatively different and substantially more intuitive distribution of wages and amenities. With the resulting model, the full range of possible wage-amenity distributions comes into view, and it is possible to characterize in a general way how the distribution of firm heterogeneity determines the

[1]For example, Manning (2003) reports an estimate using the job durations method that implies night shift workers in the UK would be willing to pay over 90% of their salary to switch to a day shift job!

[2]Lang and Majumdar (2004) consider a case with two types of worker, differing in their taste for a binary amenity, and homogeneous firms. They characterize the equilibrium for both the case in which firms can observe the worker type and make their job offers contingent on it and the case in which firms must blindly offer the same jobs to both types.

equilibrium relationship between wages and amenities, including the conditions under which the special cases explored by Hwang et al. (1998) and Lang and Majumdar (2004), respectively, would arise.

With the range of theoretical possibilities in view, the question arises of what sort of relationship between wages and amenities we should expect to actually see. I show that if we conjecture that different types of firms earn roughly equal profits in expectation, the special case of (Hwang et al., 1998) in which higher amenity jobs tend to offer higher utility is indeed the result. If this reasoning is correct, it explains the serious bias in the traditional hedonic wage methodology that empirical work using the job durations method suggests. It is also worth noting that this hypothesis that higher amenity jobs are more desirable than lower amenity jobs distinguishes the frictions theory from the unobserved worker productivity heterogeneity explanation for more positive relationships between amenities and wages. In order for the latter to explain such a correlation between overall utility and amenity level, it would be necessary to posit a seemingly ad hoc correlation between unobserved ability and preferences for the amenity.

In the next section, I lay out the search framework that gives rise to equilibrium utility dispersion. In Section 3, I extend the model to allow for general firms types and prove the main result of the paper, the ordering of firm types. I also present some representative examples. Section 4 develops a more plausible model with a continuous distribution of firm types. Then Section 5 presents the implications of assuming that firms tend to earn equal expected profits across types, and Section 6 concludes with a brief discussion of possible next steps.

2 Search Framework

The following equilibrium search framework combines elements taken from (Hwang et al., 1998) and (Lang and Majumdar, 2004). Jobs are search goods for the workers, characterized by a wage w and a scalar amenity level x, interpreted here as a good. Firms post job offers specifying w and x, seeking to maximize their expected profit per worker contacted.[3] Workers search for jobs in an undi-

[3]Nothing about this analysis limits its applicability to labor markets. The extension to other hedonic markets is straightforward, with consumers analogous to workers and suppliers to employers. The key assumption is that suppliers fix the characteristics of their good ex ante, but may sell any quantity that the market bears. This is one of three cases discussed in (Rosen, 1974) and seems the most amenable to being modeled in an undirected, stationary search framework. It is important to understand the distinction between this case and that studied recently by (Heckman et al., 2007) in which each firm only demands one worker. In this framework, firms of different productivities can survive together in equilibrium, but all

rected way both when unemployed and on-the-job. Suppose there is an infinite number, a continuum, of both workers and firms.

The flow value for a worker of being employed at a job is given by $v(w, x)$, defining each worker's preferences over jobs. Assume v is $\mathbb{C}^2$ and strictly quasiconcave. The value of being unemployed is b. Workers search for job offers at an exogenous rate, and offers arrive at rate λ_U in unemployment or λ_E when employed. Jobs are lost at a constant rate δ.

To determine their optimal search behavior, workers need only know the distribution of job offer utilities, $F(v)$, which is assumed to be common knowledge. Hwang et al. (1998) show that the optimal job acceptance strategy[4] when unemployed in this setting is to accept all jobs with value greater than

$$v^* = b + (K_U - K_E) \int_{v^*}^{\overline{v}} \frac{1 - F(v)}{1 + K_E[1 - F(v)]} dv \tag{1}$$

where $K_U = \lambda_U/\delta$ and $K_E = \lambda_E/\delta$ should be interpreted roughly as indicating the competitiveness of the labor market, as they are inversely related to the magnitude of search frictions for unemployed and on-the-job search, respectively. For employed workers, the optimal job acceptance strategy is simply to accept any offer better than their current one.

Let U be the steady-state level of unemployment, and let $G(v)$ be the steady-state proportion of employed workers with jobs worth v or less. First, we will see that no firm has an incentive to offer a job with value less than v^* in equilibrium, so we simplify the exposition by taking $F(v^*) = 0$. Then the flow out of unemployment is simply $U\lambda_U$ and the flow into unemployment is $(1 - U)\delta$. Setting these equal, we find that in steady state

$$U = \frac{1}{1 + K_U} \tag{2}$$

Similarly, the flow of workers into jobs of value v or lower, $U\lambda_U F(v)$, and the flow of workers out of such jobs by on-the-job search and job loss is $G(v)(1 - U)(\lambda_E [1 - F(v)] + \delta)$. Thus in the steady state

$$G(v) = \frac{F(v)}{1 + K_E [1 - F(v)]}. \tag{3}$$

offer wages according to the equilibrium hedonic wage function–there is no wage dispersion with equally productive workers.

[4] I follow Hwang et al. (1998) in presenting the results of the model in which there is no discounting, or $r = 0$. Allowing for $r > 0$ is straightforward, but it makes the formulas somewhat more unweildy and does not affect the qualitative features of the model.

From the firms' perspective, both the probability that a randomly contacted worker will accept their job offer and the expected amount of time the worker will stay with them depend on the utility of the job they offer. The probability that a random worker will accept their offer of utility v is simply the proportion of workers that would prefer the job to their current state $U + (1 - U)G(v)$. Once a worker accepts the job, she will leave the job at rate: $\delta + \lambda [1 - F(v)]$ due either to an exogenous job separation or to finding a better job, so the expected duration of employment is the inverse. The product of the probability of a contacted worker accepting and the expected duration of employment tells us the expected duration of employment from contacting a worker:

$$\begin{aligned} m(v) &= \frac{U + (1-U)G(v)}{\delta + \lambda_E [1 - F(v)]} \\ &= \frac{1}{(1 + K_E [1 - F(v)])^2} \frac{1 + K_E}{1 + K_U} \end{aligned} \tag{4}$$

where the second expression follows from (2) and (3).[5] Intuitively, $m'(v) > 0$ reflects the firms' incentives to offer higher utility jobs, and the dependence of $m(v)$ upon $F(v)$ shows how the equilibrium job offer distribution shapes these incentives.

Firms each have a production technology that is constant returns to scale in the labor input, with revenue product per worker given by $\phi_j(x)$, decreasing in x, with j indexing the firm type. Assume ϕ is $\mathbb{C}^2$ with $\phi''_{xx} < 0$. Then, the expected profit of a firm of type j is the product of the flow profit $\phi_j(x) - w$ and the expected duration of employment resulting from a worker contact:

$$\pi_j = [\phi_j(x) - w]\, m(v(w, x)). \tag{5}$$

The firm's problem may be decomposed into two parts: (1) choose v, and (2) choose w and x to maximize profit per worker given v. First consider the latter. Let

$$\begin{aligned} \widetilde{\pi}_j(v) = \quad & \max\nolimits_{w,x} \ \phi_j(x) - w \\ & \text{s.t. } v(w,x) = v \end{aligned} \tag{6}$$

[5] This presentation of the firm's problem is adapted from Section 2.2 of (Mortensen, 2003).

Thus we see that the firm will choose (w, x) so that

$$\phi_j'(x) = -\frac{v_x(w,x)}{v_w(w,x)}. \tag{7}$$

That is, the firm chooses the amenity level x so that the marginal revenue product of x is equal to the marginal rate of substitution of the worker. The assumptions on v and ϕ are sufficient to guarantee the existence of a unique solution for a given v. Thus $\widetilde{\pi}_j(v)$ is the maximum flow profit a firm can make from employing a worker at value v. That is, $\pi_j = \widetilde{\pi}_j(v)\cdot m(v)$. Notice $\widetilde{\pi}_j'(v) < 0$ reflects the firms incentives to lower costs by offering lower utility.

Now the unique equilibrium offer distribution $F(v)$ may be derived in the following way. First, it must satisfy the following conditions, proven in (Hwang et al., 1998):

(a) No positive mass of firms offers the same job value v.

(b) There are no gaps in the support of the job value distribution $F(v)$.

(c) The lowest offered job bundle has value $v = v^*$.

If any of these were not true, there would be an opportunity for a firm to increase profit per worker by a discrete jump with little or no cost. If (a) were not true, one of the firms in the positive mass at v could increase the value of their offer slightly for a discrete jump in $m(v)$. If (b) or (c) were not true, offering a lower-valued bundle in the gap would increase $\widetilde{\pi}_j(v)$ while maintaining the same relative position in the offer distribution, that is, with the same offer acceptance probability and average employment duration, the same m.

Now consider the case in which firms are homogeneous. In order for these identical firms to make different offers in equilibrium, each must make equal profit. Thus, we can derive the offer distribution from the condition that profits from a job of value v must equal the profit from offering $\underline{v} = v^*$:

$$\begin{aligned}
\widetilde{\pi}(v)m(v) &= \widetilde{\pi}(v^*)m(v^*) \\
\widetilde{\pi}(v)\frac{(1+K_E)/(1+K_U)}{(1+K_E\left[1-F(v)\right])^2} &= \widetilde{\pi}(v^*)\frac{(1+K_E)/(1+K_U)}{(1+K_E\left[1-F(v^*)\right])^2}
\end{aligned}$$

Since $F(v^*) = 0$, we have

$$F(v) = \frac{1+K_E}{K_E} - \frac{1+K_E}{K_E}\left(\frac{\widetilde{\pi}(v)}{\widetilde{\pi}(v^*)}\right)^{\frac{1}{2}} \tag{8}$$

And the highest job value $\overline{v}$ is determined by $F(\overline{v}) = 1$, which yields:

$$\widetilde{\pi}(\overline{v}) = \frac{1}{(1 + K_E)^2}\widetilde{\pi}(v^*) \tag{9}$$

An example of the relationship between wages and amenity levels that results can be seen in Figure 1a. As Lang and Majumdar (2004) argue will typically be the case for homogeneous firms, wages and amenities are positively related. The example is described in more detail in the following section.

3 Discrete Firm Types

Suppose there are n types of firm, characterized by $\phi_j(v)$, $j = 1, \ldots, n$, and let γ_j denote the proportion of firms of type j or lower. A reasonable single crossing condition, defined with respect to the given $v(w, x)$ specification of workers' preferences, will facilitate our solution:

$$\frac{\widetilde{\pi}_i'(v)}{\widetilde{\pi}_i(v)} < \frac{\widetilde{\pi}_j'(v)}{\widetilde{\pi}_j(v)} \quad \forall\, i < j,\, \forall\, v \tag{10}$$

This says that for firms of higher type j, the proportional, or percentage, decrease in their profit per worker from increasing the worker's utility v is everywhere higher (or less negative) than for lower type firms. In other words, lower type firms increase their profit by a greater percentage than higher type firms by decreasing the utility given to the worker. The ordering depends on a combination of the firms' productivity in producing the output good and their marginal cost of providing the job amenity for the worker, but it is misleading to think of the ordering as ranking them according to a composite productivity measure. Instead, the ordering of types describes their relative incentives to offer high utility jobs and attract workers more easily versus offering lower utility jobs and increasing the profit flow, as I will now show formally.

The following is a generalization of a proposition in (Hwang et al., 1998) that allows a complete characterization of the steady state equilibrium for general firm heterogeneity characterized by (10):

Proposition 1

Higher type firms offer jobs of at least as much utility as lower type firms. That is, for $i < j$, if v_i and v_j are the values of jobs offered by firms of types i and j, respectively, then $v_i \leq v_j$.

Proof. First, notice that

$$\int_{v_i}^{v_j} \frac{\widetilde{\pi}'(v)}{\widetilde{\pi}(v)} dv = \ln \frac{\widetilde{\pi}(v_j)}{\widetilde{\pi}(v_i)}, \tag{11}$$

which, along with the condition (10), implies that

$$v_i \leq v_j \Leftrightarrow \frac{\widetilde{\pi}_i(v_j)}{\widetilde{\pi}_i(v_i)} \leq \frac{\widetilde{\pi}_j(v_j)}{\widetilde{\pi}_j(v_i)} \tag{12}$$

Now, if a firm of type i chooses to offer value v, it must be that

$$\widetilde{\pi}_i(v_i) \cdot m(v_i) \quad \geq \quad \widetilde{\pi}_i(v_j) \cdot m(v_j) \tag{13}$$

so we have

$$\frac{\widetilde{\pi}_i(v_j)}{\widetilde{\pi}_i(v_i)} \leq \frac{m(v_i)}{m(v_j)} \tag{14}$$

Likewise

$$\frac{m(v_i)}{m(v_j)} \leq \frac{\widetilde{\pi}_j(v_j)}{\widetilde{\pi}_j(v_i)} \tag{15}$$

Thus

$$\frac{\widetilde{\pi}_i(v_j)}{\widetilde{\pi}_i(v_i)} \leq \frac{\widetilde{\pi}_j(v_j)}{\widetilde{\pi}_j(v_i)} \tag{16}$$

But then by (12), we must have $v_i \leq v_j$. □

Thus higher types will always offer higher utility jobs in equilibrium because they have less to lose from doing so. In other words, lower types have more to gain from offering lower utility jobs.

This proposition, along with conditions (a)-(c) above, implies the following distribution of wage offers. Assume that all types are capable of making positive profit, that is, that $\widetilde{\pi}_j(v^*) \geq 0$ for all j. Then the firms in each type j will offer jobs of value $v \in [\underline{v}_j, \overline{v}_j]$, with $\underline{v}_1 = v^*$, and $\overline{v}_j = \underline{v}_{j+1}$ for all $j < n$. These intervals and the distribution of offers can be determined in the following way.

We derive the distribution of offers by firms of type $j = 1$ in the same way as we did for the case of all homogeneous firms. The profits from a job offer of value $v \in [\underline{v}_1, \overline{v}_1]$ must be equal to the profit from offering $\underline{v}_1 = v^*$:

$$\widetilde{\pi}_1(v)m(v) \quad = \quad \widetilde{\pi}_1(v^*)m(v^*)$$

So we have

$$F(v) = \frac{1+K_E}{K_E} - \frac{1+K_E}{K_E}\left(\frac{\widetilde{\pi}_1(v)}{\widetilde{\pi}_1(v^*)}\right)^{\frac{1}{2}} \tag{17}$$

for $v \in [\underline{v}_1, \overline{v}_1]$. And the highest job value $\overline{v}_1$ is determined by $F(\overline{v}_1) = \gamma_1$, which yields:

$$\widetilde{\pi}_1(\overline{v}_1) = \frac{(1+K_E(1-\gamma_1))^2}{(1+K_E)^2}\widetilde{\pi}_1(v^*) \tag{18}$$

Since we have $\underline{v}_j = \overline{v}_{j-1}$, we can repeat this argument for $j = 2, \ldots, n$ and find that for $v \in [\underline{v}_j, \overline{v}_j]$,

$$F(v) = \frac{1+K_E}{K_E} - \frac{1+K_E(1-\gamma_{j-1})}{K_E}\left(\frac{\widetilde{\pi}_j(v)}{\widetilde{\pi}_j(\underline{v}_j)}\right)^{\frac{1}{2}} \tag{19}$$

so that $\overline{v}_j$ is determined by

$$\widetilde{\pi}_j(\overline{v}_j) = \frac{(1+K_E(1-\gamma_j))^2}{(1+K_E(1-\gamma_{j-1}))^2}\widetilde{\pi}_j(\underline{v}_j) \tag{20}$$

Finally, then, we have a complete expression for $F(v)$ in terms of v^* which we can put together with (1) to find an expression for v^* in terms of model parameters only, for which it can be shown that a unique solution exists. In general, the resulting expression must be solved numerically, but since we are interested here in the potential wage-amenity distributions that can result from this model, we will simply take v^* as given, with the understanding that it is determined by b, K_U, K_E, and the distribution of firm technologies. It is particularly helpful to note that b and K_U *only* affect the wage-amenity distribution through their influence on v^*. Thus the shape of the wage-amenity distribution depends only on the resulting v^*, along with K_E, the firms' technologies, and the workers' preferences. Further, it can be seen that K_E has little effect on the shape of the wage-amenity relationship, as determined by $F(v)$, but instead the main impact of K_E, in addition to affecting v^*, is on the distribution of workers in steady state within the utility dispersion $G(v)$.[6]

[6]This explanation is intended to correct the misleading diagrams in (Hwang et al., 1998) that mean to show how the K parameters affect the shape of the resulting wage-amenity distribution, but do not explain that the K parameters only matter for the most part in how they affect the difference between v^* and $\overline{v}$.

3.1 Illustrative Examples

As an example, specify worker preferences by $v(w,x) = wx^\alpha$ and firm technology by $\phi_j(x) = \rho_j - \frac{\sigma_j}{2}x^2$, with some $\{(\rho_1,\sigma_1),\ldots,(\rho_n,\sigma_n)\}$. Roughly speaking, types with higher ρ have higher productivity in producing the outside good and types with lower σ have lower costs (higher productivity) in producing the job amenity and will tend to offer more of it. Then (7) says that each firm will offer some wage-amenity pair that satisfies $w = \frac{\sigma_j}{\alpha}x^2$ depending on its type j, and we have $\widetilde{\pi}_j(v) = \rho_j - \left(1+\frac{\alpha}{2}\right)\left(\frac{\sigma_j}{\alpha}\right)^{\frac{\alpha}{\alpha+2}} v^{\frac{2}{\alpha+2}}$. It can be shown that the single crossing condition (10) is satisfied for a given α if

$$\frac{\rho_i}{\sigma_i^{\frac{\alpha}{\alpha+2}}} < \frac{\rho_j}{\sigma_j^{\frac{\alpha}{\alpha+2}}} \quad \forall\, i<j$$

Figure 1 shows samples of the equilibrium wage-amenity distribution for different distributions of firm heterogeneity. For comparison, $\alpha = 2$, $v^* = 0.7$, and $K_E = 15$ are held constant in all four cases, and the firm technologies are chosen so that the highest utility offered by any firm is also roughly the same ($\overline{v} = 1$) across cases. Thus, the utility dispersion $F(v)$ is roughly the same in each, highlighting the effects of different distributions of firm heterogeneity.

Figure 1a is a case with just one type of firm, $\rho = 2\sqrt{2}$ and $\sigma = 2$. All firms have identical technology, and they all offer wage-amenity pairs with $w = \frac{2}{2}x^2 = x^2$ in a certain range. They all receive the same profits on average, with the low-v firms enjoying higher profit flows from worker but finding it more costly to find and keep workers, while the high-v firms have lower profit flows from workers but have an easy time hiring and lower turnover. Notice that the workers' marginal rate of substitution, what we refer to as the marginal willingness to pay for the amenity (MWP), is given by

$$MWP = \frac{v_x}{v_w} = \frac{\alpha w}{x} = 2x$$

so it is roughly in the range of 1.8 (at the lowest utility jobs) to 2.0(at the highest). In a standard hedonic wage regression, the MWP would be estimated as the negative of the slope of the hedonic wage function. If that method were naively applied to this example, a negative estimate of around -2 would be the result, exactly the negative of the true MWP. However, it is not too surprising to find that the MWP could not be identified in this case if we had data on the wage-amenity pairs only. (Recall $w = \frac{\sigma}{\alpha}x^2$ so that all we could identify is

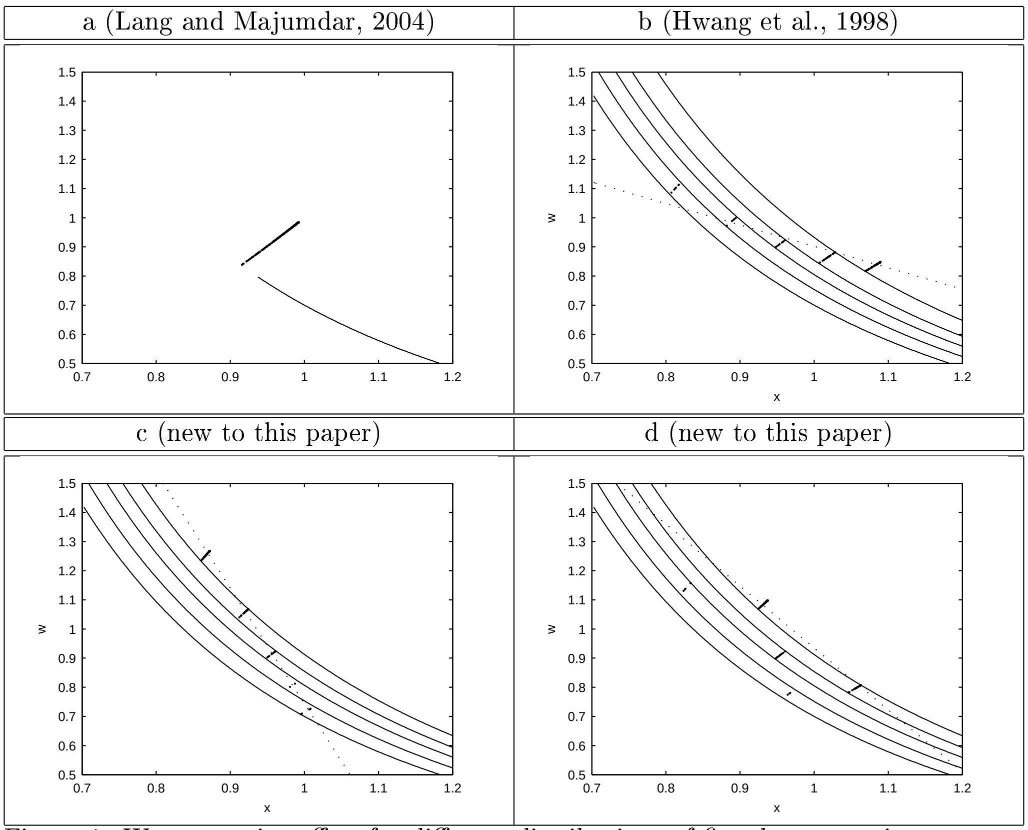

Figure 1: Wage-amenity offers for different distributions of firm heterogeneity. The curved lines are indifference curves. The other marks are wage-amenity pairs characterizing a sample of 200 jobs in steady-state equilibrium. The dotted line in (b-d) is a best-fit line through the wage-amenity pairs, such as would be used to estimate a linear specification of a hedonic wage model.
a) Homogeneous firms with $\rho = 2\sqrt{2}$ and $\sigma = 2$.
b) $\{(\rho_j, \sigma_j)\} = \{(2.4, 10/3), (2.1, 10/4), (1.9, 2), (1.8, 10/6), (1.7, 10/7)\}$.
c) $\{(\rho_j, \sigma_j)\} = \{(1.57, 10/7), (1.72, 10/6), (1.9, 2), (2.17, 10/4), (2.54, 10/3)\}$
d) $\{(\rho_j, \sigma_j)\} = \{(1.69, 10/6), (2.43, 10/3), (1.9, 2), (1.864, 10/7), (2.20, 10/4)\}$

$\frac{\sigma}{\alpha}$.) This is because this case is analogous to a perfect information hedonic wage model in which there is only one data point, at the particular (w, x) pair where the homogenous workers and firms all locate.

This is an example of the homogeneous firms case thoroughly examined by Lang and Majumdar (2004), who show that if the amenity is a normal good as it is for the Cobb-Douglass preferences here, the relationship between wages and amenity will be positive.

It is worth noting that a wage-amenity relationship similar to that displayed in Figure 1a could also result from a situation with heterogenous firms but little variation in their cost of producing the amenity σ relative to the magnitude of the utility dispersion (i.e. $\overline{v} - v^*$). In all such cases, a naive hedonic wage regression will result in a MWP estimate of the wrong sign.

Figure 1b is an example of the special case of firm heterogeneity explored by Hwang et al. (1998). Here, the firm types that have lower marginal cost of providing the amenity, σ_j, and thus offer higher levels of x are the "higher types" that offer higher valued jobs than the firms that provide lower levels of x.[7] So instead of tracing out one of the workers' indifference curves as would be expected in the perfect information hedonic wage model without utility dispersion, the relationship between x and w traced out has a systematically more positive slope than the indifference curves. This effect can be so severe that the overall relationship between wages and amenity is a positive one, but for a different reason than in Figure 1a.

Figure 1c is the opposite case, in which the firms that are less efficient at providing x have higher productivity per worker ρ so that they are the firms offering the highest value jobs. And we see that, for this example, the relationship traced out between x and w has a systematically more negative slope than the indifference curves. Ex ante, it is unclear why this should be any more or less likely than the case in Figure 1b.

Figure 1d is perhaps a more typical case, in which there is no systematic ordering of the types according to their marginal cost of providing the amenity. While far from tracing out the shape of an indifference curve, it is ambiguous whether the average slope of the relationship between x and w is higher or lower

[7] The firm types in (Hwang et al., 1998) always have this property because they only consider heterogeneity in σ. All firms share the same ρ so the ones with lower σ are necessarily the higher types. This leads them to the unambiguous conclusion that estimates of willingness to pay by the traditional hedonic wage model will always be biased downward by the presence of producer heterogeneity. However, this assumption that firms will only differ in σ is a departure from previous hedonic wage literature, and they do not offer a justification for it. They do not acknowledge that this is a special case.

than the slope of the indifference curves. This example gives some idea of the full range of distributions of wages and amenities that is possible.

3.2 Job Durations Approach to Estimating Preferences

Given that the observed wage-amenity relationship need not be tangent to the workers' indifference curves, the traditional hedonic wage approach has little hope of accurately estimating workers' MWP for an amenity. Using job durations, however, the workers' preferences are identified in this model, and the various cases in Figure 1 can be distinguished in the data.

Gronberg and Reed (1994) were the first to propose an alternative method of estimating MWP based on the durations of job spells that they claim can correctly estimate worker preferences when the observed wage-amenity pairs are generated by an equilibrium search model such as the model described above. In this model, the hazard rate for ending a job spell is a function of $v(w, x)$:

$$h(v(w,x)) = \delta + \lambda_E \left[1 - F(v(w,x))\right] \tag{21}$$

Thus

$$\frac{\partial h}{\partial x} = \lambda_E \frac{\partial[-F(v)]}{\partial v} \frac{\partial v}{\partial x} \tag{22}$$

and

$$\frac{\partial h}{\partial w} = \lambda_E \frac{\partial[-F(v)]}{\partial v} \frac{\partial v}{\partial w} \tag{23}$$

so that we have

$$\frac{\frac{\partial h}{\partial x}}{\frac{\partial h}{\partial w}} = \frac{\frac{\partial v}{\partial x}}{\frac{\partial v}{\partial w}} = MWP. \tag{24}$$

In other words, the hazard rate is simply a monotonic transformation of the workers' utility function. Jobs with equal hazard rates trace out the workers' indifference curves. Identification thus depends only on which jobs are observed.

4 Continuous Firm Types

Instead of a finite number of firm types, assume there is a joint distribution of firm types $H(\epsilon, \sigma)$, each with technology given by $\phi(x; \epsilon, \sigma)$. Suppose the unconditional distribution $H(\epsilon)$ is continuous. For given preferences $v(w, x)$, assume ϵ is a sufficient statistic for

$$\frac{\widetilde{\pi}'_v(v;\epsilon,\sigma)}{\widetilde{\pi}(v;\epsilon,\sigma)} = \psi(v;\epsilon). \tag{25}$$

The equivalent of our discrete type single crossing condition (10) is

$$\psi'_\epsilon(v;\epsilon) > 0 \quad \forall\, \epsilon, v \tag{26}$$

For a given value v, then, assume that σ alone determines the firm's choice of the amenity level x, so that we can implicitly define $x(v,\sigma)$ without reference to ϵ.

Notice that since there is not a positive mass of any one ϵ type of firm, it must be that each ϵ type maps to one unique choice of v.[8] The following derivation of this mapping is an adaptation of Burdett and Mortensen (1998). Consider the profit maximization problem of an individual firm, which takes $m(v)$ as given.

$$\max_v\ \widetilde{\pi}(v|\epsilon,\sigma)m(v) \tag{27}$$

The first order necessary condition is

$$\widetilde{\pi}'_v(v|\epsilon,\sigma)m(v) + \widetilde{\pi}(v|\epsilon,\sigma)m'(v) = 0 \tag{28}$$

or

$$-\frac{m'(v)}{m(v)} = \frac{\widetilde{\pi}'_v(v;\epsilon,\sigma)}{\widetilde{\pi}(v;\epsilon,\sigma)} = \psi(v,\epsilon) \tag{29}$$

which verifies that a firm's choice of v depends on ϵ and not σ. A second order sufficiency condition is

$$\widetilde{\pi}''_{vv}(v|\epsilon,\sigma)m(v) + 2\widetilde{\pi}'_v(v|\epsilon,\sigma)m'(v) + \widetilde{\pi}(v|\epsilon,\sigma)m''(v) < 0 \tag{30}$$

Now, notice that for $v = u(\epsilon)$, $F(u(\epsilon)) = H(\epsilon)$ in this setting. Then, from (4), we can write

$$m(u(\epsilon)) = \left(\frac{1+K_E}{\left(1+K_E\left[1-H\left(\epsilon\right)\right]\right)^2}\right)(\eta-\mu) \tag{31}$$

[8]This is because Proposition 1 requires $F(v)$ to be continuous and positive on its support, so if a single ϵ mapped to a v interval of positive measure, that would require there to be a positive mass of type ϵ firms, which we are assuming is not the case.

Now, equations (28) and (31) yield the following differential equation for $u(\epsilon)$:

$$u'(\epsilon) = -\frac{1}{\psi(u,\epsilon)} \frac{2K_E h(\epsilon)}{1 + K_E(1 - H(\epsilon))}$$

The boundary condition, as in the discrete type case, is $u(\underline{\epsilon}) = v^*$, assuming that $\widetilde{\pi}(v^*|\epsilon,\sigma) \geq 0$ for all ϵ in the support of $h(\epsilon)$.

It can then be shown, as in (Burdett and Mortensen, 1998), that the second order condition (30) is indeed satisfied on the relevant support. Note also that it can be shown formally that higher ϵ types will offer the higher utility jobs. If (30) holds, then by the Implicit Function Theorem, (28) allows us to define $u(\epsilon) = v$, that is, the optimal choice of v as a function of ϵ. Moreover, we have

$$u'(\epsilon) = -\frac{\widetilde{\pi}''_{v\epsilon}(v|\epsilon,\sigma)m(v) + \widetilde{\pi}'_v(v|\epsilon,\sigma)m'(v)}{\widetilde{\pi}''_{vv}(v|\epsilon,\sigma)m(v) + 2\widetilde{\pi}'_v(v|\epsilon,\sigma)m'(v) + \widetilde{\pi}(v|\epsilon,\sigma)m''(v)}$$

so we see $u'(\epsilon) > 0$ since we assume the denominator is less than zero, and we know the numerator is greater than zero by our assumption stated in (26).

Thus is the distribution of the utility dispersion determined. Given $u(\epsilon)$, the actual distribution of wage-amenity pairs in equilibrium in determined by $H(\sigma|\epsilon)$. A change of variables will make it possible to thus derive the joint distribution of w and x.

4.1 Example

Take $v(w,x) = wx^2$ (i.e. $\alpha = 2$) and firm technology given by by $\phi_j(x) = \epsilon\sqrt{\sigma} - \frac{\sigma}{2}x^2$ (i.e. $\epsilon = \frac{\rho}{\sqrt{\sigma}}$ in the notation of the discrete type examples). Then we have

$$\widetilde{\pi}(v|\epsilon,\sigma) = \sqrt{\sigma}(\epsilon - \sqrt{2v}). \tag{32}$$

Suppose ϵ and σ are independently distributed, with $H(\epsilon) \sim U([1,2])$ and $H(\sigma) \sim U([1.5, 2.5])$. In particular, notice $F(u(\epsilon)) = H(\epsilon) = \epsilon - 1$, for $\epsilon \in [1,2]$. Then the first order condition (29), after substituting (31) and some cancellations, yields:

$$\frac{-\frac{\sqrt{2\sigma}}{2}u(\epsilon)^{-\frac{1}{2}}}{\epsilon\sqrt{\sigma} - \sqrt{2\sigma u(\epsilon)}} = -\frac{2K_E \frac{1}{u'(\epsilon)}}{1 + K_E(1 - (\epsilon - 1))}$$

or, after some rearranging:

$$u'(\epsilon) = \frac{2\sqrt{2}\epsilon u^{\frac{1}{2}} - 4u}{\frac{1}{K_E} + 2 - \epsilon}$$

Fortunately, this has the form of a Bernoulli Equation, which has an exact solution. If we assume $v* = \frac{1}{2}$ and thus $u(1) = \frac{1}{2}$, then we get

$$u(\epsilon) = \frac{1}{2}\left(\frac{(\frac{1}{K_E}+2-\epsilon)^2}{(\frac{1}{K_E}+2)(\frac{1}{K_E}+1)} + \frac{\epsilon^2}{\frac{1}{K_E}+2}\right)$$

Using a change of variables, this expression along with the distributions of ϵ and σ could be used to find an expression for the joint distribution of w and x in equilibrium.

4.2 Discussion

Although the differential equation complicates things somewhat, the continuous type formulation appears to have the potential to be much more intuitive and clean to work with. Instead of discrete intervals scattered around the wage-amenity space, as in Figure 1, the equilibrium in the continuous type model is a continuous density of jobs over wage-amenity space, which is a more sensible model and potentially more amenible to estimation. This gives a still clearer picture of the full range of wage-amenity distributions that can result, depending primarily on the distributions of firm technologies that give rise to them.

As an aside, the smooth properties of this model allow us to consider more cleanly what happens in the model as frictions ($\frac{1}{K_E}$ and $\frac{1}{K_U}$) go to zero. The offer distribution $F(v)$ changes very little as frictions go to zero. What does change and, in fact, converges to a perfect information "one price" outcome is the observed distribution of jobs as expressed by $G(v)$. In the limit as frictions go to zero, only the very highest types (say, with equal ϵ but a range of σ values) will have a positive number of workers in equilibrium, as can be seen in (3). Thus the wage-amenity distribution as frictions go to zero converges to the indifference curve corresponding to zero profit for the highest types, which is the same as the equilibrium outcome in the traditional hedonic wage model.

5 Imposing Equal Profits on Firms: A Baseline

The discussion in Section 3 and briefly in the previous section of the various ways that utility dispersion in job offers can alter the observed wage-amenity relationship from that expected in the perfect information model begs the question of which configuration is most likely, if any.

As a baseline case, let us consider the implications of imposing equal profits among firms in equilibrium. Without explicitly modelling it, we can imagine a free entry explanation of why this would tend to be the case. For instance, suppose an economy is made up of various industries, each characterized by a different σ determining their marginal costs of providing the job amenity. The revenue productivity of each industry, and thus its ϵ in the notation of the previous section, depends negatively on the number of firms entering the industry. Now, firms would choose to enter in the industry, or σ type, that would yield the highest expected profit, lowering the profit of that type somewhat by their entry. This free entry process would continue until all σ types yield equal profits.

This entry argument is just a sketch, and there may even be reasons to believe, in some cases, that jobs that offer higher amenities will tend to yield more or less expected profit to firms.[9] However, it is still helpful to see the implications of imposing equal profits, as this will illuminate as well the implications of expected profits instead being correlated with amenity level.

Before presenting the general case, consider a simple example: two types of firm, with amenities exogenously given: $x_L = 1$ and $x_H = 2$, with worker preferences given by $v(w, x) = wx$. Then we have

$$\begin{aligned} \widetilde{\pi}_j(v) &= \rho_j - \frac{v}{x_j} \\ &= \frac{\epsilon_j - v}{x_j} \end{aligned} \tag{33}$$

where it can be shown that the type with the larger $\epsilon_j = \rho_j x_j$ will be the one offering higher utility jobs, according to Proposition 1. The question at hand is which type will have the higher ϵ_j if both received equal expected profits in equilibrium.

Recall from Section 3 that with discrete types, the lower type will offer jobs in a utility range from the reservation utility v^* up to some maximum utility $\overline{v}_1$, all of which will yield equal expected profit to the firms of that type in equilibrium. The higher type will offer jobs in an adjacent utility range starting at $\overline{v}_1$ and again earn equal expected profit in that range. Notice that both types offer jobs with utility $\overline{v}_1$ and thus face the same $m(\overline{v}_1)$ for those jobs. If their

[9] For example, larger training costs or other fixed costs for certain types of jobs may necessitate higher expected profits from the worker to compensate for them. If higher fixed costs are associated with higher or lower amenity jobs, we may expect to see those jobs tend to yield higher expected (variable) profits.

expected profits are equal then, it must be that $\widetilde{\pi}_L(\overline{v}_1)$ and $\widetilde{\pi}_H(\overline{v}_1)$ are equal. But setting these equal yields:

$$\epsilon_L - \overline{v}_1 = \frac{\epsilon_H - \overline{v}_1}{2} \tag{34}$$

If both types are offering jobs in equilibrium, then we must have $\epsilon_j > \overline{v}_1$ for both. Thus we have $\epsilon_L < \epsilon_H$ and we see that imposing equal profits means that the higher amenity type offers higher utility jobs in equilibrium.

Briefly, we can see that if ρ_H were increased so that ϵ_H were larger than the equal profit level, the higher amenity jobs would continue to be the higher utility jobs, even higher in fact. On the other hand, if ϵ_H were below the equal profit level given by (34) but still higher than ϵ_L, the higher amenity jobs would continue to be higher utility although now the type H firms would be receiving less expected profit than the type L firms. If ϵ_H were decreased still further to less than ϵ_L, that is, if ρ_H were less than $\rho_L/2$, then the lower amenity jobs would be the higher utility jobs. In this case, by again comparing the expressions for $\widetilde{\pi}_L(\overline{v}_1)$ and $\widetilde{\pi}_H(\overline{v}_1)$, we can see that the expected profits of the higher amenity firms would need to be less than half that of the lower amenity firms. In summary, the high amenity jobs will be the higher utility jobs unless the higher amenity firms earn substantially less profit than the low amenity firms.

Now consider the general case to see that this somewhat surprising result is not limited to this example.

Proposition 2

Assume preferences such that the amenity is a normal good. Consider two types of firms such that at any utility level v, type L would offer less of the amenity x than type H due to higher marginal costs of providing it. These may be two discrete types amidst others or even points along a continuum of types as in Section 4. Assume that both types of firm earn the same expected profits in equilibrium at whichever utility levels they choose to offer (labeled as v_L and v_H accordingly):

$$\widetilde{\pi}_L(v_L)m(v_L) = \widetilde{\pi}_H(v_H)m(v_H) \tag{35}$$

Finally, assume the two types are ordered according to (10) so that one of the types necessarily offers jobs of higher utility than the other type.

Type L offering less of amenity must be the lower type, offering lower utility jobs than type H.

Proof. Recall the firm's problem (6) of choosing w and x to provide a given utility level v to the worker. We see from the envelope theorem that

$$\widetilde{\pi}_j'(v) \quad = \quad -1/v_w(w,x). \tag{36}$$

It is a property of x being a normal good that along an indifference curve of utility v, the marginal utility of w increases with increasing x.[10] (See the Appendix for a proof.) Since firm L would provide less amenity x than H if both were offering utility v, $v_w(w,x)$ is less for the utility v jobs offered by firm L, so that (36) implies

$$\widetilde{\pi}_L'(v) < \widetilde{\pi}_H'(v) \quad \forall\, v \tag{37}$$

Now, from profit maximization, we know $\widetilde{\pi}_L(v_L)m(v_L) \geq \widetilde{\pi}_L(v_H)m(v_H)$. But if we substitute for the LHS using the equal profits condition (35), we find $\widetilde{\pi}_L(v_H) \leq \widetilde{\pi}_H(v_H)$. But combine this with (37) for v_H and we have:

$$\frac{\widetilde{\pi}_L'(v_H)}{\widetilde{\pi}_L(v_H)} < \frac{\widetilde{\pi}_H'(v_H)}{\widetilde{\pi}_H(v_H)}$$

That is, by Proposition 1, it must be that type L is the lower type and offers lower utility jobs than type H. □

The result depends critically on the assumption that the amenity is a normal good for the workers. If the amenity is an inferior good, the opposite is true: if the firm types earn equal profits, the lower amenity jobs will be the higher utility jobs (i.e. case (c) in Figure 1). If the workers' preferences are quasilinear, so

[10] It may seem that since we would typically assume that w (standing in for consumption) is also a normal good, there should be a symmetric argument showing the opposite result. Indeed, it is the case that $v_x(w,x)$ is decreasing along an indifference curve as x increases, so the marginal utility of x is greater for firm L when offering the same utility v as firm H. However, whereas all firms share the same unitary marginal cost of providing wages, firms differ in their costs of providing the amenity. Indeed, this is the reason firms offer different levels of the amenity at all. Recalling equation (7) , we see that $\phi'(x)/v_x(w,x) = -1/v_w(w,x)$ since optimizing firms equalize the marginal costs of providing utility by the two avenues of wages and amenities. So although low amenity firms could increase worker utility at a greater rate by increasing x, their marginal costs of increasing x are even higher and their overall marginal cost of increasing utility is therefore higher than that of firms offering more amenity at the same utility v.

that the amenity is neither normal nor inferior, all firm types would earn equal profits by all offering the same utility.

Returning to the normal good case, what is the intuition behind the above result? The decision of which utility each firm offers depends on balancing the benefit of increasing $m(v)$ and the cost of decreasing $\widetilde{\pi}(v)$ by increasing v. All firms face the same marginal benefit $m'(v)$ but those offering less of the amenity face a larger marginal cost $\widetilde{\pi}'(v)$ at each utility level v. This means that firms with higher marginal costs of providing the amenity will optimize by choosing to offer lower utility jobs than the lower cost (higher amenity) firms.

6 Conclusion

I have illuminated the full range of possible wage-amenity distributions that can result from wage dispersion in a general equilibrium search framework with homogeneous workers, correcting some mistaken implicit assumptions in the existing literature. This is important in itself because search frictions and wage dispersion are increasingly understood as important in the labor market, and the compensating wage differential is a fundamental concept in labor economics. In addition, my conjecture that firms tend to earn equal expected profits is the first attempt to explain why higher amenity jobs would tend to be higher utility jobs in equilibrium, an idea that has so far been taken for granted in the literature without justification.

Existing empirical work using the job durations method is consistent with the idea that higher amenity jobs tend to more desirable to workers, as it indicates that workers' true MWP for a job amenity is larger than the slope of the observed relationship between wages and amenities. However, the measures they report do not indicate whether or not my conjecture of equal expected profits is in fact the case, and further work is needed on the job durations method in general.

I am in the process of acquiring data to undertake a new empirical analysis. One option I am looking into is using a British data set for a more in depth study of shift work, building on the suggestive results reported in (Manning, 2003). Using a binary amenity would simplify the analysis considerably, and I believe I could structurally estimate a continuous type model and directly investigate my equal expected profits conjecture. Another option is to study the statistical value of a life. My data would likely have less than ideal measures of risk to life because of the need for job durations information, but perhaps I could nevertheless show that the potential source of bias due to utility dispersion and firm heterogeneity is relevant to this important literature.

Appendix: Property of Normal Goods

Assume the worker has wealth M and can purchase the amenity at price p: $px + w = M$. The worker's problem can be written as

$$\max_x \ v(M - px, x)$$

with F.O.C.

$$v'_w(M - px, x) \cdot (-p) + v'_x(M - px, x) = 0$$

By the implicit function theorem, we have

$$\frac{dx}{dM} = -\frac{-pv''_{ww} + v''_{wx}}{p^2 v''_{ww} - 2pv''_{wx} + v''_{xx}}$$

where the denominator must be negative due to the second order condition. Thus, if x is a normal good and $\frac{dx}{dM} > 0$, it must be that

$$(-\frac{v'_x}{v'_w})v''_{ww} + v''_{wx} > 0.$$

Finally, define $w(x)$ as the wage that gives utility v for any amenity level x. We want to show that $v_w(w(x), x)$ increases as x increases. But the total derivative with respect to x is just the above expression that we said must be positive if the good x is normal. (Notice $w'(x) = -v'_x(w(x), x)/v'_w(w(x), x)$, the marginal rate of substitution.)

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