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Abstract

We develop a model of monopsonistic wage competition with heterogenous worker ability and intra-firm production complementarities. We use this to illustrate the conditions under which: (i) the divergence between wages and productivity is an equilibrium phenomena; and (ii) this divergence is increasing in worker ability. While the first result is well-known, the second is new. It derives from the intra-firm externalities that, it has sometimes been argued, justify a firm's existence. We show how the model can be used to explain a number of empirical regularities that have hitherto been viewed as puzzles. We then confirm the empirical relevance of our model using new establishment-level data.

Keywords: Heterogeneous workers, hierarchical assignment models, monopsonistic competition, wage compression, intra-firm externalities.

JEL Classification: J24, J31, J42.

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1 Introduction

Empirical evidence shows that firms set wages rising less than one-for-one with observable differences in workers' marginal products. For example Campbell and Kamlani (1997) conducted a survey of 184 US firms and found that pay differentials represented about one half of the productivity differential between any two workers identical in all respects but productivity. Empirical evidence also shows that firms obtain a greater surplus from their more productive workers. Frank (1984b) examined wages and productivities of sales workers and university professors, and found that the more productive workers were paid less than their marginal product, while the least productive were paid more than their marginal product.

A full explanation of these stylized facts requires clarification as to why firms pay more productive workers less per unit of their output. This paper puts forward an hypothesis that is consistent with the stylized facts. Briefly, we argue that employers of productive workers have greater market power viz-a-viz their employees than employers of lower ability workers. Not all employers can provide the management, colleagues and collective ability that is required for the performance of complex tasks performed by many skilled workers. But those firms that are able to provide such an environment are able to extract a greater share of the employment surplus from skilled workers.

Our paper develops a model of wage determination in a frictional labor market with intra-firm production complementarities. We use this to illustrate the conditions under which: (i) there is a divergence between wages and productivity; and (ii) this divergence is increasing in worker ability or skills. While the first result is well-known, the second is new. It derives from the intra-firm externalities that, it has sometimes been argued, justify a firm's existence. We show how the model can be used to explain a number of empirical regularities that have hitherto been viewed as puzzles and then compare our model's implications against establishment-level survey data.

The remainder of the paper is set out as follows. In Section 2 we provide a brief literature review and highlight some empirical puzzles in the labor literature. In Section 3 we lay out our benchmark model of monopsonistic competition, in which all workers have the same abilities and are equally productive when working in different establishments. Workers differ only in their preferences for firm-specific non-wage attributes, which give firms an element of monopsony power in wage setting. In Section 4 we expand the model and allow for firm heterogeneity in terms of productivity. This gives rise to an equilibrium wage distribution, and some workers are attracted to the better firms in spite of their preferences for other firm attributes such as location. In Section 5, we then allow for different abilities across workers as well as differences in firm productivity. This generates our main results on wage compression within firms, and the answer to some of the empirical questions posed earlier. Finally, we report results of a survey of companies, where our hypothesis is tested against some of the alternatives.

2 Reasons for Wage Compression

Opinions differ about the benefits of equilibrium wage dispersion. On the one hand, a small literature shows how wage dispersion can raise productivity by providing incentives to workers. On the other hand, another literature explains why wage dispersion may be detrimental to effort and productivity. As an example of the former, tournament theory demonstrates how the intra-firml wage distribution can be used to motivate workers (see Lazear and Rosen, 1981). Workers are judged on the basis of relative performance and rewarded with occasional promotions. Effort is increasing in the level of wage dispersion. Calvo and Wellisz (1979) show that, if shirking at the top is more expensive than at the bottom because when a manager shirks all his subordinates also shirk, the manager needs to be paid more. In contrast, Lazear (1989) shows why managers can decide to compress intra-firm wages to create harmony among workers. Salary compression reduces uncooperative behavior and hence some wage compression within relevant reference groups may be efficient. It follows that wages should be more compressed in firms with overly competitive employees and also in firms that use teamwork extensively (see also Pencavel, 1977). A similar argument is put forward by Milgrom and Roberts (1990). They argue that wage inequalities may give rise to rent-seeking behaviour within firms when workers change their behaviour with the aim of ensuring wage increases. Efficiency wage models such as Akerlof and Yellen (1990) give yet another reason for the optimality of a compressed wage distribution. They argue that workers' effort depends on a comparison of actual wages and perceived fair wages. When workers are paid less than what they see as being fair, their effort will suffer to the detriment of the employer. Other reasons for wage compression can be added. For example, investment in firm-specific human capital will compress the wage distribution because workers are not paid the full value of their marginal product. Alternatively, it may be too costly to measure individual differences in productivity in order to have them reflected in wages.

Other authors argue that institutions affect the pay structure. Freeman (1982) shows that unionized firms appear to have less wage dispersion than non-unionized ones. Acemoglu and Pischke (1999) catalogue some of the effects of a compressed wage distribution that arises from institutional factors.[1] Hartog and Teulings (1998) describe the role of norms and contracts in affecting the

[1] By making firms pay the least skilled workers a higher wage than what would have otherwise been agreed on -

distribution of the surplus generated in employment contracts within the corporatist setting.

In two related papers, Frank (1984a and 1984b) shows how wage compression within firms can be an equilibrium phenomenon if workers differ in their preferences for relative standing or prestige. Workers who put the highest value on prestige will then be willing to work for a wage that is lower than their marginal product in return for having lower-level workers around who in return are paid more than their marginal product. He finds support for his theory in the case of salespeople and university professors (high-wage individuals are paid less than their marginal product and vice versa for the low-wage individuals). However, he concludes that the level of wage compression among professors in his sample is too great to be explained by considerations of status alone and suggests that production complementarities may provide part of the answer (Frank, 1984, p. 564). This is what we aim to model in this paper.

Our theory of wage compression differs from those above in that it does not depend on the existence of institutions nor does it depend on any incentive effects or concern about relative position. Our view of the firm resembles that of Alchian and Demsetz (1972), who view the firm as a centralized agent in team production. Firms exist because they facilitate cooperation between workers who can collectively perform tasks in teams that they could not do individually. Firm management then has the role of monitoring to prevent shirking, learning about the ability of each individual, matching them into teams in an optimal way, and measuring their individual contribution to output, i.e. measuring – however imperfectly – marginal product.[2]

We introduce heterogeneity into this framework. We assume that each firm enjoys certain "locational benefits" by offering workers a unique set of non-wage attributes. It is for this reason that firms can pay workers a wage below marginal product. The difference between marginal product and wages will then depend on the distance between firms. The greater the distance, the greater are the locational benefits enjoyed by each firm and the higher are profits per employed worker.[3] We will show that the distance between two potential employers of high-productivity workers is likely to be greater than for the low-productivity ones. In fact, some very skilled individuals may face only a handful of potential employers. This makes the gap between marginal product and wages increasing in worker productivity, and thus wages become compressed.

wage compression - institutions may make them invest in new technologies, as well as providing training to the least skilled, without this affecting the lowest wages. Booth and Zoega (2004) clarify the distinction between "absolute wage compression" and "relative wage compression".

[2] Acemoglu (1996) develops a model with social increasing returns to education. Increasing returns in his model are inter-firm and the externalities are pecuniary, arising from the interaction of costly bilateral search and ex ante skills investment. While we also find increasing returns to human capital and ability, our externalities are intra-firm and are technological rather than pecuniary.

[3] Thus distance is a metaphor for heterogeneity in nonwage attributes. The more "distant" is one firm from another, the more different are its nonwage characteristics, as will be further explained below.

3 Heterogeneous Preferences

We assume that firms differ in the nonpecuniary attributes of the jobs they offer, such as geographical location or other nonwage job characteristics. We also suppose, following Salop (1970), that there are R firms equally spaced around a circle of circumference C such that the distance between two adjacent firms in job characteristics space is C/R. Following Bhaskar and To (1999) and Hamilton, Thisse and Zenou (2000), we assume a simple labor market friction: that workers are characterized by heterogeneous preferences x for the nonwage job characteristics x_j offered by each firm.[4] The more distant are the j-th firm's job characteristics x_j $(j = 1, ..., R)$ from the worker's preferred characteristics x, the larger is the worker's disutility cost (denoted by $|x - x_j|$) associated with employment at firm j.

Suppose firm j is the representative firm. We follow Salop (1979), Bhaskar and To (1999) and Hamilton, Thisse and Zenou (2000) in assuming that the variable x is distributed continuously and uniformly on a circle of length C. Suppose that firms' nonwage job characteristics are equally spaced around the circumference, such that C/R is the distance between two adjacent firms in job-characteristics space. The density is given by a constant D and consequently a thick market is associated with a high value of D while a thin market is associated with a low value. Hence D is capturing the number of workers of each preference type.

The jth firm has an effective pool of labor whose outer boundary in job-characteristic space is the threshold between this firm's job characteristics x_j and the two adjacent firms $x_{j+1}$and x_{j-1}. Some workers in these two sub-segments (those closest to the jth firm and further from the thresholds) are going to be more satisfied than workers whose preferences are closer to the thresholds between pairs of firms. Wages are set to satisfy these marginal workers at the thresholds.

The R firms simultaneously choose their wage levels. The net wage a worker receives is thus $w_j - |x - x_j|$, that is the sum of the monetary and non-monetary compensation. To find the labor pool for firm j, we first establish the upper and lower bounds for that firm in job-characteristic space, represented by $\overline{x}$ and $\underline{x}$ respectively. Workers will choose to work at the firm giving them the highest wage net of their disutility associated with working at that firm. First we consider the lower bound for the jth firm. Given the wages w_{j-1} and w_j set by the two adjacent firms, the marginal worker at x will be indifferent between working at firm j and firm $j - 1$. Thus we find $\underline{x}$ by solving the following;

[4] Bhaskar and To (1999) cite various empirical studies supporting the assumption that workers have heterogenous preferences for nonwage job characteristics. Bhaskar, Manning and To (2002) note that this assumption can usefully summarize the variety of reasons for imperfect competition in the labor market.

$$w_j - (x_j - \underline{x}) = w_{j-1} - (\underline{x} - x_{j-1}) \tag{1}$$

which yields

$$\underline{x} = \frac{w_{j-1} - w_j + (x_j + x_{j-1})}{2}. \tag{2}$$

Similarly, the upper bound for the jth firm $\overline{x}$ solves:

$$w_{j+1} - (x_{j+1} - \overline{x}) = w_j - (\overline{x} - x_j) \tag{3}$$

which yields

$$\overline{x} = \frac{w_j - w_{j+1} + (x_{j+1} + x_j)}{2}. \tag{4}$$

Firm j sets wages by maximizing profits P_j, written as:

$$P_j = \int_{\underline{x}}^{\overline{x}} D\left(y - w_j\right) dx = D\left(y - w_j\right)\left(\overline{x} - \underline{x}\right) \tag{5}$$

where wages at the jth firm are denoted by w_j and y is output per worker. This brings us to our first proposition:

Proposition 1 *The smaller is the number of firms R, the larger is the gap between wages and productivity.*

Proof:

The first-order condition of (5) yields the following equation:[5]

$$D\left(y - w_j\right) = D\left(\overline{x} - \underline{x}\right) \tag{6}$$

The term on the left-side shows the marginal benefit of raising wages due to a larger workforce. The term on the right-hand side gives the marginal cost of raising wages, which consists of higher wage payments to all workers. Using equations (2) and (4), and after some manipulation, we obtain the following:

[5] The second order condition holds, $\frac{d}{dw_j}\left(\frac{d\pi_j}{dw_j}\right) < 0$.

$$(y - w_j) = \frac{[(x_{j+1} - x_{j-1}) - (w_{j+1} + w_{j-1}) + 2w_j]}{2} \quad (7)$$

We know that firms are located symmetrically around the circle of nonwage job-characteristic space, such that the distance between firms is given by C/R. Consequently $x_{j+1} - x_{j-1} = 2C/R$. In symmetric equilibrium with $w_j = w_{j+1} = w_{j-1}$ we can now simplify the equation above to obtain:

$$w_j^* = y - \frac{C}{R} \quad (8)$$

Notice in (8) that as $R \to \infty$, $w_j^* \to y$. This is the wage scenario for a perfectly competitive labor market. However, as $R \to 1$, $w_j^* \to y - C$.[6] ■

The intuition behind this result, analogous to that of Bhaskar and To (1999), is as follows: When there is a lot of heterogeneity in nonwage job characteristics for a given number of firms (C is large), each firm is faced with many workers who prefer its nonwage job characteristics to those of other firms. This makes the cost of raising wages high because by offering higher wages – aimed at attracting new recruits whose preferences do not match the jobs being offered as well – firms will have to pay higher wages to many workers who would have stayed with them anyway. However, if there are very many firms (R is large), then not many workers would settle for any given firm in the absence of wage incentives. This reduces the marginal cost of offering higher wages. It follows that, as the number of firms R increases, the marginal cost of raising wages falls, which makes the wage level rise towards marginal productivity as the number of firms approaches infinity.

Notice that labor supply n to firm j is given by

$$n = D\left(\overline{x} - \underline{x}\right) = D\left[w_j - \frac{1}{2}\left(w_{j+1} + w_{j-1}\right) + \frac{C}{R}\right] \quad (9)$$

and is increasing in the firm's own wage, in contrast to the perfectly competitive case where the labor supply is infinitely elastic.[7] Moreover, the labor supply is a positive function of the density D and the heterogeneity of workers' preferences C and a negative function of the number of firms competing for the workers R. The more workers there are of each preference type D, and the more heterogeneous are workers in their preferences, the greater the number of workers who want to join a particular firm. However, taking the density and the heterogeneity as given, a greater number of firms implies that fewer workers will apply to any single firm. In symmetric equilibrium we have

[6] To ensure $w_j^* > 0$, we impose the restriction that $y > C$.

[7] There is a small empirical literature estimating the elasticity of the labor demand curve faced by individual firms. These support our model's prediction that employers each face an upward sloping labor supply curve (see Barth and Dale-Olsen, 1999; Manning, 2003: Chapter 4).

$$n = D\left(\overline{x} - \underline{x}\right) = D\frac{C}{R} \tag{10}$$

Labor supply now only depends on the thickness of the market D, the heterogeneity of preferences C, and the number of firms R in this case. We next relax the symmetric equilibrium assumption and explore the consequences of greater firm heterogeneity.

4 Good Firms and Bad Firms

We next assume that some firms are better than others for all workers – independent of job attributes – in that the productivity of a worker with given innate abilities h depends on the cooperation of colleagues and the quality of the management team.[8] Workers cooperate more effectively in some firms because they make better teams, face superior incentive structures or are better managed. We let the continuous variable F_j denote the intra-firm productive externalities within firm j and assume that for the set of R firm the variable F_j has a distribution $g\left(F_j\right)$. The production function that shows the productivity of a given worker within firm j is the following:

$$y_j = hF_j^a \tag{11}$$

where h is the same for all workers. The equation implies, for a given level of F, constant returns to individual ability. The importance of the intra-firm spillovers is captured by the parameter a. The higher is a, the more important is the quality of the cooperation between workers as opposed to individual abilities. And in the special case of $a = 0$, output depends only on individual abilities.

Each of the R firms sets wages as before to maximize profits:

$$P_j = \int_{\underline{x}}^{\overline{x}} D\left[hF_j^a - \overline{w}_j h\right] dx = Dh\left[F_j^a - \overline{w}_j\right]\left(\overline{x} - \underline{x}\right) \tag{12}$$

where $\overline{w}_j$ now denotes the wage per unit of human capital so that wages per worker w_j are defined as $w_j = \overline{w}_j h$.

The first-order-conditions of profit maximization follow for a given level of firm productivity F_j:

$$Dh\left[F_j^a - \overline{w}_j\right] = Dh\left(\overline{x} - \underline{x}\right) \tag{13}$$

[8] We know of only two studies estimating intra-firm externalities, and both of these focus on returns to education. Battu, Belfield and Sloane (2003) use linked employer-employee British data to show that that are indeed intra-firm social returns to education that exceed individual returns. And Belfield, Battu and Sloane (2004) find a similar result for service workers.

The left-hand side shows the marginal benefit of raising wages as before and the right-hand side the marginal cost. Rearranging gives,

$$\overline{w}_j = F_j^a + \frac{1}{2}\left[(\overline{w}_{j+1} + \overline{w}_{j-1}) - 2\overline{w}_j\right] - \frac{C}{R} \tag{14}$$

Wages at firm j are influenced by three factors. The first is the level of within-firm productivity F_j, the second factor is wages at neighboring firms, $\overline{w}_{j+1}$and $\overline{w}_{j-1}$, and the third is the distance between firms C/R. Wages are increasing in the firm's productivity and in wages at other firms and decreasing in the distance between firms. It follows that wages are also dependent on wages at all other firms since $\overline{w}_{j+2}$ influences $\overline{w}_{j+1}$ and $\overline{w}_{j-2}$ influences $\overline{w}_{j-1}$ and so forth.[9]

This extension of the model with firm heterogeneity is consistent with several observations about labor markets. First, as shown by Krueger and Summers (1988), there are significant wage differences across firms and industries. Second, workers who move between industries experience wage changes comparable to the wage differentials that exist between industries (see also Gibbons and Katz, 1992). Krueger and Summers (1988) argue that these observations are compatible with efficiency wage models and not with a competitive model of the labor market. Our model - in which firms have an element of market or monopsony power because of workers' heterogeneous preferences and differences in productivities - is also consistent with these observations. But it is not an efficiency wage model. There is also the observation that high-wage industries have higher average levels of human capital, higher profits and more capital per worker. In the following section we explicitly incorporate the average level of human capital into our analysis.

5 Different Abilities and Wage Compression

We now turn to the "black box" F_j^a that measures the j-th firm's productivity. We assume that $a > 0$; that is, firm productivity matters for individual output. We explain differences in firm productivity by postulating intra-firm production externalities, whereby each worker benefits from having good management and compatible high-ability colleagues. Thus firms exist because they facilitate cooperation between workers, who collectively perform tasks in teams that they could not do individually. In this we follow Alchian and Demsetz (1972) and Acemoglu (1996), amongst others.[10]

[9] In the special case when output of a worker depends only on his abilities and is not dependent on the environment, that is $a = 0$, equation (14) becomes: $\overline{w}_j = 1 - \frac{C}{R}$.

[10] Although Acemoglu (1996) models inter-firm *pecuniary* externalities, he argues that the purely technological view of how human capital externalities affect the economy should take into account *intra*-firm rather than inter-firm externalities. Thus the "problem for the purely technological view is that, excluding education and R&D, major

We make this assumption explicit by supposing that these factors determine the number of tasks K – from the simplest to the most complicated – that can be performed at the j-th firm. In particular, we propose that the firm's ability to perform different tasks depends on the average ability level $\overline{H}_j$ doing all tasks within that firm. Thus we assume that production externalities, morale, the quality of teamwork, and the quality of management are all related to this variable. This can be expressed as:

$$K\left(\overline{H}_j\right), \quad K'\left(\overline{H}_j\right) > 0. \tag{15}$$

Due to the Central Limit Theorem, the economy-wide distribution of average ability $\overline{H}_j$ at each firm has a normal distribution $\phi_{\mu,\ \sigma^2}$ independently of the distribution of individual abilities. The expected number of firms that can perform $k\left(\overline{H}_j\right)$ tasks is then given by

$$\left\lfloor \left(1 - \int_{-\infty}^{\overline{H}_j} \phi_{\mu,\sigma^2}\left(\overline{H}_j\right) d\overline{H}\right) R \right\rfloor = R_{K\left(\overline{H}_j\right)} \tag{16}$$

where $\lfloor\rfloor$ denotes the *floor function* – defined as the function that gives the largest integer less than or equal to its element – of one minus the cumulative distribution function. Using this function is necessary to prevent the number of firms taking a non-integer value.[11] It follows that R_K is declining in $K\left(\overline{H}_j\right)$ since the right tail of the distribution is decreasing in $\overline{H}_j$.

5.1 Technology

The production function for the j-th firm takes the following form:

$$Y_j = A \prod_{k=1}^{K\left(\overline{H}_j\right)} H_k^{\alpha_k}, \qquad \alpha_m > \alpha_n \text{ for } m > n \tag{17}$$

where H_k is total human capital devoted to task k (summed over all workers doing the task) and A is a measure of overall productivity. Average ability determines the number of tasks that can be performed, as described above. The more advanced tasks have a higher elasticity of output with respect to ability devoted to the task as measured by the exponents α_m.[12] Moreover, the elasticity

human capital interactions happen among employees within a firm: for example, young workers learn from their more experienced colleagues. But these interactions should be internalized within the firm, and no economywide human capital externalities should be observed." This intra-firm interaction is precisely what we are modeling in our analysis.

[11] To take an example, when 15% of firms have average ability that is higher than that of firm H_j $(\bar{H}_j)$ and R=10, the floor function gives $\lfloor 0.15 \cdot 10 \rfloor = 1$.

[12] That the alphas are rising in task complexity means that people doing these tasks are more productive than the ones doing the simple tasks. (An x% increase in h of a worker doing the advanced task does more to increase output than an x% increase in h of a worker doing a simple task – which seems a reasonable assumption.)

of the technical rate of substitution[13] implies that a given percentage fall in inputs going into an advanced task m has to be met by a larger percentage increase in the inputs into a less advanced task n in order to keep output Y_j unchanged. It is in this sense that the more advanced tasks are more productive for the firm.

As an illustration, suppose that the j-th firm performs two tasks; $K\left(\overline{H}_j\right) = 2$. We then obtain:

$$Y_j = AH_1^{\alpha_1} H_2^{\alpha_2} \tag{18}$$

This can be written, for the special case $H_1 = H_2$, as $Y_j = AH^{\alpha_1+\alpha_2}$. This equals HA in the special case $\alpha_1 + \alpha_2 = 1$, which is the production function (11) of the previous section with $F = A$ and $a = 1$. We can also write an equation for output coming from one task as:

$$y_{j\kappa} = H_\kappa^{\alpha_k} A \prod_{k \neq \kappa}^{K\left(\overline{H}_j\right)} H_k^{\alpha_k} \tag{19}$$

which is identical to equation (11) if $\alpha_\kappa = 1$. Here $A \prod_{k \neq \kappa}^{K\left(\overline{H}_j\right)} H_k^{\alpha_k} = F_j^a$ so that the productivity of workers doing task κ is increasing in the total number of tasks being performed within the firm, i.e. increasing in the average ability of the workforce.

5.2 Wage Setting

Firms set wages for each task in order to maximize profits. Marginal productivity of a unit of human capital doing task κ is,

$$y_\kappa\left(H_\kappa, \cdot\right) = \alpha_\kappa A H_\kappa^{\alpha_\kappa - 1} \prod_{k \neq \kappa} H_k^{\alpha_k} - w_{j\kappa} \tag{20}$$

Profits from doing task κ are defined as,

$$P_{j\kappa} = \int_{\underline{x}}^{\overline{x}} D\overline{h}_\kappa \left[y_\kappa - \overline{w}_{j\kappa}\right] dx = D\overline{h}_\kappa \left[y_\kappa - \overline{w}_{j\kappa}\right]\left(\overline{x} - \underline{x}\right) \tag{21}$$

where $\overline{h}_\kappa$ denotes the average level of human capital per worker doing the task and $\overline{w}_{j\kappa}$ denotes wages per unit of human capital doing this task as in previous section. The first-order-conditions of

[13] From equation (17) it follows that:

$$\frac{\frac{dY}{dH_m}}{\frac{dY}{dH_n}} = \frac{\alpha_n}{\alpha_m} < 1$$

The technical elasticity of substitution between H_n and H_m is less than one, i.e. it takes a larger percentage increase in inputs into a simple task to make up for a given percentage fall in inputs into an advanced task.

profit maximization follow:

$$D\overline{h}_{\kappa}\left[y_{\kappa}-\overline{w}_{j\kappa}\right]=D\overline{h}_{\kappa}\left(\overline{x}-\underline{x}\right) \tag{22}$$

The left-hand side shows the marginal benefit of raising the wage – in the form of the value of new recruits – while the right-hand side has the marginal costs – taking the form of higher wage payments to those who would have stayed anyway. This gives the following expression for the wage paid per unit of human capital allocated to task κ:

$$\overline{w}_{j\kappa}=y_{j\kappa}+\frac{1}{2}\left[\left(\overline{w}_{j+1,\kappa}+\overline{w}_{j-1,\kappa}\right)-2\overline{w}_{jk}\right]-\frac{C}{R_{\kappa}} \tag{23}$$

We can then write:

$$y_{j\kappa}-\overline{w}_{j\kappa}=\frac{C}{R_{\kappa}}-\frac{1}{2}\left[\left(\overline{w}_{j+1,\kappa}+\overline{w}_{j-1,\kappa}\right)-2\overline{w}_{jk}\right] \tag{24}$$

Since R_{κ} is decreasing in κ we find that $y_{\kappa}-\overline{w}_{\kappa}$ is increasing in κ. This is our second proposition:

Proposition 2 *The difference between productivity and wages is increasing in task complexity.*

For the $K=2$ and $H_1=H_2$ case, the equation becomes the following for the more advanced task:

$$\overline{w}_{j2}=\alpha_2 A-\frac{1}{2}\left[\left(\overline{w}_{j+1,2}+\overline{w}_{j-1,2}\right)-2\overline{w}_{j2}\right]-\frac{C}{R_2} \tag{25}$$

when $\alpha_1+\alpha_2=1$, which is analogous to equation (14) above in the case $a=1$.

Notice that wages are increasing in the number of tasks because of the Cobb-Douglas setup. By adding new tasks we get workers who lift the productivity of everyone, and we capture in a plausible way the intra-firm production externalities noted by Alchian and Demsetz (1972) and Acemoglu (1996) *inter alia*. That the alphas are rising in task complexity means that people doing these tasks are more productive than the ones doing the simple tasks.[14]

5.3 Task Assignment and Induction Training

Having established optimal wages for each task, we now turn to the optimal allocation of workers of different abilities across tasks, for a given optimally chosen wages. We make two assumptions to do

[14] Notice also that worker "scarcity" leads to higher wages ceteris paribus. If there are few workers of a given skill level compared to the number of firms, the value of C/R is low, which translates into high wages. This can be seen from equations (8) and (25).

with induction training for each worker. First, each worker is trained to do one task only. Second, training costs are increasing in task complexity. The j-th firm will only hire a worker as long as it profits from doing so and there may be workers of such low abilities that it is not in the interest of any firm to hire them. The following condition will hold for every worker trained to do task k:

$$(y_k - \overline{w}_{jk})\, h_i \geq c_k \tag{26}$$

where y_k is as defined above. The term on the left-hand side is the expected profits from employing worker i. Only if this condition holds does the firm allocate and train a worker for task k. Since the number of workers applying for jobs at the representative firm is given by supply – and the firm is willing to hire any worker as long as inequality (25) holds for at least one of the tasks – we are primarily interested in the allocation of workers across tasks. We will show that the best workers should be allocated to the most advanced tasks within the firm.

Assume that there is a worker with ability level h_j doing task r – the most sophisticated within firm r – and another doing the least advanced task – task 1 – with a higher ability level h_i; $h_i > h_j$. If the firm could, ex-post, relocate them at zero cost – that is recant its earlier decision and assign workers differently to the tasks – so that the latter would be trained to do task r and the former to do task 1, the expected benefit to the firm would be the following since total training costs would be unchanged:

$$[(y_r - \overline{w}_r) - (y_1 - \overline{w}_1)]\,(h_i - h_j) > 0 \tag{27}$$

which is positive if and only if

$$(y_r - \overline{w}_r) - (y_1 - \overline{w}_1) > 0 \tag{28}$$

that is if the firm benefits more from the employment of a worker doing the sophisticated task. We have shown this to be the case because of a greater degree of monopsony power for task r. It will then become clear that the best workers would be allocated to the most advanced task and the worst to the least advanced one.

Let us now take a look at the firm rank K – which performs all tasks of complexity K and below. The most exceptional workers will then be devoted to task K. It follows from equation (25) that the threshold ability level is:

$$h_i \geq \frac{c_K}{y_K - \overline{w}_K} \tag{29}$$

Because of the high degree of monopsony for task K, the firm benefits from allocating all of its workers to the task but this comes at a cost; the cost of training a worker to do task K is higher than the cost of training him to do any other task. Workers who do not meet the grade for task K may then be allocated to task $K-1$ as long as the following condition holds:

$$\frac{c_{K-1}}{y_{K-1} - \overline{w}_{K-1}} \leq h_i < \frac{c_K}{y_K - \overline{w}_K} \tag{30}$$

The inequality to the right says that worker i is not good enough for the most advanced task while the inequality on the left says that he is good enough for task $K-1$. Note that while the monopsony profit form task K is greater than that for task $K-1$, the cost of training the worker is lower. Importantly, a worker who is judged not to be sufficiently able for task K will only be trained to do task $K-1$ if lower training costs offset the effect of lower monopsony power. Finally, there will be some workers who are not even sufficiently good for task 1:

$$h_i < \frac{c_1}{y_1 - \overline{w}_1} \tag{31}$$

These workers will not be trained for any task within this firm – in spite of the low costs of training a worker to do the most basic task – and will be turned away. This yields our third proposition:

Proposition 3 *The highest ability workers should be allocated to the most advanced task and the worst to the least advanced one.*

In the sequential production-task models of Kremer (1992) and Sobel (1992), mistakes made doing the early tasks can be easily corrected – without destroying the output of any subsequent worker. However, mistakes made performing the finishing touches can ruin the work performed doing all earlier tasks. Hence they show that a firm should put the more skilled and reliable workers in charge of the final tasks. While our model is also directed at task complexity, it is in a different context, since our production process is not sequential. Almost any employee can make serious mistakes in our model. Nonetheless, we still find that the more able workers should be delegated to the more advanced tasks, because the firm then reaps maximum profits from the greater monopsony position associated with the more difficult tasks, as we show below. It is more profitable to be in a monopsony position *vis-a-vis* the more productive workers.

It follows that the more advanced is the relevant task, the higher are profits from performing the task within the firm: all firms can perform the simplest task, hence the level of competition is highest for this task. But as firms become better, they gain elements of monopsony power in the market for labor trained to do tasks that are only feasible within their ranks – labor that can only produce output in the company of the high-quality workers currently employed.

5.4 Wage Compression

According to Proposition 3 the better workers should always be assigned to the more advanced task. Since these workers have higher ability – they embody more units of innate human capital – they also have higher take-home wages $\overline{w}_k h_i$ on that count. But Proposition 2 tells us that monopsony profits increase as we move to more advanced tasks. It is easy to combine Propositions 2 and 3 to show that the wage distribution is compressed in our model. This yields Proposition 4.

Proposition 4 *Wage compression arises quite naturally in a model with heterogeneous workers: As we move from a less advanced to a more advanced task, the increase in output per worker is greater than the increase in take-home wages, i.e. there is wage compression. For a worker h_i doing task k and a lower ability worker h_j doing task $k-1$, it follows that:*

$$h_i y_k - h_j y_{k-1} > h_i w_k - h_j w_{k-1} \tag{32}$$

Proof:

This proposition is easily verified using our earlier equations. We know that

$$h_i \left(y_k - \overline{w}_k \right) > h_j \left(y_{k-1} - \overline{w}_{k-1} \right)$$

since according to Proposition 2

$$y_k - \overline{w}_k > y_{k-1} - \overline{w}_{k-1} \tag{33}$$

and $h_i > h_j$. This can then be rewritten as

$$h_i y_k - h_j y_{k-1} > h_i \overline{w}_k - h_j \overline{w}_{k-1} \tag{34}$$

which is our definition of wage compression.■

The results in Proposition 4 shows that wage compression arises quite naturally in a world of heterogeneous workers in the absence of any specific institutional arrangements.[15] Note that the compressed wage distribution arises through monopsonistic competition (as in the benchmark model of Section 3) augmented by the presence of intrafirm production externalities arising from differences in workers' abilities. The latter are interpreted as the externalities associated with team production.

Our model is consistent with the results of Teulings and Hartog (1998). They find, for a cross-section of industries in the United States and Canada, a positive correlation between wages and average observed human capital in the industry. They also find a positive correlation between wages and profits per worker. In addition to being consistent with these findings, our model explains the presence of wage differences across industries found by Krueger and Summers (1988) and Gibbons and Katz (1992). No other single model that relies on the incentive effects of the within-firm wage distribution, or on the role of institutions in compressing the wage distribution, accounts for all these observations.

5.5 Welfare

The question remains as to whether or not the allocation of labor across firms is optimal in equilibrium. Clearly, the employer's monopsony power creates a distortion in the allocation of labor across firms. Consider two firms that are adjacent on the attribute circle, j and $j+1$, one with a most advanced task being performed κ and the other performing no task ranked higher than $\kappa-1$. The first is better in that more tasks can be performed within its ranks due to a higher average level of ability among its workers. The bound between the two firms in the job-characteristics space is defined by the equation below;

$$\overline{w}_{j,\kappa} - (\overline{x} - x_j) = \overline{w}_{j+1,\kappa-1} - (x_{j+1} - \overline{x}) \tag{35}$$

which yields

$$\overline{x} = \frac{\overline{w}_{j,\kappa} - \overline{w}_{j+1,\kappa-1} + (x_{j+1} + x_j)}{2}. \tag{36}$$

Labor supply n_κ to task κ at firm j is given by

[15] Our equations do not preclude wages from falling as we move from a less advanced to a more advanced task. However, such an eventuality can be exluded by assuming that output is sufficiently rising in task complexity to prevent rising monopsony power from lowering wages.

$$n^p = D_\kappa \left(\overline{x} - \underline{x}\right) = D_\kappa \left[\overline{w}_{j,\kappa} - \frac{1}{2}\left(\overline{w}_{j+1,\kappa-1} + \overline{w}_{j-1}\right) + \frac{C}{R}\right] \tag{37}$$

where D_κ denotes the density of workers qualified to do both tasks κ and $\kappa - 1$, and where the superscript denotes "private" to distinguish the private firm's labor supply from the socially optimal labor supply denoted as n^s below.

The optimal bound between the two firms and the optimal supply of labor are, in contrast, given by the following two equations:

$$\overline{x} = \frac{y_{j,\kappa} - y_{j+1,\kappa-1} + \left(x_{j+1} + x_j\right)}{2}. \tag{38}$$

$$n^s = D_\kappa \left(\overline{x} - \underline{x}\right) = D_\kappa \left[y_{j,\kappa} - \frac{1}{2}\left(y_{j+1,\kappa-1} + y_{j-1}\right) + \frac{C}{R}\right] \tag{39}$$

where y_κ denotes marginal product as in equation (19). According to to Proposition 2 we have $y_\kappa - \overline{w}_\kappa > y_{\kappa-1} - \overline{w}_{\kappa-1}$ since $R_\kappa < R_{\kappa-1}$; wages are compressed. If we assume that firm $j-1$ is also only doing $\kappa - 1$ tasks we find that

$$n^s - n^p = D_\kappa \left[\left(y_{j,\kappa} - \overline{w}_{j,\kappa}\right) - \frac{1}{2}\left(y_{j+1,\kappa-1} - \overline{w}_{j+1,\kappa-1}\right) - \frac{1}{2}\left(y_{j-1,\kappa-1} - \overline{w}_{j-1,\kappa-1}\right)\right] \tag{40}$$

which can be written as

$$n^s - n^p = D_\kappa \left[\left(y_\kappa - \overline{w}_\kappa\right) - \left(y_{\kappa-1} - \overline{w}_{\kappa-1}\right)\right] > 0 \tag{41}$$

This implies that the good firm, which can perform all κ tasks, does not attract a sufficient number of workers. This is because there are workers who decide to stay closer to their preferred place on the job-attributes circle, and who settle for a less challenging task and lower wages due to the monopsony power of the best firm.

6 Firm Entry

Our model shows the possibility of monopsonistic wage-setting with a particular distribution of firms and with firm and worker heterogeneity, but it does not endogenize the existing distribution of firms. We simply assume that firms are heterogenous in their nonwage characteristics and then we show that firms who get a good draw of workers are more profitable.

The number of firms could be endogenized by allowing for entry at a cost. Expected profits from setting up a new firm equal the sum of profits from the expected number of taks performed, which is a function of the expected value of average human capital. From equation (21) we find that

$$E\left(P_j\right) = \sum_{k=1}^{K\left(E\left(\overline{H}_j\right)\right)} P_{jk} = \sum_{k=1}^{K\left(E\left(\overline{H}_j\right)\right)} D_k \overline{h}_k \left[y_k - \overline{w}_k\right] \left(\overline{x}_k - \underline{x}_k\right) \tag{42}$$

where D_k denotes the density of workers eligible for doing task k and $\overline{h}_k$ is the average human capital doing task k. Using equations (21)-(23) we find that – in symmetric equilibrium – this equals

$$E\left(P_j\right) = \sum_{k=1}^{K\left(E\left(\overline{H}_j\right)\right)} D_k \overline{h}_k \left(\frac{C}{R_k}\right)^2 \tag{43}$$

It is clear that expected profits are declining in the number of firms doing each task R_k for two reasons: First, the greater the number of firms, the higher is the wage per unit of human capital. Second, the greater the number of firms, the fewer workers would be willing to work for the entrant firm. Assuming a fixed cost θ of setting up a new firm gives a zero-net-expected-profits condition for the entry of new firms:

$$\sum_{k=1}^{K\left(E\left(\overline{H}_j\right)\right)} D_k \overline{h}_k \left(\frac{C}{R_k}\right)^2 - \theta = 0 \tag{44}$$

While this equation determines the number of firms in the market, $R = R_1$, it does not determine the number of firms performing each task. Clearly, ex-post some firms will have better human capital $\overline{H}_j$ and hence perform more tasks and earn profits in excess of starting costs θ while others will be less fortunate. However, in equilibrium expected profits from entry should equal the cost, as in the above equation.

Suppose – for the sake of argument – that there is only one firm in operation. In this case $E\left(P_j\right) > \theta$ because of low wages and because of opportunities for offering a different set of non-pecuniary benefits to workers. Also, there is no benefit from such a concentration as the number of tasks performed depends on average human capital, not total human capital, by assumption. Hence new firms enter until the expected profits from doing so is just equal to the cost θ.

Note that the equation above is likely to lead to an overestimate of the number of firms in the market, because of the following arguments about worker behaviour that are not captured in the equations above. Suppose a new firm considers entering the market, attracted by the monopsonistic profits being earned, $E(P_j) > \theta$. Suppose this new firm were to set up next door – in non-wage job characteristic space – to the very best existing firm, and then to ask existing employees to move next door. Clearly, half the workers employed at the good firm would prefer working for the new firm if all tasks could also be performed there, since its characteristics will be closer to their preferences. But on the other hand, the fracturing of the workforce would also affect the pay of all workers through changes to the intra-firm externalities. Indeed, there is, for existing workers, uncertainty associated with such a move. First, the quality of management in the new firm is unknown. Second, the quality of that half of the existing firms workers who would be willing to shift is also unknown, and may turn out to be worse than that already in existence.[16] Thus it is clear that endogenizing firm entry introduces into our model an extra layer of complexity. While we think this could be handled in a dynamic framework with at least two periods, it would introduce further complexity into a model that is already quite intricate and we leave this for future work.

7 Empirical Relevance

A prediction of our model is that firms gain more from employing able workers because of the proportionately larger oligopsony rents they collect. To see if there is any empirical evidence for this, we commissioned a survey of managers.[17]

The respondents, representing establishments with four or more employees, were asked two questions that are of direct relevance to our theory. The first question asked if more able workers are worth more to the firm and, if the respondent answered in the affirmative, the second asked why this might be the case. These questions are reproduced in full below.

- Question 1: "Do the more able employees generate (a) more profits; (b) the same level of profits; (c) lower profits; than other employees?"
- Question 2: "If you chose response (a) in your answer to question 1 above, do the more able employees get paid less relative to their productivity because (a) otherwise morale among the lower paid workers would be hurt; (b) because there are not many other establishments where

[16] Note that the uncertainty involved is smaller for low ability workers since they depend less on the average ability level within the firm.

[17] The representative survey was conducted by Gallup, Iceland. The initial sampling frame yielded 900 firms (independent, not branches of larger companies), of whom 147 were dropped as they employed fewer than 4 employees and 35 were either bankrupt or had stopped operating. This left a sample of 718 firms. These 718 firms were then contacted, of whom 236 refused to answer and 81 could not be reached. The survey thus yielded 401 usable responses. This represents a response rate of 56%. All of the firms are located in Iceland although some have operations abroad. Respondents were managing directors of the different firms. For a more detailed analysis, see Karlsson and Zoega (2005).

the better employees can use their talent to the same extent as with the current employee; (c) because other potential employers do not realize how good the better employees are; (d) for other reasons."

Table 1 reports the results of this survey. The first row gives the responses for all firms, and subsequent rows give responses disaggregated by measures of firm size and industrial grouping. Responses to Question 1 reveal that the majority of respondents say that able workers contribute more to profits, that is, they are paid less compared to their productivity than the less able workers. Question 2 asks those who stated that more able workers generate more profits about the reasons for this phenomenon. From the first row, we see that 57% (203) of firms responded that more able employees generate more profits than less able employees, while 40% (141 firms) believed they generated the same level of profits. Moving along the first row, note that 38% of firms who pay more able employees less relative to their productivity attribute this to a need to maintain morale among the less well paid - response (a). Some 14% attribute it instead to a lack of outside options, defined here as being where "there are not many other establishments where the better employees can use their talent to the same extent as with the current employee" - response (b).[18] Finally, 9.7% of managers claim that it is due to asymmetric information about worker ability that they can pay the able workers less than their marginal productivity; i.e. other firms do not poach them because they do not realize their true value - response (c). Thus there is support from response (b) for our model's predictions - that monopsonistic competition leads to wage compression - but on average the morale effect in response (a) dominates. Next we see what happens when we disaggregate the results further.

Panel A - giving the results broken down by turnover per annum - shows that firms with higher turnover were more likely than lower turnover firms to believe that more able employees generate more profits than less able employees. Thus Panel A suggests that profits from better workers are higher in firms with greater turnover, which we view as a proxy for task complexity. Moreover, higher turnover firms were also more likely than lower turnover firms to attribute this profitability from more able workers to a lack of outside options (19% of high turnover as compared to 9% low turnover firms).

[18] Not all firms responsed to Question 2, even where routed that way, and hence the numbers of firms responding to this question is less than the number of firms responding to Question 1(a).

Table 1. Survey results

	Question 1				Question 2				
	responses	options			responses	options			
		a	b	c		a	b	c	d
All firms	357	**56.9**	39.5	3.6	154	38.3	**13.6**	9.7	38.3
A. Turnover (Million kronur[19])									
0-49	30	**43**	50	7	11	18	**9**	27	45
50-99	58	**62**	38	0	29	41	**14**	0	45
100-199	67	**54**	40	6	28	39	**7**	11	43
200-499	77	**60**	35	5	34	53	**12**	9	26
>500	86	**62**	37	1	43	28	**19**	12	42
B. All Employees									
4-6	87	**45**	49	6	28	25	**7**	11	57
7-10	67	**58**	39	3	31	52	**3**	10	35
11-25	89	**55**	42	3	33	36	**21**	9	33
>25	114	**67**	31	3	62	39	**18**	10	34
C. Industry									
service	139	**58**	38	4	57	32	**9**	18	42
manufacturing	105	**58**	37	5	48	48	**21**	6	25
wholesale/retail	77	**49**	48	3	27	26	**4**	7	63
other	36	**67**	33	0	22	50	**23**	0	27

Panel B gives the results broken down by the number of employees. Larger firms were more likely to respond that more able employees generate more profits than less able employees (67% of firms with more than 25 employees as compared to 45% of firms with 4-6 employees). Thus profits from the better workers are higher in the larger firms. Firm size might be viewed as a proxy for task complexity and teamwork possibilities. Moreover, larger firms were also more likely than smaller firms to attribute this to a lack of outside options (18% of larger as compared to 7% of smaller firms).

Finally, Panel C gives the responses disaggregated by sector. It is clear that the wholesale and retail sector does not fit our model, a perhaps unsurprising result given that task complexity and

[19] On 17 May 2005, there were 65 Icelandic kronur to one US dollar.

teamwork are likely to be less important in this sector. However, in the other three industrial groupings, the majority of firms responded that more able employees generate more profits than less able employees. It is also striking that in both manufacturing and in the "other" industrial grouping that one fifth of firms attribute their opinion (that more able employees generate more profits than less able employees) to a lack of outside options. Notice that the moral hazard reason - that other firms do not poach employees because they do not realize their true value - appears to be a service sector phenomenon.

We also explored the data further by looking are responses to Question 2 for manufacturing firms only. The results indicate that our proposed explanation for wage compression – response (b) – receives more support among larger manufacturing firms. In fact, response (b) receives the same support as response (a) for firms with turnover in excess of 500 Million kronur and for firms with 11-25 employees.

In summary, our survey results indicate first, that the majority of managers believe that able workers contribute more to profits than less able workers; that is, they are paid less compared to their productivity than the less able workers. Second, the survey results suggest that the outside option explanation for wage compression is important in some sectors of the economy. In particular, it is more important in establishments with high financial turnover, in firms with at least 11 employees, and in manufacturing. While not a conclusive test of the model's predictions, these results certainly suggest that our theory has empirical relevance for at least some sectors of the economy.

8 Conclusions

We have shown how wage compression arises quite naturally in market economies with monopsonistic competition in the labor market and with heterogeneous workers and firms. This result follows from several intermediate results of our analysis:

- The number of tasks that can be performed within a firm depends on the average level of ability of workers within the firm. It follows that there are good firms where the most advanced tasks can be performed, as well as bad firms where only the more simple tasks can be done.

- The degree of firms' market or monopsony power is rising in task complexity.

- Firms allocate the best workers to the most sophisticated tasks. While more talented workers get paid more on the basis of their higher ability, they do not receive the full return to their talent owing to the monopsony power enjoyed by their employers.

We have argued that each of these results is plausible – as well as expected. Moreover, combining the three to generate microeconomic foundations for wage compression may turn out to be a useful result in understanding some puzzles in labor economics.

9 Appendix

The raw numbers from the survey are shown in the two tables below.

Table A1. Question 1

Responses	number	%	st. d.
more	203	56.9	5.1
equal	141	39.5	5.1
less	13	3.6	1.9
total	357	100	
responses	357	89	
no-responses	44	11	
Number surveyed	401	100	

Table A2. Question 2

Responses	number	%	st. d.
a	59	38.2	7.7
b	21	13.6	5.4
c	15	9.7	4.7
d	59	38.3	7.7
total	154	100	
responses	154	75.9	
no-responses	49	24.1	
Number surveyed	203	100	
Number surveyed	203	50.6	
Not surveyed	198	49.4	
Total	401	100	

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