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Frustration with free-riders in group work

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Abstract

Working in teams is an important aspect of working life. This paper studies how the frustration of working with people of different ability affects sorting in a perfectly competitive labor market. Mixed firms with both low- and high-ability types arise for low levels of frustration without screening. All firms make zero profit and all workers earn the same. For the other cases, namely screening for all levels of frustration and no screening for high levels of frustration, separate low- and high-ability firms arise. With screening, both abilities gain all surplus in wages and firms make no profits. In this case a screening inefficiency can arise, in which screening leads to lower total welfare compared to not screening. Without screening but with high levels of frustration, high-ability workers take a pay cut in order to prevent working with low-ability workers. Since a high-ability firm does not want to attract low-ability workers, high-ability firms cannot transfer all of its surplus to the high-ability workers through wages. Therefore, high-ability firms make profit.

1. Introduction

Teamwork is prevalent in firms and educational institutions all over the world and often seems to be considered as an effective way to achieve a certain goal. This is illustrated by Devine et al. (1999) who found that 48 percent of U.S. firms use teams. Working in teams could lead to a situation in which inefficiencies such as free-riding and moral hazard occur. In such a situation, one team member does not pull their weight compared to the others. This can occur, among others, when it is difficult to ascertain how much each individual team member contributed to a project (Holmstrom, 1982). Much has been written about solving or reducing the moral hazard and free-riding problems. Offered solutions include intergroup competition (Erev et al., 1993; Guillen et al., 2015), partial separation of ownership and labor (Holmstrom, 1982) and peer pressure (Kandel & Lazear, 1992).

This paper does consider moral hazard, but focuses on the propensity to free-ride. This differs per worker. This assumption is based on the empirical finding by Nagin et al. (2002). In their paper they found that when individuals are monitored less, they tend to exploit this through more opportunistic behavior. However, they also find that a large fraction of employees choose not to exploit the lower monitoring even when possible. In the model discussed below, the propensity to free-ride is given by the different contributions to team production. The two types of workers discussed in this paper, low-ability and high-ability workers, could therefore also be interpreted as those that are likely to free-ride and those that are not likely to free-ride.

In short, the model in this paper works as follows. A competitive labor market is explored in which firms can employ workers in teams of two. There are two types of workers; low-ability workers and high-ability workers. The individual output of each worker is exogenous and determined by their ability. Team output is determined by the composition of the team. Both types of workers get positive utility of working with high-ability workers, but high-ability workers get frustrated, modelled as a negative shock to utility, when working with low-ability workers.

Two different settings are considered. In all cases ability and preferences are private information. In the first setting screening is either not possible or always too expensive and is therefore not an option. In the second setting the firms are able to use screening costs in order to infer the ability of the worker with certainty.

First, consider the setting in which screening is not possible or too expensive. This paper shows that an equilibrium exists in which workers self-select into a firm of their own type without screening. This is a separating equilibrium as this results in no firms in which both abilities are employed, but only low-ability and high-ability firms. This occurs when the frustration resulting from a high-ability type working with a low-ability type is sufficiently high. If this is the case, the firm cannot transfer all of its surplus to its workers through contracts without also attracting the low types. Therefore, firms with high-ability workers make profit, while firms with low-ability workers make no profit. This is an interesting result, as a perfectly competitive labor market often does not lead to profit for firms. However, high-ability workers experience a lot of frustration of working with low types and therefore their utility of working in a high-ability firm with low wages is higher compared to the utility in a mixed firm with intermediate wages. The firm cannot transfer all surplus that it gets from the production of high-ability teams to the high-ability workers as those wages would also attract low-ability workers. Therefore, high-ability firms do not transfer all surplus, but offer a wage that attracts only high-ability workers and no low-ability workers. Since the firms do not transfer all surplus to its workers, a profit margin remains.

If the frustration is low, separation is not possible, as the pay cut required to keep low-ability workers out of the firm hurts the utility of the high-ability workers more than the frustration of working with a low-ability. Therefore a pooling equilibrium exists in which all workers work in mixed firms. Both low-ability and high-ability workers get the same contract which transfers all surplus from the firm to the workers, resulting in zero profits for the firm.

Second, consider the setting in which there is the possibility of screening. If screening is possible, both the pooling and the separating equilibrium discussed above are split. For a low enough value of the screening cost, firms choose to screen and offer different contracts to high-ability and low-ability workers, which get all surplus from the firm. All firms make zero profits. If the cost of screening is relatively high, then the firms will not choose to invest in screening. Contracts and profits are the same as in the scenario without screening.

It is also shown in the second setting that screening in a perfectly competitive labor market can lead to inefficiencies. With screening there is a trade-off of inefficiencies for low values of frustration. This trade-off is between the productive inefficiency, the loss in production of mixed firms instead of separated firms, and the screening inefficiency, caused by the screening cost. Which inefficiency dominates determines whether screening is the most efficient option. It is shown that in a perfectly competitive market there is more screening for low levels of frustration than would be optimal when maximizing welfare. For high values of the frustration screening is always inefficient as it redistributes surplus from the firm to the high-ability workers, which does not affect total welfare, but does bring an inefficiency by introducing screening costs. Thus, screening for high values of frustration does not contribute to total welfare but only generates a cost.

Key for the results in this paper is the assumption that high-ability workers get frustrated when working with low-ability workers which free-ride. Evidence of this can be found in Hall and Buzwell (2012) who surveyed students and found that frustration arose when other students did less than expected or delivered work of poor quality. Moreover, Aggarwal and O'Brien (2008) found that if the free-rider is not held accountable this can lead to frustration towards group projects and the individual that free-rides, making the group work less enjoyable. Johnson and Horn (2019) also conducted research on free-riding in student work groups and noted that free-riding happens often in group projects and that it is a cause of frustration. The results in the papers above were all derived from students working in group projects. Fehr and Gätcher (2000) conducted an experiment and found that free-riders are punished by their other team members even if there is no private benefit for the other team members. This constitutes to the belief that a free-riding worker creates negative emotions for other workers, which induces the other workers to punish the free-rider even if there is no benefit for themselves. The observation that free-riding leads to frustration is also supported by Monzani et al. (2014). They conducted an experiment on real-life workgroups and virtual workgroups. If team members thought that others were free-riding it negatively affected the satisfaction and emotions of the other group members in both the real-life and the virtual workgroups. Also, Felps et al. (2006) state that if a worker negatively affects either the personal well-being or group performance this leads to frustration for the other workers.

These results can account for a number of empirical findings. Dunne et al. (2004) find that within the same industry, low- and high-skilled firms exist between which productivity differences are found. Similar to their paper it is seen in this paper that an equilibrium exists for certain values of frustration or screening costs in which there are no mixed firms but only low- and high-skilled firms. Also, Huang and Cappelli (2010) found that higher wages are observed in firms that use thorough applicant screening. This corresponds with the finding in this current paper that screening leads to higher wages. In this paper screening leads to wages that distribute all surplus to the workers. The only firms that screen are those that employ high-ability workers. Moreover, all high-ability workers gain in wage compared to a situation without screening. Therefore, the model in this paper finds that screening leads to higher wages.

This paper adds to the existing literature on the self-selection of employees into firms. Kremer and Maskin (1996) utilize the difference in ability to build a model in which workers, under constraints, self-select into separating firms. In this model, workers separate on the basis of the output they bring to the firm. If this output gap is great enough, complementary advantages between similar types overturn the cross-matching advantages between different types and the economy switches to self-matching. In Grossmann (2007), workers also differ in skill, which leads to separation into either very large productive firms or relatively small firms which are less productive. This model is dependent both on abilities of managers and employees alike and finds that an asymmetric equilibrium can occur even when entrants are ex ante symmetric. However, both of the papers above do not consider working in teams and its effects on the utility of the workers. Moreover, these papers also consider perfect observability in which firms can perfectly observe the skill level. This is in contrast to the model in this paper, in which choices are made under incomplete information and with the existence of teams.

Kosfeld and von Siemens (2011) study both incomplete information and working in teams. In their paper there are conditionally cooperative workers and selfish workers. Conditionally cooperative workers are willing to work together if the other team member cooperates. Selfish workers will never cooperate. They find that with incomplete information conditionally cooperative workers are willing to take a pay cut in order to avoid working with selfish workers. They show that this self-selection leads to firms in which people cooperate and firms in which people do not cooperate. Moreover, Venables (2010) discusses the self-selection and sorting effects which occur when choosing where to live. He shows that when there is imperfect information about the quality of workers in the cities, high-ability workers and low-ability workers separate through self-selection and sorting. This current paper contributes by considering separating equilibria through self-selection or screening under incomplete information as a result of the frustration a high-ability worker incurs from working with a low-ability worker.

In addition, this current paper complements the literature on corporate culture. In the model in this paper, corporate cultures arise under separation as there are either all high-ability workers or all low-ability workers in one particular firm, which contributes to a specific culture that differs per firm. This way of shaping corporate culture differs from those explored by others. For example, Crèmer (1993) discusses how a corporate culture can arise through shared knowledge. Van den Steen (2010) shows that shared beliefs often shape a firm. These shared beliefs will create a particular corporate culture over time because of the choices of managers and other employees within the firm which are screened. Moreover, he argues that screening induces the manager to hire those that are more like the firm. This is also shown in this paper. With cheap enough screening, either low- or high-ability firms are formed. Similar to Kosfeld and von Siemens (2011), this paper shows that separation and heterogeneity of firms can still exist even in a perfectly competitive labor market, through the difference in willingness to cooperate. This paper shows a separating equilibrium, and therefore different corporate cultures, can also arise if there is frustration between different types of workers. If the frustration of working with a low-ability worker is not low enough for a high-ability worker, a separating equilibrium only exists for low values of screening.

Lastly, this paper also adds to literature on the use of employee screening. Research by Garen (1985) shows that employee screening with differing costs of screening leads to separate compensation schemes and firms of different sizes. Huang and Cappelli (2006) found that there is a trade-off between screening and on-the-job monitoring. They concluded that the higher the level of screening, the more workers were attracted which were willing to work hard with low monitoring, leading to low monitoring costs. The choice of screening or monitoring will thus depend on the relative costs of screening costs and monitoring costs. As with both papers above, in this paper the cost of screening determines whether firms invest in screening. However, in the model discussed in this paper no monitoring costs exist. Therefore, the trade-off is between screening costs and productivity loss. It is shown that the cost of screening can determine the composition of firms. If screening costs are low, this leads to separation with low- and high-ability firms. If screening costs are high, this leads either to a firm with all types of workers or separation where high-ability workers get paid less than low-ability workers.

The rest of this paper is organized as follows: in section 2, the setup of the model used in this paper is discussed. In section 3, the results which follow from this model are presented. Section 4 concludes this paper.

2. The model

The model in this paper is based on the model by Kosfeld and von Siemens (2011). Two types of workers exist: workers of low ability and workers of high ability. There is a perfectly competitive labor market. Let $a_\theta \in \{a_l, a_h\}$ denote a worker's ability. The ability of a worker is private information. It is assumed that both types of workers make up all of the population willing to work, with a fraction $p = 0.5$ being of low ability and thus, by assumption, a fraction $(1-p) = 0.5$ being of high ability. The firm hires employees and subsequently forms teams of two. Both types of workers will want to be in teams with workers of high ability, as this will cause them to gain some utility. For the low-ability individuals, this could be due to free-riding and for the high-ability individuals this could be due to learning from each other and inspiring each other. However, when high-ability workers are paired with those of low ability, they get frustrated because they have to do more of the work and cannot rely on the other to contribute with a given quality. It is assumed that the workers' outside option is either unemployment or self-employment which is normalized to zero.

The workers in the team produce both individual and team output. The individual output is exogenous, dependent on ability and given by a_θ. The output of the team, $q_{\theta_i \theta_j}$, is dependent on the composition of abilities within the team. With two types of possible workers and teams of two, there are three possible combinations. The price for which the firm sells output is normalized to one. The profit function of the firm per team is therefore as follows:

$$\pi = \begin{cases} a_l + a_l + 2q_{ll} - 2f & if\ \theta_i = \theta_j = l \\ a_l + a_h + 2q_{lh} - 2f & if\ \theta_i \neq \theta_j \\ a_h + a_h + 2q_{hh} - 2f & if\ \theta_i = \theta_j = h \end{cases}$$

where

$$q_{ll} < q_{lh} < q_{hh}$$

$$q_{lh} - q_{ll} < q_{hh} - q_{lh}$$

The first two terms of the profit function show the individual output generated by each worker. The third term shows the team output, produced by both team members. This can take on three different values, dependent on the composition of the team. The output of a team with two workers of low ability is normalized to zero. The last term shows the wage cost the firm pays to its employees. Moreover, it is also assumed that the higher the number of high-ability individuals in the team, the higher their output is. Also, the output gain from team production from an extra high-ability worker is smaller from a low-ability team to a mixed-ability team than from a mixed-ability team to a high-ability team. The utility of employees is given by:

$$u_{il} = \begin{cases} f & if\ \theta_j = l \\ f + H & if\ \theta_j = h \end{cases}$$

$$u_{ih} = \begin{cases} f - F & if\ \theta_j = l \\ f + H & if\ \theta_j = h \end{cases}$$

The first term shows the wage that each employee gets for their work, which is a fixed amount f, which can take on both positive and negative values. The second term differs depending on one's own ability and the ability of one's team member. Low-ability workers only gain utility from the wage in a team with another low-ability worker, but get a gain of $H \geq 0$ in a team with a high-ability worker. For a high-ability worker, working with a low-ability individual who gains through free-riding is frustrating as the low-ability individual might not be able to deliver the same quality or quantity. This frustration is given by a loss of $F \geq 0$. In a team with another high-ability employee, high-ability workers gain the same benefit as a low-ability worker would from working with a high-ability individual, given by $H \geq 0$.

Given that ability and preferences are workers' private information, firms may find it helpful to have access to screening during the application process. This will allow the firm to screen the workers who apply to their firm and learn with perfect knowledge about their type. If a firm wants to screen it has to make screening cost $m > 0$ per worker to learn its ability. When making this costly investment for both workers, the firms profit function changes to:

$$\pi = \begin{cases} a_l + a_l - 2m - 2f & if\ \theta_i = \theta_j = l \\ a_l + a_h + 2q_{lh} - 2m - 2f & if\ \theta_i \neq \theta_j \\ a_h + a_h + 2q_{hh} - 2m - 2f & if\ \theta_i = \theta_j = h \end{cases}$$

In section 3 two cases will be considered with incomplete information. In the first case it is assumed that screening is not possible or too expensive as $m \to \infty$. In the second case screening is possible.

The timeline of this model is as follows:

1. Workers learn their own ability
2. If possible, firms decide whether to use screening
3. Firms offer contracts
4. Workers choose a contract
5. Teams are formed
6. Output and profits are realized

Equilibrium behavior of workers and firms

In this paper, the goal is to find contracts which create only low- and high-ability firms as opposed to firms in which both types of workers are employed. Only symmetric equilibria are considered with symmetric strategies where all workers of a certain type follow the same strategy. This also infers that if one high-ability worker finds it profitable to deviate, then all high-ability individuals find it profitable to deviate. In a competitive equilibrium firms are confined to offer contracts that have a positive probability of being accepted. Moreover, the firms should not make an expected loss with their offered contract and will offer the same contract to all workers. There is no limit on the number of workers a firm can hire. The perfectly competitive labor market is characterized by free entry. It is assumed that workers are rational and therefore always choose the wage contract that maximizes expected utility from the set of offered contracts while taking into account the actions of all other workers. Similar to the paper by Kosfeld and von Siemens (2011) there are two possible equilibria; a separating equilibrium and a pooling equilibrium. If there is no contract within the offered contracts that both ability types accept, there is a separating equilibrium. It is then possible to perfectly infer the ability type based on which contract is chosen. That is, by accepting a particular contract one reveals with certainty its ability. If at least one contract exists within the offered contracts that would be accepted by both ability types, there is a pooling equilibrium, which is an equilibrium in which the choice of contract does not lead to perfect predictability on the worker types.

3. Results

In this section several scenarios will be explored. First, as a benchmark, a competitive equilibrium with complete information will be evaluated. Thereafter, two equilibria with incomplete information will be analyzed. In the first setting screening is either not available or too costly as $m \to \infty$. In the second setting there is the possibility of screening.

Complete information

To lay down a benchmark the case will be considered in which preferences and types are perfectly observable by the firms. When looking at the utility functions of both types of workers as described above, it is seen that both types prefer to work with high-ability types over low-ability types. If types and their preferences are perfectly observable, then the firms can guarantee a separating equilibrium by targeting specific types and only hiring those.

Lemma 1 (Firms in equilibrium) In equilibrium there are only firms that hire either all high-ability workers or all low-ability workers.

Proof. Firms will choose to separate, as with the existence of firms with high- and low-ability workers, there is an incentive to deviate by offering higher wages, hiring only high-ability workers and making a profit margin. This profit margin always exists as $2a_h + q_{hh} - f > a_h + a_l + q_{lh} - f$ always holds. High-ability workers also prefer working with others of high abilities over working with workers with low ability as $f - F < f + H$. They therefore also prefer firms that hire only high-ability individuals over those that hire both types. The low-ability individuals cannot get into these firms as they will not be hired, since their type is perfectly observable. They therefore have no other option than to work with others of low ability. The only equilibrium is therefore a case in which the labor market separates, resulting in only low-ability and high-ability firms, and no firms which mix different ability types.

Lemma 2 (Efficiency) Maximum efficiency is achieved in a separating equilibrium.

Proof. Separation leads to total welfare of $TW_s = \frac{1}{2}(2a_l) + \frac{1}{2}(2a_h + 2q_{hh} + 2H)$ on average per team as by assumption half of the teams are in low-ability firms and half of the teams are in high-ability firms. Wages are not important for total welfare as they shift welfare from the firm to the worker, but do not have an effect on total welfare. When all firms are mixed a quarter of the time there is a low-ability team and a quarter of the time there is a high-ability team. The other half of the time there will be mixed teams. This leads to total welfare of $TW_p = \frac{1}{4}(2a_l) + \frac{1}{2}(a_l + a_h + q_{lh} + H - F) + \frac{1}{4}(2a_h + 2q_{hh} + 2H)$ on average per team. If $TW_s > TW_p$ holds separation would generate the most surplus and thus lead to maximum efficiency. Rearranging gives $q_{hh} + F > q_{lh}$, which by assumption always holds.

Lemma 3 (High-ability contracts under complete information) When there is complete information, contracts for high-ability workers are given by the following:

$$W_h: f = a_h + q_{hh}$$

Proof. Because of the perfectly competitive labor market, firms compete with each other for all the workers and by assumption, the firm with the highest wage attracts all the workers it wants to hire. Therefore, high-ability firms drive up each other's wages until there is no profit margin left. This is the case when:

$$2a_h + 2q_{hh} - 2f = 0$$

Rewriting this leads to $f = a_h + q_{hh}$.

High-ability firms will then only hire those with high ability, as hiring low-ability workers with the offered contract would lead to a loss. This leads to the formation of low-ability firms, since the low-ability workers still contribute a marginal benefit of a_l.

Lemma 4 (Low-ability contracts under complete information) When there is complete information, contracts for low-ability workers are given by the following:

$$W_l\colon f = a_l$$

Proof. Similar to under lemma 3, firms compete with each other for all the workers and by assumption, the firm with the highest wage attracts all the workers it wants to hire. Therefore, the low-ability firms drive up each other's wages until there is no profit margin left. This is the case when:

$$2a_l - 2f = 0$$

Rewriting this leads to $f = a_l$.

From this, the following result can be derived:

Proposition 1 (Complete information equilibrium) When the types and preferences of workers are perfectly observable, a competitive equilibrium always exists where:

i. High-ability workers accept a contract W_h
ii. Low-ability workers accept a contract W_l
iii. All firms make zero profits

In equilibrium, workers are completely separated, with part of the firms for high-ability individuals and part of the firms for low-ability individuals. All firms make zero profits because of the perfectly competitive labor market. As derived under lemma 2, this thus leads to maximum efficiency as the most possible welfare is generated by a separating equilibrium.

Incomplete information – without screening (**$m \rightarrow \infty$**)

In the case above with complete information, the types and preferences are known for everyone and this makes for easy separation. However, low-ability workers benefit from working with high-ability workers and the wages in high-ability firms are higher. Therefore, low-ability workers are incentivized to infiltrate these firms when there is incomplete information. When types and preferences are private information, one would therefore also attract the low-ability workers to the high-ability firms when offering the contracts as discussed in proposition 1. For there to be a separating equilibrium, there should thus be contracts that maximize the utility of the high-ability workers, such that they do not want to deviate to a mixed firm, without attracting the low-ability workers to the firm and without the firms making any losses. In such a scenario, no one has an incentive to deviate and it is therefore a stable equilibrium.

In a case with complete separation, low-ability workers will earn the same as under complete information. There then needs to be a contract for the high-ability types that maximizes their utility, without attracting low-ability types or causing losses for the firms. Denote W_{hh} the set of all of these possible contracts. This would then contain all the contracts which maximize:

$$f + H$$

constraint to

$$a_h + q_{hh} - f \geq 0$$

$$a_l \geq f + H$$

$$f + H \geq a_l - \frac{1}{2}F + \frac{1}{2}H$$

The first constraint ensures that the firm does not make any losses. The second constraint ensures that the low-ability workers are not tempted to infiltrate the high-ability firms. The third and last constraint ensures that the utility of the high-ability employees is higher in a high-ability firm than when they deviate to a low-ability firm, which is the best alternative for a high-ability worker. However, there is no certainty that switching leads to working with a low-ability worker, as only symmetric equilibria are considered in which all high-ability workers switch, leading to a fifty percent probability of being matched either with a high-ability type or a low-ability type. [1]

Lemma 5 (Contracts under separation) Given separation is the best option for firms and $F > H$ holds, contracts for low-ability workers are the same as under lemma 4 and contracts for high-ability workers are given by:

$$W_{hh}: f = a_l - H$$

Proof. Given the constraints of the low-ability workers, f has to be at least below $a_l - H$, and for the high-ability workers, f has to be at least above $a_l - \frac{1}{2}F - \frac{1}{2}H$. This is only possible when $F > H$. Otherwise $a_l - \frac{1}{2}F - \frac{1}{2}H \geq a_l - H$ always holds, and there is no wage contract which can separate the workers. The high-ability firms will then not be able to make the workplace unattractive enough for low-ability types and they will attract both types. However, if $F > H$ does hold, a stable separating equilibrium exists. Given that there is a perfectly competitive labor market, firms will compete for the high-ability workers and end up paying $f = a_l - H$.

Lemma 6 (Separation under incomplete information) There is only a stable separating equilibrium when $F > H + a_h - a_l + q_{lh} + \frac{q_{hh}}{2}$.

Proof. Given the contracts discussed above, low-ability workers will not want to work for high-ability firms. However, there could be firms that decide to offer a high wage such that they attract both types, but still make profits. If this is possible the equilibrium is not stable. Firms attract workers once their utility of switching is higher than their utility of staying. Their utility of staying is given by $u_{ih} = f + H = a_l - H + H = a_l$. The contract offered therefore has to provide the high-ability worker with an alternate utility which is bigger than this utility in order for the worker to switch. The utility when switching to a non-high-ability firm is given by $u_{ih}^* = f^* - \frac{1}{2}F + \frac{1}{2}H$. $u_{ih} < u_{ih}^*$ holds when $a_l < f^* - \frac{1}{2}F + \frac{1}{2}H$, and

[1] If there is certainty that deviating would lead to working with a low-ability, the constraint would be weaker and high-abilities would require a higher value of F to deviate. This value is not dependent on H.

therefore when $f^* > a_l + \frac{1}{2}F - \frac{1}{2}H$. The separating equilibrium is only stable if offering this wage contract does not lead to a profitable result. The profit functions of the firm when attracting all types of workers is given by:

$$\pi = \frac{1}{4}(2a_l - 2f^*) + \frac{1}{2}(a_l + a_h + 2q_{lh} - 2f^*) + \frac{1}{4}(2a_h + 2q_{hh} - 2f^*)$$

and is unprofitable when $\pi < 0$. This contract cannot be offered if a firm makes negative expected profits. Therefore, it is critical to find the point at which a firm cannot attract both high-ability workers and low-ability workers and still make profits. The lowest wage the firm could offer and attract all workers is slightly above $a_l + \frac{1}{2}F - \frac{1}{2}H$ as deduced above. Offering such a contract is therefore not profitable when:

$$\frac{1}{4}\left(2a_l - 2(a_l + \frac{1}{2}F - \frac{1}{2}H)\right) + \frac{1}{2}\left(a_l + a_h + 2q_{lh} - 2(a_l + \frac{1}{2}F - \frac{1}{2}H)\right) + \frac{1}{4}\left(2a_h + 2q_{hh} - 2(a_l + \frac{1}{2}F - \frac{1}{2}H)\right) < 0$$

which, after simplifying, gives $F > H + a_h - a_l + q_{lh} + \frac{q_{hh}}{2}$. $a_h > a_l$ implies that if $F > H + a_h - a_l + q_{lh} + \frac{q_{hh}}{2}$ holds, $F > H$ also automatically holds.

Above this value of F, there is separation in firms, which creates some high-ability and some low-ability firms, but no mixed firms. However, there are also values lower than this value of F in which separation is not possible, because the higher wage in the mixed firm compensates for the disutility of having a chance of working with a low-ability worker.

Lemma 7 (Contracts without separation) When there is no separation, wage contracts for all workers are given by:

$$W_{lh}: f = \frac{1}{2}(a_l + a_h) + \frac{1}{8}(4q_{lh} + 2q_{hh})$$

Proof. In the case that workers cannot be separated by wage contracts because $F > H + a_h - a_l + q_{lh} + \frac{q_{hh}}{2}$ does not hold and the costly investment m is not possible, workers are randomly sorted into teams. This leads to an expected profit function of:

$$\pi = p^2(2a_l - 2f) + 2(1-p)p(a_l + a_h + 2q_{lh} - 2f) + (1-p)^2(2a_h + 2q_{hh} - 2f)$$

Because of the perfectly competitive labor market, this will give a total expected profit of zero. Equating the equation above to 0, using the assumption that $p = 0.5$ and rewriting leads to:

$$4a_l + 4a_h + 4q_{lh} + 2q_{hh} - 8f = 0$$

Rewriting yields $f = \frac{1}{2}(a_l + a_h) + \frac{1}{8}(4q_{lh} + 2q_{hh})$. No firm has an incentive to deviate in this equilibrium, as a higher wage attracts all workers but results in a loss, and a lower wage attracts no workers. It is therefore a stable equilibrium.

Proposition 2 (incomplete information equilibrium without screening) Two different equilibria exist depending on the value of F.

i. If $F \leq H + a_h - a_l + q_{lh} + \frac{q_{hh}}{2}$
   a. Both ability types accept any contract W_{lh}
   b. All firms make zero in profits
ii. If $F > H + a_h - a_l + q_{lh} + \frac{q_{hh}}{2}$
   a. Low-ability workers accept any contract W_l
   b. High-ability workers accept any contract W_{hh}
   c. Firms employing low-ability workers make zero profit, while firms employing high-ability workers make per-team profits of $\pi = 2(a_h - a_l) + 2q_{hh} + 2H$

When the disutility of frustration is relatively small, the high-ability workers would rather have a higher salary at a mixed firm with the possibility of the disutility of F than a lower salary at a high-ability firm which ensures working with high-ability workers. However, once F is large enough, the frustration one gets from working with a low-ability worker is so high that high-ability workers rather have a lower wage but a guarantee of working with a high-ability worker than a higher wage, but not a guarantee of working with a high-ability worker. Interestingly, in the second equilibrium, high-ability firms are able to make a profit even though there is a perfectly competitive market. This occurs because the high-ability firms are not able to pay out more of its surplus without also attracting the low-ability workers. This is the reason why contracts at the high-ability firms have a lower wage than the wages at the low-ability firms. It is intuitive to think that all firms will then only employ high-ability workers as that gives a profit margin. However, this does not occur as the low ability workers still produce surplus. Therefore, if all firms would be high-ability firms, a firm could deviate and employ all low ability workers to make a profit. Hence, in equilibrium, both low-ability and high-ability firms exist.

Incomplete information – with screening

In this case, some firms can choose to use screening to, with certainty, determine whether one is of high ability or low ability. There then needs to be a contract for the high-ability types that maximizes their utility, without causing losses for the firm, while still being attractive. Instead of offering a contract which does not attract low-ability types, the firm now chooses to invest in m, with which they can then get into the situation of complete information.

If $F \leq H + a_h - a_l + q_{lh} + \frac{q_{hh}}{2}$ it is seen from proposition 2 that there is no separating equilibrium without screening. Now consider the situation where there is the possibility of screening. Denote W_{hlh} the set of all of these possible contracts. This would then contain all the contracts which maximize:

$$f + H$$

constraint to

$$a_h + q_{hh} - m - f \geq 0$$

$$f + H \geq \frac{1}{2}(a_l + a_h) + \frac{1}{8}(4q_{lh} + 2q_{hh}) - \frac{1}{2}F + \frac{1}{2}H$$

The first constraint ensures that a firm does not make losses. The second constraint ensures that the high-ability worker prefers this contract over the maximum contract other firms could profitably offer which would make them want to deviate.

Lemma 8 (Choice of investment) When $F \leq H + a_h - a_l + q_{lh} + \frac{q_{hh}}{2}$ high-ability firms will choose to invest in screening when $m < \frac{a_h - a_l - q_{lh}}{2} + \frac{3q_{hh}}{4} + \frac{1}{2}H + \frac{1}{2}F$. All other firms never invest in screening. Contracts are then given by:

$$W_{hlh}: f = a_h + q_{hh} - m$$

Proof. Since there is a perfectly competitive labor market, with screening high-ability workers would get a wage of $f = a_h + q_{hh} - m$. This gives them a utility given by $u_{ih} = a_h + q_{hh} - m + H$ as under complete information firms separate as seen in proposition 1. Deviating would give $u_{ih}^* = \frac{1}{2}(a_l + a_h) + \frac{1}{8}(4q_{lh} + 2q_{hh}) - \frac{1}{2}F + \frac{1}{2}H$. Workers accept a contract with screening if $u_{ih} > u_i^*$. This condition holds for $m < \frac{a_h - a_l - q_{lh}}{2} + \frac{3q_{hh}}{4} + \frac{1}{2}H + \frac{1}{2}F$. The right-hand side of this equation is positive for all values of $F \in \left[0, H + a_h - a_l + q_{lh} + \frac{q_{hh}}{2}\right)$ which are relevant here. For all the values within this range, there is therefore at least a value of m at which firms would choose to invest in screening. These thresholds only apply to the high-ability firms. Given that the high-ability firms screen, low-ability firms do not have to screen as the only workers that are left are those of low ability. Screening for low-ability firms would mean they have less surplus to give in wages, which means they do not attract workers as there are firms which do not screen which can thus offer higher wages. Similarly, mixed firms will not screen as they hire both abilities anyway and this would only lead to less surplus.

Next, consider the case where $F > H + a_h - a_l + q_{lh} + \frac{q_{hh}}{2}$ in which a separating equilibrium arises also in the absence of screening. Denote W_{hhh} the set of all of these possible contracts. This would then contain all the contracts which maximize:

$$f + H$$

constraint to

$$a_h + q_{hh} - m - f \geq 0$$

$$f + H \geq a_l$$

The first constraint ensures that a firm does not make losses. The second constraint ensures that high-ability workers prefer this contract over the contract they would get without screening. Screening in this case would not lead to a different outcome. With these high levels of frustration both with and without screening there would be separation of workers into firms of their own type. However, it does introduce a loss in efficiency due to screening and redistributes the surplus from the firm to the high-ability workers.

Lemma 9 (Investment choice and contracts) When $F > H + a_h - a_l + q_{lh} + \frac{q_{hh}}{2}$ high-ability firms choose to invest in screening when $m < (a_h - a_l) + q_{hh} + H$. All other firms never invest in screening. Contracts are given by:

$$W_{hhh}: f = a_h + q_{hh} - m$$

Proof. Since there is a perfectly competitive labor market and there is perfect knowledge of the type through screening, firms will compete with each other and make zero profit. The profit function is given by:

$$\pi = 2a_h + 2q_{hh} - 2m - 2f$$

Equating to zero and rewriting yields $f = a_h + q_{hh} - m$. Note that this is the same as under lemma 8. Therefore, $W_{hhh} = W_{hlh}$. This has to be bigger than the utility for an individual under incomplete information without screening, otherwise one will prefer that contract and prefer the firm not screening at all. This is the case when $a_h + q_{hh} - m + H > a_l$. This holds for all $m < (a_h - a_l) + q_{hh} + H$. Therefore, the firm will offer this contract for screening costs lower than that value. Workers will accept that contract only if $F > H + a_h - a_l + q_{lh} + \frac{q_{hh}}{2}$ and $m < (a_h - a_l) + q_{hh} + H$. The fact that no other firms invest in screening follows the same logic as discussed in lemma 8.

Proposition 3 (incomplete information equilibrium with screening) Different equilibria exist depending on the value of F and m.

i. If $F \leq H + a_h - a_l + q_{lh} + \frac{q_{hh}}{2}$ and $m \leq \frac{a_h - a_l - q_{lh}}{2} + \frac{3q_{hh}}{4} + \frac{1}{2}H + \frac{1}{2}F$
   a. Low-ability workers accept any contract W_l
   b. High-ability workers accept any contract W_{hlh}
   c. All firms make zero in profits
ii. If $F \leq H + a_h - a_l + q_{lh} + \frac{q_{hh}}{2}$ and $m > \frac{a_h - a_l - q_{lh}}{2} + \frac{3q_{hh}}{4} + \frac{1}{2}H + \frac{1}{2}F$
   a. Both ability types accept any contract W_{lh}
   b. All firms make zero in profits
iii. If $F > H + a_h - a_l + q_{lh} + \frac{q_{hh}}{2}$ and $m \leq (a_h - a_l) + q_{hh} + H$
   a. Low-ability workers accept any contract W_l
   b. High-ability workers accept any contract W_{hhh}
   c. All firms make zero in profits
iv. If $F > H + a_h - a_l + q_{lh} + \frac{q_{hh}}{2}$ and $m > (a_h - a_l) + q_{hh} + H$
   a. Low-ability workers accept any contract W_l
   b. High-ability workers accept any contract W_{hh}
   c. Firms employing low-ability workers make zero profit, while firms employing high-ability workers make per-team profits of $\pi = 2(a_h - a_l) + 2q_{hh} + 2H$

The screening splits both equilibria discussed in proposition 2. This is an intuitive result, as under complete information there was a separating equilibrium and by screening, private information is turned into complete information. With a low value of frustration, the screening changes the types of firms that form. Without screening there is a pooling equilibrium where there are only mixed firms, while with screening this changes into a separating equilibrium with low-ability firms and high-ability firms. Both equilibria have a loss in efficiency compared to the equilibrium considered in proposition 1. The pooling equilibrium loses efficiency as there are productivity losses, as also discussed in lemma 2. The separating equilibrium loses efficiency through the screening costs that have to be payed to ensure a separating equilibrium. The high-ability workers dictate the equilibria. Whichever equilibrium leads to the highest utility for them is the equilibrium which will occur. In the pooling equilibrium screening is too expensive and a separated firm can only pay the high-ability worker the production of the team minus the screening costs. If this wage contract gives the high-ability worker a lower utility than the pooling contract, the pooling equilibrium will occur and vice versa.

With a high level of frustration, screening does not change the types of firms that form. Regardless of whether screening is employed the result will always be a separating equilibrium. High-ability workers prefer higher wages and the perfectly competitive labor market ensures that if screening costs are low enough, the redistribution of surplus can lead to higher wages for high-ability workers as firms compete for the high-ability workers. Similar to above, high-ability workers dictate which equilibrium is chosen. Whichever gives them the highest wage is the equilibrium in which all workers and firms end up. Only the equilibrium without screening has maximum efficiency. This is because screening introduces screening costs which create an inefficiency.

Incomplete information – maximizing total welfare with screening

Given that there are inefficiencies in all equilibria with screening or without separation, it is interesting to consider what decisions would be made if welfare were to be maximized. For this section it is assumed that investment in screening is regulated, either by the government or another third party which observes F and m and aims to maximize total welfare. The third party can choose which firms employ screening and which firms do not. Afterwards the firms set their wages and attract workers. As already observed in lemma 8 and 9, this means that if they mandate firms to screen it will only be the high-ability firms as mandating low-ability and mixed firms to screen would lead to a welfare loss without any gain.

Lemma 10 (Maximization of welfare for low values of F) If total welfare is maximized for $F \leq H + a_h - a_l + q_{lh} + \frac{q_{hh}}{2}$, screening investments in high-ability firms will be mandated for $m < \frac{q_{hh}-q_{lh}+F}{4}$. This is lower than the cut-off in proposition 3.

Proof. When $F \leq H + a_h - a_l + q_{lh} + \frac{q_{hh}}{2}$ it can be found in proposition 3 that a separating equilibrium only exists when screening is employed. The total welfare of a separating equilibrium with screening is given by $TW_{ss} = \frac{1}{2}(2a_l) + \frac{1}{2}(2a_h + 2q_{hh} + 2H) - 2m$. The total welfare of a pooling equilibrium without screening is given by $TW_p = \frac{1}{4}(2a_l) + \frac{1}{2}(a_l + a_h + q_{lh} + H - F) + \frac{1}{4}(2a_h + 2q_{hh} + 2H)$. Screening is thus efficient when $TW_{ss} > TW_p$. After rearranging this the condition $m < \frac{q_{hh}-q_{lh}+F}{4}$ is obtained. Below this value it is thus efficient and it will be mandated to screen. Above this value of m firms will not be allowed to screen. This is lower than the value in proposition 3 if $\frac{q_{hh}-q_{lh}+F}{4} < \frac{a_h-a_l-q_{lh}}{2} + \frac{3q_{hh}}{4} + \frac{1}{2}H + \frac{1}{2}F$. After rewriting this gives $\frac{(a_h-a_l)}{2} + \frac{(q_{hh}-q_{lh})}{4} + \frac{1}{2}H + \frac{1}{4}F > 0$, which of course always holds.

Lemma 11 (Maximization of welfare for high values of F) If total welfare is maximized for $F > H + a_h - a_l + q_{lh} + \frac{q_{hh}}{2}$, firms will never be allowed to invest in screening.

Proof. When $F > H + a_h - a_l + q_{lh} + \frac{q_{hh}}{2}$ there always exists a separating equilibrium, regardless of whether screening is employed. Since wages are simply a way of redistributing the surplus that a firm creates, the different wages of the two equilibria do not affect the welfare. However, the difference between both equilibria is the screening costs. These costs are an inefficiency and it is easy to see that the total welfare with no screening given by $TW_{ns} = \frac{1}{2}(2a_l) + \frac{1}{2}(2a_h + 2q_{hh} + 2H)$ is always larger than the total welfare with screening given by $TW_{ss} = \frac{1}{2}(2a_l) + \frac{1}{2}(2a_h + 2q_{hh} + 2H) - 2m$. Therefore, when total welfare is maximized and $F > H + a_h - a_l + q_{lh} + \frac{q_{hh}}{2}$ holds, firms will never be allowed to screen as it will create an inefficiency.

Proposition 4 (Welfare maximization in incomplete information with screening) Different equilibria exist depending on the value of F and m.

i. If $F \leq H + a_h - a_l + q_{lh} + \frac{q_{hh}}{2}$ and $m \leq \frac{q_{hh}-q_{lh}+F}{4}$
   a. Low-ability workers accept any contract W_l
   b. High-ability workers accept any contract W_{hlh}
   c. All firms make zero in profits
ii. If $F \leq H + a_h - a_l + q_{lh} + \frac{q_{hh}}{2}$ and $m > \frac{q_{hh}-q_{lh}+F}{4}$
   a. Both ability types accept any contract W_{lh}
   b. All firms make zero in profits
iii. If $F > H + a_h - a_l + q_{lh} + \frac{q_{hh}}{2}$
   a. Low-ability workers accept any contract W_l
   b. High-ability workers accept any contract W_{hh}
   c. Firms employing low-ability workers make zero profit, while firms employing high-ability workers make per-team profits of $\pi = 2(a_h - a_l) + 2q_{hh} + 2H$

Maximization of total welfare leads to less screening for low levels of frustration and results in the disappearance of screening for high levels of frustration.

For low levels of frustration, firms are only allowed to screen for certain levels of m. Allowing the screening is a trade-off between the productive inefficiency caused by the forming of mixed firms instead of separated firms and the screening inefficiency caused by the screening costs. If the productive inefficiency is larger than the screening inefficiency, it is better for total welfare if the productive inefficiency is avoided and instead screening investments are made. If the productive inefficiency is smaller than the screening inefficiency, it is better not to screen.

For high levels of frustration a gain in wage for high-ability workers was enough for all firms to switch in proposition 3 because of the perfectly competitive labor market despite screening costs and an unchanged equilibrium. However, when welfare is maximized there is no screening allowed as it only redistributes the surplus from the firm to the high-ability workers while also creating a screening inefficiency. In short, there is no gain but there is a loss to total welfare. Therefore, screening will always lead to lower total welfare and the third party will not allow it.

4. Conclusion

In this paper, a model was built that analyzed a perfectly competitive labor market in which high-ability workers experienced frustration when working with someone of lower ability. The critical assumption that one gets frustrated is substantiated by research on both students and in experiments.

It is shown that in a perfectly competitive labor market high values of frustration or low values of the screening lead to a separating equilibrium. However, when a high-ability worker has low frustration and screening is very expensive, an equilibrium exists in which all workers pool into the same firms. The only situation in which a firm could make profit is when screening is expensive but the frustration is sufficiently high that high-ability workers are willing to take a pay cut to ensure that they are working only with others of high ability. The firms do still make profit, since paying out all of the surplus would attract low-ability workers. In all other cases all firms make zero profits. Lastly, it is found that when maximizing total welfare there exists a tradeoff between productive inefficiencies and screening inefficiencies for low values of the frustration. Dependent on which inefficiency dominates either screening or not screening is efficient. For high values of frustration it is never efficient to screen as the cost of screening only redistributes income and does not create more income.

The model in this paper underlines how self-selection and sorting can be a consequence of the interaction between heterogeneous workers. It provides a rationale for the occurrence of different corporate cultures in ability types, the existence of low- and high-ability firms as found in Dunne et al. (2004), why high-ability workers would be willing to take a pay cut to work in teams with others of high ability and why applicant screening can lead to higher wages as found in Huang and Cappelli (2010).

The model built in this paper can most certainly be extended. Several extensions would be of particular interest. Continuous instead of binary ability could be considered, where the frustration is based on the difference in ability. These differences in frustration could lead to particular intervals behaving in a particular way and lead to more than just two types of firms. Moreover, endogenous as opposed to exogenous output for workers could be considered. This way the workers themselves can adapt to different corporate cultures they would encounter. It would be compelling to see whether types would adapt in order to work with other types. Finally, it would be interesting to discover how the results change when the empirical fact of overconfidence is applied, where people think that they have higher capabilities than they actually have, especially when of low ability (Kruger & Dunning, 1999). This fact has been proven over time and it could affect the results quite dramatically. For example, if in the model in this paper a low-ability worker thinks it is a high-ability worker, this would affect his choice on which firm to choose. This may subsequently affect the decisions of other types and lead to different equilibria.

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