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ESSEC RESEARCH CENTER

WORKING PAPER 2008

MAY 2021

May 3, 2021

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Abstract

Upskilling is an investment in human capital that allows a worker to successfully undertake a new task or new project within his/her existing job. It involves costly effort on behalf of the employee to acquire new skills and new knowledge. A firm-financed training scheme allows to screen the applicants to the programme, but comes with the cost of hidden actions, as some employees train on their own yet keep on working on low-value projects. A *laissez- faire* policy relying on worker self-training and incentive compatible contracts allows to attract more workers to high-value projects, yet it must grant to flexible workers a positive informational rent. The profit comparison reveals a paradoxical situation where it might be in the interest of a company to rely on worker self-training rather than to provide a training programme.

Keywords: Contract theory, Upskilling, Screening, Hidden action.
JEL Classification: J33, J41, D86

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1 Introduction

The constant need for companies to set up processes to ensure that their workforce adapts to technological advances is a characteristic of modern industrial societies. The HR management literature refers to the processes set up by firms to improve the correlation between the capabilities of their employees and the broad requirements of new tasks as "upskilling" (Capelli and Rogovsky 1994, Leigh et al., 1999, Cohen, 2019). This skill transformation reached preeminence with the advent of the information technology revolution in the 1990s, driven by the massive deployment of computers and the Internet (Gordon, 2000; 2012). In the 2010s, the digital transformation shifted to the systematic generation and exploitation of big data via machine learning and AI. Automation is also displacing traditional tasks (Acemoglu and Restrepo, 2019), requiring new interactions between humans and machines that heavily draw on new skills, new knowledge, and new work-attitudes (Grand-Clement et al., 2017). Recently, the Covid-19 sanitary crisis rapidly imposed the massive deployment of distance work (Brynjolfsson et al., 2020) and a radical transformation of work organization in many sectors, including e-commerce, banking, health care, consulting, education (Agrawal et al., 2020). According to a survey of business executives (July 2020) by the consultancy firm McKinsey, changes in digital and technology adoption are taking place these days about 25 times faster than before the pandemic.[1]

Both the management and employees are concerned with the constant need to cope with these technological challenges. Before the recession caused by Covid-19, the shortage of skills was considered the main factor limiting the expansion of the US manufacturing sector, which planned to invest 26.2 billion dollars in upskilling programs.[2] In a survey of 22000 employees in 2019, consultancy firm PwC revealed that 77% of employees would learn new skills or be completely retrained to improve their future employability.[3] Another survey by PwC revealed that in January

[1] See McKinsey *Global Survey of Executives*, July 2020.

[2] CNBC, January 17, 2020. www.cnbc.com/2020/01/17/manufacturers-to-spend-26point2-billion-on-upskilling-workers-in-2020.html

[3] PwC's report *Upskilling Hopes and Fears* survey was conducted in July 2019.

2020, 74% of the managers of 1581 global companies were concerned about the availability of key skills within their workforce.[4] According to a survey of 300 US firms by the *TrainingJournal* in August 2020, 42% of companies stepped up their investment in upskilling and reskilling, while 42% of employees pursued training on their own after the coronavirus outbreak.

This paper addresses the question of the optimal upskilling contract when firms have only imperfect information about workers' skills. It also addresses the important managerial question whether a company or its employees should bear the cost of upskilling. Finally, the analysis allows to determine the equilibrium proportion of workers who choose to pay the learning cost (to upskill).

We therefore build a model that is largely inspired by the contract theory literature[5] . In the model, workers can perform a stepwise investment in human capital – for instance, learn a new software or a foreign language, or a new managerial method – that allows them to successfully carry out complex projects of high value added for their company. Employees are heterogenous with respect to the learning cost required to successfully upskill (Jackman, 2020). The proportion of employees who decide to invest in the new skills is endogenous. Information about the type of worker is either private or public, depending on who is investing in upskilling. When employees do upskill, it is in their interest to hide it from their manager. If their manager knows the distribution of types, but cannot identify the types, he/she must offer a menu of contracts that prompts employees to self-select for the projects where they are most efficient. This brings an informational rent to the most skilled workers. In an alternative setting, a firm offers vouchers for upskilling, which workers can use to cover their learning cost. The use of the voucher reveals the type of worker, thus allowing the firm to offer type-specific contracts. However, in this case too some employees might find it optimal to upskill on their own and select a low quality project.

www.pwc.com/gx/en/issues/upskilling/hopes-and-fears.html

[4] PwC's 23rd Annual Global CEO Survey, January 2020, *Navigating the rising tide of uncertainty.* See www.pwc.com/gx/en/ceo-survey/2020/trends/pwc-talent-trends-2020.pdf

[5] Bolton and Dewatripont, 2005; Salanié, 2005; Laffont and Martimort, 2009.

These hidden actions represent an opportunity cost for the firm which cannot employ this flexible workforce on high value projects.

A comparison of the profits reveals that profits are higher in the self-training scheme compared to the voucher based scheme. In the self-financed scheme, flexible workers benefit of an informational rent, which is a cost for the firm. However, in the voucher based scheme, hidden actions bring about an even higher cost.

One important limitation of the analysis is its static nature; in our model, the manager does not consider the possibility of replacing obsolete-skill workers with more qualified workers. This is tantamount to assuming that the cost of upskilling is low compared to the cost of massive turnover, which is a plausible assumption for many sectors.[6] Modestino et al. (2019) explain that in recruitment, companies now require a higher level of competencies for the same jobs compared to the recent past, as they prefer upskilling to worker replacement. We do not consider the possibility that workers who benefit from a firm-financed upskilling program might leave for a better paying job elsewhere (Benson et al. 2004) or that upskilling could be an efficient worker retention policy (Manchester, 2010; 2012; Dietz and Zwick, 2020). In a dynamic setting, the fact that workers benefit from information rent when upskilling is self-financed might make self-financing a more interesting education strategy. Our static analysis is therefore better suited for sectors where human capital is highly specific. Despite these simplifications, the "static" situation sheds light on the design of the optimal upskilling contract, which is a meaningful question for both theorists and managers. It calls attention on the cost of hidden actions, which, by its very nature, is difficult to grasp.

The paper is organized as follows. After introducing the main assumptions in Section 2, we determine the optimal upskilling contract for each of the two education strategies in Section 3 and 4 respectively. Section 5 compares the profits in the two scenarios to determine the optimal

[6] The *World Economic Forum* argued that it costs roughly \$4,425 to hire a new employee, and the *Association for Talent Development*'s discovery that upskilling an existing employee costs a company about \$1,300.

training strategy for the firm. The last section presents our conclusion.

2 Main assumptions

The problem is cast as a game between workers, who must choose whether to undertake the upskilling effort or not, and the firm, which must decide on a compensation policy. The initiative to upskill always sits with the workers. We study two distinct cases: when the firm sets up an upskilling program (funded by the firm) and when the firm does not invest in upskilling and let workers decide whether to upskill or not (with personal funding).

The firm, which seeks to maximize profits, can develop a portfolio of projects based either on the old technology (of complexity q^L) or on the new technology (of complexity q^H). The level of complexity is exogenously given. If properly implemented, a complex project brings more value to the firm, $v^H > v^L$. The difference $\left(v^H - v^L\right)$ is an essential source of profit for the firm.

There is a continuum of employees of mass one; at the outset of the game, they are all of the s type (standard type) with basic competencies. Employees can evolve toward the flexible type, denoted f, if they acquire essential knowledge for successful implementation of a complex project.[7]

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Let c denote the *learning (upskilling) cost* required to an individual to acquire the essential competency. Individuals are heterogenous with respect to this cost (have different learning abilities).[8] The cost is uniformly distributed in the interval $[0, \bar{c}]$ and this distribution is common knowledge. To rule out corner solutions, we assume that the upper bound of the cost distribution is large enough, $\bar{c} > \left(v^H - v^L\right)$. Throughout the paper we assume that this cost is an unobservable characteristic of the worker (it is private information).

A flexible-type worker (f) can efficiently implement any project q^H (or q^L) and deliver the value v^H (and v^L, respectively). A standard-type worker (s) can efficiently implement only a

[7] For instance, people who aim to make efficient use of large Internet databases might need to invest in learning programming language such as Python.

[8] Jackman (2020) documents that the ability to acquire new human capital quickly varies considerably among a large sample of Danish workers.

project q^L, and not a project q^H. If he/she takes a project H, the value of the project is v^L because he/she lacks the essential skills for the successful implementation of this project. Such an asymmetry is revealed by Jeremy and Postel-Vinay (2020) who argue that employing a worker who is under-qualified in either cognitive or manual skills is several orders of magnitude more costly than employing an over-qualified worker.

Let r^H and r^L be the compensation offered by a firm to a worker for undertaking a project of complexity H and L, respectively. In other words, the firm offers bundles of project complexity-compensation (q^H, r^H) and (q^L, r^L). Thus r^H and r^L are the key variables to be optimally determined by the firm.

The personal effort required by a project depends on the nature of the project, and the type (skills) of the worker. The flexible type of worker can easily switch from simple to complex projects. The s type of worker can also work on a complex project but at a higher personal cost (and without performing well). Let e_f^H and e_f^L be the "execution effort" required of $f-$workers to carry out one of the projects. Let e_s^H and e_s^L be the execution effort required to type s workers to execute one of the projects. We assume that for a given type of worker i, the execution effort on the complex project is higher than the execution effort on the basic project: $e_i^H > e_i^L$ with $i = (s, f)$. We also assume that for a given project (q^j), the execution effort is higher for the standard type compared to the flexible type, $e_s^j > e_f^j$, with $j = (L, H)$.[9]

To keep the analysis as simple as possible, we assume that the effort structure is $e_f^L = e_0$, $e_s^L = e_f^H = e_1$ and $e_s^H = e_2$ with $e_0 < e_1 < e_2$. Working on a complex project instead of a basic one requires an incremental effort $(e_1 - e_0)$ to the flexible worker and $(e_2 - e_1)$ to the standard worker. The problem is the most interesting if, in line with intuitive reasoning, the incremental effort of the flexible worker is smaller than the incremental effort of the standard worker:

$$(e_1 - e_0) < (e_2 - e_1). \tag{1}$$

[9] The effort to execute a project, e, depends on the type of worker, but is unrelated to the learning (upskilling) cost, c. The latter is a "personal characteristic" reflecting learning abilities, while the former is specific to the difficulty of the project, requiring given skills.

We assume throughout this paper that this condition holds.

Table 1 summarizes the execution effort (for the worker) and project value for the firm, by type of worker and type of project.

	project L	project H
Employee s	(e_1, v^L)	(e_2, v^L)
Employee f	(e_0, v^L)	(e_1, v^H)

Table 1: Execution effort and value, by type of employee and type of project

An upskilling program that attracts some employees to the high value project is efficient only if the benefit of having a worker switching to the complex project is larger than the incremental effort of a flexible worker to switch to the complex project:

$$\left(v^H - v^L\right) > (e_1 - e_0) \tag{2}$$

otherwise no contract can ensure a positive gain for both the firm and the worker. We will consider that this condition is fulfilled.

A Nash equilibrium of this game is a situation in which employees choose their best education strategy depending on the firm compensation scheme, and the firm chooses the optimal compensation scheme given the workers' education strategy.

Two cases can be considered. In the first case, the firm sets up a standard upskilling programme, and lets workers apply for it. In the second case, the firm does not set up a training scheme, and relies only on the private initiatives of the workers to train themselves. In the first case, applying for the training scheme signals a flexible worker, yet the training scheme is an explicit cost for the firm; furthermore, some workers with a low training cost might find interesting to train on their own. In the second case, the worker pays for the upskilling; then, he/she can hide this information from the employer, which involves an information cost to the firm.

3 A firm-financed upskilling program

The firm may choose to set up an upskilling program. Rather than enrolling all employees in one-size-fits-all classes, a voucher-based policy is highly recommended under the plausible assumption that the employee knows better than the firm what are his/her missing skills. We therefore assume that the firm offers education vouchers – of an undifferentiated amount b to be decided optimally – to any employee who applies for the programme.[10] However, employees have the option to upskill on their own and behave opportunistically, which might reduce the efficiency of the training programme.

We further assume that the principal can contract on the complexity (or value) of the project and not only on its execution. Therefore, if an agent divest the money from the voucher in his/her private interest and cannot deliver q^H (or v^H) he/she will incur a sanction akin at dissuading him/her from cheating. A worker who applies to the training program reveals that he/she is of the flexible type. We show in the Appendix that if cheating were possible, the firm-financed training is no longer a viable option.

Let us assume that the company offers to all voucher applicants (obviously of the $f-$type) the contract $(q^H, r^H = e_1)$ and offers to all non-applicants the contract $(q^L, r^L = e_1)$. These contracts fulfill the participation constraints of employees.

The sequence of decisions is the following: first step, the firm sets the employment contracts; second step, it offers the training programme; third step, workers who want, apply for the program; four step, workers upskill (either on their own, or using the voucher). Finally, production is carried on.

3.1 The optimal voucher

Employees have the choice between the status quo (no training) strategy, and two training strategies. The status quo strategy brings them a zero surplus: they chose the low complexity project,

[10] In many countries the labor law or trade unions would oppose to any form of educational discrimination, or what can be perceived as educational discrimination.

with an effort e_1 and they are paid $r^L = e_1$.

The training strategies are:

1. Strategy vo (voucher): apply for the voucher, train, and receive a complex project, with a reward $r^H = e_1$ and an effort e_1 (the worker is now of the type f). While the voucher can cover any cost $c < b$, the reminder cannot be used for personal consumption. The utility of a such a flexible worker (who applied for a voucher) is:

$$U_f^{vo}(r^H, q^H) = r^H - e_1 - \max\{c - b, 0\} = \begin{cases} 0, \text{ if } c < b \\ -(c - b), \text{ if } c > b \end{cases} \tag{3}$$

2. Strategy st (self-training): they can train on their own to become an $f-$type worker, yet they do not reveal this information and chose a low complexity project, which rewards $r^L = e_1$ but now requires only an effort e_0. Their utility resulting from this "hidden action" is:

$$U_f^{st}(r^L, q^L) = (e_1 - e_0) - c. \tag{4}$$

If they chose a complex project their utility would be lower ($-c$): such a privately trained worker has no incentive to reveal this information, and accept a high value project.

In Figure 1 we represent their utilities from the three strategies, in the case where $b > (e_1 - e_0)$. This correspond to a non-trivial situation, since the set of workers who prefer the voucher strategy is not empty.[11] If $b < (e_1 - e_0)$, the voucher strategy is dominated by the self-training strategy; we show latter that this case is impossible.

Let α be the proportion of workers who apply for the upskilling programme, the other $(1 - \alpha)$ chose the low value project. The profit function is:

$$\begin{aligned} \pi &= \alpha(v^H - e_1) + (1 - \alpha)(v^L - e_1) - \alpha b \\ &= (v^L - e_1) + \alpha(v^H - v^L - b) \end{aligned} \tag{5}$$

From Figure 1, we see that only workers with $(e_1 - e_0) \leq c \leq b$ have an incentive to apply for the

[11] By providing a small benefit ($\varepsilon \to 0$) on the top of the compensation for the complex project, the firm can ensure that the workers with $c < b$ prefer this strategy (more valuable for the firm) to the status quo strategy.

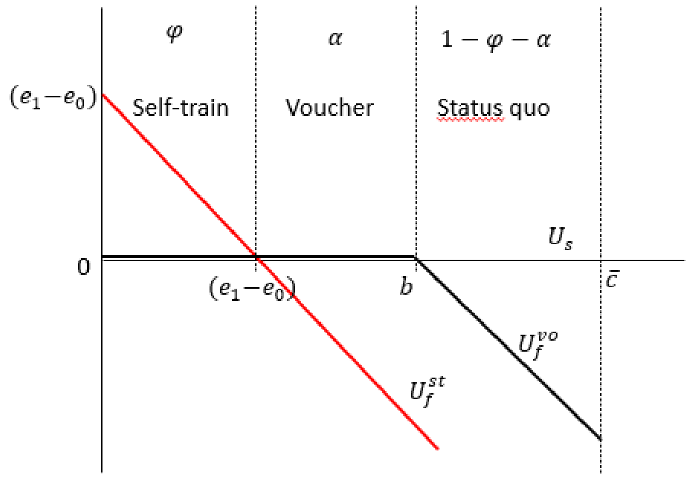

Figure 1: Worker utility by training strategy and learning cost

voucher, since $U_f^{vo}(r^H, q^H) > U_f^{st}(r^L, q^L)$. Under the assumption of a uniform distribution for c, we can write $\alpha = \Pr[(e_1 - e_0) \leq c \leq b]$:

$$\alpha = \frac{1}{\bar{c}}[b - (e_1 - e_0)] \tag{6}$$

leading to profit function:

$$\pi = (v^L - e_1) + \frac{1}{\bar{c}}[b - (e_1 - e_0)](v^H - v^L - b) \tag{7}$$

The FOC for profit maximization allows us to determine the optimal amount of the voucher:

$$\tilde{b} = \frac{(v^H - v^L) + (e_1 - e_0)}{2}, \tag{8}$$

We can check that $\tilde{b} > (e_1 - e_0)$, which is exactly the situation described in Figure 1. It turns out that the voucher strategy is always feasible.

The proportion of workers applying for the voucher is $\tilde{\alpha} = \frac{1}{2\bar{c}}[(v^H - v^L) - (e_1 - e_0)] > 0$.

The optimal profit is:

$$\tilde{\pi} = (v^L - e_1) + \frac{1}{4\bar{c}}\left[(v^H - v^L) - (e_1 - e_0)\right]^2. \tag{9}$$

We remark that $\tilde{\pi}$ is larger than $(v^L - e_1)$, which is the profit that could be obtained without the training programme.

3.2 Discussion

In the former configuration, there is a stock of flexible workers (those with $c < (e_1 - e_0)$) who have upskilled on their own and work on the low value project. The firm might be tempted to "exploit" this resource by paying to (all) those who work on the low value project an income r^L lower than e_1. Workers with $c < (r^L - e_0)$ would train themselves and accept this contract. At the same time, more workers are prompted to use the voucher scheme and move to the high value project. On the other hand, workers with a high learning cost (those who did not upskill in the first place) obtain now a negative surplus $(r^L - e_1)$ and leave the firm (adverse selection).[12]

It can be shown that, under our assumptions, this strategy is not optimal for the firm.

In this framework, the profit function is:

$$\pi = \varphi(v^L - r^L) + \alpha\left(v^H - e_1 - b\right) \tag{10}$$

Under the uniform distribution assumption, the frequency of hidden flexible workers is $\varphi = \Pr[c \leq \left(r^L - e_1\right)] = \frac{1}{c}\left(r^L - e_1\right)$, and the frequency of workers who apply for the voucher program is $\alpha = \frac{1}{c}\left[b - \left(r^L - e_1\right)\right]$. The profit function becomes:

$$\pi = \frac{1}{c}\left\{\left(r^L - e_1\right)\left(v^L - r^L\right) + \left[b - \left(r^L - e_1\right)\right]\left[\left(v^H - e_1\right) - b\right]\right\} \tag{11}$$

The firm has now two control variables, the compensation r^L and the voucher b.

There are two FOCs for the (free) profit maximization:

$$\frac{d\pi}{db} = \left(v^H - e_1\right) + \left(r^L - e_1\right) - 2b = 0 \tag{12}$$

$$\frac{d\pi}{dr^L} = \left(v^L - r^L\right) - \left(v^H - e_1\right) + b = 0. \tag{13}$$

[12] The firm cannot discriminate between the s and the $f-type$ workers since the information on who has upskilled is not public.

Solving the system of equations we obtain:

$$\hat{r}^L = 2v^L - v^H \tag{14}$$

$$\hat{b} = v^L - e_1 \tag{15}$$

We can check that condition $\left(v^H - v^L\right) > (e_1 - e_0)$, as introduced before, ensures that $\hat{b} > \hat{r}^L - e_0$ ($\alpha > 0$, i.e., there are workers who apply for the voucher). There are workers who continue to self-train ($\varphi > 0$) if $\hat{r}^L - e_0 > 0$, or $\left(v^L - e_0\right) > \left(v^H - v^L\right)$.

The optimal profit is:

$$\hat{\pi} = \frac{1}{c}\left(v^H - v^L\right)\left(v^L - e_1\right). \tag{16}$$

For $\bar{c} > \left(v^H - v^L\right)$ (as assumed in the introduction) it can be checked that $\tilde{\pi} > \hat{\pi}$. The strategy of diminishing the informational rent of the workers who self-train (by cutting their compensation) at the expense of losing the $s-$type employees is an inefficient strategy.

4 Optimal contracts under self-financed training

If the firm provides no training facility, workers have two training strategies, either the status quo (or no training, which preserves their s-type) or the upskilling strategy, which allows them to switch from s to the $f-$ type of worker. When employees opt for self-training the information about their type is private information to them. Because the firm does not know which worker is of the flexible type, it must offer a menu of contracts (r^H, q^H) and (r^L, q^L) and let workers self-select. Ideally, from the firm point of view, all $f - type$ workers should choose a complex project q^H (and deliver v^H) and all $s - type$ workers should choose a basic project q^L (and deliver v^L). The number of workers who decide to upskill is an endogenous variable, resulting form the profit maximization problem. The research question (and a managerial one) is how to determine r^H and r^L to achieve this goal.

The sequence of decisions is as follows. At the outset of this game, the firm posts a menu of contracts. Then, employees chose whether to pay the cost of upskilling or not. They then choose the preferred contract from the menu offered by the firm. Production follows and the game ends.

4.1 Participation and incentive compatibility constraints

The utility of the worker from upskilling is U_f, and the utility of the worker from the status quo is U_s.

A worker who maintains his/her s status and selects the low complexity project will obtain $U_s(r^L, q^L) = r^L - e_1$ where we acknowledge that his/her execution effort is e_1. The participation constraint of the $s - type$ worker is:

$$U_s(r^L, q^H) = r^L - e_1 \geq 0 \tag{17}$$

A worker who self-trains and selects the highly complex project will obtain utility $U_f(r^H, q^H) = r^H - e_1 - c$; the execution effort of the flexible worker who takes the q^H project is e_1;he/she also must incur the learning cost c. His/her participation constraint is:

$$U_f(r^H, q^H) = r^H - e_1 - c \geq 0 \tag{18}$$

Only workers with $c < \left(r^H - e_1\right)$ can follow the self-training strategy, and become $f - type$ workers.

To ensure that each worker selects a contract tailored for his/her type of employee, and rejects a contract tailored for the other type of employee, we must take into account the incentive compatibility (IC) constraints:

$$U_f(r^H, q^H) \geq U_f(r^L, q^L) \tag{19}$$

$$U_s(r^H, q^H) \leq U_s(r^L, q^L) \tag{20}$$

Which are equivalent to:

$$r^H - e_1 - c \geq r^L - e_0 - c \tag{21}$$

$$r^L - e_1 \geq r^H - e_2 \tag{22}$$

where we remind that the effort of the $f - type$ selecting q^L is e_0, and the effort of $s - type$ selecting q^H is e_2.

The saturated PC for $s - type$ workers requires $r^L = e_1$. Thus, the two IC conditions can be written:

$$(IC_f) \qquad r^H \quad \geq \quad e_1 + (e_1 - e_0). \tag{23}$$

$$(IC_s) \qquad r^H \quad \leq \quad e_2 \tag{24}$$

The firm profit maximization problem with employee self-training has a solution if $(2e_1 - e_0) \leq r^H \leq e_2$. A necessary condition for the existence of the separating contracts is: $(2e_1 - e_0) < e_2 \Leftrightarrow (e_1 - e_0) < (e_2 - e_1)$, stating that the incremental effort (of working on the H project instead of L) of the standard worker is higher than the incremental effort of the flexible worker. We have assumed in Section 2 that this condition (condition 1) is fulfilled.

Under self-training, upskilling provides an employee who adopts this strategy with a positive informational rent $\left(r^H - e_1\right) \geq (e_1 - e_0)$. If $\left(r^H - e_1\right) < (e_1 - e_0)$, all workers with a low training cost would train on their own, then choose the low value project (q^L) and obtain the utility $(e_1 - e_0) - c$ (i.e., they follow a hidden action strategy).

Why would a firm pay an f-worker more than the compensation that saturates IC1, $r^H = (2e_1 - e_0)$? By paying more than the minimum required for self-selection, it might prompt more workers to invest in upskilling (workers with a higher learning cost would have an incentive to incur it) and then undertake the high-value project.

4.2 The optimal contracts

The contract (r^H, q^H) is designed for the flexible workers, who can deliver v^H if they undertake the project. Because $r^H - e_1 \geq (e_1 - e_0)$, workers with a learning cost $c < \left(r^H - e_1\right)$ have an incentive to invest in learning (this strategy dominates the hidden action strategy: train and chooses the q^L project).

We denoted with α the share of employees who choose to invest in upspkilling ($\alpha = \Pr[c <$

$\left(r^H - e_1\right)]$). Under the assumption of a uniformly distributed c on $[0, \bar{c}]$, its explicit form is:

$$\alpha^* = \frac{1}{\bar{c}}\left(r^H - e_1\right). \tag{25}$$

The profit can be written as a function of r^H:

$$\begin{aligned}
\pi(r^H) &= \alpha v^H + (1-\alpha)v^L - \alpha r^H - (1-\alpha)r^L \\
&= \left(v^L - e_1\right) + \alpha\left[\left(v^H - v^L\right) - \left(r^H - e_1\right)\right] \\
&= \left(v^L - e_1\right) + \frac{1}{\bar{c}}\left(r^H - e_1\right)\left[\left(v^H - v^L\right) - \left(r^H - e_1\right)\right]. \qquad (26)
\end{aligned}$$

If no worker follows the upskilling strategy, the profit is $\left(v^L - e_1\right)$. Obviously, an equilibrium with self-training in which the firm offers the (q^H, r^H) contract and $\alpha > 0$ workers pay the cost of upskilling is possible only if: $\left(r^H - e_1\right) < \left(v^H - v^L\right)$. But the highest compensation is $r^H = e_2$. This entails as a necessary condition for this equilibrium: $(e_2 - e_1) < \left(v^H - v^L\right)$.

The FOC indicates as the first-best optimal r^H:

$$r^H = e_1 + \frac{\left(v^H - v^L\right)}{2} \Leftrightarrow \left(r^H - e_1\right) = \frac{\left(v^H - v^L\right)}{2} \tag{27}$$

This represents a higher payment for the firm than in the firm-financed scheme, $e_1 + \tilde{b}$, justified by the vanished hidden actions (and their opportunity cost for the firm).

However, it must be verified that this first-best compensation fulfills the two ICs (equations 23 and 24), otherwise the effective compensation is a corner solution as indicated by the saturated constraint.

$$\begin{aligned}
(IC_f) \qquad r^H - e_1 &= \frac{\left(v^H - v^L\right)}{2} \geq (e_1 - e_0) \qquad (28) \\
(IC_s) \qquad r^H - e_1 &= \frac{\left(v^H - v^L\right)}{2} \leq (e_2 - e_1). \qquad (29)
\end{aligned}$$

Three cases can be taken into account, depending on the parameters of the problem. In the first case, IC_s is not binding, yet IC_f is binding (thus the f-employee receives the lowest compensation $r^H = 2e_1 - e_0$); in the second case, none of the two IC constraints is binding thus the first-best optimum prevails; the latter case is the situation in which IC_s is binding, thus the employee receives the highest possible compensation in this problem $r^H = e_2$ (for a higher compensation, $s-$employees would accept the H project).

The optimal compensations (in their implicit form $r^H - e_1$) are:

$$r^H - e_1 = \begin{cases} (e_1 - e_0) & \text{if } \frac{(v^H - v^L)}{2} < (e_1 - e_0) & IC_f \text{ saturated, } IC_s \text{ non-saturated} \\ \frac{(v^H - v^L)}{2} & \text{if } (e_1 - e_0) \leq \frac{(v^H - v^L)}{2} \leq (e_2 - e_1) & IC_f \text{ and } IC_s \text{ non-saturated} \\ (e_2 - e_1) & \text{if } \frac{(v^H - v^L)}{2} > (e_2 - e_1) & IC_s \text{ saturated, } \; IC_f \text{ non-saturated} \end{cases} \tag{30}$$

For an intermediate value of upskilling $(v^H - v^L)$, the payment $\frac{(v^H - v^L)}{2}$ suffices to induced truthful revelation of whether the agent is upskilled. For a low value of upskilling, the payment is not enough for a flexible agent to take a project H, and an additional payment is needed. For a high value of upskilling, the payment $\frac{(v^H - v^L)}{2}$ exceeds the minimum required for truthful revelation.

The case-specific optimal profits are:

$$\begin{array}{ll} \pi^*_{ICf} = (v^L - e_1) + \frac{1}{\bar{c}} (e_1 - e_0) \left[(v^H - v^L) - (e_1 - e_0) \right] & \text{if } \frac{(v^H - v^L)}{2} < (e_1 - e_0) \\ \pi^*_{FB} = (v^L - e_1) + \frac{1}{4\bar{c}} (v^H - v^L)^2 & \text{if } (e_1 - e_0) \leq \frac{(v^H - v^L)}{2} \leq (e_2 - e_1) \\ \pi^*_{ICs} = (v^L - e_1) + \frac{1}{\bar{c}} (e_2 - e_1) \left[(v^H - v^L) - (e_2 - e_1) \right] & \text{if } \frac{(v^H - v^L)}{2} > (e_2 - e_1) \end{array} \tag{31}$$

It can be easily verified that the first-best optimal profit, as obtained when the two incentive compatibility constraints do not bind, corresponds to the highest profit in the self-training scenario:

$$\pi^*_{FB} > \max\{\pi^*_{ICf}, \pi^*_{ICs}\}$$

We can check that $\pi^*_{ICs} > \pi^*_{ICf}$ if $(v^H - v^L) > (e_2 - e_0)$ and vice-versa.

5 The best training policy for the firm

A comparison of the profits allows us to show that *the self-training policy entails higher profits than the voucher-based scheme*, irrespective of the parameters.

As shown in Section 3, the profit of the firm in the voucher based training scheme (financed by the firm) is (Eq. 9): $\tilde{\pi} = (v^L - e_1) + \frac{1}{4\bar{c}}\left[(v^H - v^L) - (e_1 - e_0)\right]^2$.

For $(e_1 - e_0) \leq \frac{\left(v^H - v^L\right)}{2} \leq (e_2 - e_1)$, the profit of the firm in the self-financed programme is $\pi^*_{FB} = \left(v^L - e_1\right) + \frac{1}{4\bar{c}}\left(v^H - v^L\right)^2$. Obviously $\tilde{\pi} < \pi^*_{FB}$.

For $\frac{\left(v^H - v^L\right)}{2} < (e_1 - e_0)$, the profit of the firm in the self-financed programme is $\left(v^L - e_1\right) + \frac{1}{\bar{c}}(e_1 - e_0)\left[\left(v^H - v^L\right) - (e_1 - e_0)\right]$. An elementary calculus shows that $\tilde{\pi} < \pi^*_{ICf} \Leftrightarrow \frac{\left(v^H - v^L\right)}{5} < (e_1 - e_0)$, which is obviously true because $\frac{\left(v^H - v^L\right)}{2} < (e_1 - e_0)$.

For $\frac{\left(v^H - v^L\right)}{2} > (e_2 - e_1)$ we can show that $\tilde{\pi} < \pi^*_{ICs}$ at least for $\frac{\left(v^H - v^L\right)}{2}$ bigger, but close to $(e_2 - e_1)$. Indeed, the inequality $\tilde{\pi} < \pi^*_{ICs}$ is equivalent to:

$$\left(v^L - e_1\right) + \frac{1}{4\bar{c}}\left[\left(v^H - v^L\right) - (e_1 - e_0)\right]^2 < \left(v^L - e_1\right) + \frac{1}{\bar{c}}(e_2 - e_1)\left[\left(v^H - v^L\right) - (e_2 - e_1)\right] \quad (32)$$

Let us introduce the variable $v = (v^H - v^L)$, and let $L(v) = \left[v - (e_1 - e_0)\right]^2$ and $R(v) = 4(e_2 - e_1)\left[v - (e_2 - e_1)\right]$. Then: $\tilde{\pi} < \pi^*_{ICs} \Leftrightarrow L(v) < R(v)$. It can be easily shown that, for $v_{\inf} = 2(e_2 - e_1)$, which is the leftward bound of v, $L(v_{\inf}) = \left[2(e_2 - e_1) - (e_1 - e_0)\right]^2 < R(v_{\inf}) = 4(e_2 - e_1)^2$, and also $L'(v_{\inf}) = \left[4(e_2 - e_1) - 2(e_1 - e_0)\right] < R'(v_{\inf}) = 4(e_2 - e_1)$. For a $v/2 > (e_2 - e_1)$ in the neighborhood to the lower bound $(e_2 - e_1)$, the profit gap is positive and is increasing with v. For a very large, and improbable value of v, the inequality might be reversed.

6 Conclusion

Many surveys have revealed that a shortage of skills is one essential factor limiting firm development all over the world. In the nineties, the Internet revolution tremendously changed the nature of work, placing substantial value on computer literacy. In the wake of the Covid-19 crisis, the massive and unexpected need for reducing direct work contacts and increasing physical and social distance brought about important changes in the organization of work. Distance work and distance learning draw heavily on new competencies, both technical and psychological, from online endurance to online communication talent. In the waves of massive adaptation of competencies to the new needs of firms, employees appear to be heterogeneous, with substantial variability in their ability to learn and adapt to the new work requirements. The process through which workers raise their human capital to align their skills to new needs has been referred to as upskilling.

Traditionally the learning cost of upskilling is paid by both firms, which set up specific programs, and employees, who train themselves in their free time. Currently, the development of online education is giving new momentum to the self-improvement strategy. This paper has addressed one important managerial question: which of the employees or the companies should bear the cost of upskilling?

To answer this question, this paper has developed an analysis of the optimal upskilling contract, building on traditional contract theory principles. The analysis has revealed the complex compensation structure a firm must use to achieve worker truthful revelation of types when their skills are private information to them. As an original element of this analysis, the frequency of employees who decide to incur the upskilling effort is endogenous. We also have analyzed the optimal contract to be offered by a firm that finances in-house the training program by means of a voucher for education. We pointed out that in this case, some workers might train on their own, and prefer to work on the low complexity projects.

The comparison of the profits reveals that the self-financed training dominates the firm-financed training. This result is driven by the costs of hidden action in the firm-financed scheme: the fact that some workers can train on their own and select the low complexity project takes these flexible workers out of the internal market for high value projects. The firm has more leverage to diminish the informational rent in the self-training case than in the firm-financed program, which can be seen as a paradoxical situation.

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A Appendix. Cheating in the firm-financed program

We assume here that the firm the firm cannot verify the quality (or the value) and therefore can contract only on the execution of a contract. In this case, a worker can apply for the upskilling program and divest all of the voucher in his own private interest, by undertaking training unrelated to the productive needs of the firm. Because he is not uspkilled, working on a q^H project would cost him $e_2 - e_1$. Let $u(x)$ be the utility of the voucher funds, with $u(0) = 0, u' > 0$ and $u'' < 0$. If the worker cheats, he obtains the private utility $u(b)$, if he is honest, he uses c to upskill, and obtains a private utility $u(b - c)$.

The cheating condition is:

$$u(b) - (e_2 - e_1) > u(b - c) \tag{33}$$

Let us denote by c_0 the solution to;

$$u(b) - u(b - c_0) = (e_2 - e_1) \tag{34}$$

Workers with $c < c_0$ will be honest, those with $c > c_0$ will be dishonest (i.e., apply for the upskilling funds but do not use them in the interest of the firm). In this context, all workers do apply for upskilling. The honest one will produce v^H, the dishonest ones v^L.

Differentiating condition (34), we obtain:

$$\frac{dc_0}{db} = \frac{u'(b - c_0) - u'(b)}{u'(b - c_0)} > 0 \tag{35}$$

The frequency of honest persons increases with the amount of the voucher. However, we can check that $\frac{dc_0}{db} < 1$. This has an important implication for the optimal profit.

Let us denote the probability of being honest by $\mu = \Pr[c < c_0]$. The profit of the firm is:

$$\pi = \mu v^H + (1 - \mu)v^L - b \tag{36}$$

of, under the assumption of the uniform distribution of c,

$$\pi = v^L + c_0 \left(\frac{v^H - v^L}{\bar{c}} \right) - b. \tag{37}$$

Because $\left(\frac{v^H - v^L}{\bar{c}}\right) < 1$ and $\frac{dc_0}{db} < 1$, it turns out that $\frac{d\pi}{db} < 0$: the optimal voucher is the corner solution $b = 0$, i.e., the voucher policy cannot be beneficial to the firm if workers have the option to cheat.

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ESSEC | CPE Registration number 200511927D
Period of registration: 30 June 2017 - 29 June 2023
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