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Motivation crowding-out: Is there a risk for science?

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Abstract

Performance related pay is playing an increasing role in scientific research. This development, which applies the results of standard economic theories (the principal-agent model), aims at increasing incentives and thus productivity in science. The objective of this paper is then to cross the works of various economic fields, including those in economics of science and those on the theories of individual motivation, in order to explore the consequences of this development on scientists' incentives and to focus on its possible "perverse effects".

Two key elements emerge from our literature review: firstly, the motivations of researchers are complex and multiple and do not depend solely on their salary level; secondly, the literature on the theories of incentives identifies a risk that increasing monetary incentives, paradoxically, reduce the overall level of staff motivation, especially when there exist other sources of motivation (as is usually the case in science). According to this literature there may therefore exist a "hidden cost" to financially reward scientists. These teachings lead us to construct empirically testable propositions about the implications of performance related pay in science and the conditions of emergence of a motivation crowding-out effect.

Keywords: science, merit pay, university, "motivation crowding-out", research, incentives.

1. Introduction

"*When creative, innovative, entrepreneurial, scientific and artistic services are desired, they are more efficiently supplied when the individuals concerned are intrinsically motivated. A substitution to monetary incentives is likely to decrease the quality of the service which is often not easily observable*" Bruno Frey (1997, p. 111)

Performance related pay (PRP in the following) is playing an increasing role in scientific research. This development, which applies the results of standard economic theories (the principal-agent model), aims at increasing incentives and thus scientific productivity. The objective of this paper is then to cross the works of various economic fields, including those in economics of science and those on the theories of individual motivation, in order to explore the consequences of this development on scientists' incentives and to focus on its possible "perverse effects", especially when, as mentioned by Frey in the above quotation, scientific production is largely unobservable.

Many studies, in economics, management and psychology, have emphasized that, paradoxically, control and rewards/punishments can sometimes reduce the overall level of incentives for individuals (Fehr and Gächter, 2000a and 2000b; Jegen and Frey, 2001, Mulder *et al.,* 2006, Houser *et al.,* 2008). This negative effect of monetary reward on incentives is, it seems, all the more likely that agents are motivated to accomplish their tasks by other non-monetary elements as, for example, intrinsic motivations (Deci, 1975), compliance with civic virtues and social norms or a sense of duty. In this case it is possible that the introduction of a monetary item in the incentive structure crowds-out other types of motivation and thus, ultimately, reduces the overall level of incentive for the agent.

This result is one of the greatest curiosities of economics as it clearly goes against the "price effect". As part of an agency relationship it is indeed usually acknowledged that in order to align the incentives of the agent with those of the principal, the cheapest solution is to offer the agent a share of the value he has helped create (Laffont and Martimort, 2002). In other words, to link the salary to the agents' performances is expected to boost their motivations and levels of effort. Moreover, several studies have provided empirical evidence to validate the positive effect of PRP on workers' productivity (Lazear, 2000).

Yet, in many situations, such as the agency relationship between parents and their children, between neighbors or between members of charitable organizations, the issue of PRP is completely absent. For example, parents seldom reward their children when they participate in daily household chores (Frey and Jegen, 2001; Benabou and Tirole, 2003). Similarly, many studies in management science show that corporate managers are usually aware of the limitations of rewards and/or monetary penalties to promote the efforts of their employees and teamwork (Nalbantian, 1987; Baker et al., 1988).

If the works on the existence of a possible crowding-out effect of the introduction of PRP on the overall level of motivation of agents are growing, this hypothesis has to our knowledge not yet been explored in the field of scientific production (with the exception of Osterloh and Frey, 2009). This absence is surprising for at least two reasons:

- Firstly, because, if the compensation structure in science historically has relied on a small part of monetary incentives, things seem to be changing. Many universities around the world no longer hesitate to link researchers' remunerations to their research performances in the very short run (Osterloh and Frey, 2009). As witness, for example, in France the introduction of the "Prime d'Excellence Scientifique" in 2009; or the growing number of institutions that award bonuses for publication. This is part of a wider trend which sees income inequality steadily growing in science, thus departing from a historical tendency of the earning profile to be relatively flat, especially in some European countries (Stephan, 2012)[1].

- Secondly, because scholars have for long emphasized the importance of non-monetary sources of motivation in the activity of scientific research (Merton, 1973, Stephan, 1996). Scientists are generally motivated by the intellectual challenge or by the search for a reputation. Also, to offer them a stable remuneration, relatively disconnected from their performances in the short run, is often seen as the best way to get them to carry out true basic research, not immediately profitable and difficult to measure, but extremely challenging from an intellectual point of view and potentially a source of important recognition by the scientific community.

[1] Stephan (2012, p. 44) argues that in some countries, for example in China and South Korea, publication bonuses can be as high as 50% of the total income of the researcher. She also adds that, beyond these cash bonuses, researchers can increase their income via patenting and licensing, consulting and start-up creation.

The combination of these two elements makes therefore the emergence of a crowding out effect of PRP on scientists' motivation possible, in particular in countries which historically did not rely on PRP but progressively tend to introduce it. Thus, it seems important to study the relevance of such an effect, and especially to analyze the conditions of its emergence. This is precisely the aim of this contribution. To be more precise, we analyze the impact of PRP on scientists' motivation, i.e. on their level of effort. We do not analyze the consequences on the quality of the research which is undertaken, although it is possible that the introduction of PRP also affects this dimension. This important issue is let for another work.

In the next section we recall the question of incentives for researchers in science (Section 2). Then we provide a survey of the works that analyzed the issue of motivation crowding-out (Section 3). This allows us to draw the main lessons of this literature (Section 4) and to construct empirically testable propositions concerning the impact of PRP in science and the conditions of emergence of a motivation crowding-out effect (Section 5). Finally, in the last section we discuss the normative implications of this research by distinguishing two scenarios, depending on whether the production of basic knowledge is primarily a matter of isolated geniuses or rather a collective epic enriched through the contribution of all (Section 6).

2. The diversity of the sources of motivation in science

Why do researchers do research? Since the work of Merton in the 1960s, this issue has been the subject of much scientific research. For Stephan (1996), the incentives of researchers are based on elements both intrinsic and extrinsic and can be grouped into three categories: "Gold, puzzle, reputation". In addition to these three elements, we also discuss here two others, namely the desire to be useful and to improve the fate of mankind and researchers' sense of duty.

i) **Gold**. First, researchers' motivations are obviously linked to their remunerations[2]. The fact that historically, the remuneration of researchers only weakly has depended on their

[2] Stephan (2012, p. 59) states that: "No one would become a scientist solely for the money. There are too many other, more lucrative careers that require fewer years of training and fewer hours of work

performances in the short term (it usually depends on the long-term performance) does not in any way mean that researchers do not pay attention to their salaries. We have many indications that researchers do react to monetary incentives. For instance, they do not hesitate to move to universities which offer the highest pay (Stephan, 2012). But unlike many other activities, the scientific motivation is far from relying exclusively on the financial dimension.

ii) **Puzzle** (or Sudoku). Researchers are motivated by scientific curiosity, a taste for science and the pleasure of solving puzzles. Most renowned scientists, when asked about their motivations, put forward the pleasure of searching, the fact that research is akin to a game in which finding the answer is a reward in itself. This motivation is completely intrinsic. It is not linked to any reward other than the mere performance of the research activity[3].

iii) **Reputation.** Studies on the motivations of researchers also highlight their narcissism and need for recognition by society in general and by their scientific community (at the international or local level) in particular. Many scientists may therefore be more (or at least as) sensitive to an honorific award than to an increase in their salary. This search for reputation has one essential consequence, highlighted by Merton in the 1960s: the race for priority. The purpose of researchers in order to increase their reputation is to be the first to publish their research (Stephan, 2004). This system of "winner takes all" induces an important paradox: to appropriate its research the researcher does not protect it as in industry (through secrecy or patent, for example) but, instead, it publishes it and shares it. In other words, appropriation comes with the diffusion of the research![4] Hence, the race for priority in science has at least two good properties (Dasgupta and David 1994): it encourages researchers to do

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and pay higher salaries. Nonetheless, success in science is accompanied by monetary rewards and scientists are not immune to their allure".

[3] Note here that the intrinsic motivation of researchers implies that it is generally not necessary to pay them at their marginal productivity to encourage them to provide an optimal effort level. For example, Stern (2004) shows empirically that researchers are often willing to pay, that is to say, to accept substantial reductions in salary when they work in private firms, merely for the right to perform truly fundamental research and to publish it. Empirically by examining the relationship between the nature of research conducted by the researcher and his salary, he concludes that "conditional on perceived ability, scientists do indeed pay to be scientists" (On the question of the motivations of researchers and their impact on careers, see also Roach and Sauermann, 2010).

[4] Merton (1988, p. 620) thus explains that: "in science "one's private property is established by giving its substance away".

good basic research (in order to be recognized by their peers) and it encourages them to publish their research rather than to keep it secret (it increases the cost of secrecy)[5].

It is important to note that reputation is not only about research ability but also about the seriousness and the ethics of the researcher, i.e. researchers have a ***desire for social approval*** (Fehr and Falk, 2002). Consequently, many researchers do perform research due to social pressures from their local scientific community. Deviant behaviors are easily detectable by co-workers. Thus, the researcher who does not provide the level considered as minimal effort by the community undermines his reputation. Knowing that they are observed by their local communities, agents may then provide significant efforts just to show that they "play the game", i.e. in order to improve their local reputation of serious researchers. The difference with the reputation effect discussed above (where reputation is about the ability of the researcher) is that, in this latter case, scientists devote resources to do research even though they do not expect to obtain significant results and become scientifically "famous". In other words, for many researchers, the obligation of means may be more important than the obligation of result.

iv) **Desire to be useful**. In addition to these three elements, a fourth one is sometimes highlighted in the literature, which is the desire to improve the fate of mankind, the desire to be useful in improving the general level of knowledge. For instance, researchers may aim at discovering new essential drugs that will cure diseases, even though there is no monetary reward or fame associated to it.

v) **Sense of duty** (self-esteem). Last, but not least; we introduce here a fifth source of motivation that has been neglected by the literature in economics of science: the moral obligation that can be felt by the researchers and that may prevent them from behaving as free riders in the absence of formal control. Indeed, where remuneration is entirely disconnected from the performance of the agent, the agency model predicts a minimal effort. However, this prediction assumes that free-riding is not expensive. But this is often not the case. Deviating, not doing the job he is supposed to do, is expensive when the agent has an ethical and moral

[5] In the end, this incentive system based on the race for priority is very powerful. As noted by Arrow (1987, p. 687): “The incentive compatibility literature needs to learn the lesson of the priority system; rewards to overcome shirking and free-rider problems need not be monetary in nature; society is more ingenious than the market”.

sense of duty; it lowers his self-esteem. Also, in the case of science, ethics, morality can lead scientists to do research, to devote time and resources to search, even (and especially) in the absence of any financial recognition. It is a matter of moral commitment for them. This motivation is very similar to what other authors have called a "***desire of reciprocity***" (Fehr and Falk, 2002).

Linked to this moral obligation, it is also worth mentioning the feeling of guilt that researchers may experience when they free ride. This feeling may be especially high when there is no formal control and/or no punishment associated to deviation. Hence, agents may provide significant efforts in order to avoid feeling guilty towards their communities. This feeling of guilt is different from the desire for social approval stressed above, in the sense that it can emerge even though nobody notices that the agent free rides. It therefore does not depend on the perception of others but only on the agent's own perception of what he is.

For the purpose of our work, it is important to emphasize this fifth source of motivation, because, as we shall see later, it is precisely the one that seems most vulnerable to the introduction of PRP in science. Merit pay may be neutral or even reinforce puzzle and reputation effects, but it is likely to completely destroy the sense of duty, the desire for social approval and the feeling of guilt felt by the researchers, as they arise precisely because researchers operate in a space of freedom without too much formal control in the short run.

In summary, the incentive system in science does not exclusively rely on monetary aspects. Furthermore, this system appears to be relatively effective in promoting the production and dissemination of basic knowledge. However, in recent years, particularly in France but not only, the remuneration of scientists tends to be increasingly linked to their short term performances. What are the possible consequences of these developments on the incentives of researchers? In particular, is it possible that this generates "perverse effects" in some contexts and reduces the incentives of some researchers? To examine these issues, we introduce in the next section the literature on motivation crowding.

3. Motivation crowding-out effect: Definition and examples

The first authors to have pointed out a possible hidden cost of monetary compensation were interested in the case of blood donation activity, often considered the most selfless kind

(especially because the relationship being completely anonymous, no explicit mechanism can ensure a counter-gift back to the donor). Standard economic theory predicted that a monetary compensation given to the donor, all things being equal, should increase the amount of blood available. But very soon, this prediction was challenged. Titmuss (1970), for example, suggested that the introduction of money in the relationship may reduce donors' other sources of motivation and, ultimately, reduce the amount of blood available and its quality.

Ireland and Koch (1973) tested the theory of Titmuss on a population of students and found that, indeed, for moderate levels of remuneration, the introduction of the latter reduces the amount of blood available. But for more significant levels of remuneration, the blood supply increases again. Upton (1973) obtained a similar result[6].

The case of blood donation clearly indicates that the introduction of a fee, if it can increase performance, does not do it systematically. In some contexts, introducing compensation can reduce agents' motivations. This is known as the motivation crowding-out effect of reward and/or control (Frey, 1997; Frey and Jegen 2001).

The main explanation of this effect is the existence of multiple sources of motivation for most people: financial interest but also non-monetary motivations, such as a sense of duty for instance or motivations that are intrinsic (Deci, 1975). Consequently, the effect of the introduction of monetary compensation in an agency relationship is double: on the one hand it obviously increases the monetary side of the motivation; on the other hand it can reduce the other sources of motivation by decreasing, for example, the determination of the agent, his self-esteem or his possibilities of individual expression[7]. The motivation crowding-out effect appears therefore when the decline in these other sources of motivation more than offsets the increase in monetary motivation[8]. It should be noted, however - and we return to this point

[6] Also, it is interesting to observe that if, in the vast majority of countries, donors are entitled to certain benefits in kind, such as drinks and meals, agencies' staffs are very careful not to show these benefits as remuneration, but rather as material signs of recognition in order to encourage the donors (while remaining outside a market relationship).

[7] Historically, the concept of motivation crowding-out was about the risk that increasing the extrinsic side of individual motivation reduces the intrinsic side, i.e. the motivation which comes from the accomplishment of the task itself, irrespectively of social interactions (Fehr and Falk, 2002). However, in line with Frey (1997) we adopt here a wider view of this concept by extending it to all types of non-monetary motivations, including those that are not purely intrinsic (social approval, reciprocity).

[8] Benabou and Tirole (2003) proposed an alternative explanation, more rooted in economic theory. They suggest that the introduction of a fee may decrease the motivation of an agent because it may

later - that most often, for significant compensation levels, the increase in the monetary side of motivation outweighs the decrease in the other sources of motivation and hence PRP increases the overall level of incentives of the individual[9].

The motivation crowding-out effect was identified in a variety of situations. For example, in the case of tax collection, it was shown that citizens are less likely to cheat when operating in an environment of trust, which does not immediately assume that they are swindlers (Frey, 1997). Also, in most countries, civil servants are willing to work for wages significantly lower than when working for private firms, which may mean that those civil servants are not motivated only by monetary elements. Furthermore, when these civil servants are more controlled, their level of motivation tends to decrease and it becomes necessary to offer them higher salaries only to maintain the same level of services as before (Poterba and Rueben, 1994; Weibel *et al.*, 2009). Similarly, in the environmental field, Frey and Oberholzer-Gee (1997) suggested the existence of an environmental ethics on the part of Swiss citizens who, paradoxically, were shown to be less inclined to accept the installation of a noxious facility near their homes when a monetary compensation was offered!

More recently, Gneezy and Rustichini (2000a) put forward a result which we see as essential to explain the motivation crowding-out effect: the introduction of a fee (or a penalty) can transform a moral obligation into a commercial service and, thereby, reduce individuals' motivation when the latter was previously caused by a moral sense of duty. This was highlighted in the case of a field experiment in Israel. The experience was about the behaviors of parents who had to collect their children from the daycare center. Often the parents arrived late, which was obviously expensive for the daycare center, since it required staff to stay on longer in order to look after the children. To deter from these delays, a small financial penalty was then set up for laggards. As a result, the introduction of the penalty increased significantly the number of delays and their average length compared to a control group[10].

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signal that the task is thankless and / or difficult or it may signal a lack of confidence from the principal. This signal can then induce a reduction in the motivation of the agent. A similar explanation is developed in Ellingsen and Johannesson (2008) who show that PRP can signal to the agent a lack of interest of the principal for everything related to the work ethics (the principal cannot be impressed by a purposeful agent) and thus, ultimately, reduce the motivation of the agent.

[9] Fehr and Falk (2002, p; 717) note that: "Even if crowding-out effect is operative it may still be efficient to use material incentives. This is so because, from an economic point of view, it is the *total sum* of incentives that matters".

[10] It should be noted that this result can largely be explained by the fact that the penalty was modest, about 2 euros per delay.

One possible explanation put forward by the authors is that the introduction of the penalty transformed a moral obligation (not to arrive too late out of respect for childcare staff) into a commercial service (now parents have the right to be late since they "buy" this delay). In other words, a fine is equivalent to introducing a price ("A fine is a price" to quote the title of the article by Gneezy and Rustichini)[11].

Another important result of this experiment is that, once the financial penalty was abolished, the number of delays did not decrease significantly, thus tending to indicate that once non-monetary sources of motivations are crowded-out, they are extremely complicated and expensive to rebuild.

In another field experiment conducted among children in charge of collecting donations for charity, Gneezy and Rustichini (2000b) highlighted the importance of the amount of the remuneration on agents' motivation. They compared three treatments: in the first children were not paid to collect donations; in the second they received a very small percentage of the collected donations (1%); and in the last they received a higher percentage (10%). The results are significant. The second treatment was the least efficient (the one in which the amount of collected donations was the smallest) and the first was the most efficient. In short, when the pay is low, the motivation crowding-out effect plays full well. The introduction of PRP reduces non-monetary sources of motivations and the overall impact is a reduction of the total motivation of children. To counter this motivation crowding-out effect one must then introduce a more significant compensation.

Even more recently, the field of experimental economics has reinforced these initial results. For example, Houser *et al.* (2008) confirm Gneezy and Rustichini's results, showing that agents can actually behave less cooperatively when threatened with punishment. They explain this by the fact that sanctions or threats of sanctions "can be interpreted as the price for self-interested behaviors and the price is an excuse for selfishness" (Houser *et al.*, 2008, p. 523). Hence, in the absence of a prize or a punishment, most individuals feel they have to provide a minimum level of collaboration. Fehr and Gächter (2000b) found also that in some cases the

[11] The fact that the market reduces agents' moral obligation had already been highlighted by Dostoevsky in the 19th century in his novel *The Insulted and the Injured* in a beautiful sentence, "pay for services you receive and you have completed all your duties towards your neighbor".

introduction of monetary incentives may reduce incentives to reciprocate, especially because they induce a hostile atmosphere of threat and defiance. Finally, Mulder *et al.* (2006) show that in situations like the prisoner's dilemma, the introduction of monetary incentives or sanctions can point out to players that other players are not friendly and not very willing to collaborate, thus increasing the temptation to deviate. They find in particular that the introduction of sanctions can significantly reduce the level of cooperation when trust between the players was initially very high. They conclude (p. 148) that: "Penalties change the perception of people and might transform ethical motives in more calculative motives".

4. Mains lessons from the literature on motivation crowding-out

As shown in the previous section, the issue of motivation crowding-out proved to be relevant in many different studies and contexts. It is, however, still often difficult to find a common denominator to all these works and a single explanation for the observed behavior. Nevertheless, with respect to our research on incentives in science, a limited number of key points emerge from the literature which, in the next section, will enable us to build theoretical (empirically testable) propositions on the consequences of PRP and the possible emergence of a motivation crowding-out effect in science. We have identified four of those key-points:

1) A first important element which comes out of the literature on the motivation crowding-out effect is that, by definition, it can only occur when agents' motivations are not based only on monetary elements. In particular, motivation crowding-out effect can be very significant when the agent's motivation is strongly intrinsic or driven by a moral and/or social sense of duty. In addition, Frey (1997) stresses that the moral and work ethics of agents is likely to be important when the work is interesting and non-routine[12], when there are personal ties between principal and agent[13] and when agents are involved in decision making (participative management). Ariely *et al.* (2007) add that when the task is a social or charitable one, non-monetary sources of motivation

[12] Weibel *et al.* (2010) have conducted a meta-analysis on 46 published papers and showed that PRP significantly increases performance in the case of non-interesting tasks but significantly decreases it in case of more interesting tasks.

[13] For example, games of prisoner's dilemma that are played in laboratory do not provide similar results when participants know and appreciate each others and when they are anonymous. In the latter case collaboration is much less common. Similar results are obtained in experiments on ultimatum games and/or dictator games.

are also higher (the effect of the image, the perception of the others or the agent's own self-esteem provide powerful incentives)[14].

2) A second important result that comes out of the literature is that a motivation crowding-out effect is the most likely when the amount of money introduced is small. Indeed, since the non-monetary part of incentives vanishes as soon as money appears in the relationship, irrespectively of the amount of money which is introduced, when the monetary award is low the crowding-out effect plays full and tends to dominate the positive effect coming from an increase in monetary incentives, which is weak. Thus, the overall level of incentives decreases. But this may not be the case for high levels of remuneration for which the positive effect of monetary incentives dominates, i.e. the link between pay and effort becomes positive. In other words, to increase the incentives of an agent, the reward must be substantial. As stated so well by Gneezy and Rustichini (2000b): "Pay enough or do not pay at all". This point is likely to be essential in the case of public organizations (for example universities) which are subject to important budget constraints and may hence be unable to fix significant rewards, thus being more exposed to motivation crowding-out (Weibel *et al.*, 2010).

3) The introduction of PRP may reduce the ethics and work morale of employees. But, conversely, it can also increase them if it is seen as encouraging and recognizing the efforts provided by the agent (there is a crowding-in effect in this case). In particular, Fehr and Gächter (2000b) emphasize that sanctions and rewards are not symmetrical (a penalty is not a negative reward) in the sense that the introduction of sanctions may reduce the other sources of motivation more than the introduction of a reward may do. An important consequence is that compensation must always be individualized and must not be completely uniform over the population of agents in order to be perceived as fair.

4) The introduction of a monetary reward leads to an irreversible effect on the other sources of motivation. The non-monetary part of motivation that has been destroyed by the introduction of PRP is extremely difficult to rebuild in the future, even if the

[14] This explains in particular that (good) managers spend significant time developing personal relationships with their employees. Also, this explains why you do not pay a friend who helps you move, but you offer him a beer and lunch!

monetary reward is removed. The principal must hence be aware that by introducing a monetary reward it will be difficult to reduce or remove it in the future, without taking the risk of destroying entirely all the sources of motivation of the agent[15].

5. Some propositions about the risk of motivation crowding-out in science

All those four points may have considerable implications in the field of science, which we aim at discussing now. However, it must be recalled that the following discussion applies to a very specific context, more European than North American: We explore the consequences of the introduction of PRP on scientists' motivations (1) by taking as point of comparison an initial situation in which researchers' remunerations are fixed and almost entirely disconnected from their short run performance (as is essentially the case in France for instance) and (2) by assuming that PRP comes in addition to the fixed wage and does not substitute for it (as is the case of publication bonuses for instance).

A first important result highlighted above is that the introduction of PRP is most likely to crowd-out elements of motivations based on the sense of duty and/or the willingness to avoid social disapproval. It is thus critical to understand which profile of researcher may be motivated by those factors. We claim here that it is mostly the case for researchers who are, *ceteris paribus,* less productive, older, and/or have experienced some disappointments in their careers that they consider as unfair.

Indeed, at first glance it might seem that the more talented and productive researchers, who can anticipate obtaining the bounty, have a greater incentive than others. But this reasoning ignores the fact that the motivation level of those researchers is generally already very high. They are passionate about their research (puzzle effect) and, moreover, they are already adequately remunerated. This makes it difficult to further increase their motivation by adding an extra fee based on their performances. On the other hand, it is also unlikely that the introduction of PRP reduces their level of incentives since it will increase their own wage

[15] Among other things, this is due to the *overjustification effect*, which may occur when a reward is administered for performing an activity which is already rewarding in itself. In this case, people will attribute their behavior to the reward and, as a consequence, when the reward is no longer offered, interest in the performance is lost and effort, *ceteris paribus* decreases to a level that is lower than the original one. This means therefore that, as soon as monetary reward has been introduced, it must be continuously offered just to sustain the same level of effort.

without inducing them to provide higher effort. Therefore, we can bet on an almost neutral effect of PRP on the motivation of highly productive researchers (at least for the senior ones, the junior ones possibly feeling encouraged - the bonus they receive being perceived as a just reward for their efforts, thus leading them to increase slightly their level of effort[16]).

However, this is probably not the case for the least productive researchers (or those considering themselves as such). Indeed, the motivation of the (many) less productive researchers, who publish less and in less prestigious journals, is often not the money, let alone the research reputation, but the moral and social obligation they feel to do research. They feel an obligation of means rather than an obligation of result! Hence, it is possible that the introduction of PRP destroys this obligation, thus inducing a motivation crowding-out effect for this category of researchers. As shown by Gneezy and Rustichini (2000a), the risk here is to transform a moral and/or social obligation in a market service. In a sense, the introduction of PRP acts as the price for not doing research. Now, researchers who no longer want to do research pay for it (they renounce to the PRP).

In addition, this motivation crowding-out effect seems all the more probable as the researcher is older because in this case, the incentive coming from the puzzle effect may become smaller (the search is more routine, less passionate) and the fixed part of the salary is higher (see proposition 2). Furthermore, one can predict that the likelihood of motivation crowding-out increases when the researcher suffers a feeling of injustice, for example, because he performs tasks which are useful but not recognized in the life of a research laboratory or because he has been refused an important publication. This brings us to our first proposition:

Proposition 1: A motivation crowding-out effect is more likely when the researcher's motivation is mostly based on his sense of duty and/or a desire to avoid social disapproval, that is to say when:

(a) the researcher is not among the most productive ones (he is motivated rather by an obligation of means than an obligation of results)

(b) the researcher has experienced a long career without significant feats of arms

[16] This positive impact is still reinforced by a self-selection effect. For similar research abilities, the older researchers, from experience, know their research capacities and whether or not they are eligible for the bonus. Therefore they do not much adjust their level of effort. On the contrary, the younger, perhaps more optimistic and less experienced researchers may all be largely tempted by the introduction of a premium.

(c) the researcher feels a strong sense of injustice due, for instance, to recent publication or promotion refusal.

A second important implication for science is that PRP, in order to have a positive effect on researchers' incentives, must be significant. This may be highly problematic in Europe where, since public budgets are tight, PRP are likely to be of a limited amount. Furthermore, since PRP comes in addition to a researcher's fixed wage and does not substitute for it, it means that its amount must be relatively important as compared to the fixed part. A bonus of an equivalent amount has probably a greater effect when the researcher's base salary is lower because in this case, the relative impact is higher. An important consequence is then that, in systems where pay tends to increase mechanically with seniority (as is the case in France), introducing an element of PRP is likely to be more efficient for younger researchers (if the amount of performance bonus is the same). This leads to our second proposition and its two corollaries:

Proposition 2: According to the principle of "pay enough or don't pay at all", the risk of motivation crowding-out effect is greater for very small amount of PRP.

Proposition 2a: The risk of motivation crowding-out effect is greater when the fixed part of the scientist's salary is relatively high as compared to the PRP part.

Proposition 2b: In countries where the fixed part of the salary automatically increases with seniority, the risk of motivation crowding-out effect is more important for senior researchers.

Furthermore, in order to minimize risks of motivation crowding-out, the introduction of PRP must be seen as fair and supportive, so as to encourage and strengthen the agent's other sources of motivation. If the introduction of a monetary compensation is seen as a way to control the agent, to force him, if it pays too little attention to his real level of effort (because it is based on limited indicators), then it may have a counterproductive effect by reducing other sources of motivation and, ultimately, by discouraging the effort of the agent. This point leads therefore to the issue of what a fair reward in science may look like?

- First, the reward should be based on a level of performance constant and regular in time, not just on brilliant feats of arms but punctual. Since research is a long-term

activity that requires persistence from scientists (Stephan, 2012), the award must obviously take this time dimension into account. Also, it is preferable that the reward is not linked to specific and precise task engagement. In this respect, prizes that are based on the researchers' activities over several years (like the "prime d'excellence scientifique" in France) are more suitable than systems based on publication bonuses.

- Second, since science is a multi-tasks activity, the reward must be based on a combination of performance indicators. To base the reward on a single indicator would be the best way to make it counterproductive in generating feelings of injustice and frustration. In addition, the multiplicity of indicators ensures that incentives are not biased toward some aspects of scientific performance, more easily visible, easier to measure, and appearing as more objective, such as publishing for instance (Fehr and Schmidt, 2004)[17].

- Third, the reward must be individualized and take into account the characteristics and contexts of each agent. A reward too uniform between agents is often the best way to frustrate the efforts of the most deserving ones.

- And fourth, the reward, although it aims at encouraging and rewarding the best researchers, must not be regarded as a sanction to researchers considered the least efficient. For instance, it must not be perceived as decreasing the wages of those latter researchers. This leads us to our third proposition:

Proposition 3: A motivation crowding-out effect is less likely to occur when the monetary reward which is introduced seems fair and encouraging that is to say, when it is (a) not based on the performance of researchers in the very short term; (b) based on a combination of several indicators of performance, (c) individualized and (d) is not seen as a way to introduce sanctions.

[17] This argument is perfectly summarized by Gibbons (1998, p. 115): "Steven Kerr published in 1975 "On the Folly of Rewarding A, While Hoping for B" The argument was simple: you get what you pay for. Kerr distilled this unifying theme from a disparate set of examples involving politicians, soldiers, doctors, orphanage directors, professors, and students, as well as manufacturing and clerical employees and even human-resource managers. From these examples, Kerr (pp. 779- 80) concluded that two main causes of distorted incentives are "*fascination with an 'objective' criterion*, [where] individuals seek to establish simple, quantifiable standards against which to measure and reward performance" and "*overemphasis on highly visible behaviors*, [when] some parts of the task are highly visible while others are not." It took agency theory 15 years to express Kerr's title, not to mention to evaluate or extend his conclusions" (Note: we added the italics).

The last point that comes out of the literature on motivation crowding-out is that the introduction of a financial bonus can generate a strong irreversibility in the sense that, once the other sources of motivation are completely destroyed, they are extremely difficult to reconstruct. Applied to the case of science this means that the introduction of PRP should be lasting. It would be extremely dangerous to introduce it only for a certain period of time and then to remove it. In this case, the risk would be high that the removal of the PRP would reduce dramatically the overall level of motivation of scientists.

Also it means that one should pay extreme attention to the transition phases when, for example, one researcher who is eligible to a bonus sees it removed. In this case it is possible that the researcher comes out completely demotivated. In particular, there is no symmetry between the introduction of a bonus and its disappearance. Also, paradoxically, researchers for whom obtaining a bonus had had no significant positive effect on their motivations may be found highly demotivated once the bonus disappears. Finally, it means that the system of PRP in science contains the seeds of a highly inflationary wage. Indeed, after the introduction of a PRP system, very soon many researchers may consider it normal to get the bonus, thus providing a level of effort just normal. Therefore, to maintain a maximum level of effort, the principal must regularly increase the amount of the premium. Hence our fourth and final proposition and its two corollaries:

Proposition 4: The introduction of PRP in science leads to a fundamental irreversibility. Once introduced, a reduction or a removal can greatly decrease the motivations of researchers.

Proposition 4a: In particular, there is an asymmetry between the introduction and removal of a bonus. Researchers for whom obtaining a bonus had had no positive effect on their motivation can, however, significantly reduce their levels of effort when the bonus is removed.

Proposal 4b: The introduction of PRP in science, for long-term incentive, must be continuously inflationary.

In conclusion, as summarized in Table 1, the impact of PRP on the dynamics of researchers' careers is not the same according to their ages and research potentials (for simplification we

assume that researchers have either a high or a low potential of research). It is indeed likely that the introduction of PRP provides more incentives for younger researchers (and even more so for the most productive ones who may feel encouraged in their efforts). But the positive effect can quickly dry up to become zero for the most productive researchers or even negative for the less productive ones and for bright researchers, who would not have seen their efforts rewarded. It is indeed likely that, for those bright researchers, incentives are increased early in their careers (the younger researcher wanting to get the premium), but then the effect of merit pay becomes at the best zero and at worst negative, depending on the trajectory taken by the career.

Moreover, in this dynamic approach, special attention must be paid to issues of irreversibility and path dependency. Failure at some point in time in the researcher's career, thus punished by a reduction in pay, may have significant negative consequences on the motivation of a researcher in the rest of his career.

Table 1: Consequences of PRP in science: The role of career dynamics

Researcher's potential / Age	High potential		Weak potential
Younger researchers	+ (1) (2)		**0**
Older researchers	**0**	**-**	**-**

Note: (1) implies that the researcher managed to hold on to the desired career path (he was successful). In this case his motivation level remains high, but over time, increasing motivation induced by the merit pay is fading, (2) the second situation implies that the researcher, for any reason (possibly a random event), fails to maintain the scientific career path he wanted. Non monetary sources of motivation are then completely destroyed by the existence of PRP.

6. Normative implications for science: Two extreme scenarios

The introduction of PRP in science can have very different implications on the overall motivation of a researcher, according to his age, potential and career evolution. It is therefore important to analyze the normative implications of the introduction of PRP in science. In

particular, it is not obvious at all, given the propositions developed in the previous section, that it may be to the detriment of the social welfare since it can have positive impacts on younger researcher. We show here that the propositions developed in the previous section can lead to completely different normative implications. We outline two extreme scenarios, based on two distinct hypotheses about how science works: (1) the progress of scientific research is largely based on the performance of a few "star scientists", and the work of the vast majority of other researchers does not matter in order to advance the progress of science and; (2) the pace of scientific research depends on the interaction of the entire scientific community and, in this collective setting, the contribution of each researcher is important.

In the first case, if science is a matter of a few isolated geniuses, then it is likely that the introduction of more merit pay does not change significantly the efficiency of the research system. The propositions developed in the previous paragraphs indeed suggest that merit pay does not influence significantly the motivation of highly productive researchers. Provided that their living is ensured, leading scientists are usually not motivated primarily by money but rather by the willingness to solve challenging intellectual problems or the desire to contribute to social progress (Stephan, 1996). Monetary prizes, even though they are important, are very weak motivations as compared to those non-monetary ones.

At most, the introduction of PRP might increase the motivation of the younger researchers, who may feel encouraged in their efforts by this additional remuneration. It can also have a positive effect by attracting more talents to science, due to the relative increase in revenues as compared to jobs in other sectors (But this effect is not specific to performance pay. It also applies to an increase in the share of fixed remuneration). Therefore, if the global performance of science is based solely on the work of these top researchers, introducing a PRP will be at worst inconsequential.

In this first scenario, the most important implication of the introduction of PRP may be an increase in the remuneration of the most productive researchers when precisely, due to the presence of a significant amount of non monetary motivations, these researchers are often paid below their productivity. However, this result affects the distribution of revenue (it may be a matter of social justice and equity) and has little or no effect in terms of incentives and thus of efficiency.

If, conversely, science is a collective affair that cannot be performed in isolation and scientific performance depends on each contribution, however modest, then it is likely that the introduction of merit pay reduces the overall system performance of scientific research. The discussion in the previous section indeed indicates that the new pay structure, although neutral to the best researchers, may significantly reduce the level of motivation of certain categories of researchers, in particular the oldest and less productive ones.

Those researchers are often motivated essentially by non monetary elements such as a moral obligation, a sense of duty and social pressures by the local environment. Hence, although they are not directly rewarded for doing research, they are likely to consider that it is a "moral obligation" to devote (a considerable amount of) time and resource to this activity (among others because they are paid and not really controlled for it). Yet, this type of motivation that stems from compliance with a social or moral norm is highly vulnerable with respect to the introduction of monetary prizes (Gneezy and Rustichini, 2000a and 2000b).

Therefore, in case science is a collective epic in which it is important that all researchers, independently of their talents, contribute, there is clearly a risk that the introduction of PRP damages the pace of scientific discovery by reducing the incentives of many researchers. Moreover, it is also likely that excessive differences of pay will reduce the exchange and collaboration among researchers, thus also impeding the process of collective production of knowledge[18].

7. Conclusion

This work was a first step in our project to understand the consequences of PRP in science. We first discussed the multiple motivations that lead researchers to devote time and resources to do research. Then, we discussed the eventuality of a motivation crowding-out effect due to the introduction of PRP in a context in which the remuneration was historically disconnected from short run performance. This led to the building of some propositions about the possible consequences of PRP in science and to a discussion of the normative implications.

[18] This is consistent with the findings of Pfeffer and Langton (1993) who show that wage dispersion in a research laboratory significantly reduces the likelihood that members of the laboratory work together.

In particular, we suggested that the introduction of PRP in science, if it may encourage and increase to some extent the motivation of the younger and brighter researchers, may conversely significantly reduce the motivation of the older and less productive scientists and/or those who may have been disappointed during their careers, eventually by a negative random event. Therefore, the intermediate conclusion of our work is that one should be very cautious about the introduction of PRP in science, in particular because the characteristics of the researcher and the bonus system can lead to possible adverse effects. Our work is therefore partly in line with the conclusion of Weibel *et al.* (2010, p. 406) who argued that "pay for performance in the public sector may offer more disadvantages than advantages".

An interesting question, yet beyond the scope of this research, is whether the introduction of PRP aims at increasing researchers' incentives to do research or incentives to publish this research? We proposed in this work that PRP may have only little effect on the incentives to do research of the best scientists, who are already highly encouraged by other sources of motivation. Hence, another explanation about why PRP is growing all around the world in science is that it may increase scientists' motivations to publish their research and to do it in prestigious journals. Once a research has been performed there is indeed still a long way before it can be published. And this activity may be considered as less interesting by true researchers. Therefore, as patents may serve as an incentive to transform an invention into an innovation, publication bonuses may serve as an incentive to transform research into a publication.

If this is true (PRP aims at increasing incentives to publish, not incentives to do research), then an immediate question emerges: Is there a danger that PRP and other types of incentives that contribute to generate a publication race are detrimental to the quality of the research which is performed? Is it possible that scientists devote more time to publishing their research than to doing original research? Is it possible that the over-emphasis on short-run publication diverts scientists from genuine basic research? It is the opinion of Osterloh and Frey (2009), who therefore call for a governance system based on a stronger emphasis on selection and socialization than one based on the simple principles of the principal-agent model[19].

[19] Osterloh and Frey (2009, p. 20) explain that due to more PRP and control: "intrinsically motivated curiosity to do research tends to be crowded-out and is in danger of being substituted by extrinsic motivation to score high in rankings. Content loses importance". Also, they add (p.25) that "in contrast to variable pay for performance, awards are not perceived as controlling. Instead, they are of a symbolic nature that gives supportive feedbacks".

Linked to this question is the issue of the impact of PRP on the quality of research. This paper examined only the impact of PRP on the agent's level of effort, i.e. on the quantity of research which is performed (the time and effort devoted to the research). But another research question, maybe even more important, deals with the type of research undertaken by scientists. In other words, is it possible that the introduction of PRP decrease the quality of scientific research? For instance, many studies tend to highlight the negative effect of control and rewards on creativity (Amabile *et al.*, 1986). This important question will have to be examined in future research. In particular, the framing of the reward is likely to play an important role (Fehr and Falk, 2002).

Another direct extension of our research will be to complete this conceptual work by more formal analysis and, most of all, by empirical insights. We intend to conduct such a thorough empirical study on the case of the University of Strasbourg. First, a questionnaire will soon be sent to researchers from the University of Strasbourg in order to gauge their motivations and possible consequences of PRP. Then, our goal is to work on a potentially rich natural experiment which may say a lot about the consequences of merit pay in science, namely the introduction of the "prime d'excellence scientifique" in France in 2009. Also in the case of the University of Strasbourg our goal is to mobilize statistical techniques to determine whether, three years after its introduction, it has significantly changed researchers' behaviors and, in particular, to see if it has affected younger and older scientists differently.

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