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Why are researchers paid bonuses? On technology spillovers and market rivalry

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ABSTRACT

A temporary change in pay to employed inventors around the time of patent application has been documented. A theoretical model is here developed to provide an explanation to said findings based on the idea that inventors may be able to use the knowledge previously generated while working in a firm, in a rival company. The model features firms who hire workers in R&D functions to make product innovations. The innovation process consists of distinct phases each with different access to information about the innovation value for firms. Firms compete to attract workers, and workers can transfer part of the generated new knowledge to a new employer. Results suggest that the capital intensity of R&D investments, and the type and size of knowledge spillovers, may affect the probability to observe bonus pay at the time of a patent application.

Different tax incentives and subsidies are then studied as a means to correct for possible underinvestment of capital. We study the effect of a patent box, a subsidy to R&D capital investments, and a subsidy to bonus pay. When market rivalry prevails over positive knowledge externalities, a bonus pay incentive was found to obtain the social first-best while a patent box or a subsidy to capital investment would cause overinvestment. When positive knowledge externalities prevail, either a patent box or a subsidy to capital investment obtain the social optimal level of capital investments.

1. Introduction

Tax incentives and subsidies for R&D activities conducted by private companies are widely used in many developed countries. Our understanding of the structure of incentives that employed inventors face is however limited, regardless of the fact that labor costs account for a large part of private R&D expenses (about 70% according to Harhoff et al., 2003). Both monetary and non-monetary incentives (Stern, 2004; Cohen and Sauermann, 2007; Sauermann and Cohen, 2010) appear to be important drivers for inventors' decisions about where to work (Roach and Sauermann, 2010; Akcigit et al., 2015) and, possibly, about the allocation of time and effort among multiple job tasks (Manso, 2011; Hellmann and Thiele, 2011).

That R&D workers mobility between firms is a potential conduit for knowledge transfers is a recognized fact. Such transfers can produce positive knowledge spillovers (Møen, 2005), but also make competing firms steal market shares from previous employers through partial imitation of product innovations (Bloom et al., 2013). In Kim and Marschke (2005) the authors report that the latter form of rivalry can be so intense at times that "*a number of Silicon Valley firms, such as Adobe Systems, Apple, Google, Intel Corporation, Intuit, and Pixar, agreed in 2009 not to approach each other's employees, even at the risk of violating the U.S. competition law.*"

The model presented in this study contributes to the literature in two ways. First, it explores the market conditions under which some observed regularities in employed inventors' pay (an average rise in pay around the time of a patent application) are compatible with rational expectations, inventors mobility, capital investments in R&D, and the existence of knowledge externalities that are transmitted between companies through labor mobility. Second, it derives implications for policymakers with regard to the optimal tax and subsidy scheme to use in order to reach the social optimal capital investment in R&D activities under different types of knowledge transfer regimes. We study the effect of a patent box, a subsidy to R&D capital investments, and a new form of subsidy to bonus pay.

The model assumes costless mobility of workers across firms and, as in the superstars literature *à la* Rosen (1981), workers in the model extract all the surplus from firms thanks to a competitive

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bidding over pay in which multiple firms participate. The model is particularly suited to address conditions that could potentially arise in a market for star scientists employed in private companies. Star scientists and technologists are known for being particularly mobile across firms and countries, so the full mobility assumption taken here fits well to them. The model can also provide insight for specific markets and situations where R&D workers ability to move is large, their supply is rationed in the short run while demand is increasing fast. Such a description reminds of the New Economy boom in Silicon Valley during the second half of the 1990s, when skill shortage was a common issue for firms with a high propensity to invest in innovative projects.

The structure of the paper is as follows. Section 2 reviews the relevant literature and discusses some recent empirical results about changes in inventors' pay around the time a patentable innovation is produced. Some of the key assumption of our model are also discussed. Sections 3 and 4 present the general framework and solve the model to obtain equilibrium pay and capital investment. Section 5 derives the relevant policy implications from a reduced model based on expected values. Section 6 concludes.

2. Previous literature

2.1. The mobility of workers, knowledge spillovers, and innovation

A traditional rationale for public intervention in private R&D productions is the existence of positive externalities in the form of knowledge spillovers (Arrow, 1962). Positive externalities motivate the use of subsidies and tax incentives, in line with standard arguments supporting Pigouvian taxes and subsidies in presence of externalities and large coordination costs preventing to reach first-best equilibria by decentralized contracting alone. The exact nature of such transfers of knowledge between firms is however subject to debate as they could operate through distinct channels (Griliches, 1992). In the following sections our focus is on employed inventors and on the transmission of knowledge caused by their mobility.

Several studies (see as examples: Saxenian, 1996; Almeida and Kogut, 1999; Scarpetta and Tressel, 2004; Miguélez and Moreno, 2013) have documented that a larger inter-firm mobility of technical workers is associated with more intense innovation at regional level. The channel identified by researchers through which mobility can enhance innovation is the transfer of knowledge caused by highly skilled workers moving between companies. This finding may explain why a region where mobility is particularly high (like Silicon Valley, where as shown in Fallick et al., 2006 the practice of "job-hopping" is common) features more intense production of innovations in comparison to lower-mobility regions. The evidence also suggests that the benefit of knowledge transfers through mobility may dissipate over time (Hoisl, 2006), and that firms may anticipate the possibility of a leaving inventor by reducing their R&D investments and by increasing their propensity to patent (Kim and Marschke, 2005). The benefits a firm obtains from knowledge contributed by newly hired workers also depend on the firm's absorptive capacity which is determined by past investments as well as by organizational characteristics (Cohen and Levinthal, 1990).

The mobility of R&D workers is strictly related to the structure of their pay, because the labor market can internalize the possibility of knowledge transmission. The equilibrium pay offered to inventors can be reduced to anticipate for the possibility of leaving, or variable pay can be employed to retain the worker after an innovation is produced (Pakes and Nitzan, 1983; Møen, 2005; Franco and Filson, 2006).

2.2. Profit sharing pay, innovation, and mobility

With regard to the pay structure, Balkin and Gomez-Mejia (1984) empirically show that firms with a faster job turnover are more likely to offer forms of variable compensation to R&D workers. The PatVal survey documented that a large share of employed inventors in the E.U. receives a temporary bonus pay when an innovation is produced (Giuri et al., 2007). Subsequent empirical research has shown that around the time of a patent grant (Toivanen and Väänänen, 2012) or patent application (Depalo and Di Addario, 2014) employed inventors in Finland and Italy, respectively, experience a rise in pay. Part of this bonus pay is permanent, while part is temporary and last just some years after the time of patent application or grant. Results similar to the ones reported in Depalo and Di Addario (2014) are obtained in a study using U.S. data (Bell et al., 2015), even though some differences arise between the U.S. and the E.U., maybe due to the fact that in the U.S. it is more common to employ stock-based compensation.

The study by Depalo and Di Addario (2014) is particularly relevant for the sake of the present research: the dataset they exploit links uncensored income data from social security registries with patent data. In Italy, contrary to other countries like Germany or Finland, employed inventors are not entitled by law to gain some parametrized or predefined pay when a patent is produced. Therefore any observed variation in pay is only due to market forces. The authors report that the part of the increased pay which is permanent positively correlates with the stock of patents the inventor produced in the past, and argue it might be related to the fact that patents also signal an inventor's ability to produce valuable innovations.

However the reason why firms might want to grant a temporary increase in pay around the time a patent is applied for, is not fully clear. As a first hypothesis, it might be that work contracts include *ex ante* profit sharing schemes, as we know that these payment forms are common in R&D-intensive firms (refer to d'Andria and Uebelmesser, 2014 and the literature cited therein). The temporary rise in pay at the time of patent application could then just reflect the automatic effect of profit sharing schemes. But it is unlikely that, already at the time of patent application, the value (profits, sales, stock value) upon which profit sharing schemes are computed upon is known to the parties. Moreover the evidence in Toivanen and Väänänen (2012) and Depalo and Di Addario (2014) that pay also rises several years before a patent application can hardly be explained by the existence of *ex ante* contracts, and points instead to a bargaining process over pay after a patentable innovation has been observed by firms and employees. Note however that even if such pay is determined *ex post* (by *ex post* here we mean that the bonus pay is established only after the firm realizes that a patentable innovation is generated and identified), rational workers will anticipate its existence and base their decisions in earlier stages also on such rational expectations.

A second hypothesis is related to the informational content of patents. A patent application launches signals to other agents in the market (Anton and Yao, 2004; Hsu and Ziedonis, 2008). Technical details have to be disclosed to patent offices at the time of a patent application, thus making such knowledge (which could otherwise remain secret) observable by competing firms. This means that a patent application might provide information about an innovation value and trigger either imitation by competing firms or competitive bidding over this innovation by potential investors. Imitation can use as input the knowledge possessed by technical workers previously employed in the patenting firm, therefore the competitive bidding could take the form of a bid over pay in order to acquire such workers. A rise in pay offered by current employers could then have the purpose to impede a transfer of internally generated knowledge to competitors who could benefit from it and

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