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Innovation, on-the-job learning, and labor contracts: an organizational equilibria approach

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Abstract: An established tenet of the literature is that the use of flexible labor tends to lead to less innovation. Yet, less attention has been paid to the possibility that it is the decision to innovate that conversely generates the incentive to hire on a permanent basis. The main goal of this paper is to show the existence of interlocking complementarities between the firm's technological and employment strategies. To do so, we develop a simple model where the workers' decision to invest in human capital is affected by the type of employment contract (temporary vs permanent) and by the type of technological investments (routine vs innovative). When the firm is unable to coordinate its actions across these different domains, two equilibria simultaneously exist: in the "high-road" equilibrium, firms invest more in innovative projects and hire on a permanent basis; in the "low-road" equilibrium, they invest more in routine projects and hire on a temporary basis.

Key words: organizational equilibria · institutional complementarities · firm-level innovation · human capital accumulation · learning incentives

JEL codes: J24, J41, M51, M52, M54, O31

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1. Introduction

A wide body of literature has documented the positive effects of innovation and technological change on economic growth, both at the macro and micro level, as well as on firms' survival and international competition (Solow, 1957; Aghion and Howitt, 1992; Ganotakis, 2012; Slaper et al., 2011; Cefis an Marsili, 2006; Kuhlmann and Edler, 2003). Consequently, empirical analyses have focused on the determinants of innovation in firms, countries and regions, based on the one hand on the well-known knowledge production function approach (Griliches, 1984; Jaffe, 1989) and on the other hand on the Crepon-Duguet-Mairess (CDM) model (Crepon et al., 1998)[1].

The voluminous literature that analyzes the determinants of innovation has stressed the importance of firms' size, sectoral specificities, R&D investments and R&D personnel as key drivers of variance in innovation outcomes both at the micro and macro level. The role of institutions has also been acknowledged.[2] Yet, early institutional contributions moving from a national system of innovation perspective, mainly focused on the country-level determinants of innovation (Freeman, 1987; Lundvall, 1992; Nelson, 1993; Patel and Pavitt, 1994; Metcalfe, 1995; OECD, 1997), while more micro-level analyses have been developing thenceforth. Among the latter, a growing strand of empirical research has devoted attention to the relationship between labor flexibility and the firms' innovative performance (Guarascio et al., 2019; Wachsen and Blind, 2016; Franceschini and Mariani, 2015; Kleinknecth et al., 2014; Malgarini et al., 2013; Dekker et al., 2011; Altuzarra and Serrano, 2010; Lucidi and Kleinknecht, 2009; Michie and Sheenan, 2003). The key finding from this emerging literature is that temporary workers are detrimental to innovation.[3] Further support comes from Acharaya et al. (2014),

[1] For a review, see Souitaris (2003) and Bhattacharya and Bloch (2004).
[2] For a review, see Harper's (2018) introduction to the "JOIE Special Issue on Innovation and Institutions from the Bottom Up" and the contributions therein.
[3] This, however, is not confirmed by both Arvanitis (2005), and, to some extent, by Altuzarra and Serrano (2010).

who show that wrongful discharge laws have a positive effect on the employees' innovative effort, and from Belloc (2019), who finds that aggregate innovation outcomes are positively affected by the complementarity between two legal institutions in the domain of labor regulation, namely, between employment protection legislation and employee representation legislation.[4]

Among the possible mechanisms explaining this piece of evidence of particular interest is the relationship between labor contracts and human capital accumulation, or, to put it differently, between the former and the different learning incentives that they generate (Kleinknecth et al., 2014). The starting point is that human capital is an essential element of successful innovation (Leiponen, 2005; OECD, 2011). Hence, a key challenge for innovators is how to design the right contract that motivates their personnel to invest in innovative skills. Several studies in both economics and management science have analyzed the innovation-motivating incentives that push organizational leaders to pursue an innovative project. Manso (2011), for instance, develops a principal-agent model that studies the optimal contract when it is the agent (i.e., the manager) who choses whether to innovate or not.[5] The problem, at this point, is that innovation is mostly firm-specific, and so are the skills required to carry it through. Hence, since temporary workers do not acquire any capability that does not increase their employability on the job market (Belot et al., 2007), flexible labor contracts match poorly with investments in firm-specific human capital, and thus, by extension, with innovation.

Implicit in the above discussion is the idea whereby it is the use of flexible labor that ultimately leads to less innovation. In this view, firms deciding to cut on labor costs or

[4] Since temporary workers have lesser rights to voice their needs and ideas and are often less protected against unfair dismissal, we see these pieces of evidence as supporting the argument advanced in this paper.

[5] The situation we consider, however, is quite different, since we analyze the incentives for lower-level agents (such as workers) to acquire firm-specific skills when the decision to innovate is made by some upper-level agent. This does not entail, of course, that this approach is inconsistent or alternative with the analysis of the managerial incentives recalled in the above. Conversely, it extends the study of innovation-motivating incentives to lower agents within a framework that explicitly acknowledges the role of workers in the creation of novelty.

increasing the share of easily dismissible workers, end up innovating less because of their workers' unwillingness to invest in human capital, though this is simply a byproduct of their "low-road" human resource management strategy.[6] This view is also consistent with the "efficiency-wage" theory, according to which employees' effort, including the innovative one, is a positive function of wages (Akerloff and Yellen, 1986; Shapiro and Stiglitz, 1984; Antonelli and Quatraro, 2013).

Yet, there are no reasons to exclude that it is the decision to invest in innovative projects that conversely generates the incentives to hire on a permanent basis. Anticipating that workers will acquire firm-specific skills only if offered a permanent contract, in fact, firms may find it rational to recruit on a permanent basis to provide greater learning incentives and improve their innovation performance. In the first case, a prominent direction of causality going from technology to institutions, that is, from innovation to labor contracts, is identified, while the second argument puts relative emphasis on the role of labor contracts on the firm's decision to innovate.

The main goal of this paper is to show that these one-way causations are not mutually exclusive; quite the contrary, there exist situations where they complement and influence each other. In this case, the firm's technological and employment decisions are characterized by interlocking complementarities. A growing literature on organizational equilibria has indeed shown that, when a two-way causation between different elements of the firm's strategy exist, multiple organizational equilibria may arise, potentially leading to inefficient situations due to the firms' inability to coordinate their actions across their multiple domains of choice (Gürpinar, 2016; Nicita and Pagano, 2015; Landini, 2013; Pagano, 2011, 1993; Earle et al., 2006; Pagano and Rossi, 2004; Pagano and Rowthorn, 1994). While previous works from Belloc (2019) and Vatiero (2017) show that country-level innovation is spurred by macro

[6] For a discussion of the high-road/low-road distinction, see Kochan and Osterman (1994).

complementarities between labor laws, ownership concentration and innovation incentives, our analysis is more micro in nature, as it shows that multiple equilibria may also exist at the firm-level. We see our contribution as highly complementary to the above studies, leaving open the opportunity to explore the "meta-complementarities" between the macro and micro synergies affecting the firms' innovation performance for future research.[7]

Our contribution to the extant literature is threefold. First, we extend the analysis of organizational equilibria to a novel field of inquiry, that is, to the relationship between flexible labor and innovation. In doing so, we argue that the emphasis put by previous studies on the detrimental effect of temporary workers on the creation of novelty must be complemented by similar considerations regarding the effect of the firm's decision to innovate on its employment structure. Second, we show that these complementarities may exist because of the different learning incentives generated by different types of labor contracts (temporary vs permanent) and different types of evolutionary technological strategies (routine vs innovative). While most of previous studies rely on some exogenous assumption to show the existence of multiple equilibria, we get at this conclusion through an endogenous mechanism.[8] Third, we deepen our understanding of the relationship between human capital accumulation and innovation by drawing attention to a strategic dimension of learning that has not received cursory attention in the literature—see section 3 for further discussion. In doing so, we rationalize a mechanism that may explain the massive evidence supporting the idea that the use of temporary workers is detrimental to innovation.

The reminder of the paper is organized as follows. Section 2 introduces the notion of organizational equilibrium and briefly reviews the related literature, while section 3 outlines a theoretical framework where the role of on-the-job learning on innovation is identified. In

[7] For a definition of "meta-complementarities", see Nicita and Pagano (2005) and Landini and Pagano (2018).
[8] Belloc et al. (2020) rely on a similar endogenous mechanism.

section 4, we expand on the theoretical insights presented in sections 2 and 3 and apply the notion of organizational equilibria to the relationship between innovation incentives and labor contracts. We do so through a simple game-theoretic model where a two-departments firm have to hire a new set of employees to run its business. The human resource manager chooses whether to recruit the newly hired on a temporary or permanent basis, while the project manager selects the optimal mix of routine and innovative activities. In this framework, complementarities may arise because both take each other's decision as given. As a result, the game is characterized by multiple equilibria: in the "high-road" equilibrium, the organization invests relatively more in innovation and hires on a permanent basis, while the "low-road" equilibrium is characterized by greater emphasis on routine activities and temporary contracts. Section 5 analyzes the welfare implications of the model and shows that the "low-road" equilibrium is always inefficient, since workers are always better off in the other equilibrium. In addition, it shows that there exist parametrizations where the "high-road" equilibrium is efficient for both the organization and its personnel. In this case, the policy implication is straightforward: deregulating labor markets has negative repercussion on both profitability and worker well-being. Indeed, when firms "take the low-road" because of the self-reinforcing character of institutional complementarities, the system may remain stuck into what may be called an "organizational poverty trap". To revert such a situation, the policymaker must operate simultaneously at multiple levels, altering both innovation incentives and labor market institutions. Section 6 comments and concludes.

2. Organizational equilibria

Coordinating decisions at the corporate level is a multidimensional task. Hence, organizational changes require transformations in multiple domains of the firm's strategy that are not always easy to coordinate throughout. As corporations grow in both complexity and size, in fact, they face an increasing trade-off between adaptivity and coordination (Dessein and Santos, 2066) due to the fact that the greater autonomy of the single operating units implies that each selects its strategy taking the others' as given. Hence, what appears to be a network of independent choices, in reality, is a self-reinforcing system characterized by path-dependency and irreversibility. In this framework, an organizational equilibrium is defined as a set of interlocking elements that are kept together by the uncoordinated actions of the different decision-makers in the organization, who best-respond to each other's strategy taking the latter as given. The upshot is that when the optimal arrangement is not unique, the selection of the efficient organizational mode cannot be taken for granted.

Before the development of the literature on organizational equilibria, different strands of research put relative emphasis on elements that were supposed to be somewhat predominant in the organization of firms. Neo-Institutionalists following the seminal works of Coase (1937) and Williamson (1985), for instance, explained the emergence of efficient institutions within a world of exogenous technology. Radical political economists inspired by authors such as Marglin (1974), Braverman (1974) and Bowles (1985), in turn, claimed that it is the initial allocation of property rights over the assets used in production that chiefly determines the form and organization of firms. However, as Pagano and Rowthorn (1994) argued in their seminal contribution, both views are unsatisfactory, as organizations are not technological units that operate in an institutional vacuum, and neither, they are "nexuses of contracts and organizational rules" that produce free of technological constraints. When both technology and institutions constitute endogenous and independent domains of choice, in fact, one cannot overlook the influence they exert over each other.

The idea that there are complementarities among the elements of firms' strategy was first introduced by Milgrom and Roberts (1990) and later conceptualized in terms of institutional complementarities by Aoki (1994).[9] In the same year, Pagano and Rowthorn (1994) showed the existence of a two-ways relation between technology and property rights. Thereafter, a growing body of works applied the notion of organizational equilibrium to a variety of different domains, identifying interlocking complementarities within the domain of information production (Landini, 2012), between technology and finance (Nicita and Pagano, 2005), intellectual property rights and cognitive labor (Gürpinar, 2013), unionization and job-automation (Belloc et al., 2020) and, at a higher level of the economy, between ownership concentration and the emergence of systems of worker representation (Landini and Pagano, 2018). The notion of organizational equilibrium has proven insightful to explain the emergence and persistence of different organizational forms that endure over time in spite of their inefficiency, and thus, that it can be used as a valid tool to formulate policy recommendations.

3. Temporary workers and innovation

Evolutionary economics stresses the importance of organizational learning and tacit knowledge for the introduction of change in firms and sectors (Nelson and Winter, 1982). In line with the resource-based view of the firm, on-the-job learning is deemed to be a necessary requirement for the generation of tacit knowledge, that in turn, stands as an antecedent for the emergence of new organizational and technical knowledge (Foss, 1997, 1998; Penrose, 1959). In this framework, innovation depends on the combination of formalized R&D and unformalized on-the-job learning.[10] Hence, since human capital accumulation requires long-lasting processes of organizational learning that involve a two-way exchange between the

[9] For more general appraisals of the role of institutional complementarities in economic systems see Aoki (2001) and Pagano and Vatiero (2015).

[10] Grinza and Quatraro (2019: 7) find support to this hypothesis by showing that workers' replacements have a negative effect on the number of patent applications, consistently with the idea that "when workers leave, they take with them firm-specific knowledge about competencies and routines, as well as about the potential for resource combination for the creation of novelty."

organization and its personnel[11] (Schneider et al., 2010), or between routines and individual skills, it comes as no surprise that the available evidence is almost unanimous in claiming that the use of temporary workers is detrimental to innovation—see, e.g., Guarascio et al. (2019); Wachsen and Blind (2016); Franceschini and Mariani (2015); Kleinknecth et al. (2014); Malgarini et al. (2013); Dekker et al. (2011), Lucidi and Kleinknecht (2009) and Michie and Sheenan (2003). Opposite predictions, however, come from Arvanitis (2005), while Altuzarra and Serrano (2010) find a non-monotonic relationship between labor flexibility and innovation. In their study, the firms employing only permanent workers have the lowest propensity to innovate, but the probability of filing a successful innovation decreases as the rate of fixed-term workers increases beyond the innovation-compatible threshold.

Given the above, it may be the case that some kind of mechanism is at play when it comes to the effect of labor contracts on worker learning. Indeed, a key but often forgotten requirement for workers to invest in human capital is their willingness to learn. As rightfully recalled by Kräkel (2016: 627), in fact, "traditional human capital theory assumes that a worker has no choice whether to acquire knowledge or not. When a firm decides to invest in human capital, a worker is considered more like a robot to be programmed rather than a human being who is free to learn or not. Often, however, such programming is not possible". The strategic dimension of learning becomes a key point around which to design the work incentives to spur innovation, as clarified by the model developed in the next section.

4. The model

We develop a two-stage game where a project (P) and a human resource manager (H) have to hire a set of additional employees (individually indicate as E) to run their business. At

[11] Knowledge exchange dynamics between the firm and its personnel may unfold across multiple routes, from face-to-face communication (Asheim et al., 2007), to teamwork (Lloréns Montes et al., 2005), absorptive capacity (Cohen and Levinthal, 1990), work experience (Schneider et al., 2010) and on-the-job training.

stage 1, P and H make separate choices taking each other's as given. In the technological domain, P selects a project portfolio comprising an optimal mix of "routine" (R) and "innovative" (I) projects[12]. We assume that each project requires a single unit of labor.[13] Similarly to Acharya et al. (2014), we also assume that I-projects are riskier but potentially more profitable than R-projects—see section 3.2. In the institutional domain, H chooses whether to recruit the new workers on a temporary (T) or permanent (O, "open ended") basis. In this framework, complementarities arise because of the managers' inability to coordinate their actions.

At stage 2, employees make a learning choice and decide whether to invest in firm-specific human capital. As in Kräkel (2016), we assume that human capital investments reduce the cost of effort. In addition, we assume that the benefits of effort-reduction vary according to the type of project selected by P and to type employment regime chosen by H.

A key driver of these learning decisions is the degree of human capital portability. When skills are purely firm-specific, temporary workers have lesser incentives to learn, as the future gains from their human-capital investment are nil.[14]

We derive the sub-game perfect equilibrium by backward induction. Since employees are identical, we will first analyze the decision to invest in human capital referring to a generic employee E, and then, given this, we will derive P's investment strategy and H's choice of the employment regime.

4.1. *E*'s learning decision

[12] According to Nelson and Winter (1982), firms are bundles of routines. These in turn represent "deep channels in which behavior runs smoothly and effectively" (Nelson and Winter, 1982: p. 84). Routines are therefore associated to the business-as-usual organizational conduct. Innovating instead involves the change of organizational and production routines.

[13] Hence, denoting the number of employees as N, the quantity of I-projects chosen by P as $I \geq 0$ and the quantity of R-projects chosen by P as $R \geq 0$, we have that $N = I + R$.

[14] That human capital is neither completely general nor completely firm-specific is now empirically established—see, e.g., Neal (1995), Poletaev and Robinson (2008), Zangelidis (2008), and Suleman and Lagoa (2013).

E lives for two periods, t_1 and t_2. At the beginning of t_1, H offers E a labor contract, while P assigns E to a labor project. As employees are identical, P has no prior information for matching employees and projects and thus, the distribution of the different types of activities across the newly hired is random. All the activities in the portfolio last for one period, at the end of which, wages are paid, and profits are collected. For the sake of simplicity, we assume that E has no incentive to leave H when she is offered a permanent contract. Conversely, when she is offered a temporary contract, we assume that she will work as a temporary worker for an alternative employer H' in t_2.[15]

At the beginning of t_1, E decides whether to costly invest in innovative or routine skills depending on the time of project she is assigned to. As in Kräkel (2016), we assume that learning reduces the cost of effort when E works for H. In addition—and always in line with Kräkel (2016)—we assume that E may be able to recover some of her human capital investments also when she works for H', depending on the degree of portability (or generality) of the acquired skills.

Our working hypothesis is that the skills acquired in innovative projects (hereafter, innovative skills) are less portable than those acquired in routine projects (hereafter, routine skills). The idea is that while innovation is firm-specific, routine activities tend to be more similar across firms. Hence, when P assigns E to an innovative project and H offers a temporary contract, E knows that she will lose her human capital investment in t_2.

Formally, we assume that when E is offered a temporary contract, she chooses $\lambda \in (0,1)$—where $\lambda = 1$ indicates that the worker learns and $\lambda = 0$ indicates that she does not learn—to maximize:

[15] This is amounts to assuming that first, there is no unemployment, and second, that E's second period employer, call her H', has no incentive to offer a temporary contract, for instance, because she anticipates that $\underline{E}$ will retire at the end of t_2 and thus, that the there is no point of providing E with greater incentives to invest in human capital. Results are all robust to alternative specifications.

$$U_T^I(\lambda) = w_T - e(1-\lambda) + r(w_T - e) - c\lambda \tag{1}$$

$$U_T^R(\lambda) = w_T - e(1-\lambda) + r[w_T - e(1-\lambda p)] - c\lambda \tag{2}$$

where the superscript (I, R) indicates the type of project and the subscript (T) the type of labor contract. The first and second terms on the right-hand side of equations (1) and (2) measure E's payoff when she works for H in t_1; the third and fourth terms measures E's payoff when she works for H' in t_2; and the fifth term measures the cost of learning. Hence, $w_T \geq 0$ is the temporary wage, $e > 0$ measures the cost of effort, $0 < r < 1$ is the discount rate and $c > 0$ is a learning cost associated to human capital accumulation.

Our first assumption, that learning reduces the cost of effort when E works for H, is captured by the second term in equations (1) and (2), where we have specified the cost of effort in t_1—$e(1-\lambda)$—as a decreasing function of λ. Our second assumption, that routine skills are partly portable outside the firm, is captured by the fourth term in equation (2), where we have specified the expected cost of effort in t_2—$re(1-\lambda p)$—as a decreasing function of λ and p, where $0 \leq p \leq 1$ measures the portability of human capital or, alternatively, its degree of generality.

Similarly, when E is offered a permanent contract, we assume that she chooses $\lambda \in (0,1)$ to maximize:

$$U_O^I(\lambda) = U_O^R(\lambda) = w_O - e(1-\lambda) + r[w_O - e(1-\lambda)] - c\lambda \tag{3}$$

where the superscript (I, R) indicates the type of project and the subscript (O) the type of labor contract. The interpretation of equation (3) is analogous to equations (1) and (2), but for the fact that permanent workers receive higher salaries, so that $w_O > w_T$. In what follows and without loss of generality, we shall normalize $w_T = 0$.

The following Proposition analyzes the different learning incentives in the four combinations of types of projects and labor contracts:

Proposition 1—*The incentives to invest in human capital vary across the different combinations of types of projects and labor contract. In particular:*

(i) *When E is offered a temporary contract and is assigned to an innovative project, she invests in human capital if* $c \leq e$*;*

(ii) *When E is offered a temporary contract and is assigned to a routine project, she invests in human capital if* $c \leq e(1 + rp)$*;*

(iii) *When E is offered a permanent contract, she invests in human capital if* $c \leq e(1 + r)$*; regardless of the type of project.*

Proof: see the Appendix.

Proposition 1 makes clear that the key point of offering a permanent rather than temporary contract is that the former is more conducive to human capital investments. In addition, given that innovation is firm-specific and innovative skills are of valueless outside the firm, routine projects are more conducive to human capital investments when E is recruited on a temporary basis. Hence, learning incentives are high for permanent workers; intermediate for temporary employees working on routine projects, and low for temporary employees working on innovative projects, as captured by the ordering implied by Proposition 1, whereby $e(1 + r) > e(1 + rp) > e$.

4.2. Innovative vs routine projects

At stage 2, P takes H's employment decision as given and composes a project portfolio by selecting the optimal quantity of innovative and routine activities, denoted, respectively, as $I > 0$ and $R > 0$. Similarly, H takes P's technological decision as given and decides whether to recruit the newly hired on a temporary or permanent basis. While the linear cost of labor $w_i, i = T, O$, depends on the type of labor contract chosen by P, we assume that the technological costs of investing in innovative and routine projects are described, respectively, by the convex cost functions $C(I)$ and $K(R)$, where $C(0) = 0$, $C'(I) > 0$ and $C''(I) > 0$ and $K(0) = 0$, $K'(R) > 0$ and $K''(I) > 0$ by assumption.

To model the idea that I-projects are riskier but potentially more profitable than R-projects, we follow Acharya et al. (2014) and assume that I-projects yield greater payoffs than R-projects when both are successful, while R-projects yields greater payoffs than I-projects when both are unsuccessful. Hence, denoting the returns to project $j = I, R$ when the latter is successful as a_j and the returns to project j when the latter is unsuccessful as b_j, we assume that $a_I = A$; $a_R = B$; $b_R = C; b_I = D$, where the ordering $A > B > C > D$ naturally follows from the above assumptions. In addition, we impose the following restriction upon the set of parameters' values:

Assumption 1—*Offering a permanent contract to induce a worker to learn in project $j = I, R$ is efficient, so that $A - w_i > D$ and $B - w_i > C, i = T, O$.*

To keep things simple and avoid obfuscating the mechanisms at play, we assume that project $j = I, R$ is successful when E decides to learn ($\lambda = 1$) and unsuccessful when E does not learn ($\lambda = 0$).[16] Hence, assuming that H and P split the operating profit 50:50, the managers' profit function is given by:

$$\Pi_O(R, I) = \frac{1}{2}\{[\lambda A + (1-\lambda)D - w_O]I + [\lambda B + (1-\lambda)C - w_O]R - [C(I) + K(R)]\} \quad (4)$$

$$\Pi_T(R, I) = \frac{1}{2}\{[\lambda A + (1-\lambda)D - w_T]I + [\lambda B + (1-\lambda)C - w_T]R - [C(I) + K(R)]\} \quad (5)$$

When H choses to hire on a permanent base, P maximizes equation (1) with respect to I and R. Denote as I_O and R_O the arguments that maximize Π_O. Conversely, when H choses to hire on a temporary base, P maximizes equation (2) with respect to I and R. Denote as I_T and R_T the arguments that maximize Π_T. Whether I_O will be higher or lower than I_T and R_O will be higher or lower than R_T, of course, depends on the employees' learning decision at stage 1.

H, in turn, takes *P*'s decision as given and chooses the type of labor contract that provides the higher benefits. Hence, applying a tie-breaking rule whereby H choses to hire on a permanent base when s/he is indifferent between the two types of labor contract, s/he will play O when $\Pi_O(I_O, R_O) \geq \Pi_T(I_T, R_T)$ and, conversely, she will play T when $\Pi_T(I_T, R_T) > \Pi_O(I_O, R_O)$.

4.3. Results: organizational equilibria

When H chooses to offer a temporary contract, the first order conditions for optimal profit are given by:

$$\frac{\partial \Pi_O}{\partial I} = \lambda A + (1-\lambda)D - w_O - C'(I) = 0 \quad (6)$$

$$\frac{\partial \Pi_O}{\partial R} = \lambda B + (1-\lambda)C - w_O - K'(R) = 0 \quad (7)$$

[16] Alternatively, we may assume that E produces valuable output with probability $s(\lambda)$ and zero output with probability $1 - s(\lambda)$, where E's learning decision affects positively the success probability so that $1 > s(1) > s(0) > 0$. Despite more realistic, this specification adds little to our results.

where (I_O, R_O) describes the firm's technology when H hires on a permanent base. For future reference, it will be handy to define the firm's technology as $T_O \equiv I_O/R_O$.

Similarly, when H chooses to offer a temporary contract, the first order conditions for optimal profit are given by:

$$\frac{\partial \Pi_T}{\partial I} = \lambda A + (1-\lambda)D - w_T - C'(I) = 0 \tag{8}$$

$$\frac{\partial \Pi_T}{\partial R} = \lambda B + (1-\lambda)C - w_T - K'(R) = 0 \tag{9}$$

where (I_T, R_T) describes the firm's technology when H hires on a temporary base. As before, define $T_T \equiv I_T/R_T$. The larger is $T_i, i = T, O$, the more "innovative" is the project portfolio. The smaller is $T_i, i = T, O$, the more "routinary" is the project portfolio. Table 1 resumes the exact expression of the first order conditions expressed in equations (6), (7), (8) and (9) under the different learning incentives analyzed in Proposition 1.

[insert table 1 about here]

We are now in the position to analyze the equilibrium outcomes of the game, which are summarized in the following Proposition:

Proposition 2—*Given the ordering $e < e(1+rp) < e(1+r)$, we have that:*

(i) *When learning costs are either high—$c > e(1+r)$—or low—$c < e$—temporary contracts lead to greater technological investments in both routine and innovative projects, since $I_T > I_O$ and $R_T > R_O$. In this case, there exists a unique equilibrium where H hires on a temporary base;*

(ii) *When learning costs are medium-high—$e(1+rp) < c < e(1+r)$—permanent contracts lead to greater technological investments in both routine and innovative projects, since $I_O >$*

I_T and $R_O > R_T$. In this case, there exists a unique equilibrium where H hires on a permanent base;

(iii) *When learning costs are medium-low—$e < c < e(1 + rp)$—permanent contracts lead to greater technological investments in innovative projects, while temporary contracts lead to greater technological investment in routine projects, since $I_O > I_T$ and $R_T > R_O$, which implies that $T_O > T_T$. In this case, a unique equilibrium where H hires on a permanent base exists if $T > w_O/(A - D - w_O)$, while a unique equilibrium where H hires on a temporary base exists if $w_O/(A - D - w_O) > T$.*

Proof: see the Appendix.

The results from Proposition 2 follow directly from those derived in Proposition 1. Given the different learning incentives generated by different types of labor contracts and the different types of technological investments, the firm's managers will find it rational to best-respond to each other's strategy by taking decisions in their respective domains of choice. In particular, observe that when learning costs are either high, low or medium-high, there exist a unique organizational equilibrium stemming from the managers' best-responses to E's human capital investment. Conversely, when learning costs are medium-low, P's and H's choices are more interdependent, and the possibility of multiple equilibria may arise. To analyze this possibility in greater detail, we put forward the following Proposition:

Proposition 3—*When learning costs are medium-low and $w_O/(A - D - w_O)$ falls within the interval (T_T, T_O), multiple organizational equilibria exist. Conversely, when $w_O/(A - D - w_O)$ is smaller than T_T, a unique "high-road" equilibrium exists. In this case, workers are recruited on a permanent basis and firm-level innovation is high. Conversely, when $w_O/(A - D - w_O)$ is larger than T_O, a unique "low-road" equilibrium exists. In this* *case, workers are recruited on a temporary basis and firm-level innovation is low. In addition, the threshold* $w_O/(A-D-w_O)$ *is increasing in* w_O*.*

Proof: see the Appendix.

[insert Table 2 about here]

The results from Proposition 3 are visualized in Table 2. Proposition 3 makes clear that when learning costs are medium-low and the threshold $w_O/(A-D-w_O)$ falls between (T_T, T_O), H's and P's choices are mutually reinforcing. Indeed, when H chooses to hire on a temporary basis, P will select a project portfolio that is more "routine-intensive", while, when H chooses to hire on a permanent basis, P will select a project portfolio that is more "innovation-intensive". Vice-versa, if it is P that initially choses a "routinary" portfolio, H will best-respond by hiring on a temporary basis, while, if P selects an "innovative" portfolio, H will best-respond by hiring on a permanent base. Hence, initial conditions matter, as both the technological and the institutional architecture of the firm can shape its managers' future decisions. In this case, path-dependency looms large on the evolution of the relationship between innovation and employment regimes. Interestingly, a sort of high-road/low-road story (Kochan and Osterman, 1994) endogenously emerges, as those who innovate more are also the ones who pay higher salaries, provide greater employment protection and greater incentives to invest in human capital. However, as the last part of Proposition 3 makes clear, a unique "low-road" equilibrium is more likely to occur when the permanent wage is "excessively" high. Excessive bargaining power of workers' organizations, in this case, may erode the gains from innovation up to the point of discouraging firms to engage in innovative efforts. To qualify further our multiple equilibria, we will now analyze the welfare properties of the model.

5. Welfare

To measure welfare under the assumption of multiple equilibria, we need to compare the operating profit of the firm and the utility of the representative employee in both the "high-road" and "low-road" equilibria. To do so, we need to make specific assumptions on the functional form of $C(I)$ and $K(R)$. To keep things simple, we assume that $C(I) = I^2/2$ and $K(R) = R^2/2$. Hence, given the employees' strategy to invest in human capital when learning cost are medium-low—see Proposition 1—we can rewrite equations (4) and (5) as:

$$\Pi_O(I,R) = \frac{1}{2}[(A - w_O)I + (B - w_O)R - (I^2 + R^2)/2] \tag{10}$$

$$\Pi_T(I,R) = \frac{1}{2}[DI + BR - (I^2 + R^2)/2] \tag{11}$$

which yield the following set of optimal solutions: $(I_O, R_O) = (A - w_O, B - w_O)$ and $(I_T, R_T) = (D, B)$. Plugging these in equations (10) and (11), we derive the equilibrium profit under the different types of labor contracts and technological investments, which are given, respectively, by:

$$\Pi_O(I_O, R_O) = \frac{1}{4}[A^2 + B^2 + 2w_O^2 - (A + B)w_O] \tag{12}$$

$$\Pi_T(I_T, R_T) = \frac{1}{4}(D^2 + B^2) \tag{13}$$

The workers' utility, in turn, depends on the type of labor contract and on the associated learning incentives. Since temporary employees working on innovative projects find it rational not to invest in human capital when learning cost are medium-low, the equilibrium-utility of a temporary employee working on an innovative project can be derived by evaluating equation (1) at $\lambda = 0$, which gives:

$$U_T^I(\lambda = 0) = w_T(1 + r) - e(1 + r) \quad (14)$$

Similarly, since temporary employees working on routine projects find it rational to invest in human capital when learning cost are medium-low, the equilibrium-utility of a temporary employee working on a routine project can be derived by evaluating equation (2) at $\lambda = 1$, which gives:

$$U_T^R(\lambda = 1) = w_T(1 + r) - re(1 - p) - c \quad (15)$$

Finally, observe that under a permanent contract, workers have the same utility regardless of the project they are assigned to—see equation (3). Hence, since permanent employees find it rational to invest in human capital when learning cost are medium-low, the equilibrium-utility of a permanent worker can be calculated evaluating equation (3) at $\lambda = 1$, which gives:

$$U_O^I(\lambda = 1) = U_O^R(\lambda = 1) = w_O(1 + r) - c \quad (16)$$

We are now in the position to advance the following Proposition:

Proposition 4—*When multiple equilibria exist, employees are always better off in the "high-road" equilibrium. Hence, the "high-road" equilibrium is efficient iff:*

$$2w_O^2 - (A + B)w_O + A^2 - D^2 \geq 0 \quad (17)$$

In addition, condition (17) *is always satisfied if the innovative project is risky enough, formally, if* $D \leq w_O$.

Proof: see the Appendix.

Proposition 4 makes clear that the "high-road" equilibrium is the only candidate to be efficient for both the organization and its employees. Therefore, when condition (17) is satisfied but the system has gravitated towards the "low equilibrium" due to adverse initial conditions or poor equilibrium selection, both the managers and their employees are stuck in what may be called an "organizational poverty trap". This can be used as a policy argument against the plea for deregulation that has characterized the public debate over the last couple of decades or so. If our reasoning is correct, in fact, increasing the flexibility of labor markets not only has negative repercussions on worker well-being, which is somewhat unsurprising, but it also endangers profitability and firm growth. In this framework, the possibility to "take the low-road" may block firms in a situation that is difficult to upset due to the self-reinforcing character of organizational equilibria. In this case, multiple policies targeting labor market institutions and innovation incentives simultaneously are needed to incentivize firms to "take the high-road" and modify both their technological and employment structures.

6. Conclusions

In this paper, we have shown the existence of interlocking complementarities between the firms' decision to innovate and its choice to hire on a permanent basis. By analyzing how different types of labor contracts (temporary vs permanent) and different types of technological strategies (routine vs innovative) generate different learning incentives for workers to invest in firm-specific skills, we have highlighted a strategic dimension of learning that has major implications for firm-level innovation. When learning costs are such that both temporary employees working on routine projects and permanent employees working on innovative projects invest in human capital, we have found that two organizational equilibria simultaneously exist. In the "high-road" equilibrium, the human resource manager finds it rational to hire on a permanent basis given the project manager's decision to invest relatively more in innovation. Conversely, in the "low-road equilibrium", the human resource manager finds it rational to hire on a temporary basis given the project manager's decision to invest relatively more in routine activities. To qualify further these equally possible scenarios, we have additionally shown under which conditions the "high-road" equilibrium is efficient for both the organization and its personnel, while we have proven that the "low-road" equilibrium is always inefficient, at least for workers. The upshot is that the inability of the two managers to coordinate their strategies may lead the system to gravitate towards what we call an "organizational poverty trap", with negative repercussions for both profitability and worker well-being. Given the self-reinforcing character of organizational equilibria, the upshot is that regulation-induced changes in labor market institutions may have little or no effect on the firms' innovation performances unless they are coupled with the fine-tuning of innovation incentives, and vice-versa, that regulatory interventions aimed at influencing the firms' technological investment will be useless without complementary maneuvers in the regulation of labor markets.

The peculiar kind of complementarities analyzed in this paper is just one among the many structural interdependencies that characterize our economic systems. Indeed, our results pave the way to further research avenues. First, it would be interesting to use this framework to investigate the so called "meta institutional complementarities"—see Nicita and Pagano (2005) and Landini and Pagano (2018)—to bridge together the institutional complementarities examined in this paper with the literature on organizational equilibria. Second, in this paper we include wages as a positive term in the employee's utility function. However, theoretical and empirical literature stresses that one should expect earnings for permanent and temporary workers to be different. An extension of the model to address these wage differentials would be therefore particularly important. Third, firms' may decide to pursue innovation strategies aiming either at exploit existing capabilities, or at exploring new technological domains. The model could be accordingly extended to study how equilibria differ in incremental vis-à-vis radical innovation dynamics.

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Appendix: Proofs

1. Proof of Proposition 1

Evaluating equations (1), (2) and (3) at $\lambda = 0$ and $\lambda = 1$ we see that $U_T^I(\lambda = 1) \geq U_T^I(\lambda = 0)$ iff $c \leq e$; that $U_T^R(\lambda = 1) \geq U_T^R(\lambda = 0)$ iff $c \leq e(1 + rp)$ and that $U_O^j(\lambda = 1) \geq U_O^j(\lambda = 0)$ iff $c \leq e(1 + r), j = I, R$. Applying the tie-breaking rule for which E chooses $\lambda = 1$ when indifferent between $\lambda = 0$ and $\lambda = 1$—see Kräkel (2016)—the results follow ■

2. Proof of Proposition 2

When learning costs are either high or low, temporary and permanent contracts provide the same learning incentives. Hence, when $c < e$, E chooses $\lambda = 1$ regardless of the type of project and labor contract, while, if $c > e(1 + r)$, E chooses $\lambda = 1$ regardless of the type of project and labor contract—see Proposition 1. In both cases, H choses the type of contract that minimizes labor costs and, thus, hires on a temporary base. Point (i) follows. Conversely, when learning costs are medium-high and $e(1 + rp) < c < e(1 + r)$, E chooses $\lambda = 0$ when offered a temporary contract, regardless of the type of project, while E chooses $\lambda = 1$ when offered a permanent contract, regardless of the type of project. Given Assumption 1, point (ii) follows. Finally, when learning costs are medium-low, the choice of the employment contract depends on the composition of the project portfolio. When the latter is "innovative" and T is large—formally, when $T > w_O/(A - D - w_O)$—H finds it rational to hire on a permanent basis; conversely, when he latter is "routinary" and T is small—formally, when $w_O/(A - D - w_O) > T$—H finds it rational to hire on a permanent basis. Point (iii) follows ■

3. Proof of Proposition 3

From point (iii) in Proposition 2, we know that a unique equilibrium where H finds it rational to hire on a permanent basis exist if $T > w_O/(A - D - w_O)$, that a unique equilibrium where H finds it rational to hire on a temporary basis exist if $w_O/(A - D - w_O) > T$, and that $T_O > T_T$, that is, that the project portfolio is more "innovative" when H hires on a permanent basis and that it is more "routinary" when H hires on a temporary basis. The first part of the Proposition follows. The last part of the Proposition, in turn, follows from the fact that $\partial[w_O/(A - D - w_O)]/\partial w_O = A - D/[w_O/(A - D - w_O)]^2$, which is > 0 by Assumption 1 ■

4. Proof of Proposition 4

Comparing equations (14) and (15) and equations (15) and (16) under the assumption $e < c < e(1 + r)$, it is straightforward to see that permanent workers have higher payoffs than temporary workers, regardless of the type of project they are assigned to. The rest of the Proposition is obtained by calculating $\Pi_O(I_O, R_O) - \Pi_T(I_T, R_T)$ from equations (12) and (13) ■

Tables

	$\frac{\partial \Pi_O}{\partial I}$	$\frac{\partial \Pi_T}{\partial I}$	$\frac{\partial \Pi_O}{\partial R}$	$\frac{\partial \Pi_T}{\partial R}$
$c < e$	$A - w_O - c'(I)$	$A - c'(I)$	$B - w_O - c'(R)$	$B - c'(R)$
$e < c < e(1 + rp)$	$A - w_O - c'(I)$	$D - c'(I)$	$B - w_O - c'(R)$	$B - c'(R)$
$e(1 + rp) < c < e(1 + r)$	$A - w_O - c'(I)$	$D - c'(I)$	$B - w_O - c'(R)$	$C - c'(R)$
$c > e(1 + r)$	$D - w_O - c'(I)$	$D - c'(I)$	$C - w_O - c'(R)$	$C - c'(R)$

Table 1: *P*'s technological decision

	$I_O > I_T$	$R_T > R_P$	$\Pi_O > \Pi_T$
$c < e$	never	always	never
$e < c < e(1 + rp)$	always	always	if $T > w_O/(A - D - w_O)$
$e(1 + rp) < c < e(1 + r)$	always	never	always
$c > e(1 + r)$	never	always	never

Table 2: Comparison of technological investments